Assessment of environmental implications of energy consumption towards sustainable development in G7 countries

Bright Akwasi Gyamfi*, Murad A. Bein*, Festus Victor Bekun**,***, Sarpong Steve Yaw* and Xuan Vinh VO****

*Faculty of Economics and Administrative Sciences, Cyprus International University, Nicosia, North CyprusVia Mersin 10, Turkey. Email: brightgyamfi1987@gmail.com Email: muradabdurahmanb@gmail.com Email: stevesarp414@gmail.com

**Faculty of Economics Administrative and Social sciences, Istanbul Gelisim University, Istanbul, Turkey. Email: fbekun@gelisim.edu.tr

***Institute of Business Research, University of Economics Ho Chi Minh City, Vietnam. Email: fbekun@gelisim.edu.tr

****Institute of Business Research and CFVG, University of Economics Ho Chi Minh City, Vietnam. Email: vinhvx@ueh.edu; vnvxvinh@yahoo.com

Abstract

Following universal debate for energy sources and sustainable development across the globe, with its far-reaching implications on the environment, this crusade aligns with the United Nations Sustainable Development Goals (UN-SDGs). The study variables are based on the SDGs-7, 8, and 13 that highlights access to clean energy, sustainable economic growth and mitigation of climate change issues. Awareness of environmental sustainability has received much consideration because of the hazards associated with climate change issues in recent times. Studies on environmental quality and pollution emissions (CO_2) are becoming increasingly interesting. It is reported that human activities and increasing economic issues resolve environmental-related challenges. In the light of this, we assess how employment moderates energy consumption and climate change for G7 countries. We utilise panel co-integration and long-run regression using dynamic ordinary and fully modified ordinary least squares to institute the magnitude of long-run elasticity among the outlined variables. Panel heterogeneous techniques are used to detect the direction of causality for the annual data from 1990 to 2016. The empirical result shows a clear significant correlation between variables and the long-run relationship between pollutant releases and energy utilisation, employment and real output. The study finds an inverse relationship between trade and pollutant emissions, thus suggesting that openness trade mitigates against environmental degradation in the sampled blocs. The causality analysis reveals a bidirectional causality between emissions and employment and a unidirectional causality between emissions,

[Correction added on 8 August 2021, after first online publication: Affiliations for Festus Victor Bekun and Xuan Vinh VO have updated in this version.]

real GDP, energy utilisation and trade. These results have far-reaching outcomes on environmental fronts and economic growth highlighted in this study.

1. Introduction

Environmental climate studies on sustainability and degradation create a great deal of interest and debate in energy and environmental economics literature. Ecofriendly waste and environmental improvements are the subjects of several studies in different disciplines. Environmental Kuznets curve (EKC) hypothesis is a key approach embraced for analysing the part of harsh economic events associated with pollution or environmental change (Heidari *et al.*, 2013; Anatasia, 2015; Kalayci and Koksal, 2015; Owusu and Asumadu-Sarkodie, 2016; Emir and Bekun, 2019; Gyamfi *et al.*, 2021b). Previous studies (Istaiteyeh, 2016; Ozcan and Ari, 2017; Bekun and Gyamfi, 2020; Gyamfi *et al.*, 2021a) further address the extension of the EKC model in a form that includes energy utilisation in contamination and environmental revolution. There is literature supporting the role of energy usage and macroeconomic participation in ecofriendly pollutants and improvements in climatic conditions across nations. Nevertheless, there are two forms of EKC identified through the literature review, namely U-shape and inverted U-shape. This phenomenon is widely applied in countries and the debate on which one applies to which country or economy is still inconclusive in the extant literature.

The current study concludes that economic stakeholders are the most likely to increase ecofriendly pollution and environmental improvements in energy-consuming areas (Gyamfi *et al.*, 2021b; Katircioglu *et al.*, 2020), financial sector (Jalil and Feridun, 2011; Cetin and Ecevit, 2017) and tourism activities (Lee and Brahmasrene, 2013; Sarpong *et al.*, 2020). Such studies show that by investing in the services sector, including education, finance and tourism, there are major enhancements in the energy division of the country in the form of an increase in energy use and that they have a growing effect on pollution and climate change. In addition, some proposed studies prove that perhaps the effect of these economic factors on the energy industry through pollution and environmental change needs to be discussed in the light of future studies (Katircioglu, 2014). Some researchers also assume that energy use in countries is driven by economic agents (Kaitibie *et al.*, 2016; Gyamfi *et al.*, 2020). The growth of manufacturing, which leads to job creation, urbanisation movements and the number of houses and the country's population, determines the energy needs that result in higher energy consumption (Baloch *et al.*, 2021). Furthermore, the study of Ahmed *et al.* (2019) supports the outcome of the partnership involving pollutants and urbanisation commencing the perspective of Indonesia.

Cetin and Ecevit (2017) argue that developments in the manufacturing sector add much to employment, but other sectors such as tourism, education, finance and banking have growing energy demand. Such industries are Jobs Creation Avenue, enhance fiscal development in nations and, at the same time, become an indicator of increased income development and, in the long run, become a high level of energy utilisation.

Empirical outcomes from the combination of energy utilisation and sustainable development resulting from employment, education, tourism and other income-raising activities for countries attract significant attention in the past decades (Ozturk, 2010; Kapusuzoğlu, 2014; Anatasia, 2015). Other studies establish a major influence of the energy intake on actual production. A high level of employment, which raises the primary level of output in the manufacturing and industrial sectors, is the key determinant of energy consumption in diverse nations. Dagher and Yacoubian (2012); Tiwari (2014); Bozoklu and Yilanci (2013); Zhang *et al.* (2019); and Ulucak and Khan (2020) are among the current authors who mention the important impact of real production on energy consumption.

In addition, most researchers are making a great deal of effort in economic development or in sectors that contribute a great deal to energy consumption. The key driving force behind energy consumption is work, which is the main contribution resource. Furthermore, Jalil and Feridun (2011) develop a connection between the financial-sector and energy usage. Meanwhile, Lee and Brahmasrene (2013) build up a connection between energy use and tourism growth among European Union (EU) countries. Their findings are that the tourism and financial sectors are contributing significantly to the construction of houses on a large scale and hotel buildings. Moreover, they also conclude that visitors to a destination country also require certain goods and services such as transportation and electrical equipment for their services in these host countries, leading to the increase in the economic circumstances of the receiving country's citizens. It would allow additional resources to be added to the country's economy, resulting in a substantial increase in overall energy consumption by fuel oil and electronic usage, among others. Sadorsky (2011) believes that foreign trade is a regent to understanding the total energy intake of the Middle East, which is similar to the study of Narayan and Smyth (2009).

Shahbaz *et al.* (2014) consider 91 states with different levels of income and state that U cooperates between free trade and energy use in high countries, while U cooperates in middle and low countries, utilising a board of 91 countries. Additionally, Shahbaz *et al.* (2014) find a bidirectional cause-and-effect relation regarding trade accessibility and energy usage. Bourmpoula *et al.* (2015) argue that according to ILOSTAT statistics, labour is a branch of economic activity. If people get a job, their lifestyle changes because of the change in their income. For instance, they can buy cars, build new homes, buy additional fuel or use energy. All this new equipment would add to the potential of the agriculture, manufacturing and services sectors due to rising energy consumption in the countries. Getzner (2002) determines that the acceptance of renewable machinery would make a significant contribution to the three pillars of maintainable expansion (economic, environmental and public benefits), while, at the same time, improving the well-being of people serving as a medium for job creation also increases energy use by producing more CO_2 emissions.

As a result, with the current research question, it is very fitting to create an empiric correlation between job creation and other energy elements and environmental degradation and global warming. Whether job creation substantially promotes the increased use of fuel oil, resulting in pollution or global warnings or not.

1.1. Motivation and originality of the study

The existing literature on energy-emission growth nexus is very scanty and inconclusive in results. Few studies usually evaluate the whole energy usage but only give credence to a narrow source of energy consumption. These studies do not consider the aspects of employment to reflect on the contribution of the labour force in environmental issues. For exmaple, Shahbaz and Farhani (2014) merely consider electricity energy utilisation and pollutants in the MENA region. The influence of the labour force on the environment is not taken into account as an imperative factor of economic development and well-being in the MENA region. Also, Ahmad and Zhao (2018) study the connection regarding energy use, pollution in addition to economic development without focus on the effects of employment on the Chinese economy.

Our study demonstrates power from the income emission-induced environmental degradation hypothesis anchored on the linear compromise between carbon dioxide release and income level advanced by Simeon Kuznets (1955) which in the energy literature is the trade-off between income level and environmental degradation (Apergis and Ozturk, 2015). Energy utilisation and global trade flow have been identified as key drivers of pollution release.

This study leverages the EKC phenomenon (linear version) on the inverse relationship between GDP growth and environmental quality (Stern, 2004). Global energy need contributes to environmental status especially those energy sources from fossil fuel origin which seems to be the most accessible among energy mix. To this end, the current study advances the linear trade-off between GDP growth trajectory in G7 using an augmented carbon-income function that accounts for the role of employment, trade flows, energy mix and GDP growth in the G7 blocs. Thus, the present examination pursues to seal this gap by accounting for employment concerning the connection regarding energy use, emissions and output in the G7 states. The economic provision of this research is the effect of job rate on global warming for the G7 countries including the United States of America, the United Kingdom, Japan, Italy, Germany, France and

Canada. Data[1] indicate that all of the mentioned countries are among the top 25 releasing the most CO_2 in the world (1970–2017). The United States is the second country that produces the most CO_2 emission with 5269.3 million metric tonnes; Japan stands at the fifth position with 1205.1 million metric tonnes, followed by German with 799.4 million metric tonnes of CO_2 production. Canada is placed at the tenth position with 572.8 million metric tonnes while the United Kingdom has produced 386.3 million metric tonnes and is ranked seventeenth on the list, followed by France with a total of 356.3 million metric tonnes. Finally, Italy has produced 355.45 million metric tonnes of CO_2 emission and is ranked 21st on the list.

The research shows that these countries are highly industrialised, explaining the reason why they generate so many emissions. The industrial sector is one of the sectors that contribute greatly to reduce the unemployment rate of which the aforementioned countries are not an exception. Therefore, this study is aimed to support this debate and extend the proposition that the energy-emission nexus is highly correlated with the employment sector and policymakers could benefit in their employment policy direction within the energy sector as a result. The World Bank's statistical data index reveals that at the end of 2018, Canada's overall employment is 4.5 per cent, France witnesses 4.2 per cent of total jobs, Germany has 4.3 per cent of total employment, Japan has 2 per cent, the United States has 2.5 per cent, and the United Kingdom has 2.4 per cent of total GDP employment.

In conclusion, those countries which are highly industrialised and enjoy high GDP levels tend to face issues with CO_2 emission generated by the employed percentage of the total population. The authors consider the degree to which the energy sector contributes to employment within the G7 countries and suggest policies to tackle the pollution menace in the bid to contribute to the clean environment concerning Agenda 2030 of the International Environmental Agency (IEA). The authors believe that this is among the very first papers conducted using the background of G7 countries. The results of such a study are intended to help scholars and policymakers besides expanding the current energy literature studies.

2. Materials and method

2.1. Conceptual construction

The debate of this study is that job levels are a key factor in economic development as well as in the energy sector, which is itself significantly influenced by changes in the environment as a result of such a rise in energy usage. The energy sector provides great opportunities for job creation as the work within the sector is labour-intensive. The energy growth literature proves that employment thrives on energy consumption which results in high levels of employment for a wider number of people leading to improved growth.

As all these countries are developed countries, their economies are dominated by industrialisation and imported fuel oil, and they are essential for the sustainability in oil industries, fiscal activities and public actions; they make trade liberalisation a major driver not only for the industries but also for the people who, using this liberalisation and high production efficiency, can do so.

In reality, global climate change is also frequently described as greenhouse gas (CO_2) pollution in the energy/environmental science literature (see Cetin and Ecevit, 2017). The general fiscal trend is seen as a significant factor not only for electricity needs but also for the use of oil in electricity economics research (Heidari *et al*., 2013). The authors claim that growth in the production of more job opportunities for citizens of a nation has an important outcome on the use of fuel oil in such a world that the G7 countries are not left out of business and industry. This study leverages a balance and annually annual frequency data from 1990 to 2016[2]. The study applies the emission of carbon dioxide (CO_2) (kilotonnes of solid, liquid and gas fossil fuel combustion, gas flaring and cement production) as a dependent variable. The control variables used are actual gross domestic product (GDP) per capita (calculated in 2010 USD), energy consumption (non-renewable energy use referred to as EC) in the kilogram of oil equivalent per capital shall be calculated in the form of an initial energy source before alteration into another end use, employment (total employment as a percentage of modelled ILO estimate denoted as EMP) and trade as a percentage of GDP as denoted as TRD. **Table 1** reports the summary of the data description.

Table 1 Data description

Name of variable	Meaning	Code	Sources
Employment	Employers, total (% of total employment) (modelled ILO estimate)	EMP	WDI
CO_2 emission	CO_2 emissions (metric tonnes per capita)	CO_2	WDI
Energy consumption	Fossil fuel energy consumption (% of total)	EC	WDI
Economic growth	GDP per capita (constant 2010 US$)	GDP	WDI
Trade	Trade (% of GDP)	TRD	WDI

Source: Authors compilation.WDI denotes the World Development indicators, the World Bank database. Employment (EMP) as a percentage of total employment modelled ILO estimate, CO_2 emissions calculated in metric tonne per capital, energy consumption (EC) is the fossil fuel energy utilisation as a percentage of total GDP and gauged in the form of initial energy source alternation into the end use, gross domestic product (GDP) per capita (measured in constant 2010USD), and trade (TRD) is trade percentage of GDP.

2.2. Model estimation

From the available studies, the observation of the nexus of non-renewable energy usage is the form of energy utilisation with carbon dioxide emissions (CO_2). Thus, the present study draws empirical strength (Shakouri and Khoshnevis Yazdi, 2017; Dogan and Inglesi-Lotz, 2018; Bekun *et al*., 2019a; Kakinaka and Nguyen, 2019). In addition, total employment percentage is incorporated to replace resource rent (rent) as in the study of Bekun *et al*. (2019b):

$$CO_2 = f(\text{GDP, EMP, TRD, EC}), \tag{1}$$

$$\text{LnCO}_{2_{it}} = \alpha_0 + \beta_1 \text{LnGDP}_{it} + \beta_2 \text{LnEMP}_{it} + \beta_3 \text{LnTRD}_{it} + \beta_4 \text{LnEC}_{it} + \varepsilon_{it}. \tag{2}$$

The data series proof-of-constant variance and logarithmic transformation are estimated in the study.

Here, $\text{LnCO}_{2_{it}}$, LnGDP_{it}, LnEMP_{it}, LnTRD_{it} and LnEC_{it} represent the logarithmically transformed variables that are dependent against the independent variables. α denotes the terms which are intercept and β is the slope coefficients or parameters to be estimated.

Consequently, three estimation techniques are utilised in this research, fully modified least square (FMOLS), dynamic ordinals least square (DOLS) and the ordinals least square (OLS). Althought, interestingly, the DOLS can rectify for correlation between the dependent variable and the stochastic term, which also adds lags of the independent variables. Before the valuation of relationship estimation, we conduct the unit root test of the outlined variables to ascertain the stationarity properties of the variables and avoid the pitfall of spurious regression.

The DOLS is estimated using Equation (2) which is given as:

$$\begin{aligned} \text{LnCO}_{2_{it}} &= \mu_i + x_{i,t}\Psi_{i,t} + \sum_{j=-p}^{p} \beta_j \text{LNCO}_{2_{i.t-j}} + \sum_{j=-q0}^{q0} p_{1.j} \text{LNAVAGDP}_{i.t-j} \\ &+ p_{2.j} \sum_{j=-q1}^{q1} \text{LNEC}_{i.t-j} + p_{3.j} \sum_{j=-q2}^{q2} \text{LNGDP}_{i.t-j} + \varepsilon_{it}. \end{aligned} \tag{3}$$

p and q are the numbers of leads/lags. The long-run relationship is assessed from the FMOLS equation given as:

$$\text{LnCO}_{2_{i,t}} = \mu_{i,t} + x_{i.t}\psi + v_{it}, \tag{4}$$

$$x_{i.t} = x_{i.t} + \mathfrak{C}_{i.t},$$

where x 5*1 vector of explanatory variables is, μ_i is the intercept, while $\mathfrak{C}_{i.t}$ and v_{it} are the error terms. However, the estimation of ψ is expressed as (**Fig. 1**):

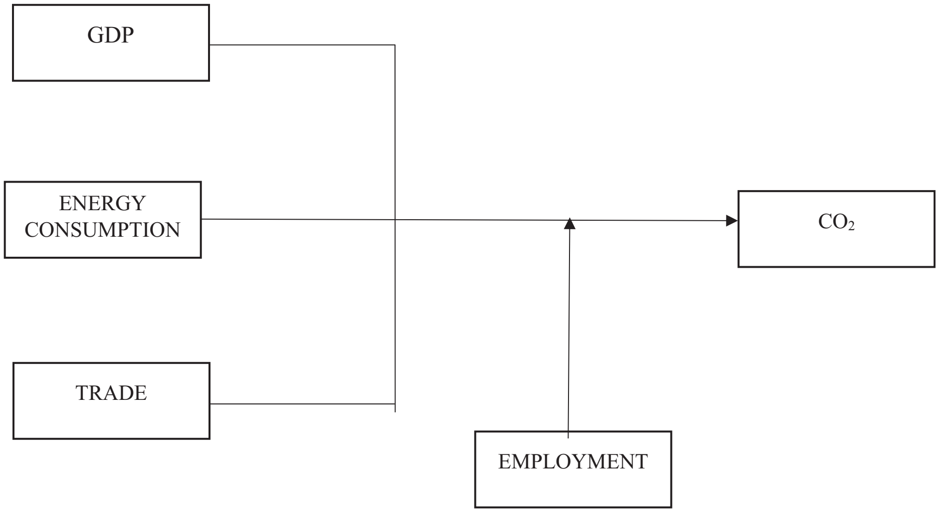

Figure 1 The moderating role of employment in the energy-emission growth nexus.

$$\hat{\psi}_{\mathrm{FMOLS}} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{i.t} - \bar{x}_{i.t}) \times (x_{i.t} - \bar{x}_{i.t})' \right)^{-1} \times \left(\sum_{i=1}^{N} \left(\sum_{t=1}^{T} (x_{i.t} - \bar{x}_{i.t}) \times \widehat{\mathrm{LNCO}}_{2_{it}} - T\hat{\Delta}_{v\varepsilon} \right) \right). \quad (5)$$

The current study empirical tests are fourfold. Firstly, the test is to recognise the integration of the data through testing of the unit root properties. Secondly, the test is to identify the co-integration properties of the outlined variables of interest in the long run. Thirdly, we use the panel approach to test for the significance of the variable relationship among each other by applying the ordinal OLS, DOLS and FMOLS. Finally, a causality test is carried at last to detect the direction of causal relationship among the variables.

Preliminary basic summary statistics and correlation analysis of the underlined variables are reported in **Tables 2** and **3**, respectively. The summary statistics of Table 2 shows that economic development (GDP) exhibited the highest average over the sampled period, followed by energy consumption. All investigated series show light tail as reported by Kurtosis except energy utilisation with more than 3. Subsequently, Table 3 presents the correlation matrix which reveals that all investigated series are correlated either positively/negatively. For instance, we observe a statistically significant relationship between CO_2 emission and energy consumption likewise between GDP and CO_2. All this and more has its implication. However, correlation analysis only shows the pairwise relationship between outlined indicators; as such, there is a need to conduct more analysis to either accept or refute the level of relationship. The present study proceeds to conduct more econometrics analysis accordingly in the rest section.

Table 2 Statistical summary

	CO_2	EC	EMP	GDP	TRD
Mean	10.7946	79.1036	4.3366	40,130.47	48.3565
Median	9.4484	83.2155	4.3650	39,794.64	50.1751
Maximum	20.1788	94.6333	7.3280	54,579.02	88.6708
Minimum	4.5732	46.2259	1.9750	27,992.39	16.0139
Std. Dev.	4.4902	12.3701	1.5200	5764.874	18.2438
Skewness	0.7323	−1.4077	0.4635	0.2341	0.0496
Kurtosis	2.1629	3.9514	2.2211	2.3889	2.3090
Jarque–Bera	24.0728	74.7050	12.3996	5.012876	4.1216
Probability	0.0000	0.0000	0.0020	0.0816	0.1274

All variables are within their form of level.

Table 3 Pearson correlation application

	CO_2	EC	EMP	GDP	TRD
CO_2	1				
EC	0.2850***	1			
P-value	0.0000	—			
EMP	−0.1800***	−0.0710	1		
P-value	0.0098	0.3091	—		
GDP	0.4000***	−0.0270	−0.5000***	1	
P-value	0.0000	0.6989	0.0000	—	
TRD	−0.2190***	−0.2770***	0.4120***	−0.0460	1
P-value	0.0020	0.0001	0.0000	0.5085	—

It is the correlation coefficient of Pearson that the variable from the table is reported. The marginal probability is denoted as *P*-value from the table above.
***, ** and * are 1%, 5% and 10% significant rejection level respectively.

2.3. Unit root estimation

To maintain the presumption of the logarithmic interaction of time series, it is vital to check for stationarity. The unit root is important to achieve the full order of incorporation before moving to the long-run co-integration approach. The general form of the root equation of the unit is given as:

$$\Delta Y_i = \beta_1 + \beta_2 + \beta_3 + \beta_4 + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_t \Delta Y_{i-t} + \varepsilon_t. \quad (6)$$

As ϵ_t contains Gaussian white noise, which is believed to have an average value of zero, potential autocorrelation represents a sequence to be regressed at time t.

3. Empirical results

The null concept of the unit root is focused on the essential quality towards the stationary option for Dickey–Fuller (ADF) (Dickey and Fuller, 1988) and Phillips–Perron (PP) (Phillips and Perron, 1988). Both individual intercept, individual and trend for PP and ADF are reported under the unit root test. It is identified that the variables are not motionless at a level but become stationary when the first difference integrated of zero is found. Consequences for the unit root estimation are presented in **Table 4**.

3.1. Co-integration estimation

When all variables are combined of order one, the presence of a long-term connection regarding pollutants as well as their predictors is tested utilising two-panel co-integration tests recommended by Pedroni (1999, 2004) and Kao (1999) for a panel data set of G7 nations.

Exhibitions of the quantitative findings of the Pedroni panel co-integration study in **Table 5** are split into dual categories: within-dimensional method in addition to between-dimensional approach. The opening category of the within-dimensional method comprises of four statistics which are panel V-statistics, panel Rho-statistics, panel PP-statistics and panel ADF-statistics; however, the last comprises of group Rho-statistics, group PP-statistics and group ADF-statistics. The null theory is rejected by five statics with co-integration assumptions except for panel V-statistics and group Rho-statistics for all example nations. In particular, most statistical studies reject the invalid theory of non-co-integration at the correlation coefficient points. The findings of the Pedroni panel co-integration test indicate a long-term association among all parameters.

In contrast, the Kao residual co-integration test (Kao, 1999) is, however, conducted as a substitute to validate the presence of co-integration as a consequence of the Pedroni co-integration test. **Table 6** proves that we reject the invalid theory, which points out that there is co-integration at a 5 per cent significant level. This result is consistent with the results of the Pedroni panel co-integration test, which confirms the presence of a long-term relationship among variables.

3.2. Long-run relationships

After establishing the possibility of a long-run equilibrium connection using both the Kao (1999) and Pedroni's (2004) co-integration tests, we apply the ordinary least squares (OLS), dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) approaches of Pedroni (2001, 2004) to identify the long-run springiness of pollutants emissions for employment, real GDP, non-renewable energy usage in the form of energy intake and trade liberalisation. The findings from the panel OLS, DOLS as well as FMOLS approximations in **Table 7** show that all the variables have reliable

Table 4 Unit root test result

Unit root test result table (ADF)

At level

		$LNCO_2$	LNEC	LNEMP	LNGDP	LNTRD
$\pi\tau$	*t*-Statistic	0.8544	0.9851	0.6797	0.9243	0.8600
	Prob.	0.5908	0.9613	0.9990	0.3006	0.6864
$\pi\vartheta$	*t*-Statistic	0.0000	0.2148	0.0011	0.0028	0.6029
	Prob.	0.5928	0.7276	0.8932	0.8830	0.2842

At first difference

		$\Delta LNCO_2$	ΔLNEC	ΔLNEMP	ΔLNGDP	ΔLNTRD
$\pi\tau$	*t*-Statistic	0.0000**	0.0001	0.0035***	0.0000***	0.0009***
	Prob.	0.0002	0.0385	0.0000	0.0237	0.0000
$\pi\vartheta$	*t*-Statistic	0.0000***	0.0004	0.0013***	0.0000*	0.0057***
	Prob.	0.0016	0.1272	0.0000	0.0728	0.0000

Unit root test table (PP)

At level

		$LNCO_2$	LNEC	LNEMP	LNGDP	LNTRD
$\pi\tau$	*t*-Statistic	0.7214***	0.9168	0.7949	0.9707	0.8506
	Prob.	0.0001	0.9664	0.9999	0.3189	0.5778
$\pi\vartheta$	*t*-Statistic	0.0044***	0.1359	0.2707	0.0006	0.6029*
	Prob.	0.0006	0.3733	0.9562	0.8830	0.0600

At first difference

		$\Delta LNCO_2$	ΔLNEC	ΔLNEMP	ΔLNGDP	ΔLNTRD
$\pi\tau$	*t*-Statistic	0.0000	0.0001***	0.0034***	0.0000**	0.0009***
	Prob.	0.1723	0.0047	0.0000	0.0225	0.0000
$\pi\vartheta$	*t*-Statistic	0.0000	0.0004**	0.0013*	0.0001*	0.0056***
	Prob.	0.5528	0.0172	0.0283	0.0588	0.0003

***, ** and * are 1%, 5% and 10% significant level, respectively; thus, $\pi\tau$ is with constant, and $\pi\vartheta$ is with constant and trend.

Table 5 Co-integration estimation finding by Pedroni (2004)

	Within-dimension			Between-dimension	
	Statistic	*P*-value		Statistic	*P*-value
No deterministic trend					
Panel V-stat	1.3231*	0.0929	Group Rho-stat	−0.5791	0.2812
Panel Rho-stat	−1.147323	0.1256	Group PP-stat	−7.9556***	0.0000
Panel PP-stat	−4.1109***	0.0000	Group ADF-stat	−5.6010***	0.0000
Panel ADF-stat	−4.1494***	0.0000			
Deterministic intercept and trend					
Panel V-stat	0.9379	0.1742	Group Rho-stat	0.2020	0.5800
Panel Rho-stat	−0.1271	0.4494	Group PP-stat	−11.5077***	0.0000
Panel PP-stat	−3.6513***	0.0001	Group ADF-stat	−5.3135***	0.0000
Panel ADF-stat	−3.2329**	0.0006			
No deterministic intercept or trend					
Panel V-stat	−0.5554	0.7107	Group Rho-stat	0.6346	0.7372
Panel Rho-stat	0.4909	0.6883	Group PP-stat	−5.0732***	0.0000
Panel PP-stat	−1.1059	0.1344	Group ADF-stat	−3.0014***	0.0013
Panel ADF-stat	−1.2016	0.1148			

Variables are considered not to be co-integrated by accepting the null hypothesis. *, ** and *** are denoted by statistical significant at 10%, 5% and 1%, respectively.

Table 6 Kao's co-integration test results

	t-Statistic	Prob.
ADF	−2.2611**	0.0119
Residual variance	0.0011	
HAC variance	0.0008	

Variables are considered not to be co-integrated by accepting the null hypothesis. *, ** and *** denote statistical significant at 10%, 5% and 1%, respectively.

outcomes in terms of the indication and significance and are statistically meaningful at 1 per cent.

Thus, the results are assumed to be tough and accurate for inferential statistics. All the findings prove a positive relationship regarding emissions from pollutants and energy consumption, employment and real GDP in the long run, whereas proof-of-negative association is shown among releases from pollutants and trade openness. The panel DOLS shows that there is an elasticity of emissions from CO_2 and the development of

Table 7 Long-run results

	EC	EMP	GDP	TRD	*R*-square
OLS	0.5833***	−0.0348	0.0560	−0.2071***	0.2121
P-value	0.0000	0.6737	0.3746	0.0033	
DOLS	1.6021***	0.5975***	0.2469***	0.0237	0.9961
P-value	0.0000	0.0000	0.0035	0.5556	
FMOLS	1.3644***	0.4070***	0.0606	0.0089	0.9848
P-value	0.0000	0.0001	0.5041	0.8344	

*, **, *** denote rejection of null hypothesis at 10%, 5% and 1% significant level.

sustainability, showing a 0.25. It indicates that a 1 per cent increase in the sustainable expansion shows that emissions from CO_2 increase by 0.25 per cent, which approves the reality of the environmental Kuznets curve (EKC) theory in the G7 nations. The positive sign of real GDP shows the EKC existence and it implies that, in the meantime, the development of the economy increases pollutants from CO_2 to some level before it falls and affirms the observation from the studies of Shahbaz and Farhani (2014), Bölük and Mert (2015), Ben Jebli *et al.* (2016), Zafeiriou and Azam (2017), Shabani and Shahnazi (2019). This result implies that the G7 countries experience increased levels of emissions from increased economic growth unless it reaches a point where the economy can withstand the shocks of emissions through advanced technological changes which can handle reduced emissions. It is also observed from Table 7 that non-renewable energy intake has a noteworthy positive effect on releases in all three estimations, including OLS, DOLS and FMOLS. From the analysis, it is observed that, from the panel OLS technique, a 1 per cent rise in energy utilisation gives a rise in emissions from CO_2 by 0.58 per cent. On the other hand, analysis from the DOLS, we can conclude that there is a 1 per cent rise in energy usage by 1.6 per cent. Lastly, from the FMOLS estimation, a 1 per cent increase in emission from CO_2 boosts energy usage by 1.36 per cent. The outcomes are consistent with studies of Shahbaz and Farhani (2014) and Al-Mulali *et al.* (2016) which proves that energy intake in the form of non-renewable shows ecofriendly filth. In the case of employment, the significant levels are at DOLS and FMOLS. It is clear that as employment increases by 1 per cent in the DOLS technique, emissions from CO_2 increase by 0.60 per cent, and as to employment increase by 1 per cent in the panel FMOLS technique, emissions from CO_2 increase by 0.41 per cent. The same findings can be found in the studies of Dagher and Yacoubian (2012), Bozoklu and Yilanci (2013), Tiwari (2014) that as the employment rate increases, the energy intake also increases. This shows that the employment percentage of the total population within the G7 countries still uses more of fossil fuel in their normal activities.

3.3. Heterogeneous panel causality test

Upon determining a long-term elasticity among the variables, it is essential to determine whether the causality is detected throughout the short run. To this end, we adopt the use of Dumitrescu and Hurlin (2012) causality analysis to explore the causality relationship among the highlighted variables over studies period. The causality analysis is pertinent for policy crafting and formulation. The crucial aspect of this approach is that it accepts all correlation variables to be stationary, which are cross-sectional variations.

The approximation from **Table 8** confirms a bidirectional causality among employment and emissions from CO_2, which all are significant at a 1 per cent level. There is proof-of-unidirectional causality among emissions from CO_2 and real GDP at a 5 per cent significant level, emissions from CO_2 and trade openness at 1 per cent significant level, pollutant and non-renewable energy utilisation at a 1 per cent level.

4. Discussions

From the findings, our estimation is in line with the hypothesis and the approximations that employment rate from the total population from the G7 countries as well as non-renewable energy which is represented in the estimation as energy consumption increases emission levels. The association of the long-term restrictions with the short-term heterogonous limitation of the calculation from the econometric model will be checked if EKC occurs, suggesting the validity of the EKC theory. Our estimation reveals that real GDP has a significant positive level in the DOLS panel technique in the long run, which proves the existence of EKC theory, and in the short run, the heterogeneous causality panel technique is significant at a 5 per cent level. As real GDP rises, emission from pollutants can also rise in both the short and long run for some time

Table 8 Causality analysis

Null hypothesis	Z-bar stat.	*P*-value
LNEC $\neq$ $LNCO_2$	1.1798	0.2381
$LNCO_2$ $\neq$ LNEC	4.0287***	6.E-05
LNEMP $\neq$ $LNCO_2$	8.4500***	0.0000
$LNCO_2$ $\neq$ LNEMP	3.8482***	0.0001
LNGDP $\neq$ $LNCO_2$	2.1467**	0.0318
$LNCO_2$ $\neq$ LNGDP	1.2439	0.2135
LNTRD $\neq$ $LNCO_2$	3.4164***	0.0006
$LNCO_2$ $\neq$ LNTRD	1.4088	0.1589

*, **, *** denote rejection of null hypothesis at 10%, 5% and 1% significant level. $\neq$ means do not homogeneously cause.

before dropping, which affirms the findings of Bölük and Mert (2015), Ben Jebli *et al.* (2016), Zafeiriou and Azam (2017), as well as Shabani and Shahnazi (2019).

Furthermore, there is a significant positive effect in both DOLS and FMOLS from the employment rate of the total population. It implies that the total employment rate from the total population causes more emissions from CO_2 in the long-run and from the short-run analysis; it proves a bidirectional of 1 per cent significant level. The conclusion from the analysis is that in both the long and short run, employment percentage from the total population within the G7 countries produces many emissions from CO_2 which is significant and it affirms the findings of Dagher and Yacoubian (2012), Ozoklu and Yilanci (2013) and Tiwari (2014). The negative impact of labour is that the labour force lacks the required technological know-how to handle matters of energy consumption which inures positively to environmental health. Governments and stakeholders of the G7 countries should provide the requisite technological training for the labour force to enable them to handle today's advancement in energy use and its associated ramifications such as pollution. The results could also be as a result of poor and obsolete use of equipment and technology which are capable of producing high pollution levels.

Moreover, all three-panel techniques indicate a significant positive association between CO_2 and energy consumption. There is a clear indication that non-renewable energy which is represented as energy usage has a huge effect on ecological deprivation within the G7 countries in the long run, but it is not significant in the short run. The observation confirms the findings of Farhani and Shahbaz (2014). It is also clear that trade openness has a significant negative connection with pollutants in the long run, and there is a significant association among them at a 1 per cent level in the short run. This result implies that aggregate trade as a percentage of GDP among G7 nations and other countries is proven to have a great influence on the fight against poor environmental governance and health. Economies within the G7 obtain benefits greatly from trade liberalisation as it has impacted positively on their environment. Furthermore, the result reveals that the employment percentage of the G7 countries produce more CO_2 emission. It is, therefore, important for the governments from these countries to invest more in technologies that help the employment sector to control the use of non-renewable energy and focus more on renewable energy which is a good source of handling issues of CO_2 emission. Moreover, governments should enforce policies in the form of benefits for taxes and subsidise the investments towards renewable energy facilities or establishments. Investors who are willing to, for example, import equipment and technologies into the countries should be given the necessary assistance in this regard to cushion their effort. By doing so, the cost of energy production would be lower for investing in clean energy sources such as bioenergy, solar or wind energy. This would even encourage job creation to tackle the issue of unemployment as the energy sector for instance biomass energy is labour-intensive in the long run. There would be a necessity to preserve the existing movement in the light of the emergence of global awareness to create a maintainable world.

5. Conclusion and policy implications

The initial purpose of this research is to explore the long-run and causality relationship between energy utilisation, carbon dioxide release and GDP growth while accounting for the combined impact of employment and trade flow in the G7 countries. Empirical results show a unidirectional causality between carbon dioxide emission and the real GDP, CO_2, energy utilisation, carbon dioxide emission and trade openness. Furthermore, empirical results indicate a positive long-run equilibrium association among emissions from CO2 release and energy utilisation, emissions from CO_2 emission and total employment, emission from CO_2 emission and real GDP as well as a negative association among emissions from CO_2 emission and trade openness. It, therefore, implies that as the real GDP of the countries increases, it shows an increase in emission level in the long run. This result suggests that any shift in the level of emissions can affect the increase of fossil fuels consumed, total employment percentage of the total population and real GDP in those countries. Additionally, experimental result from causality through heterogeneous panel technique shows a bidirectional causality between CO_2 emissions in addition to employment. The outcomes also show that as employment increases, it leads to a rise in CO2 emissions. This outcome is a clear indication of the direct relationship that exists between the increased labour force and the disadvantages it has on environmental health.

It is, therefore, necessary for governments of these economies to establish effective environmental strategies that would put industries and organisations involved in carbon dioxide productions to arrest the situation of increased carbon emission levels. Moreover, an increment in energy consumption means increased emissions from CO_2 emission. This result means that industries, construction and other organisations that require higher levels of energy use are possible for candidates of producing higher CO_2 emission levels. Rules and regulations regarding quality energy use must be enforced by energy regulatory bodies in the study countries. Those organisations who are consuming higher energy levels would be checked and abided by the environmental protection regulations, thereby reducing the effects of CO_2 emissions. It is noticeable that a rise in trade liberalisation leads to a decrease in emission levels. The inference of this outcome is that percentage of exports and imports of GDP does not contribute to pollutant emission in the long run. This is because trade regulations on imports and exports are effective and good enough to check which types of good and services are being exported and imported into the countries so that they do not damage the environment by applying the polluter pays principles (PPP), a concept that stresses the need to oblige regulation(s) on those who pollute the environment subject to cost of damage on the environment, therefore, pointing to a policy implication for the countries to ensure that they hold unto the trade policies and strengthen all areas on trade so that these positive indications could be sustained. Moreover, any strategy on non-renewable energy intake leads to a disruption of the emission pattern.

As a take-home for policymakers and stakeholders, the G7 countries should continue increasing their portion of the renewable energy mix for the development towards a green environment by lessening fossil energy usage which is a precondition for environmental sustainability through reduced emissions. To accomplish steady and long-term progress in the consumption of renewable energy, stakeholders should establish and enforce strategies that promote investment in developing the existing renewable energy infrastructure.

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Ethics approval

The present study does not involve any laboratory analysis or experimentation, nor involve animals.

Conflict of interests

We wish to disclose here that there are no potential conflicts of interest at any level of this study among all authors.

Authors' contributions

B.A.G- Conceptualization, Conceived and designed of the study; M.A.G- Analyzed and interpreted the data; F.B.V- Data curation, Materials, analysis; S.S.Y- Writing – original draft, Wrote the paper; X.V.O- Professional editing and supervision. All authors read and approved the final manuscript.

Consent to participate

Not applicable.

Consent for publication

The current manuscript does not contain any image or videos from previous study that requires permission.

Data availability statement

The current study uses an open access and easily downloaded database of world banks development indicators which has been duly referenced in the related section in the manuscript.

Notes

1. www.usatoday.com
2. All data were sourced from the world bank development indicators (WDI).

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