CO2 Discharges, Consumption of Energy, and Growth of GDP in KSA: A Pragmatic Analysis

Chapter · July 2023

DOI: 10.1007/978-981-99-3878-0_58

Md. Ashraful Babu
Independent University, Bangladesh

Md. Mortuza Ahmmed
American International University-Bangladesh

Sayedul Anam
Daffodil International University

CO_2 Discharges, Consumption of Energy, and Growth of GDP in KSA: A Pragmatic Analysis

Md. Ashraful Babu, Md. Mortuza Ahmmed, Sayedul Anam, and M. Mostafizur Rahman

Abstract In this study, we inspect the consequences of energy utilization and CO_2 discharges on GDP growth in Kingdom of Saudi Arabia (KSA) during the period 1971–2014. The Granger causality test is employed to assess the short-run and long-run relationships among these variables. The result shows that a strong bi-directional association between utilization of energy and financial growth at the 5% level of significance in KSA. The other variables have independent relationships to each other. The results of our experiments clearly indicate that consumption of energy performs a noteworthy role in the basis of GDP growth in KSA. The Kingdom of Saudi Arabia could improve GDP growth by increasing energy consumption but reducing CO_2 emissions.

Keywords CO_2 emission · Energy consumption · GDP growth · Granger causality · Cointegration

Md. A. Babu (✉)
Department of Quantitative Sciences, International University of Business Agriculture and Technology, Dhaka 1230, Bangladesh
e-mail: ashraful388@gmail.com

Md. M. Ahmmed · M. M. Rahman
Department of Mathematics, American International University—Bangladesh (AIUB), Dhaka 1229, Bangladesh
e-mail: mortuza123034@gmail.com

M. M. Rahman
e-mail: mostafiz.math@aiub.edu

S. Anam
Department of Business Administration, Daffodil International University, Birulia, Dhaka 1216, Bangladesh
e-mail: anam.ba@diu.edu.bd

N. Chaki et al. (eds.), *Proceedings of International Conference on Data Analytics and Insights, ICDAI 2023*, Lecture Notes in Networks and Systems 727,
https://doi.org/10.1007/978-981-99-3878-0_58

1 Introduction

CO_2 discharges, consumption of energy, and growth of GDP are currently being discussed by researchers worldwide. In the twenty-first century, CO_2 emissions are a challenging issue caused by energy consumption and are mainly generated through the usage of petroleum, natural gas, and coal. Energy uses is the major criterion in the rapid economic growth in rich and emerging countries. But CO_2 emission is responsible for nearly two-third of total greenhouse gas emissions [1].

Presently, it is likely impossible to attain sustained economic growth except expanding energy use, which causes greenhouse gas emissions. Developed and developing countries have recommended that to reduce global warming, developed countries should raise funds, as the current heating is concerned a consequence of greenhouse gas releases by rich countries. This is partially relevant to the post-Kyoto agreement on climate variation issues [2]. To lessen global warming, many national and international organizations have introduced congressional structures to mitigate the amount of CO_2 discharges. Among these structures, trading CO_2 discharges is commonly acknowledged as an essential operational market-based approach which has been grasped by numerous policymakers and governments. The approach of trading CO_2 has become known as cap and trade (C&T), where companies are allocated a bound to CO_2 emanations. If the amount of CO_2 emanations exceeds the limit, decision makers in an organization can purchase additional CO_2 emission rights [3].

In this study, we explored the causality between CO_2 discharges, energy utilization, and financial growth; the role and effect of energy usage in financial growth; and the effects of CO_2 discharges. Additionally, policy implications to reduce carbon emissions without disturbing economic development were noted. It is expected that the empirical findings obtained by analyzing the data of the KSA between 1971 and 2014, based on the methods presented in this paper, will be useful to researchers, energy users, and policymakers.

2 Literature Review

In earlier researches, researchers have mainly focused on the effect of energy utilization approaching growth of GDP [4–8]. Their investigation was based on cointegration method and the Granger causality tactic, and they inspected the linkage between energy utilization and GDP growth. More recently, Ang [9] explored the causality linkages among CO_2 discharges, energy utilization, and GDP growth from 1960 to 2000, based on the ARDL test of cointegration. They found that rise in GDP increased both energy utilization and contamination in the long-run. Also, they pointed out a unidirectional causal relation from an upsurge in energy utilization to GDP growth in the short-run. Zhang and Cheng [10] studied the relationships among GDP growth, use of energy, and CO_2 emanations in China from 1960 to 2007. In their study, they did not find that either energy utilization or carbon discharges contributed to financial progress.

Farhani and Shahbaz [11] studied the causality relations between the economic growth, electricity usage, and CO_2 discharges of 10 North African and Middle Eastern countries. They found long-run bi-directional nexus between electricity usage and CO_2 releases. Long-run estimation held the U-shaped EKC Curve hypothesis and has shown that electricity usage raises carbon emanations. Aye and Edoja [12] investigated causal link between energy uses, economic development, and urbanization between 1971 and 2014 in modern emerging-market countries. They found causal link from use of energy and urbanization to financial growth, from financial growth and urbanization to use of energy, and finally, from use of energy and financial growth to urbanization. Hundie [13] estimated the causality links between use of energy, CO_2 discharges, and GDP growth in Ethiopia from 1970 to 2014. It was found that there is a positive effect of energy usage, population, and financial growth on CO_2 emissions in the long-run, although financial growth balances an undesirable relationship with CO_2 emissions.

Nguyen [14] discovered the link between energy usage, CO_2 discharges, and financial progress from five developing nations in Central Asia for the period 1998 to 2017. They discovered that energy usage influences an optimistic correlation with GDP, while CO_2 discharges impact adversely on GDP. In addition, directional relations exist that running from GDP to energy usage and CO_2 discharges; and from energy usage to GDP in the short-run and a nexus between variables in long-run.

3 Data and Methods

There are numerous empirical research articles available on causal relationship analysis in the fields of energy usage, CO_2 emanations, and GDP growth. The aims of this study have been accomplished through broadly acknowledged cointegration and causality analysis. An empirical analysis of the investigation was carried out on data during 1971 to 2014. The utilization of energy included usage of oil, petroleum, hydro, and some other renewables. The financial growth in the KSA was measured by the indicator of GDP. In this paper, the linkage between energy uses, carbon releases, and GDP growth is estimated. The URT, cointegration, Granger causality, and ARDL with error correction models are described below.

3.1 Unit Root Test (URT)

The URT is performed to carry out an integration analysis. The main objective is to identify stationary relations among variables of time series data. An Augmented Dickey–Fuller (ADF) test has been executed to examine whether the time series data has unit root or not. The theoretical model can be written as

$$\Delta X_t = \beta_0 + \beta_1 t + \omega X_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta X_{t-i} + \varepsilon_t \tag{1}$$

Here

$\Delta = 1^{\text{st}}$ difference operator,
$\beta_0 =$ a constant,
$X_t =$ time series factors (energy utilization, growth of GDP, carbon discharges),
$\beta_1 =$ a coefficient on a time trend,
$\varepsilon_t =$ random error.

The URT is then implemented considering the null hypothesis as $H_0 : \omega = 0$ (implying X_t is non-stationary or the presence of unit root) against the alternative hypothesis $H_1 : \omega < 0$ (implying X_t is stationary or no unit root is present). The corresponding test statistic is defined as

$$\text{DF}_\tau = \frac{\hat{\omega}}{\text{se}\left(\hat{\omega}\right)} \tag{2}$$

where $\hat{\omega}$ and $\text{se}\left(\hat{\omega}\right)$ are the estimated value of ω and estimated standard error of $\hat{\omega}$, respectively.

3.2 Johansen's Cointegration Test (JCT)

Cointegration is usually applied to test correlation among variables of time series data in the long-run. Johansen's cointegration test is used to check cointegration relationships among various non-stationary data in a time series and it has two forms: the trace test and the maximum eigenvalue test. JCT has been performed to assess the presence of cointegrating vectors for certain 1st order $I(1)$ data. The test is performed through the following model:

$$X_t = \alpha + A_1 X_{t-1} + \cdots + A_p X_{p-1} + \vartheta_t \tag{3}$$

here

$X_t =$ vector of 1st order variables,
$\vartheta_t =$ vector of innovations.

Equation (3) is then becomes

$$\Delta X_t = \alpha + \Pi X_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \vartheta_t \tag{4}$$

where

$$\Pi = i = 1Ai - I \tag{5}$$

$$\Gamma_i = -\sum_{j=i+1}^{p} A_j \tag{6}$$

Following likelihood ratio tests (LRTs) are performed to verify the significance of r:

3.2.1 Trace Test

$$\text{Test statistic}: \zeta_{\text{trace}} = -N \sum_{i=r+1}^{n} \ln\left(1 - \hat{\zeta}_i\right) \tag{7}$$

here

N = size of the sample,
$\hat{\zeta}_i$ = assessed eigenvalues in descending order.

3.2.2 Maximum Eigenvalue Test

$$\text{Test statistic}: \zeta_{max} = -N \ln\left(1 - \hat{\zeta}_{r+1}\right) \tag{8}$$

3.3 Causality Test

The framework of the causal linkages between variables is analyzed by the Granger causality approach [15]. The Granger causality test is a widely applicable and interpretable method for detecting causal relationships in time series data, but alternative methods like intervention analysis, CCM, DI, TE, DBNs, and Pearl's Causal Calculus offer complementary insights and address some of its limitations. The Granger causality approach is a statistical assumption test to define whether or not the time series data are effective for forecasting one another. The Granger causality test is mainly based on a vector error correction model (VECM), which incorporates an error correction term as below:

$$\begin{bmatrix} \Delta E_t \\ \Delta G_t \\ \Delta C_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{bmatrix} + \begin{bmatrix} B_{11i} & B_{12i} & B_{13i} \\ B_{21i} & B_{22i} & B_{23i} \\ B_{31i} & B_{32i} & B_{33i} \end{bmatrix} \begin{bmatrix} \Delta E_{t-i} \\ \Delta G_{t-i} \\ \Delta C_{t-i} \end{bmatrix} + \begin{bmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \end{bmatrix} [ECT_{t-1}] + \begin{bmatrix} \xi_{1t} \\ \xi_{2t} \\ \xi_{3t} \end{bmatrix} \tag{9}$$

where E_t, G_t, and C_t are energy utilization per capita, growth of GDP per capita, and carbon emanations per capita, respectively. ECT_{t-1} is an error correction term.

4 Empirical and Analytical Results

4.1 Analytical Tools

In this study, the statistical package EViews Version 11 was utilized for analytical purposes and Microsoft Excel 2016 was used for graphical analyses.

4.2 Variables Under Study

The analyses in this study were performed through time series data on CO_2 emanations (metric tons per capita), utilization of energy (ENG) (kilograms of oil equivalent per capita), and GDP growth (annual percentage) of the KSA for the period 1971 to 2014. Figure 1 shows the trends in the selected variables during the aforesaid period. Other than the GDP growth, both CO_2 emissions and energy consumption (ENG) have shown increasing trends over the years. GDP growth has performed continuous fluctuations over the years in the KSA.

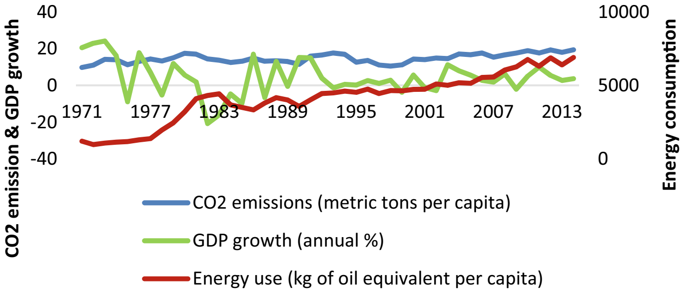

Fig. 1 Trends in CO_2, ENG, and GDP in KSA from 1971 to 2014

Table 1 Summary of descriptive statistics

	Minimum	Maximum	Mean	Standard deviation	Coefficient of variation (CV) (%)	Skewness
CO_2 emission	9.80	19.44	14.74	2.52	17.09	0.024
Energy consumption	977.75	6905.75	4136.64	1681.15	40.64	– 0.459
GDP growth	– 20.72	24.17	4.18	9.62	230.14	– 0.097

Table 2 Results of Kerl–Pearson's product-moment correlation coefficient

		CO_2 emission	Energy consumption	GDP growth
CO_2 emission	Pearson correlation	1	0.631**	– 0.029
	p-value	–	0.000	0.851
Energy consumption	Pearson correlation	0.631**	1	– 0.327*
	p-value	0.000	–	0.030
GDP growth	Pearson correlation	– 0.029	– 0.327*	1
	p-value	0.851	0.030	–

*Statistically significant at 5% level of significance (two-tailed test), **Statistically significant at 1% level of significance (two-tailed test)

4.3 Descriptive Statistics

The summery measures of the data considered for the study have been abridged in Table 1. Since the variables have different units of measurements, a coefficient of variation (CV) has been estimated to assess the amount of variation within the variables. GDP growth is observed to have the highest variation whereas CO_2 emission has the lowest variation. Data for both GDP growth and energy consumption are negatively skewed, while CO_2 data are positively skewed.

The bivariate associations between the variables have been detected by estimating correlation coefficient. Table 2 represents the corresponding outcomes.

Energy consumption has a highly significant positive correlation with CO_2 emission and a significant negative correlation with GDP growth. CO_2 emission and GDP growth have an insignificant negative correlation between them.

4.4 URT Results

Table 3 demonstrates the URT results. The *t*-statistic results for CO_2 and ENG in levels were found to be statistically insignificant, suggesting that the relevant null hypotheses should be accepted at a 5% level of significance, while a highly significant test result for GDP suggests that the relevant null hypothesis should be rejected at a

Table 3 Summary of URT

	1. No constant. no trend		2. Constant. no trend		3. Constant. Trend	
Variables	*t*	*p*-value	*t*	*p*-value	*t*	*p*-value
Augmented Dickey–Fuller URTs						
Levels						
CO_2	0.412050	0.7978	– 2.574496	0.1060	– 3.124961	0.1136
ENG	1.982811	0.9874	– 0.805535	0.8074	– 3.381299	0.0680
GDP	– 4.642543	0.0000***	– 5.070482	0.0001***	– 5.013093	0.0010***
First difference						
ΔCO_2	– 7.256120	0.0000***	– 7.271241	0.0000***	– 7.173296	0.0000***
ΔENG	– 3.576906	0.0007***	– 4.478089	0.0009***	– 4.471909	0.0050***
ΔGDP	– 11.37443	0.0000***	– 11.27009	0.0000***	– 11.22491	0.0000***

***Statistically significant at 1% level of significance

5% level of significance. Therefore, the GDP variable is said to be stationary as it has no unit root. However, the test results for the first differences in CO_2 and ENG are observed to be highly significant, indicating that these two variables are individually combined of order one and GDP is integrated of order zero. Hence, the members of the series are of different integration orders; that is, a combination of both level and first difference stationary.

4.5 Cointegration Test Results

The optimal lag order of the VAR is two, as per the Akaike information criterion. The Johansen cointegration test is not apposite here as the data have the combination of level and first difference stationary. Therefore, the F-bounds test was performed for the cointegration tests whose results are presented in Table 4. The null hypothesis of no cointegration has been rejected at a 5% level of significance as per the F-statistic value. In addition, the F-statistic value is higher than the values of I (0) and I (1) in each of the 10, 5%, and 1% levels of significance, indicating a long-run and a possible short-run association among the GDP, CO_2, and ENG.

Table 4 Summary of cointegration test

F-bounds test				
Null hypothesis	F-statistic	Significance (%)	I (0)	I (1)
No levels of CO_2 integration	6.344062	10	2.63	3.35
		5	3.1	3.87
		1	4.13	5

Table 5 Error correction model estimation

Error correction model estimation	ΔENG	ΔCO_2	ΔGDP
CointEq1	− 0.031332	7.64E−08	0.001082
	(0.0049)*	(0.9990)	(0.0002)*
	[− 2.87024]	[0.00128]	[3.84419]
ΔENG (− 1)	0.008630	− 0.001583	− 0.004920
	(0.9599)	(0.0930)	(0.2676)
	[0.05040]	[− 1.69453]	[− 1.11410]
ΔCO_2 (− 1)	− 58.76032	− 0.047246	0.913171
	(0.1307)	(0.8228)	(0.3609)
	[− 1.52255]	[− 0.22441]	[0.91745]
ΔGDP (− 1)	− 6.280729	0.008870	− 0.311898
	(0.2398)	(0.7602)	(0.0248)*
	[− 1.18187]	[0.30595]	[− 2.27570]

* Rejected at 5% level of significance
()Represents *p*-values, [] *t*-statistics, Δ first difference and (− 1) one lag value

4.6 Error Correction Model (ECM) Estimation

Even though the cointegration test suggests associations between the variables, it does not specify the direction of those associations. Hence, an estimation of ECM has been performed that emphasized the types of relationship among the variables. It is shown from Table 5 that the ECT coefficient for ΔENG is negative and statistically significant at the 5% level of significance, inferring long-run causality running from CO_2 and GDP to ENG. The following cointegration equation measures the nexus from CO_2 and GDP to ENG:

$$\begin{aligned}\Delta(\mathrm{ENG}) = &- 0.031332 * (\mathrm{ENG}(-1) - 1179.62952732 * \mathrm{CO}_2(-1) \\ &-562.817795649 * \mathrm{GDP}(-1) + 15410.1981137) \\ &+ 0.008630 * D(\mathrm{ENG}(-1) - 58.76032 * D(\mathrm{CO}_2(-1)) \\ &- 6.280729 * D(\mathrm{GDP}(-1)) + 148.8847\end{aligned}$$

4.7 Granger Causality Test

Granger causality test defines the dependencies and relationship among the variables. The analytical results of this test are demonstrated in Table 6. This shows no causal association at the 5% level of significance between energy consumption and CO_2 emission in both the long-run and the short-run; instead they have an independent

Table 6 Granger causality test

Null hypothesis	Short-run		Long-run	
	χ^2	*p*-value	*t*	*p*-values
CO_2 has no Granger causal link with ENG	2.318174	0.1279	2.62282	0.0864
ENG has no Granger causal link with CO_2	2.871422	0.0902	1.30221	0.2844
GDP has no Granger causal link with ENG	1.396814	0.2373	4.07858	0.0253*
ENG has no Granger causal link with GDP	1.241222	0.2652	3.54091	0.0395*
GDP has no Granger causal link with CO_2	0.093605	0.7596	0.50872	0.6055
CO_2 has no Granger causal link with GDP	0.841718	0.3589	1.06385	0.3557

*Represents significant at 5% level

relationship. Energy consumption and GDP show a strong bi-directional causality, whereas the energy consumption and GDP have no short-run association at the 5% level of significance. GDP and CO_2 also seem to have no causal relationship in either the long-run or short-run at the 5% level of significance; instead, they have an independent relationship.

5 Discussion

Alkhathlan and Javid [16] investigated the role of CO_2 capture and storage (CCS) in building the future energy strategy for the KSA, which can reduce CO_2 emissions accordingly. The study demonstrated that renewable energy, nuclear energy, and energy efficiency are of special interest to the KSA. The KSA also has enormous potential for underground storage of CO_2 due to a large suitable storage area. A practical policy approach for the KSA as a major oil producing and exporting country is to establish commercial commitment to CO_2 capture, shipping, and storage in an entirely integrated chain, although there are no clear official guidelines or regulatory structure for CCS. Also, many similar kind of analysis has been done in previous years indicating the impact of energy usages and economic development on CO_2 discharges for many different countries [17–19].

The results of our study clearly indicate that in the KSA the rise in energy consumption has accelerated economic growth and, similarly, the rise in economic growth has accelerated energy consumption, without any severe consequences owing to CO_2 emission.

Energy is used in a variety of areas in industry as well as domestically. So, it is important to improve energy stability by enhancing energy efficiency. CO_2 emissions cause different types of air pollution, resulting in environmental issues such as the greenhouse effect, climate change, acid rain. Accordingly, an increase in CO_2 emissions can cause ill health and damage to the planet.

The efficient use of energy demonstrates an important role in sustainable economic development. More useful and efficient uses of energy could improve economic performance measures such as GDP growth, inflation rates, unemployment rates. In addition, economic growth spurts occur in different countries at different rates according to Nguyen [14].

6 Conclusion

We studied the linkages between energy usage, CO_2 emanations, and financial growth through the Granger causality test over the years 1971–2014 in this study. The F-bound test for cointegration has demonstrated a long-run and a possible short-run association amongst the variables. However, according to the Granger causality test, it was noticed that energy utilization has a strong bi-directional association with GDP, where other variables shown an independent relationship to each other. Based on the above analysis, the KSA may increase its energy usage to enhance financial growth, but it must reduce its CO_2 emanations as well. The government should introduce a policy to ensure the reduction of CO_2 emissions and upsurge the usage of renewable energy for the sake of saving the environment.

According to empirical results on linkages between energy usage, CO_2 discharges, and financial growth, different strategies to decrease carbon emissions that will not weaken economic development need to be considered. If further renewable energy is consumed, the causality amongst the variables will become weaker because renewable energy causes less CO_2 emanations. A practical policy needs to be established by developing a technological approach for CO_2 capturing, shipping, and storage in the Kingdom of Saudi Arabia.

References

1. Kaygusuz K (2009) Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey. Renew Sustain Energy Rev 13:253–270
2. Lee SR, Yoo S-H (2016) Energy consumption, CO2 emissions, and economic growth in Korea: A causality analysis. Energy Sources Part B Econ Planning Policy 11(5):412–417. https://doi.org/10.1080/15567249.2011.635752
3. Daryanto Y, Wee HM, Widyadana GA (2019) Low carbon supply chain coordination for imperfect quality deteriorating items. Mathematics 7(3):234
4. Kraft J, Kraft A (1978) Relationship between energy and GNP. J Energy Dev 3(2):401–403
5. Cheng BS, Lai TW (1997) An investigation of co-integration and causality between energy consumption and economic activity in Taiwan. Energy Econ 19(4):435–444
6. Stern DI (2000) A multivariate cointegration analysis of the role of energy in the US macro economy. Energy Econ 22(2):267–283
7. Paul S, Bhattacharya RN (2004) Causality between energy consumption and economic growth in India: a note on conflicting results. Energy Econ 26(6):977–983
8. Wolde-Rufael Y (2005) Energy demand and economic growth: the African experience. J Policy Model 27(8):891–903
9. Ang JB (2007) CO2 emissions, energy consumption, and output in France. Energy Policy 35(10):4772–4778

10. Zhang XP, Cheng XM (2009) Energy consumption, carbon emissions, and economic growth in China. Ecol Econ 68(10):2706–2712
11. Farhani S, Shahbaz M (2014) What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO2 emissions in MENA region? Renew Sustain Energy Rev 40:80–90
12. Aye GC, Edoja PE (2017) Effect of economic growth on CO2 emission in developing countries: evidence from a dynamic panel threshold model. Cogent Econ Finance 5(1):1379239
13. Hundie SK (2018) Modelling energy consumption, carbon dioxide emissions and economic growth nexus in Ethiopia: evidence from cointegration and causality analysis. Turkish J Agric Food Sci Technol 6(6):699–709
14. Nguyen AT (2019) The relationship between economic growth, energy consumption and carbon dioxide emissions: evidence from Central Asia. Eurasian J Bus Econ 12(24):1–15
15. Granger CW (1969) Investigating causal relations by econometric models and cross-spectral methods. Econometr J Econometr Soc 37:424–438.
16. Alkhathlan K, Javid M (2013) Energy consumption, carbon emissions and economic growth in Saudi Arabia: an aggregate and disaggregate analysis. Energy Policy 62:1525–1532
17. Pao H-T, Tsai C-M (2010) CO2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy 38:7850–7860. https://doi.org/10.1016/j.enpol.2010.08.045
18. Wang SS, Zhou DQ, Zhou P, Wang QW (2011) CO2 emissions, energy consumption and economic growth in China: a panel data analysis. Energy Policy 39:4870–4875
19. Tamba JG (2017) Crude oil production and economic growth: evidence from Cameroon. Energy Sources Part B Econ Planning Policy. https://doi.org/10.1080/15567249.2015.1101511