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The Relationship among GDP, Carbon Dioxide Emissions, Energy Consumption, and Energy Production from Oil and Gas in Saudi Arabia

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ABSTRACT

The purpose of this paper is to investigate the causal relationship among economic growth, carbon dioxide (CO_2) emissions, energy consumption, and energy production from oil and gas during 1990-2017. By vector autoregressive models and Granger causality Wald tests, this study suggests that there is bidirectional relationship between: Economic growth and energy consumption, economic growth and CO_2 emissions, and electricity production from gas and CO_2 emissions. Moreover, there is a unidirectional causality runs from energy consumption and CO_2 emission to growth of electricity production from gas, and from energy production from oil to growth of CO_2 emissions. This result confirms that energy consumption is a critical input of production and plays as a complement to the important factors of labor, capital, and land in Saudi Arabia.

Keywords: Energy Consumption, Energy Production, Economic Growth, Saudi Arabia
JEL Classifications: C32, O13, Q43

1. INTRODUCTION

Energy production and consumption play an important role in the human welfare and social-economic development of a country. Energy consumption and electricity production from oil and gas are considered a strategic commodity for Saudi Arabia. However, the question of whether there is a relationship among energy consumption, energy production from oil and gas, carbon dioxide (CO_2) emission, and economic growth needs to be answered. Energy consumption and CO_2 emissions in Saudi Arabia have grown dramatically in the past two decades because of human activities, specifically by use of fossil fuels. Saudi Arabian people are part of the global population who consume energy for transportation, industries, and building services, and the fast growth of Saudi Arabia has significantly increased the consumption of energy, which accordingly has caused an increase in CO_2 emissions. CO_2 emissions are classified as one of the main driving forces behind climate change today. Even though Saudi Arabia is the world's largest exporter of oil, not surprisingly consumption of petroleum products leads to more CO_2 emissions that conduct to climate change (Alkhathlan and Javid, 2013). For example, in 2014, CO_2 emission is 19.5 metric tons per capita in Saudi Arabia compared to that in the USA which is 16.5 metric tons per capita (World Bank, 2018). CO_2 emissions are increasing year by year despite common efforts to implement internationally binding agreements such as the Kyoto Protocol designed to reduce the use of fossil fuels. A turning point in the positive relationship between emissions and per capita income has not yet been identified, at least not on a global scale. CO_2 emission from industrial processes and fossil-fuel burning accelerated at a global scale, with their growth rate increasing from 1.1% in the period 1990-1999 to 3% in the period 2000-2004 (Raupach et al., 2007). Energy consumption is as important an input as other factors of production, such as labor and capital, and it is clear that energy is required for economic growth (Kalyoncu et al., 2013).

Use of natural gas has become increasingly important since the mid 1980s and it most recently accounts for 32.1% of total fossil fuels. Increased use of natural gas in industries provides greater energy efficiency and reduces harmful atmosphere emissions[1]. Figures 1 and 2 show the relationship between GDP and CO_2 emissions for Saudi Arabia during the period from 1990 to 2017. The total amount of CO_2 emission, as illustrated in Figure 2, increased until 1996, then it decreased between 1996 and 2001 and it continues to increase until the current study. CO_2 emissions increased dramatically during the period of the study. In 2017, CO_2 emission in Saudi Arabia grew by 11%, while the global emissions of CO_2 rose only by 2%[2]. Therefore, it is very important for policymakers to recognize the causal relationship between the two variables and also between the sources of the energy and the CO_2 emission.

The purpose of this paper is to investigate the causal relationship among economic growth, CO_2 emissions, energy consumption, and energy production from oil and gas. This study concerns the largest oil producing country in the world and one of the countries that have large amounts of pollution, as indicated by vector autoregressive (VAR) models and Granger causality Wald tests for time series data. To confirm the choice of a short run model, we use Augmented Dickey Fuller (ADF) analysis to demonstrate the absence of non-stationary relationships between CO_2 emissions, economic growth, energy consumption, and electricity production from Oil and gas.

The rest of this paper is organized as follows: section 2 reviews the literature on this subject, while section 3 shows the data and some descriptive statistics. Section 4 presents the methodology and describes the econometric approach for modeling. Section 5 provides a discussion of the observed relationship between CO_2 emissions, GDP growth and energy consumption in Saudi Arabia by Granger Causality, and the last section describes the conclusions derived from these observations.

Figure 1: GDP in Saudi Arabia from 1990 to 2017

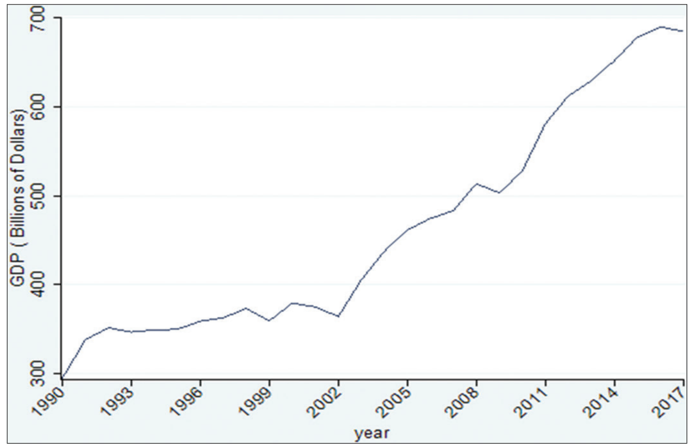
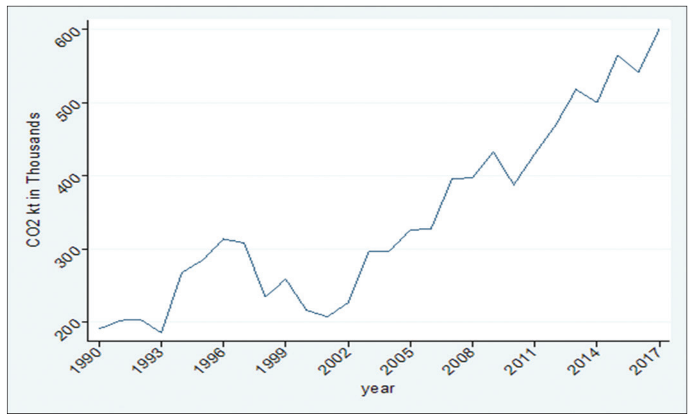


Figure 2: Carbon dioxide KT in Saudi Arabia from 1990 to 2017



2. LITERATURE REVIEW

This previous studies result in two groups of empirical researches on relationship between CO_2 emissions and economic growth in various countries: studies investigating only one country, and study investigating more than one country. Literature review reveals that subjects of the studies are not limed to relationship between CO_2 emissions and economic growth but also investigating relationship between the two variables (CO_2 emissions and economic growth) and other variables such as energy consumption and energy production.

Arrow et al. (1995) point out that there is a relationship between carbon emissions and income at all levels of per capita income and this relationship is a linear between CO_2 emission and GDP per capita. Friedl and Getzner (2003) find that a cubic relationship between GDP and CO_2 emissions in Austrian has to be split into two periods. Before the oil price shock in the mid-1970s, CO_2 emissions follow a strong path of economic growth. After this period, growth of CO_2 emissions is significantly smaller than economic growth as result of altered energy and some government policies. For studies that use the Environmental Kuznets Curve (EKC), Jaunky (2011) finds that CO_2 emissions and GDP series are integrated to an order of one and co-integrated, especially after controlling for cross-sectional dependence for 36 rich countries for the period 1980-2005. He observes that, for the whole panel, a 1% increase in GDP generates an increase of 0.68% in CO_2 emissions in the short run and 22% in the long run.

On the other side, Zeshan (2013) studies the relationship between electricity production and economic growth in Pakistan during 1975-2010. He finds bidirectional causal relationship between the two variables in the long run whereas no causal relationship in the short run. In Italy, Bento and Moutinho (2016) show that per capita renewable electricity production reduces the level of CO_2 emissions per capita in case of short and long run. Moreover, they find unidirectional Granger causality relation running from GDP per capita to renewable electricity production per capita and also from non-renewable electricity per capita to renewable electricity production per capita. Sharma (2011) finds that openness, per capita GDP, and energy consumption have positive effects on

1 Carbon Dioxide Information Analysis Center (CDIAC): https://cdiac.ess-dive.lbl.gov/trace_gas_emissions.html.

2 https://news.nationalgeographic.com/2017/11/climate-change-carbon-emissions-rising-environment/.

CO_2 emissions. However, he finds that the urban environment is found to have a negative impact on CO_2 emissions in high income, middle income, and low-income panels. Stolyarova (2009) studies 93 countries over the period 1960-2008, and examines the dynamic panel data and models to explain the growth rate of per capita CO_2 emissions. He finds that the growth rate of per capita CO_2 emissions depends positively on the growth rate of per capita GDP and negatively on the growth rate of the energy mix. Kalyoncu et al. (2013) find unidirectional causality from per capita GDP to per capita energy consumption for Armenia while these two variables are not cointegrated for Georgia and Azerbaijan. For G7 countries, Narayan and Smyth (2008) find that energy consumption and real GDP are cointegrated and energy consumption Granger causes real GDP positively in the long run. Fodha and Zaghdoud (2010) investigate the relationship between economic growth and pollutant emissions for Tunisia, during the period 1961-2004. They find that the relationship between pollution and income is one of unidirectional causality with income causing environmental changes and not vice versa, both in the long and short run. So, emissions reduction policies and more investment in pollution abatement expense will not hurt economic growth. In Njoke et al. (2019) reveal a unidirectional causality running from CO_2 to GDP growth. However, a neutrality hypothesis holds between economic growth and electricity consumption during the period 1971-2014. In India, Sultan and Alkhateeb (2019) find long run stable relationship between energy consumption and real GDP. Moreover, they find bidirectional relationship between economic propensity and energy consumption in the long run while energy consumption Granger causes economic activities in the short run. In South East Sulawesi, Rahim et al. (2018) reveal a strong positive causal relationship between energy consumption and GDP growth in the long run. They find that 1% increase in energy consumption causes 0.31% increase in GDP growth; however, this relationship between the two variables is weak in the short run.

3. DATA AND DESCRIPTIVE STATISTICS

We use annual time series data covering the period from 1990 to 2017. The data on CO_2 emissions, GDP, electricity product of oil, electricity product of gas, and energy consumption per capita are obtained from the World Development indicators (WDI) of the World Bank (2018). CO_2 emissions have two standard sources. The largest source is coming from fossil fuels such as natural gas and crude oil. The source is large because Saudi Arabia is the world's largest exporter of oil. The second source is from industrial processes that emit CO_2 emissions as a result of a chemical reaction. In both cases, these emissions are as result of consumption of energy, by both chemical and physical processes. However, the relationship changes according to the types of burning, means of production and energy generation, and energy efficiency. This study proposes that the relationships among CO_2 emissions, production of energy from oil and gas, energy consumption, and GDP may differ according this causality relationship. All variables considered in the model are expressed as growth as following: *ggdp*: Economic growth, *gCO_2*: Growth of CO_2 emission (KT), *gepc*: Growth of energy consumption (Kwh per capita), *gepoil*: Growth of electricity production from oil (% of total), and *gepgas*: Growth electricity production from gas (% of total).

Table 1 summarizes the descriptive statistics associated with the five variables. The empirical investigation is based on 27 annual observations. The mean of carbon emissions (CO_2) is 5.17%, while the maximum and minimum are 44.11% and -23.63%, respectively. It is evident from the table that the standard deviation of growth of energy production from oil is the highest (13.72) because Saudi depends on the revenue of the oil that increased in recent years and the standard deviation of the growth of CO_2 emission comes in second place (13.63).

On other side, Nelson and Plosser (1982) find that all historical time series have a unit root except for the unemployment rate. Consequently, the ADF test should be used to examine the stationary in the time series of the GDP, CO_2 emissions, product of oil and gas, and energy consumption. Table 2 shows that the findings reveal that the unit root null hypothesis for all the series time are rejected under intercept, intercept and trend, and no intercept and no trend. Consequently, the results show that the five series time of the variables; GDP, CO_2, energy consumption, and energy production from oil and gas are stationary at 5% level, i.e. those variables are integrated in order of I(0). This test indicates clearly that there is no cointegration among *ggdp*, *gCO_2*, *gepoil*, *gepgas*, and *gepc*. Therefore the Granger test (Granger, 1969) is appropriate in this case.

4. THE METHODOLOGY

This paper employs VAR with great effectiveness in different works. We are following Jinke et al. (2008) who examine the correlation relationship between real GDP and consumption of coal for 100 countries. Others, such as Belloumi (2009) and Farhani et al. (2014) use the VAR model for the difference period. This paper uses a VAR model to analyze the relationship between *ggdp*, *gCO_2*, *gepoil*, *gepgas*, and *gepc*. This relation could be written by VAR (p) as the following:

$$ggdp_t = \gamma + \sum_{i=1}^{p} \alpha_i ggdp_{t-i} + \sum_{j=0}^{p} \beta_J gCO_{2t-j} + \sum_{k=0}^{p} \theta_k gepoily_{t-k} + \sum_{k=0}^{p} \rho_k gepgas_{t-k} + \sum_{k=0}^{p} \delta_k gepc_{t-k} + \varepsilon_{t1} \quad (1)$$

Table 1: Descriptive statistics

Variables	Observations	Mean	Standard dev.	Minimization	Maximization
ggdp	27	3.27	4.37	−3.76	15.00
gCO_2	27	5.17	13.63	−23.63	44.11
gepoil	27	−2.09	13.72	−53.89	15.78
gepgas	27	0.64	6.42	−8.21	18.05
gepc	27	3.62	2.48	−2.26	7.92

Table 2: Unit root test results using ADF

Variables	Intercept	Intercept and trend	No. intercept and No. trend
ggdp	−5.315*	−5.398*	−4.172*
gCO_2	−5.939*	−5.815*	−5.213*
gepoil	−4.848*	−4.755*	−4.844*
gepgas	−3.907*	−3.973**	−3.963*
gepc	−6.554*	−6.440*	−2.285**
Critical value at 1%	−3.743	−4.371	−2.658
Critical value at 5%	−2.997	−3.596	−1.950

H_0: *ggdp* (gCO_2, *gepoil*, *gepgas*, *gepc*) has a unit root, H_1: *ggdp* (gCO_2, *gepoil*, *gepgas*, *gepc*) does not have a unit root. ADF: Augmented Dickey Fuller

$$gco2_t = \gamma + \sum_{i=1}^{p}\alpha_i ggdp_{t-i} + \sum_{j=0}^{p}\beta_J gCO_{2t-j} + \sum_{k=0}^{p}\theta_k gepoily_{t-k} + \sum_{k=0}^{p}\rho_k gepgas_{t-k} + \sum_{k=0}^{p}\delta_k gepc_{t-k} + \varepsilon_{t2} \quad (2)$$

$$gepoil_t = \gamma + \sum_{i=1}^{p}\alpha_i ggdp_{t-i} + \sum_{j=0}^{p}\beta_J gCO_{2t-j} + \sum_{k=0}^{p}\theta_k gepoily_{t-k} + \sum_{k=0}^{p}\rho_k gepgas_{t-k} + \sum_{k=0}^{p}\delta_k gepc_{t-k} + \varepsilon_{t3} \quad (3)$$

$$gepgas_t = \gamma + \sum_{i=1}^{p}\alpha_i ggdp_{t-i} + \sum_{j=0}^{p}\beta_J gCO_{2t-j} + \sum_{k=0}^{p}\theta_k gepoily_{t-k} + \sum_{k=0}^{p}\rho_k gepgas_{t-k} + \sum_{k=0}^{p}\delta_k gepc_{t-k} + \varepsilon_{t4} \quad (4)$$

$$gepc_t = \gamma + \sum_{i=1}^{p}\alpha_i ggdp_{t-i} + \sum_{j=0}^{p}\beta_J gCO_{2t-j} + \sum_{k=0}^{p}\theta_k gepoily_{t-k} + \sum_{k=0}^{p}\rho_k gepgas_{t-k} + \sum_{k=0}^{p}\delta_k gepc_{t-k} + \varepsilon_{t5} \quad (5)$$

Where ε_{ti} and i = 1, 2, 3, 4, 5 is expressed as a white noise process verifying $E(\varepsilon_{ti}) = 0$, and gdp_{t-1}, gCO_{2t-1}, $gepoil_{t-1}$, $gepgas_{t-1}$, and $gepc_{t-1}$ represent a VAR process of lag (p) endogenous variables, and α_i, β_J, θ_k, ρ_k, and δ_k are (n × 1) intercept vector of the VAR model. Before any econometric analysis, the p lag length of the model should be determined. This paper uses the Akaike's information criterion (AIC) and Schwarz's Bayesian criterion (SAC) to determine the optimal lag length of *ggdp*, gCO_2, *gepoil*, *gepgas*, and *gepc*. The second of Table 3 shows that the optimal p lag length of the model is P* = 3 by using FPE and AIC test.

5. GRANGER CAUSALITY TEST

Granger Causality tests are used to determine the causal relationship between two variables. For example, there are four possible outcomes regarding causal relationships between *ggdp* and gCO_2: unidirectional causality from *ggdp* to gCO_2 or vice versa; bidirectional causality between the two variables; and, lack of any causal relationship. The equations of conventional Granger test could be written as the following:

$$ggdp_t = \gamma + \sum_{k=1}^{p}\beta_J gCO_{2t-k} + \sum_{k=0}^{p}\theta_k gepoily_{t-k} + \sum_{k=0}^{p}\rho_k gepgas_{t-k} + \sum_{k=0}^{p}\delta_k gepc_{t-k} + \varepsilon_{t1} \quad (6)$$

$$gCO_{2t} = \gamma + \sum_{k=1}^{p}\alpha_i ggdp_{t-k} + \sum_{k=0}^{p}\theta_k gepoily_{t-k} + \sum_{k=0}^{p}\rho_k gepgas_{t-k} + \sum_{k=0}^{p}\delta_k gepc_{t-k} + \varepsilon_{t2} \quad (7)$$

$$gepoil_t = \gamma + \sum_{k=1}^{p}\alpha_i ggdp_{t-k} + \sum_{j=0}^{p}\beta_J gCO_{2t-k} + \sum_{k=0}^{p}\rho_k gepgas_{t-k} + \sum_{k=0}^{p}\delta_k gepc_{t-k} + \varepsilon_{t3} \quad (8)$$

$$gepgas_t = \gamma + \sum_{k=1}^{p}\alpha_i ggdp_{t-k} + \sum_{k=0}^{p}\beta_J gCO_{2t-k} + \sum_{k=0}^{p}\theta_k gepoily_{t-k} + \sum_{k=0}^{p}\delta_k gepc_{t-k} + \varepsilon_{t4} \quad (9)$$

$$gepc_t = \gamma + \sum_{k=1}^{p}\alpha_i ggdp_{t-k} + \sum_{j=0}^{p}\beta_J gCO_{2t-k} + \sum_{k=0}^{p}\theta_k gepoily_{t-k} + \sum_{k=0}^{p}\rho_k gepgas_{t-k} + \varepsilon_{t5} \quad (10)$$

Sims (1980) states that a series time could be recognized as causal for another series time if the first innovations contribute to the forecast error variance of the second. However, recent studies, such as: Jbir and Zouari (2009) and Belloumi (2009), further develop this statistical hypothesis test. To explain this relationship between *ggdp* and gCO_2, we examine a unidirectional causality from gCO_2 to *ggdp* if $\sum_{k=1}^{p}\beta_k \neq 0$, $\sum_{k=0}^{p}\theta_k = \sum_{k=0}^{p}\rho_k = \sum_{k=0}^{p}\delta_k = 0$ and found quite the reverse. A unidirectional causality from *ggdp* to gCO_2 will be found if $\sum_{k=1}^{p}\theta_k = \sum_{k=0}^{p}\rho_k = \sum_{k=0}^{p}\delta_k = 0, but \sum_{k=0}^{p}\alpha_k \neq 0$ so, there will be bidirectional causality between *ggdp* and gCO_2, if both the conditions obtain. Finally, *ggdp* and gCO_2 are independent and insignificant if both the factors are zero as: $\sum_{k=1}^{p}\beta_k = \sum_{k=0}^{p}\alpha_k = 0$.

6. EMPIRICAL RESULTS

Table 3 presents the results of the Granger causality test for 3 time periods lag that would be appropriate for Granger Causality tests among all variables; *ggdp*: Economic growth, gCO_2: Growth of CO_2 emission (KT), *gepc*: Growth of energy

Table 3: VAR granger causality wald tests

Sample 1990-2017				
Lag 3				
Group	**Null hypothesis (H_0)**	**Chi-square statistic**	**Probability**	**Results**
First	*gCO_2* does not cause *ggdp*	6.3453	0.096	Reject H_0**
	gepoil does not cause *ggdp*	5.9488	0.114	Accept H_0
	gepgas does not cause *ggdp*	5.033	0.169	Accept H_0
	gepc does not cause *ggdp*	8.8456	0.031	Reject H_0*
	All variables does not cause *ggdp*	36.705	0.001	Reject H_0*
Second	*ggdp* does not cause *gCO_2*	7.7259	0.052	Reject H_0**
	gepoil does not cause *gCO_2*	13.048	0.005	Reject H_0*
	gepgas does not cause *gCO_2*	14.73	0.002	Reject H_0*
	gepc does not cause *gCO_2*	2.7898	0.425	Accept H_0
	All variables does not cause *gCO_2*	38.22	0.001	Reject H_0*
Third	*ggdp* does not cause *gepoil*	.92281	0.820	Accept H_0
	gCO_2 does not cause *gepoil*	1.1361	0.768	Accept H_0
	gepgas does not cause *gepoil*	1.97	0.579	Accept H_0
	gepc does not cause *gepoil*	2.0089	0.571	Accept H_0
	All variables does not cause *gepoil*	4.5924	0.970	Accept H_0
Fourth	*ggdp* does not cause *gepgas*	3.2791	0.351	Accept H_0
	gCO_2 does not cause *gepgas*	7.7289	0.052	Reject H_0**
	gepoil does not cause *gepgas*	3.5688	0.312	Accept H_0
	gepc does not cause *gepgas*	12.6	0.006	Reject H_0*
	All variables does not cause *gepgas*	19.781	0.071	Reject H_0**
Fifth	*ggdp* does not cause *gepc*	6.2672	0.099	Reject H_0**
	gCO_2 does not cause *gepc*	3.473	0.324	Accept H_0
	gepoil does not cause *gepc*	3.163	0.367	Accept H_0
	gepgas does not cause *gepc*	1.7409	0.628	Accept H_0
	All variables does not cause *gepc*	16.812	0.157	Accept H_0

The null hypothesis (H_0) is: the dependent variable in lagged time causes independent variable in left. An alternative hypothesis (H_1) is: the dependent variable in lagged does not cause dependent variable in left. * and ** represent significance at the 5% and 10% level, respectively. VAR: Vector autoregressive

consumption (Kwh per capita), *gepoil*: Growth of electricity production from oil, and *gepgas*: Growth electricity production from gas. Table 3 shows the empirical results as following: In the first group of Table 3, the Granger causality test suggests causality from growth of energy consumption (*gepc*) to the economic growth (*ggdp*) at the 5% level and from growth of electricity production from oil (*gepoil*) to the economic growth (*ggdp*) at 10% level over a short run. However, all variables, including growth of energy consumption (*gepc*), growth of CO_2 emission (*gCO_2*), growth of electricity production from oil (*gepoil*), and growth electricity production from gas (*gepgas*), cause economic growth (*ggdp*) at the 1% level over a long run.

The second group of table 3 shows that economic growth causes a growth of CO_2 emission (*gCO_2*) at level 10% and both growth of electricity production from oil and gas (*gepoil* and *gepgas*) cause a growth of CO_2 emissions (*gCO_2*) at level 5% over a short run. However, in long run, all variables cause growth of CO_2 emissions (*gCO_2*) at the 5% level. The Third group shows that each variable does not cause growth of electricity production from oil (*gepoil*) in the short run and also all variables do not cause growth of electricity production from oil (*gepoil*) at 5% level over a long run. The fourth group suggests that the growth of CO2 emissions and energy consumption (*gepc*) causes growth electricity production from gas (*gepgas*) at the 10% and 5% level, respectively, over a short run and all variables cause growth electricity production from gas (*gepgas*) at the 10% over a long run. Finally, fifth group shows that only economic growth causes growth of energy consumption (*gepc*) at the 10% level over a short run. The results show that there is bidirectional relationship between economic growth and CO_2 emissions growth, between economic growth and energy consumption growth, and between growth electricity production from gas and CO_2 emissions growth. While, there is a unidirectional causality runs from growth of electricity production from oil and gas to growth of CO_2 emission; from growth of energy consumption to growth of electricity production from gas; and from growth of energy consumption to growth of electricity production from gas. This observation shows that economic growth in Saudi Arabia is determined by the energy consumption, the CO_2 emissions that are gotten from electricity production from oil and gas.

7. CONCLUSION AND POLICY IMPLICATIONS

This study aims to analyze the relationship between economic growth, energy consumption, CO_2 emission, electricity production from oil, and electricity production from gas during 1990 to 2017. Using time series data and econometrics analysis, the result suggests that there is bidirectional relationship between: economic growth and CO_2 emissions, and electricity production from gas and CO_2 emissions. While, there is a unidirectional causality running from growth of electricity from gas to growth of CO_2 emissions, from growth of CO_2 emissions to growth of electricity production from gas, and from growth of energy consumption to growth of electricity production from gas. The finding of bidirectional causality between economic growth, energy consumption growth, and electricity production growth from gas in the short run implies that Saudi Arabia is an energy-independent economy. Moreover, the finding of a unidirectional causality from growth of electricity production from oil to growth of CO_2 emissions implies that reducing electricity production from oil fuel seems to be active way to reduce emissions in case of Saudi Arabia.

The policy makers should have to implement expansive energy policies. They should rather have to invest in increasing efficiency of electricity production from gas than from oil in order to decrease CO_2 emissions without negatively impacting energy consumption and thereby economic growth. Energy consumption is positively and significantly contributing to electricity production from gas, and the electricity production from gas and oil contribute positively and significantly to CO_2 emissions. However, this study emphasizes that energy consumption and electricity production from gas is crucially required for economic growth and likewise confirms that energy consumption is a critical input of production and plays as a complement to the basic factors of labor, capital, and land.

Policy makers should improve public transportation to reduce the need for people to use their own transportation. Train transportation should be improved in Saudi Arabia to enable people to use public transportation instead of their own cars. Moreover, Saudi Arabia should depend more on nuclear power to keep energy consumption up while lowering carbon emissions.

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