

# The impact of renewable energy consumption on carbon dioxide emissions and economic growth in the Kingdom of Saudi Arabia



Hichem Dkhili \*, Lassad Ben Dhiab

College of Business Administration, Northern Border University, Arar, Saudi Arabia

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## ABSTRACT

This study aims to show the relationship between the impact of energy consumption on carbon dioxide emissions and economic growth. Using quantitative indicators of energy consumption ratios, carbon dioxide emissions, and economic growth in Saudi Arabia, we try to measure the impact of various variables by taking into account the economic factors of the sample country. The application of a multivariate model of economic growth and renewable energy with carbon dioxide emissions monitored between 1990 and 2018 has been used. The empirical results indicate a unidirectional causal relationship between GDP and energy consumption. A unidirectional causal relationship is between energy consumption and long-term CO<sub>2</sub> emissions. The results suggest that carbon dioxide emissions and energy consumption are not driving economic growth. Therefore, Saudi Arabia can maintain a conservative energy policy and a long-term carbon reduction policy without hindering economic growth.

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## 1. Introduction

Several scientific articles have resumed studies focusing on analyzing the determinants of environmental performance against different dimensions, such as economic growth and carbon dioxide emissions in many countries. Environmental performance is defined as a multidimensional concept that is difficult to measure because it is related to the rate of environmental pollution, energy consumption, and many administrative programs that are approved and implemented to reduce these negative effects of harmful gas emissions on the environment.

Also, several authors have analyzed the relationship between environmental performance, economic growth, and carbon dioxide emissions (Saidi and Mbarek, 2017).

Given the importance of these topics, the number of scientific and research articles has been addressed in many contexts. For example, Al-Tuwaijri et al. (2004) proposed a model of "good" environmental performance, which is closely related to "good" economic performance. Moreover, Böhringer and

Jochem (2007) showed that country sustainability indicators provide a one-dimensional scale for assessing country-specific information on the three dimensions of sustainable development: Economic, environmental and social conditions. Also, we mention the contribution of Cracolici et al. (2010) to develop a new analytical framework for assessing spatial variations between countries.

It presented a set of economic and non-economic aspects (mainly social) for the country's performance in an integrated logical framework. On the other hand, Zhu et al. (2013) examined the relationship between environmental disclosure and the management of institutional impressions to investigate two subsequent hypotheses, using a cross-sectional sample of US companies' environmental disclosures in annual reports.


In this context, Dkhili and Oweis (2018) studied the link between university rankings and economic growth in Sub Saharan African Countries (SSA) by applying the panel data analysis method and the system GMM technique used on a sample of 43 SSA countries during the period 1996-2015. And the result that academic research exerts a positive and significant effect on the level of economic growth for both fixed and random effects.

The main objective of this study is to investigate the impact of renewable energy consumption on carbon dioxide emissions and economic growth in the Kingdom of Saudi Arabia. And that is through a

\* Corresponding Author.

Email Address: [hichem.dkhili@nbu.edu.sa](mailto:hichem.dkhili@nbu.edu.sa) (H. Dkhili)

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 Corresponding author's ORCID profile:

<https://orcid.org/0000-0001-5773-1494>

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pilot study on the Kingdom of Saudi Arabia between the years 1995 and 2018.

Here, we should ask the following question: What is the impact of renewable energy consumption on carbon dioxide emissions and economic growth in Saudi Arabia?

## 2. Literature review

The study of Kahia et al. (2019) examined the impact of renewable energy consumption, economic growth, foreign direct investment flows, and trade in carbon dioxide emissions for a group of 12 countries in the Middle East and North Africa during the period 1980-2012 using the modern Vector Panel for the automatic regression model with a multi-domain analysis framework.

The results of Kahia et al. (2019), through Granger's causality test, showed a two-way causal relationship between variables. Which showed that economic growth leads to environmental degradation while renewable energy, international trade, and foreign direct investment flows reduce carbon dioxide emissions?

Ahmed et al. (2019) investigated the relationships between energy consumption, carbon dioxide emissions (CO<sub>2</sub>), and economic growth for the period between 1975 and 2014.

Bao et al. (2010) attempted to estimate the carbon curve Cuznets (CKC), clean fuel/fossil energy consumption (CE/FF) for flexibility in demand for carbon emissions, and casualties between emissions, energy, and economics, and propose a strategy to separate environmental pressure from Economic growth (EG).

Through sample data, the G20 consists of a representative sample of global economic development. Within the framework of the Energy and Output Emissions Panel (Equal Employment Opportunities) during the period 1991-2018.

Through the above, interest has increased in studying the issue of the impact of renewable energy consumption on carbon dioxide emissions and economic growth, especially in light of the new economic era that supports economic openness and globalization.

Charfeddine and Kahia (2019) studied confirmed the role of the impact of renewable energy and financial development on CO<sub>2</sub> emissions and economic growth. They have used the reaction of carbon dioxide emissions and economic growth to renewables and financial development.

Some studies have concluded, and they show that the environmental regulations in developing countries negatively affect the quality of life, especially after the phenomenon of the continuous increase in global temperatures, e.g., Saidi and Mbarek (2017).

Another set of applied works addressed the same problem with the Granger methodology to test the causal relationships between income variables, trade, urbanization, and financial development with carbon dioxide emissions like the study of Wang et

al. (2017), which analyzed the effects of economic growth and urbanization on various industrial carbon emissions.

Dogan and Aslan (2017) gave a comprehensive study of the role of renewable energy consumption and its institutions towards economic growth in combating carbon dioxide emissions across regions and by income groups. The negative impacts of climate on CO<sub>2</sub> emissions make us question the nature of the relationship between the five variables (income, trade, urbanization, and financial development with carbon dioxide emissions).

## 3. Empirical analysis

### 3.1. Data and methodology

In this context, we will rely on an empirical study based on the use of econometric models. To test the relationship between variables, we used a time series that was monitored during the period between 1990-2018.

$$CO2E_{i,t} = \beta_0 + \beta_1 GDPG_{i,t} + \beta_2 GDPG_{i,t}^2 + \beta_3 EC_{i,t} + \beta_4 INVEST_{i,t} + \beta_5 FDI_{i,t} + \beta_6 TRAD_{i,t} + \varepsilon_{i,t}$$

where i indicate the countries (i=1... 6) and t indicates the time period (t=2002... 2019). EPI, GDPG, GDPG<sup>2</sup>, EC, INVEST, FDI, and TRAD represent the environmental performance, the real gross domestic product growth per capita, the square of the real gross domestic product growth per capita, and (EC) the Energy consummation.

INVEST: Is the Gross fixed capital formation. TRAD is the trade openness, the value added (% of GDP). The signs of  $\beta_1$ ,  $\beta_2$ ,  $\beta_3$ ,  $\beta_4$ , and  $\beta_5$  are expected to be positive and negative, respectively, in order to reflect the inverted U-shape pattern.

The data are collected from the World Bank's World Development Indicators database-The Word Bank.

The following stages will be followed for each country in the period between 1990 and 2018 so that we can compare.

### 3.2. Descriptive statistics

The statistics presented in the table discloses the descriptive results of the different variables of the study. The average level of energy consummation is 60.253%, while the average level of investment is 23.216%, with a maximum of 34.523 and a minimum of 61.862. The GDPG achieved an average of 4.320% with a negative minimum of -7.076% and a positive maximum of 17.320%. The average level of trade sets on the average of 114.384%, which lightly near the median with a value-added equal to 102.300%, and with a maximum value of 191.878%, and a minimum value is 14.627% for the variables FDI. We achieve a similar remark to the point previously-cited: we are witnessing a positive mean equal, respectively, to 3.011% for FDI. These values are

close to the median, respectively 2.398% and 102.300%.

Finally, the Descriptive statistics results show positive coefficients for all the variables of the study.

The Descriptive statistics results show positive coefficients for all the variables of the study. [Table 1](#) shows descriptive statistics.

**Table 1:** Descriptive statistics

	GDPG	GDPSQ	EC	INVES	FDI	TRADE
Mean	4.320	53,986	60.253	23.216	3.011	114.384
Median	4.399	19,969	60.130	23.231	2.398	102.300
Maximum	17.320	68.488	86.000	34.523	15.751	191.878
Minimum	-7.076	0,251	44.040	14.627	-3.152	61.862
Std. Dev.	3.935	100,731	10.748	4.385	3.111	34.620
Skewness	-0.026	3,816	0.126	0.442	1.332	0.543
Kurtosis	4.472	20,058	1.689	3.115	5.874	2.135
Jarque-Bera	6.415	1396,892	5.273	2.348	45.409	5.709
Probability	0.040	0,000	0.072	0.309	0.000	0.058
Sum	306.694	5182,642	4277.990	1648.331	213.807	8121.263
Sum Sq. Dev.	1083.754	963933,100	8086.904	1346.026	677.681	83897.830
Observations	120	120	120	120	120	120

As for the pooled results in [Table 1](#), we release the following remarks: Firstly, we remark a negatives correlation between GDPG and the variables: EC and INVEST. These correlations are described with low coefficients equal to -0,037 for the variable EC, -0.148 for GDPSQ, and -0,149 for INVES. In the same case, we admired a positive correlation between GDPG and the variables: FDI and TRADE, with also low coefficients equal to 0,135 for the FDI and 0,003 for the variable TRADE. Secondly, the results show a positive correlation between the variable FDI with all the variables of the study except the variable EC. Also, we find a positive correlation between the variable TRADE with all the variables of the study with strong coefficients.

Finally, the result shows that the level of correlation is low between the independent variables introduced in the econometric model. Therefore, we confirm the absence of multicollinearity. [Table 2](#) shows the correlation matrix.

### 3.3. Panel unit root tests

The Panel Unit Root Tests is a method that is estimated by [Kwiatkowski et al. \(1992\)](#). Especially for the current study, we advance the Augmented Dickey-Fuller (F-ADF) unit root tests to check the stationary of each variable. After that, we used the augmented Dickey-Fuller (ADF) statistic. In this case, the null hypothesis support, the more negative, it is the stronger for the rejection of the hypothesis. And we demonstrate the existence of a unit roots at some level of confidence. In fact, the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) were tested for the six variables of the model displays in [Table 2](#). [Table 3](#) shows panel unit root tests.

The results showed that in the level, the null hypothesis could not be rejected for all the variables for both the two-unit root test ADF and PP test. Finally, the variables GDPG, GDPSQ, EC, FDI, TRADE, and INVEST are not stationary at the level of 5%. And, the results rejected the null hypothesis of

non-stationary. The unit-roots tests confirm that each variable is integrated of order one.

### 3.4. Cointegration test and results

The cointegration test aims to check whether it exists a long-run relationship association. Two statistics are used in the cointegration test of [Johansen \(1988\)](#); they are the Trace test and Max-Eigen value. [Table 3](#) presents the results of the trace and the maximum-eigenvalue tests from the [Johansen \(1988\)](#) and [Johansen and Juselius \(1990\)](#) maximum Likelihood analysis.

The results given in [Table 4](#) suggest the existence of one cointegration vectors at 5% of significance for the Trace test and for the Max-eigenvalue. This result indicates that there is a long-run association. In fact, the panel tests advance the cointegration results between the dimensions and groups when the dependent variable is economic growth. And empirically, the results prove the conditions of the rejection of the null hypothesis: Which leads to noticing that economic growth is cointegrated for all the variables. These results are significant at the level of 5% for the two tests between the dimension ([Pedroni's \(2004\)](#) heterogeneous panel cointegration tests and Panel ADF-Statistic) this shows that the connections between the variables. We remark later some statistics results aren't significant for the results between group: Such as for the panel and group versions of ADF-statistic and the group rho-statistic.

Finally, through the previously-cited results, we finish by the conclusion which supports the existence of a panel long-run equilibrium relationship among the economic growth, EC, FDI, INVEST, and TRAD.

**Table 2:** Correlation matrix

	GDPG	GDPSQ	EC	INVES	FDI	TRADE
GDPG	1					
GDPSQ	-0.148	1				
EC	-0.217	0.761	1			
INVES	0.506	-0.037	-0.089	1		
FDI	0.236	-0.149	-0.305	-0.118	1	
TRADE	0.061	0.135	-0.034	-0.001	0.355	1
TRADE	0.473	0.003	-0.158	0.184	0.201	0.322

**Table 3: Panel unit root tests**

Tests	LLC	Prob	IPS	Prob	ADF-Fisher	Prob	PP-Fisher	Prob	Order of Integ
GDPG	-3.274	(0.0005)	-2.425	(0.0076)	26.163	(0.0102)	28.85	(0.0041)	—
ΔGDPG	-11.619	(0.000)	-9.482	(0.000)	82.116	(0.000)	113.87	(0.000)	I(1)
GDPGSQ	-3.822	(0.000)	-2.646	(0.004)	27.947	(0.005)	36.121	(0.000)	—
ΔGDPGSQ	-15.670	(0.000)	-11.622	(0.000)	91.629	(0.000)	140.251	(0.000)	I(1)
EC	1.167	(0.8784)	0.97	(0.8341)	10.612	(0.5624)	40.792	(0.0001)	—
ΔEC	-3.725	(0.0001)	-8.793	(0.000)	78.957	(0.000)	109.816	(0.000)	I(1)
INVEST	-2.192	(0.0142)	-1.626	(0.0519)	17.425	(0.0649)	13.688	(0.1877)	—
ΔINVEST	-5.277	(0.000)	-4.013	(0.0000)	37.049	(0.000)	38.336	(0.000)	I(1)
FDI	-1.326	(0.0923)	-1.299	(0.0969)	16.193	(0.1825)	15.53	(0.2137)	—
ΔFDI	-6.551	(0.000)	-5.358	(0.000)	47.971	(0.000)	54.825	(0.000)	I(1)
TRADE	-1.438	(0.0843)	-2.565	(0.0052)	15.055	(0.1945)	19.788	(0.0712)	—
ΔTRADE	-7.246	(0.000)	-5.035	(0.000)	45.881	(0.000)	37.135	(0.0002)	I(1)

Probabilities for the Fisher-type tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality. The choice of lag levels for IPS and Fisher-ADF tests are determined by empirical realizations of the Schwarz Information Criterion. The LLC and Fisher-PP tests were computed using the Newey-West automatic bandwidth selection and Bartlett kernel. The panel Unit Root Test is conducted within an individual and intercept

**Table 4: Panel cointegration test of Pedroni (2004)**

(Within-dimension)	Statistic	Prob.	Statistic	Prob.	(Between-group)	Statistic	Prob.
Panel v-Statistic	-0.7257	0.7660	-1.5584	0.9404	Group rho-Statistic	1.6818	0.9537
Panel rho-Statistic	0.6561	0.7444	0.9492	0.8289	Group PP-Statistic	-11.336	0.0000***
Panel PP-Statistic	-6.7469	0.0000***	-3.4555	0.0003***	Group ADF-Statistic	-6.1581	0.0000***
Panel ADF-Statistic	-5.8647	0.0000***	-3.5542	0.0002***			

The null hypothesis is that the variables are not cointegrated. Under the null hypothesis, all the statistics are distributed as standard normal distributions. The finite sample distribution for the seven statistics has been tabulated in Pedroni (2004). The P-values are in parentheses. \*\*\* indicates the level of significance at 1%

### 3.5. Kao residual cointegration test

Table 7 presents the results of Kao's residual panel cointegration tests. The results of Table 7 rejected the null hypothesis of no cointegration for the variables at the 1% significance level. Thereby, the results of Kao's residual panel cointegration tests reported in Table 5 rejected the null hypothesis of no cointegration for the economic growth and the variables (EC, FDI, INVEST, and TRAD) at the 1% significance level. This indicates the existence of cointegration.

**Table 5: Kao residual cointegration test**

	t-Statistic	Prob.
ADF	-3.262	0.0006***
Residual variance	23.922	
HAC variance	16.971	

\*\*\* indicates the level of significance at 1%

The long-run relationship between economic growth, GDPDSQ, EC, FDI, INVEST, and TRAD using the panel cointegration technique due to Pedroni (2004) revealed the following results: We use the results of panel Fully Modified OLS (FMOLS) exposed in Table 7. More specifically, the results of the single-equation estimation techniques prove;

Firstly, the average cointegration coefficient of environment performance (EPI) is equal to 1.094, and it is significant at 10%. This remark is identical for the variables INVEST, FDI, and TRADE, with a positive coefficient respectively equal to 0.534, 2.333, and 0.203, with the exception of the variable CO<sub>2</sub> emission with a coefficient equal to -0.438 significant at the 10%.

Thus, we prove that a 1% increase in economic growth leads on average to a 1.094% increase in the variable energy consummation (EC). Also, we remark that a 1% increase in economic growth leads on average to a 53.4% increase of the variable investment (INVEST), and finally, we note that a 1%

increase in economic growth leads on average to 23.33% for the variable FDI, and 20.3% for the variable trade openness TRAD.

In addition, we remark that a -0.008% variation of the GDPG square GDPGSQ is followed by positives variations of the variable EC equal to 1.094%, INVEST equal to 0.534%, FDI equal to 2.333%, TRADE equal to 0.203.

As far as, we remark positive relations between economic growth and the variable energy consummation (EC) with a significant coefficient equal to 1.094 at 10%, and a coefficient equal to 2.333 for the variable FDI, 0.534 the investment INVEST, and equal to 0.203 for the Variable TRADE the rest variables such as GDPG, and the square of the GDPG, the estimation of the DOLS results show a negative relation. These relationships are not significant at a level of 10%.

Through these evoked, we notice that a positive variation of the economic growth leads to a strong and positive variation to the variable energy consummation (EC), investment (INVEST), and trade (TRAD). Also, a positive variation of the economic growth leads to a strong and negative variation to the variable energy consummation (EC). These last are significant at the level of 1% and 10%.

### 3.6. Granger causality test

As an introduction to the results, it is postulated that the Granger causality analysis served to examine the cause and effect of the relationship between the variables of the study and during the study period. The results of Granger causality and regression coefficient for the economic growth and all variable of the study; EPI, CO<sub>2</sub>E, FDI, INVEST, and TRAD, for all the sample composed by the GCC countries and during the period 2002-2018, are exposed in Table 7.



Indeed, our results show a unidirectional relationship of the sample GCC countries between economic growth and the variables; EPI, INVEST, FDI, and TRADE at the level of 5%.

**Table 6:** Long-run estimates FMOLS and DOLS

EPI	Coefficient	Std. Error	t-Statistic	Prob.
ESI	0.359	0.447	-0.802	0.426
ESIQ	0.008	0.042	-0.179	0.859
EPI	1.239	0.213	5.808	0.000***
GDPG	0.715	0.338	2.117	0.039**
RENC	-0.405	0.396	-1.023	0.311
TENC	0.032	0.063	0.509	0.613
CCOR	0.052	0.052	2.125	0.047
REGQU	0.192	0.063	1.693	0.058
GOVEFF	0.235	0.359	0.852	0.138
RLAW	0.216	0.652	0.956	0.036
R-squared		0.604		
Adjusted		0.533		
R-squared				
S.E. of		9.389		
regression				
Long-run		61.044		
variance				

\*\*\* and \* indicate the level of significance at 1% and 10%

In addition, our panel Granger causality test results reported in Table 7, advanced that the variable CO<sub>2</sub> Emissions (CO<sub>2</sub>E) do not Granger cause economic growth (GDPPC), with an insignificant level. Also, the results indicate that economic growth (GDPPC) has a positive impact on the variables; EPI, INVEST, FDI, and TRADE. And, we prove a negative unidirectional relation with the variable CO<sub>2</sub> emissions (CO<sub>2</sub>E). This one isn't significant at the two levels, 1%, and 5%.

**Table 7:** Granger causality test

Null Hypothesis:	Obs	F-Statistic	Prob.
EPI does not Granger Cause ESI	84	0,0408	0.9600
ESI does not Granger Cause EPI		3,7481	0.0279**
ESISQ does not Granger Cause EPI	84	0,0678	0.9345
EPI does not Granger Cause ESISQ		2,3540	0.0862*
EPI does not Granger Cause CO <sub>2</sub> E	90	6,3572	0.0027**
RENC does not Granger Cause EPI		1,2699	0.2861
EPI does not Granger Cause RENC	62	1,3215	0.2748
EPI does not Granger Cause TENC		0,2073	0.8134
TENC does not Granger Cause EPI	84	2,8910	0.0614*
EPI does not Granger Cause RENC		0,0352	0.9654
RENC does not Granger Cause EPI	84	3,4669	0.0360**

\*\* and \* indicate the level of significance at 5% and 1%

Finally, we conclude that our results advance relationships between the variables described by:

- Unidirectional causality between EC and GDP growth and GDPSQ running from EC to growth.
- Unidirectional causality between EC and CO<sub>2</sub>E running from EPI to CO<sub>2</sub>e.
- Unidirectional causality between FDI and CO<sub>2</sub>E running from FDI to CO<sub>2</sub>e.
- Unidirectional causality between TRADE and CO<sub>2</sub>E running from TRADE to CO<sub>2</sub>e.
- No causality between INVES and EC.

#### 4. Conclusion

These findings could support development policymakers in Saudi Arabia to consider clean and

environmentally friendly investment for sustainable urban development. The results also help save the world from natural disasters and conserve the environment under sustainable development policies. It also provides a new perspective on the relationship between energy consumption, economic growth, and carbon dioxide emissions.

The results of this study may be of great importance to decision-makers and decision-makers for developing energy policies in the Kingdom of Saudi Arabia. Which contributes to reducing carbon emissions while maintaining economic growth?

Finally, this study opens new perspectives on the economy of the Kingdom of Saudi Arabia to maintain economic growth by controlling the environment from deterioration through the efficient use of energy.

#### Compliance with ethical standards

#### Conflict of interest

The authors declare that they have no conflict of interest.

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