Energy and CO_2 emissions in the Gulf Cooperation Council region

Mohammed Al-Mahish

Department of Agribusiness and Consumer Science,
College of Agriculture and Food Science,
King Faisal University,
Al-Ahsa, Saudi Arabia
Email: malmahish@kfu.edu.sa

Abstract: This paper evaluates the factors that cause environmental contamination in the Gulf Cooperation Council (GCC) region through carbon dioxide (CO_2) emissions. The paper conducts qualitative analysis by focusing on the IPAT equation and quantitative analysis using panel data methods. The results of the qualitative analysis show that political factors, such as wars and unrest, affect the environmental quality in the GCC region. The results of comparative static analysis show that the increase in population, GDP, and energy production increase CO_2 emissions. Through panel regression methods, we fail to reject the null hypotheses as suggested by the comparative static analysis, hence the paper concludes that population, GDP, and energy supply cause environmental pollution in the GCC region.

Keywords: GDP; Kuznets environmental curve; panel regression; IPAT.

Reference to this paper should be made as follows: Al-Mahish, M. (2021) 'Energy and CO_2 emissions in the Gulf Cooperation Council region', *Int. J. Energy Technology and Policy*, Vol. 17, No. 1, pp.1–11.

Biographical notes: Mohammed Al-Mahish is an Assistant Professor in the Department of Agribusiness and Consumer Science, College of Agriculture, King Faisal University, Saudi Arabia.

1 Introduction

Clean environment and good environmental quality are non-tangible goods that a citizen of any country should have. Having a contaminated environment causes a lot of illness, such as cough, asthma, and other respiratory diseases. These diseases associated with bad environmental quality increase healthcare costs for both government and individuals living in a country. Thus, it is necessary to have good environmental quality.

The primary purpose of this paper is to analyse the environmental quality of the Gulf Cooperation Council (GCC) Region because these countries are producers of fossil fuel and its derivatives, and rely on natural gas and petroleum in generating electricity. Also, GDP and per capita income in the GCC region are high, which may influence pollution since high income increases demand for food and services. The environmental contamination associated with petroleum production is high in the GCC region.

Therefore, the purpose of this paper is to qualitatively and quantitatively analyse carbon dioxide (CO_2) emissions as a proxy for environmental pollution, in the GCC region.

2 Literature review

Lane (2011) analysed the linkage between CO_2 emissions and economic development and found that economic expansion, in the form of GDP, increases CO_2 emissions. In arriving at these findings, the author regressed GDP on emissions data and found a clear connection between economic energy output and CO_2 emissions.

Sinha and Mehta (2014) analysed India's energy growth and CO_2 emissions, finding that GDP growth affects CO_2 emissions and environmental Kuznets curve ensures the interaction between income level and environmental degradation.

Azlina et al. (2014) studied the relationship between energy use, income, and CO_2 emissions. The findings showed that the u-shape inverted Kuznets curve hypothesis does not entirely agree with theory, and there is a long- term relationship between energy use, income, and CO_2 emissions.

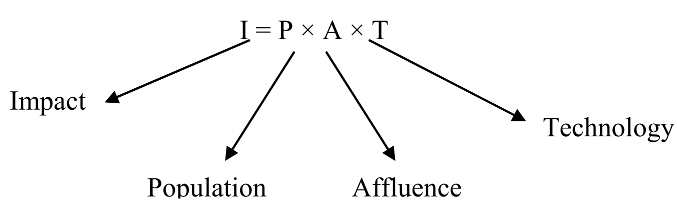
Farhani et al. (2014) examined the relationship between CO_2 emissions, GDP, energy consumption, and trade in Tunisia. They found that real GDP, squared GDP, energy consumption, and trade cause CO_2 emissions.

Kasman and Duman (2015) used the panel data method to analyse the causal relationship between energy consumption, CO_2 emissions, economic growth, trade openness, and urbanisation on a panel of new European country members and candidates. Their findings support the environmental Kuznets curve hypothesis: they found a u-shaped relationship between environment and income. Thus, CO_2 emissions increase with income, stabilise, and then decrease. Also, they found that the amount of CO_2 emissions will not decline soon, so long as the economic output is increasing.

3 Qualitative analysis

An excellent method of analysing CO_2 emissions and the effect of other factors that contribute to CO_2 emissions is through an equation called IPAT. The IPAT equation can be explained in Figure 1.

Figure 1 Definition of IPAT abbreviation



The equation states that the impact on the environment is simply the product of population, affluence, and technology. Population, by hypothesis, conversely affects the environment; a country with a large population will consume and demand more goods and services than a country with a small population. The negative externality inflicted by the large population will affect the environment through CO_2 and other greenhouse gas emissions.

Affluence represents the income per capita or GDP per capita. On the other hand, technology is considered by many analysts to be the primary component of the IPAT equation since green and advanced technology will reduce emissions and a backward technology will increase emissions.

The IPAT equation that will be analysed in this paper is the IPAT in its operational expression (Hamilton and Turton, 2002; Chertow, 2001) with CO_2 emissions as follows:

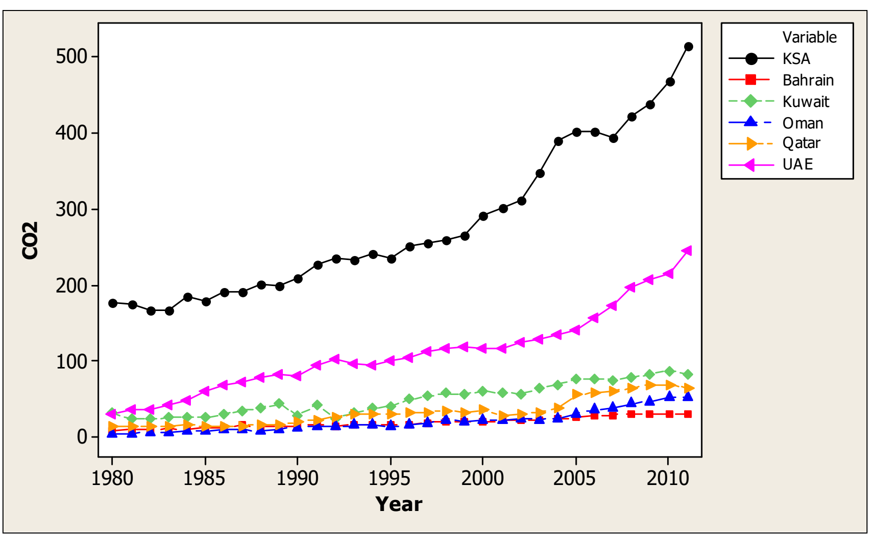
$$CO2 = \frac{CO2}{FOSS}\frac{FOSS}{TPES}\frac{TPES}{TFC}\frac{TFC}{GDP}\frac{GDP}{POP}POP \quad (1)$$

The equation has been expressed in terms of CO_2 since every single term will cancel out, except CO_2. This equation will be the skeleton of this paper and each of its factors will be analysed for its impact on the environment. The sample of this study includes the GCC countries. GCC consists of Saudi Arabia, United Arab Emirates (UAE), Bahrain, Oman, Qatar, and Kuwait.

4 CO_2 emissions of GCC countries

CO_2 emissions of GCC countries from 1980 to 2011 is illustrated in Figure 2.

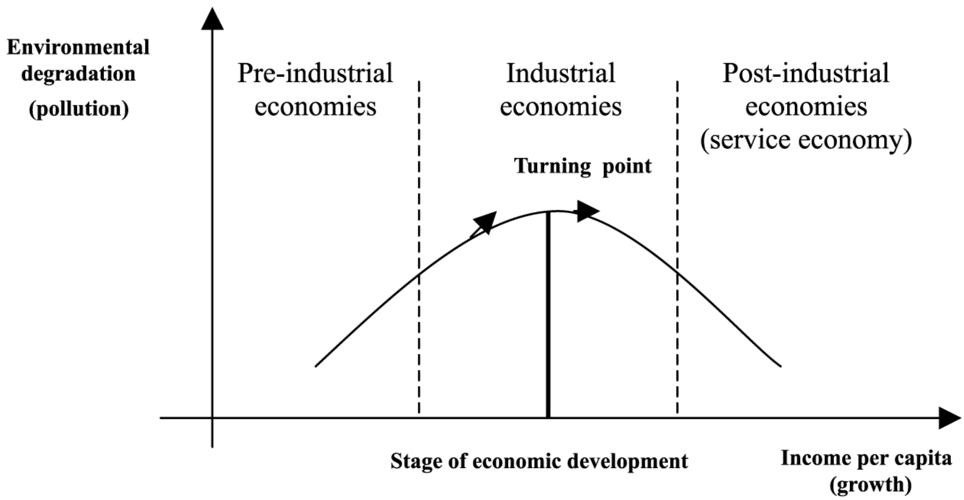
Figure 2 CO_2 emissions (million metric tons) in GCC countries (see online version for colours)



From Figure 2, it is clear that Saudi Arabia has the highest CO_2 emissions among other GCC countries, followed by the UAE, Kuwait, and Qatar, respectively. Bahrain and Oman share almost similar emissions. For Saudi Arabia to be the largest emitter among other GCC countries is not surprising because Saudi Arabia has more land and a larger population compared to other GCC countries. Also, Saudi Arabia was ranked as the second biggest crude oil producer and biggest petroleum liquids producer in the world in 2010 (EIA, 2012; Liu et al., 2012).

The critical point that should be noted here is the relationship between income increase and CO_2 emissions. As mentioned by Arrow et al. (1995), when income increases, environmental emissions increase then start to decrease, which leads to the u-shape Kuznets environmental curve. This can be attributed to countries at the beginning of economic development, when little attention is given to environmental quality. However, after high standards of living have been achieved, people start to appreciate the environment and spend more money on environmental quality (Arrow et al., 1995). This fact is illustrated in Figure 3.

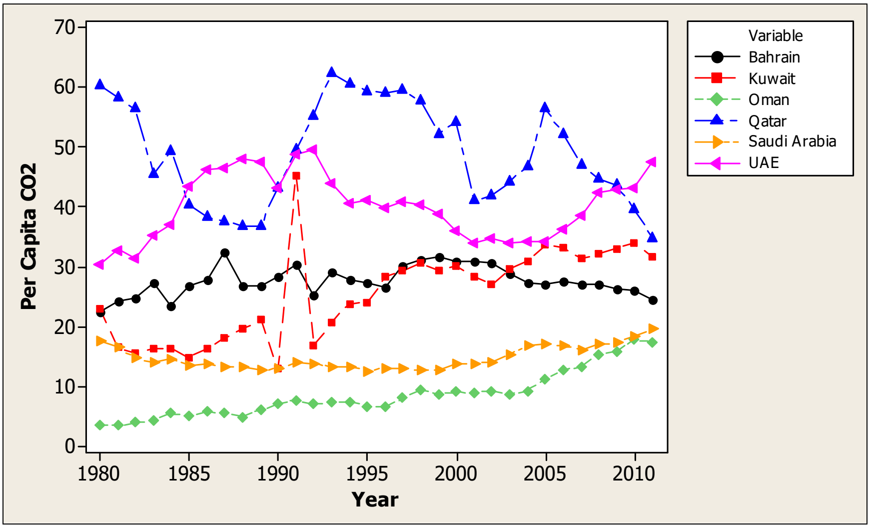
Figure 3 Kuznets environmental curve



Source: Panayotou (1993)

CO_2 emissions in Saudi Arabia were constantly increasing, since 1993 until 2007. Then it plunged to 392.7 million metric tons compared to 402 million metric tons in 2006, which can be clearly seen in Figure 2. This can be attributed to King Abdullah's decision, following his coronation as a King in 2004, to increase public employees and retired employees in both public and private sectors by 15%. A similar scenario happened in Qatar when salaries increased in 2009, which lead to an increase in emissions in 2010 (68.2 million metric tons), followed by a reduction in CO_2 emissions in 2011 (64.4 million metric tons). On the other hand, the UAE's CO_2 emissions seem insensitive to salary increase; when Sheikh Khalifa became the ruler of the UAE in 2004, he increased the salaries of all public employees. Another salary increase was given in the UAE in 2008 to some public employees, which again had not affected the increasing CO_2 emissions of the UAE. The increasing emissions in the UAE can be attributed to the mega infrastructure and tourism projects that the UAE have been implementing, which include Dubai Metro, an extension of Dubai Airport, Khalifa tower, the Palm Islands, and many big hotels and conference centres. Another explanation could be that the receivers of the salary increase in the UAE were only UAE citizens. According to the UAE National Bureau of Statistics report, UAE citizens in 2010 represented 13% of the total population. Figure 4 shows the per capita CO_2 emissions in the GCC countries.

Figure 4 Per capita CO_2 emissions in the GCC (see online version for colours)



Surprisingly, from Figures 2 and 4, it can be concluded that Oman has the lowest CO_2 emissions, whether by total emissions or by per capita emissions. Politically, the ruler of Oman, Sultan Qaboos, has been the ruler of Oman since 1970. Conversely, the rulers of the other GCC countries have changed during the timeframe of this study. Also, Oman relied more on subsidy in combating inflation while other GCC countries relied more on salary increases as a means to offset inflation.

In Kuwait, CO_2 emissions decreased in 1990 to 28.8 million metric tons compared to 43 million metric tons in 1989. The decrease in emissions in 1990 in Kuwait can be explained by the migration of the population from Kuwait when Iraq invaded Kuwait. As a result, fossil fuel consumption (FOSS) in Kuwait reached its lowest level in Kuwait history. In 1991, following the end of Gulf War and withdrawal of Iraqi army from Kuwait, CO_2 emissions increased again, which was due to the Iraqi Army's action to burn oil wells prior to their withdrawal. In 2003, CO_2 emissions in Kuwait increased by 13% when Kuwait was the starting point for the coalition forces to invade Iraq.

In Bahrain, unlike other GCC countries, the coronation of King Hamad in 1999did not affect CO_2 emissions, which was increasing at a very low rate from one year to another. However, CO_2 emissions decreased in 2011 after a constant increase in the past years. The decrease in CO_2 emissions could be a result of the government's decision to declare a state of emergency following a massive demonstration in 2011. Furthermore, Bahrain is considered to be one of the best tourist destinations in the GCC. Tourists refrained from visiting Bahrain during and shortly after the end of demonstration due to concerns of political unrest. As a result, the decline in the numbers of visitors to Bahrain may be a good cause for the decrease in CO_2 emissions.

5 IPAT component analysis for GCC

The components of the IPAT equation were defined by Hamilton and Turton (2002) are expressed as below:

- $\frac{CO2}{FOSS}$ is CO_2 intensity showing the CO_2 intensity of fossil fuel combustion.
- $\frac{FOSS}{TPES}$ is the fossil fuel intensity effect revealing the reliance on fossil sources in generating energy.
- $\frac{TPES}{TFC}$ is the conversion efficiency effect reflecting the amount of energy that is needed for final consumption.
- $\frac{TFC}{GDP}$ is the energy intensity effect. It measures the efficiency of energy use and economic structure.
- $\frac{GDP}{POP}$ is the growth effect, which can be interpreted as a measure of income/economic output per capita.

POP is population effect, which measures the impact of population growth.

Before analysing the above components, it will be interesting to first start by highlighting the growth rate of each factor in the above equation during the timeframe this paper is focused on (1980–2011) for GCC countries.

Table 1 IPAT's components' growth rates

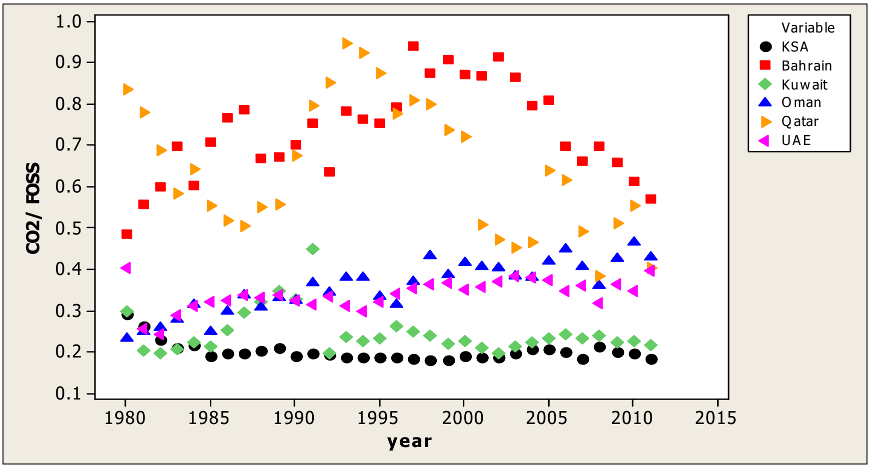
Factor	*KSA*	*Bahrain*	*Kuwait*	*Oman*	*Qatar*	*UAE*	*Total*
CO_2	190%	283%	162%	1,230%	365%	710%	2,940%
FOSS	362%	224%	261%	617%	864%	724%	3,052%
TPES	17%	148%	55%	348%	600%	112%	1,280%
TFC	411%	305%	191%	1,269%	408%	1,438%	4,022%
GDP	358%	845%	462%	1,070%	2,090%	700%	5,524%
POP	205%	249%	89%	155%	707%	415%	1,821%
Total	1,543%	2,055%	1,221%	4,689%	5,035%	4,098%	

As shown in Table 1, the highest growth in CO_2 emissions is in Oman and the lowest is in Kuwait. Qatar is ranked first in terms of FOSS growth and energy supply growth. The UAE achieved the highest growth in energy consumption, which can be attributed to the mega developmental projects that were implemented in the UAE. The highest increase in GDP has been attained in Qatar. Also, Qatar is ranked first compared with other GCC countries in terms of aggregate growth in all of the mentioned six factors.

The IPAT equation components will be graphically analysed to compare the environmental performance of the GCC countries.

Figure 5 shows a scatterplot of the CO_2 intensity effect in the GCC region.

Figure 5 CO_2 intensity effect in the GCC region (see online version for colours)



It is clear from Figure 5 that Bahrain and Qatar have the largest CO_2 intensity effect during the timeframe of this study, which can be attributed to the growth rate of FOSS.

Figure 6 Fossil fuel intensity effect in the GCC region (see online version for colours)

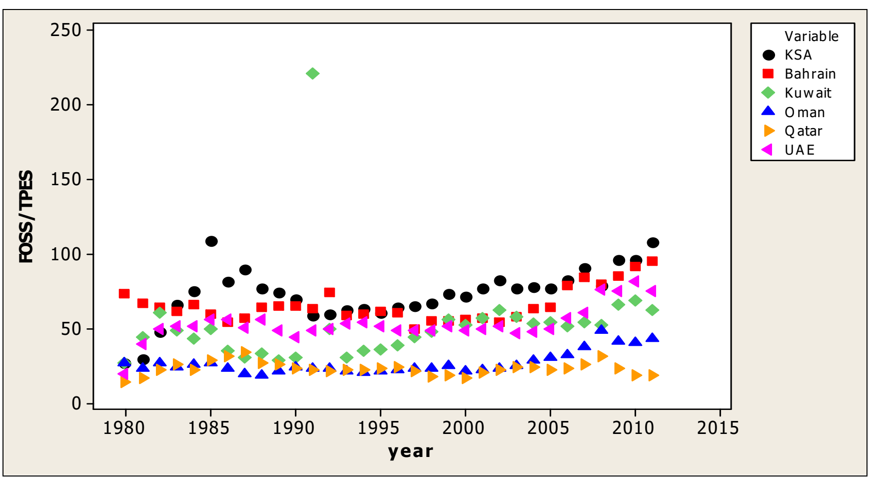


Figure 6 shows that Saudi Arabia has the highest proportion of total energy obtained from fossil sources. As mention in British Petroleum (BP) Statistical Review of World Energy report in 2011 and Liu et al. (2012), the energy mix of Saudi Arabia consists of 62% oil and 38% gas. Therefore, the BP report provides a good explanation for the increase in Saudi Arabia fossil Fuel intensity effect due to its reliance on fossil sources in energy generation. Moreover, it can be seen from Figure 6 that in 1991, Kuwait had unusual observation in fossil fuel intensity effect, which can be justified by the Gulf War, when Iraq invaded Kuwait.

Figure 7 Conversion efficiency effect in the GCC region (see online version for colours)

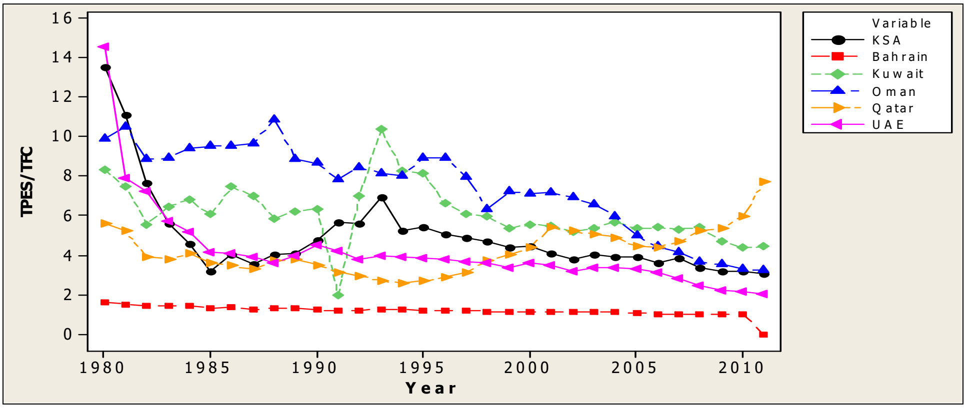


Figure 7 shows that most of the GCC countries' conversion efficiency effect is volatile. However, the conversion efficiency effect in Bahrain is flat and stable over the period of this study (please note that the conversion efficiency effect of Bahrain in 2011 is missing).

Regarding energy intensity effect, almost all GCC countries have similar energy intensity effect, except Saudi Arabia, which has higher trends compared to other GCC countries, which could be caused by the higher TFC than other countries.

In terms of growth effect, Qatar and the UAE have the highest growth effect compared to other GCC countries due to the growth rate of GDP and low proportion of citizens in total population.

It is important to note that during the timeframe of this study, the prices of energy for consumer and industrial users were highly subsidised by governments of the GCC countries. Al-Mahish (2017) indicated that the subsidy rate in the GCC, in general, is well above 50%. Thus, the supported energy prices in the GCC have encouraged industrial and personal users to increase their consumption. As a result, the CO_2 emissions resulting from energy consumption have increased. However, starting from 2017, the GCC countries have reformulated their energy policies and reduced their energy subsidy with an aim to liberate energy prices and link it to international prices.

6 Model

Before starting econometrics analysis, it would be ideal to come up with a theory to help establish testable hypotheses. Thus, comparative static analysis will be used to derive testable hypotheses.

Let the demand for energy products and services be a function of CO_2 emissions, GDP, and population. Supply of energy products and services are assumed to be a function of energy supplied and CO_2 emissions.

$$\begin{aligned}&\text{Demandfor energy products and services}\\&=\mathrm{D}(\mathrm{CO2},\mathrm{GDP},\mathrm{pop})\left(\mathrm{D}_{\mathrm{GDP}}>0,\mathrm{D}_{\mathrm{pop}}>0,\mathrm{D}_{\mathrm{CO2}}<0\right)\end{aligned} \tag{2}$$

$$\text{Supplyof energy products and services}=\mathrm{S}(\mathrm{CO2},\ \text{energy})\left(\mathrm{S}_{\text{energy}}>0,S_{\mathrm{CO2}}>0\right) \tag{3}$$

The equilibrium point is found where $Q_d = Q_s$ or equivalently when excess demand equals zero as shown below:

$$D(CO2, GDP, pop) - S(CO2, energy) = 0 \tag{4}$$

Then the implicit function rule is used to find comparative static derivatives as shown below:

$$\frac{\partial CO2}{\partial GDP} = \frac{D_{GDP}}{D_{CO2} - S_{CO2}} > 0 \tag{5}$$

$$\frac{\partial CO2}{\partial pop} = \frac{D_{pop}}{D_{CO2} - S_{CO2}} > 0 \tag{6}$$

$$\frac{\partial CO2}{\partial energy} = \frac{S_{energy}}{D_{CO2} - S_{CO2}} > 0 \tag{7}$$

Thus, the above comparative static results will serve as the hypotheses of this paper. Based on these comparative static results, we expect the increase in GDP, population, and energy supply to increase CO_2 emissions. Since the data of this paper is panel data consisting of six countries, panel regression methods will be used to examine the effect of GDP, population, and energy supply on CO_2 emissions. The estimated panel regression model is expressed as below:

$$CO2_{it} = a_i + \beta_1 GDP_{it} + \beta_2 pop_{it} + \beta_3 energy\ supply_{it} + U_{it} \tag{8}$$

The data for GDP and population (which includes total residents)were obtained from the World Bank and data for total energy supply, and CO_2 were obtained from the International Energy Agency (IEA).

7 Results and discussion

Table 2 shows the estimated parameters of equation (8) using the Pooled OLS, random effect, and fixed effect methods.

Table 2 Estimated parameters of panel regression model (8)

Variables	*Pooled OLS*	*Fixed effect*	*Random effect*
GDP	0.0004***	0.0003***	0.0003***
	(19.31)	(17.15)	(17.99)
POP	6.237***	10.253***	10.085***
	(10.45)	(16.93)	(17.18)
TPES	3.764***	1.133**	1.165**
	(6.25)	(2.07)	(2.17)
R-square	0.97	0.98	0.95

Notes: ***Significant at the 1% level, **significant at the 5% level.
Values in parentheses are t-ratios.

The GDP variable has been scaled by one million in order to express the GDP in a million dollars. Thus, the regression results concerning the GDP should be multiplied by one million to measure the actual effect of GDP on CO_2 emissions. The results in Table 2 are consistent with the comparative static derivatives hypothesis in that they have the same signs, as shown in the comparative static derivatives (5), (6), and (7).

In order to select the optimal estimator, we tested the fixed effect model using the F-test. The F-test for no fixed effect is significant at the one percent level. Thus, there is no fixed effect and we should consider the random effect model. Then the Breusch-Pagan test was used to test the random effect model, and the results were significant at the one percent level. Thus, the random effect model is the optimal model in this case and it will be used in interpreting the regression results.

A unit increase in the GDP of GCC countries will cause CO_2 emissions to increase by approximately 300 metric tons. Furthermore, a one-unit increase in population increases CO_2 emissions by 10.09 metric tons. A one quadrillion BTU increase in the energy supply increases CO_2 emissions by 1.16 metric tons.

8 Conclusions

The IPAT equation and each of its components have been analysed in this paper for the GCC countries. It was showed that the Kuznets Environmental curve U-shape assumptions hold for Saudi Arabia, Bahrain, and Qatar. This is because the salary increases in these countries first caused the CO_2 emissions to increase and then the emissions to decrease. Conversely, in the UAE, the CO_2 emissions continued to increase and did not decrease even after the salary increase, which is interpreted mainly by the proportion of the receivers of the salary increase; most of the beneficiaries of the salary increase were citizens and citizens represent a small proportion of the population (approxamtly13%). Furthermore, several mega infrastructure and development projects were implemented in the UAE that may be another cause for the increasing CO_2 emissions. Also, the paper demonstrated how wars affected Kuwait CO_2 emissions and the fossil fuel intensity effect. The largest FOSS growth and energy supply growth were in Qatar. The UAE was the first in total final consumption of energy compared with other GCC countries. Concerning the CO_2 intensity effect, Saudi Arabia was the lowest and Qatar and Bahrain were the highest.

This paper uses comparative static hypothesis to derive testable hypotheses. The results of the comparative static hypotheses show that population, GDP, and energy supply increase CO_2 emissions. As a result, we used panel regression methods to compare static hypotheses. Panel model selection results show that the random effect method is the appropriate method in this paper. The panel regression results showed that we fail to reject the null hypothesis of the comparative static analysis, and the paper concludes that the increase in GDP, population, and energy supply increases CO_2 emissions.

Acknowledgements

The author would like to thank Dr. Radi Tawfiq and two anonymous reviewers for their helpful comments, which have enhanced the quality of the manuscript. Also, the author would like to thank Victoria J. Tice for professional English language editing and proofreading.

References

Al-Mahish, M. (2017) 'The impact of energy subsidy on nitrogen fertilizer producers in the GCC', *Applied Econometrics and International Development*, Vol. 17, No. 2, pp.99–118.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S. and Pimentel, D. (1995) 'Economic growth, carrying capacity, and the environment', *Ecological Economics*, Vol. 15, No. 2, pp.91–95.

Azlina, A.A., Law, S.H. and Mustapha, N.H.N. (2014) 'Dynamic linkages among transport energy consumption, income and CO2 emission in Malaysia', *Energy Policy*, Vol. 73, No. 10, pp.598–606.

Chertow, M.R. (2001) 'The IPAT equation and its variants', *Journal of Industrial Ecology*, Vol. 4, No. 4, pp.13–29.

Energy Information Administration (US) (EIA) (2012) *Annual Energy Review 2011*, Government Printing Office, Washington DC.

Farhani, S., Chaibi, A. and Rault, C. (2014) 'CO_2 emissions, output, energy consumption, and trade in Tunisia. *Economic Modelling*, February, Vol. 38, pp.426–434.

Hamilton, C. and Turton, H. (2002) 'Determinants of emissions growth in OECD countries', *Energy Policy*, Vol. 30, No. 1, pp.63–71.

Kasman, A. and Duman, Y.S. (2015) 'CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis', *Economic Modelling*, Vol. 44, No. C, pp.97–103.

Lane, J.E. (2011) 'CO_2 emissions and GDP', *International Journal of Social Economics*, Vol. 38, No. 11, pp.911–918.

Liu, H., Tellez, B.G., Atallah, T. and Barghouty, M. (2012) 'The role of CO 2 capture and storage in Saudi Arabia's energy future', *International Journal of Greenhouse Gas Control*, November, Vol. 11, pp.163–171.

National Bureau of Statistics (2010) *National Bureau Population Estimation 2006–2010*, United Arab Emirates, Abu Dhabi.

Panayotou, T. (1993) *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*, No. 992927783402676, International Labour Organization, Geneva, Switzerland.

Petroleum, B. (2011) *BP Statistical Review of World Energy*, London, UK.

Sinha, A. and Mehta, A. (2014) 'Causal analysis of India's energy-led growth and CO_2 emission (1960–2010)', *Indian Journal of Economics and Business*, Vol. 13, No. 1, pp.81–89.