Trade, Energy Consumption, Economic Growth and Ecological Quality: An Empirical Evidence from D-8 and G-7 Countries

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Abstract

While pursuing sustainable growth there is a need to inculcate the procedure of a sustainable environment for coming generations. This study investigates the association between carbon dioxide emissions (CO₂) and gross domestic product (GDP), disaggregate and aggregate energy usage, trade, using yearly data for the time component of 1980–2019 for D-8 and G-7 countries. The study employs second-generation unit root tests namely cross sectionally augmented Dickey Fuller (CADF) and cross sectionally augmented IPS (CIPS). Further, Kao, Pedroni, and Westerlund cointegration tests are employed to test for cointegration. To estimate models, fully modified least squares (FMOLS), dynamic ordinary least squares (DOLS) and heterogeneous panel estimators (MG, AMG, CCEMG, DCEMG) are used. Finally, to verify the causality among the study variables the Dumitrescu and Hurlin, (2012) causality test is used. The findings of the study reveal that income, aggregate, and disaggregate energy consumptions (oil, coal, gas), and trade exacerbate ecological quality in D-8 countries while income and trade improve it in G-7 economies. However, oil, coal, and gas usage are detrimental for ecological quality in G-7 economies. The study validates an inverted U-shaped environmental Kuznets curve in D-8 while U-shaped in G-7 countries. It is recommended that both groups of countries need to adopt green strategies and sustainable patterns for growth and development.

Introduction

Ecological degradation is a very primitive topic that has been under discussion since the 20th century. An increasing rate of global carbon emissions is considered the major determinant of deteriorating ecological quality. The agglomeration of CO₂ emissions in the atmosphere has intensified by almost 45 percent in the previous 130 years (Carbon footprint, 2018). **British Petroleum (2018)** highlighted that level of CO₂ emissions intensified from 29,714.2 million tons in 2009 to 33,444.0 million tons in 2017. Global climate change persistently threatening the lives and assets, thus restraining the climate changes is a concern of urgency.

Resultantly, climate change has become a momentous global concern. The implication of mitigating CO₂ for opposing the worldwide ecological changes vulnerabilities, via refining ecological conditions, has been properly recognized in the international perspective. As per the execution of the Kyoto protocol in 1997, under the United Nations Convention on climate change, has stressed curbing CO₂ emissions globally. IPCC (2018) projected that to maintain the worldwide temperature at 1.5 °C above the pre-industrial stages, the worldwide emissions have to be fetched down by about 45% from the level where it was in 2010 till 2030 and secondly, totally bump off it by 2050. According to a recent global climate risk index report, countries largely affected by climate change are mainly developing economies (Eckstein et al., 2019).

Energy is a fundamental factor used in the manufacturing course and enhancing the industrial expansion and economic progress, but the high level of energy consumption increases CO₂ emissions which further deteriorate environmental quality (Alkhatlan & Javid, 2013). In the current era, many countries are now predominantly based on the utilization of fossil fuel which include coal, oil, and natural gas and they bring severe changes in the ecological condition worldwide. The rapidity of securing energy sources leads to

intensifying the energy demand among the leading economies of the world (Munir & Riaz, 2020). Similarly, a report by **EIA (2016)** states that energy demand will grow by 50 percent projected from 2005 to 2030.

The motivation for selecting D-8 economies comes from the fact that these economies are ranked as the top economies of total ecological footprint in global hectars (**Global footprint Network, 2016**). In 1980 the level of emissions in D-8 region was 10.00 metric tons per capita (MTPC) and raised up to 27.26 MTPC in 2019. The energy usage in 1980 was 4376.30 kg of oil equivalent per capita (KOEPC) and 10589.24 KOEPC in 2019 burgeoning with the growth rate of 141.97 %. The coal consumption was 9.91 million tons of oil equivalent (MTOE) in 1980 and upsurge to 121.83 MTOE in 2019. Similarly, oil usage in 1980 was 96.12 and intensified to 320.41 MTOE in 2019 with the growth rate of 1.26 in the region. The gas usage increased from 20.49 in 1980 to 381.82 MTOE in 2019 with the growth rate of 12.42 times.

The G-7 economies represent the developed world. These economies use renewable energy resources, green technologies, with stringent rules trying to meet the path of sustainable economic progress. In G-8 region 84.42 MTPC CO₂ emission was recorded in 1980 but in 2019 the trend of emissions goes down to 66.42 MTPC and average growth during the period 1980–2019 was 0.93 %. The energy usage in 1980 was 32602.12 and 31063.40 KOEPC in 2019 and the growth rate was 0.99 %. The coal consumption was 705.72 MTOE in 1980 and slackened to 605.78 MTOE in 2019. However, the average growth rate was 0.97 %. Similarly, oil usage in 1980 was 1597.60 and reduce to 1525.88 MTOE in 2019 with the growth rate of 0.99 % in the G-8 region. The gas usage increased from 660.36 in 1980 to 1075.11 MTOE in 2019 with the growth rate of 1.07 %.

Now the economists, eco-activists, and policymakers are increasingly paying attention to analyze the associations among growth, trade, energy, and ecological degradation. To explore the association between economic development and ecological degradation famous Environmental Kuznets Curve (EKC) hypothesis states that the ecological quality starts to degrade at the preliminary level of economic development, and the quality of the environment improves as the economy grows (Grossman & Krueger, 1991).

Theoretically the effect of trade on ecological quality is not certain. As opponents argued that growth and liberalization of trade cause systematic harm to the earth's natural resources. Similarly, increasing trade flows elevate fuel consumption as it is extensively used in the energy generation and transportation. The study of Grossman & Krueger, (1995) highlighted that how foreign trade affects the ecological quality, depends on the various effects of trade on the economy it can be through scale effect, technological effect, and lastly technological effect. Scale effect claims that trade escalates the scale of yield and economic growth level, but the aftermath will be that this will intensify the level of CO₂ emissions due to more production and usage of energy. Secondly, the composition effect whereas free trade moves the country's production where it has a comparative advantage. The last technological effect says that trade can bring competitiveness, efficacy, and environment-friendly, clean technologies that will mitigate the emissions. However, it depends on the magnitude of these effects, what will be the effect of trade volume on CO₂ emissions positive or negative.

This study contributes to existing literature on ecological degradation in several ways. Firstly, this study segregates non-renewable energy sources (oil, coal, gas) consumption to explore the how these sources affect ecological quality in both regions. Moreover, the current study analyzes the impact of aggregate energy use on ecological quality as well. Secondly, the current study uses a panel data set of D-8 countries, and G-7 economies and conducted a comprehensive comparative analysis that how macroeconomic indicators (growth, trade) are contributing to ecological quality. Thirdly, the validity of EKC hypothesis is tested for both groups as well as country level. Fourthly, to deal with different econometric issues this study employs second-generation panel techniques and heterogenous panel estimators which include MG, AMG, CCEMG, DCCEMG to provide better, robust, and conclusive findings.

The research is presented as follows: Sect. 2 takes an evocative review of existing literature and section three elaborates the methodology, theoretical framework, and empirical model and section four data and variables and section five results and discussions, section six will conclude the study.

2. Literature Review

The theoretical framework for this study is based on the environmental Kuznets curve (EKC) theory which suggest that initially economic growth degrades the environment but after a certain level of growth, environmental degradation starts declining. The EKC has been substantially studied but the empirical validity of EKC is mixed. Since the pioneering work by **Grossman & Krueger (1991)**, **Holtz-Eakin & Selden (1995)**, **Narayan & Narayan (2010)**, **Ahmed *et al.* (2016)** supported inverted U-shaped relationships. Studies have typically adopted different types of data sets in analyzing the EKC hypothesis (e.g. **Panayotou, 1993**; **Apergis *et al.*, 2010**; **Kahia *et al.*, 2019**). These studies provide mixed outcomes. **Apergis *et al.* (2010)** did not confirm the hypothesis as there was a positive and linear effect of growth on emissions.

2.1 Energy Consumption and Ecological Quality

In this recent age of advancement, energy is considered an indispensable factor for economic expansion but also a vital strategic reserve for an economy. Similarly, sustainable economic progress relies on energy consumption (**Kraft & Kraft, 1978**). The study of **Ozokeu and Ozedmir (2017)** indicated that a surge in energy use will be pernicious for ecological quality in both developed and emerging states. Empirical evidence of **Majeed & Mazhar (2019b)** demonstrated the impact of energy consumption on CO₂ emissions by using data of 131 economies (1971-2017). The results suggested that energy consumption is deleterious for the environment. Similar findings have been highlighted by **Kohler, (2013)** in South Africa, and **Baek, (2015)** in Arctic economies. The study by **Dogan *et al.* (2017)** examined the nexus between energy usage and ecological degradation using data (1981-2016) of OECD economies. The results confirmed that energy consumption is a significant indicator in deteriorating ecological quality. Furthermore, the study of **kasman & Duman (2015)** on EU members economies, concluded that energy usage is detrimental for environment. The study of **Gours & Aydin (2019)** examined the causal relationships among the carbon dioxide emissions, and energy consumption. However, energy consumption cause escalation in CO₂ emissions in the case of MENA countries.

2.2 Coal, Oil, Gas and Ecological Quality

The consumption of coal, oil, and gas has escorted severe changes in the ecological condition worldwide. A report published by the *European Union Joint Research Centre*, elaborated that the combustion of fossil fuel accounted for about 90 percent of total worldwide CO₂ emissions (**Oliver et al., 2012**). Every non-renewable source either gas, coal, or oil has a calamitous effect on the environment at both levels, whether it is extraction or consumption of the resource. A report by **British petroleum (2020)** highlighted that at the global level energy usage upsurges the level of emissions by 2.3 percent. Moreover, elevation in oil consumption by 0.9 percent, gas consumption and production 2 and 3.4 percent was observed especially in emerging countries. But globally there was a reduction in coal consumption by 0.6 percent other than the case of OECD economies where a reduction in its demand was observed. The recent literature suggests that disaggregated research at regional or national levels is more felicitous (**Li et al., 2018**).

Empirical evidence supports that raising the level of oil, coal, and consumption are exacerbating ecological quality. According to a study by **Alkhathlan & Javid (2013)** using autoregressive distributive lag (ARDL) over the period from 1980-2011 analyzed that oil, coal, and gas usage are positively associated with CO₂ emissions. The study by **Khan et al. (2019)** concludes that coal, oil, and natural gas consumption escalate environmental degradation. Likewise, using the data of South Asian economies **Munir and Riaz (2019)** concluded that coal, oil, and gas usage are increasing the level of CO₂ emissions in the region. Similarly, another study by **Valadkhani et al. (2019)** examined the threshold effects of oil, coal, and gas on CO₂ emissions for the panel data set of 79 countries from 1965 to 2017. The results of the study confirmed that an increase in the consumption of oil, coal, and gas intensifies the level of CO₂ emissions. A recent study by **Munir & Riaz (2020)** investigated the impact of oil, coal, gas, and electricity consumption by applying the econometric technique non-linear autoregressive distributive lag (NARDL) for the time from 1975 to 2018 in the case of the United States of America, China and Australia on ecological degradation. The results indicate that oil, coal, and gas are significant factors in enhancing the CO₂ emissions in the USA, in Australia, oil and coal are the main contributors to escalating emissions, and lastly in china oil, and gas are key factors that increasing the level of CO₂ emissions. **Shabaz et al. (2013)** documented that coal consumption is a major factor in raising emissions in South Africa.

2.3 Trade and Ecological Quality

The famous theory of trade Hecksher-Ohlin trade recommends that if there is free trade developing economies should specialize in manufacturing and exporting those goods which are plentiful or cheap for instance labor and ample natural resources while on other hand developed nations will lead towards capital intensive affairs. Trade necessitates the transfer of goods from a country to another country. Sometimes it can be for consumption or it can be for further processing. This indicates that pollution is usually generated during production and consumption is in other countries. Now, more engagement of developing economies into foreign trade has made trade openness imperative discussion for the EKC hypothesis (**Stern et al., 1994; Lean & Smyth, 2010; Baek, 2015**).

Shafik and Bandyopadhyay (1992) recommend that an economy that is more open to trade will be less polluted. The reason is when the economies are more open, they face an advanced level of competition and they must invest in advance efficient technologies which in return leads towards lessening pollution. **Suri and Chapman (1998)** discussed the trade in both form energy-intensive and second is non-energy intensive commodities. For instance, in the case of non-energy intensive production of automobiles needs more pollution-intensive inputs. The industrialized economies usually manage by exporting those more energy-intensive goods to curtail the level of pollution. On the other hand, developing economies face the challenge of mounting pollution due to more exports of energy-intensive products. This hypothesis got more interest in the previous literature, which is known as the famous displacement or PHH hypothesis (**Kellenberg, 2009; Kearsley & Riddel, 2010**).

Trade can ameliorate and degrade ecological quality. To boost growth, production is elevated which needs more energy to bring resurgence in output and repercussion will be high emissions; it is known as scale effect. Similarly, if the process of production is more energy intensive and comprised by primary commodities, it causes more emissions and is said composition effect. Although, advanced technologies or substitution with green technology improve ecological quality and this is called technological effect (**Grossman & Krueger 1995; Antweiler *et al.*, 2001**). The study of **Zafar *et al.* 2019** concluded that trade can curb ecological degradation if the technological effect is higher than both scale and composition effect.

Secondly, a surge in exports of natural resources like coal, gas especially its extraction through conventional means, deforestation dissipates natural resources, and the repercussion will be an escalation in CO₂ emissions a worse ecological quality (**Schmalensee *et al.*, 1998**).

The empirical evidence shows mixed results, like trade may worse, improve, or may have an insignificant effect on ecological quality. In the case of developing economies, a recent study by **Van Tran (2020)** explored the repercussion of international trade on ecological quality. Two-step system Generalized method of moments (GMM) was employed for the period 1971 to 2016. Results of the study indicate that a 1% surge in trade openness leads to 0.2% proliferation in CO₂ emissions in the case of 66 developing countries. **Fang *et al.* (2019)** used the panel data set of 82 developing nations for the period from 1970 to 2014 to explore the impact of the quality of exports on CO₂ emissions utilizing the fixed effect estimation technique. **Al-Mulali & Ozturk, (2015)** employed FMOLS and investigated the reason for environmental degradation during the period 1996 to 2012 and concluded that trade damages the ecological quality in the case of 14 MENA economies. **Al-Mulali & Sheau-Ting (2014)** empirically investigated the data set of 189 countries of different regions. The study used Fully modified least square (FMOLS) for the period from 1990 to 2011. The results of the study confirmed a positive relationship between trade variables (Sum of exports of goods and services and imports) and CO₂ emissions. The study of **Salman *et al.* (2019)** using panel quantile regression validate that both imports and exports have unpropitious effects to improve the ecological quality in ASEAN economies.

Similarly, the study of **Ahemd *et al.* 2019** in the case of D-8 economies examined how exports affect the environment using panel data for the time 1980-2014. The study employed the FMOLS and the DOLS

method and the result confirmed that exports adversely affect ecological quality moreover, similar findings were concluded by **Rahman (2017)** in the case of China.

Contrary to this, studies also analyzed that trade may compact on CO₂ emissions. A study by **Jayanthakumaran et al. (2012)** explored the relationship between trade and CO₂ emissions in the case of China and India. The study used the time series data of India and China for the period from 1971 to 2007. The results of ARDL concludes that international trade tends to reduce CO₂ emissions in the short run. Furthermore, an empirical examination of the causal association between trade openness and environmental pollution was carried out by **(Ahmed et al., 2016)**. The data of BRICS economies was utilized for the time 1970-2013. The result of FMOLS confirmed that trade openness mitigates CO₂ emissions in the long run as deforestation amongst the main concern.

Aller et al. (2015) using the Three-stage least square (3SLS) technique, indicates that in low-income countries indirect effects of trade harm the ecological conditions while it improves the environmental conditions in high-income countries. In the existing literature, few studies have mixed findings. The study by **Le et al. (2016)** observed the data set of 98 countries (1990-2013) utilizing the GMM approach. The study found that trade openness is good for the environment in high-income countries, and it pollutes the environment in developing economies.

3. Methodology

3.1 Theoretical Framework

Different Studies had discussed the impact of Growth, trade, and FDI on CO₂ emissions. A study by **Grossman & Kruger (1991)**, Examined the EKC which elaborates the relationship between economic development and ecological degradation with an inverted U-Shaped curve. Previously equation used by different studies **(Holtz-Eakin & Selden, 1995; Chandran & Tang, 2013)** is as:

$$Enviromental\ degradation_{it} = f(GDP, GDP^2)_{it}$$

3.2 Empirical Model and variable Description

Generally, in existing literature, carbon emission is a proxy used for ecological degradation **(Ozturk & Acarvic, 2013; Ozokeu & Ozdemir, 2017)**. Therefore, to understand the relationship between environmental distortion and trade, growth, aggregate and disaggregate energy usage, our model specified as by **Halicioglu & Ketenci (2016)** and formulation for the impact of trade on the environment was as:

$$\ln CO_{2it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP^2_{it} + \beta_3 \ln EC_{it} + \beta_4 \ln TR_{it} + \varepsilon_t \quad (1)$$

In above eq.1 CO_{2it} is the CO₂ emissions per capita measured in Metric tons, ENRG is the energy used per capita measured in Kg of oil equivalent, GDP is per capita GDP measured in US\$ Constant 2010, GDP² is

square of GDP following the EKC hypothesis and measure of trade EXP and IMP are measured in current US\$. Since to measure estimates log-linear transformation of eq.1 is being made to make interpretation easier in percentage form.

Extensive energy usage of non-renewable sources is pernicious for the environment as well as leads economies towards an unsustainable path of development. This study will assess the association between the segregation of non-renewable energy usage namely oil, gas, and coal consumption, specified in equation 2:

$$\ln CO_{2it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP^2_{it} + \beta_3 \ln TR_{it} + \beta_4 \ln PCC_{it} + \beta_5 \ln POC_{it} + \beta_6 \ln PGC_{it} + \varepsilon_{it} \quad (2)$$

The above model is used for both in the case of D-8 and G-7 countries. Here, in eq.2 $\ln$ represents the natural log for each variable. The proxies used for ecological degradation CO₂ emissions (Kt), emissions which are originated from the consumption of fossils fuels and the production of cement, which includes the usage of gas, liquid, and solid fuels. GDP is GDP per capita constant 2010 US\$ and POC, PGC, PCC are per capita oil, gas, and coal consumption. TR is the sum of merchandise imports current US\$ and merchandise exports current US\$. All the variables collected are in per capita form except imports and exports; therefore, these two variables are divided by the respective country population to transform them into per capita form. Energy use is measured in kg of oil equivalent per capita.

3.3 Data and Econometric Tools

The data of CO₂ emissions, GDP per capita, energy consumption, trade volume (imports + exports), and the total population is retrieved from WDI while data regarding disaggregate consumption which includes oil, coal, and gas consumption is taken from British petroleum 2019. D-8 economies include Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan and Turkey. G-7 economies comprise Canada, France, Italy, Japan, United Kingdom and United States.

As the study uses panel time-series data, so different tests of panel unit root which includes Levin, Lin & Chu (LLC), I'm, Pesaran (IPS) and from second-generation unit root tests, CIPs, and CADF tests will be used to examine whether data is stationary or non-stationary (**Pesaran, 2007**). To test cointegration among variables, Pedroni, Kao, cointegration test, proposed by (**Kao, 1999; Pedroni, 1999**) and the test suggested by **Westerlund (2007)** and **Westerlund (2008)**, consider four tests that include two group stats and two-panel statistics. Furthermore, it also allows cross-sectional dependence (CD).

This study used FMOLS, and DOLS to estimates the results. It provides robust findings and efficaciously analyze the small sample size. The FMOLS and DOLS also consider the serial correlation and account endogeneity in the regressors but it does not account CD. However, unlike earlier studies, the current study control for distinct economic and econometric concerns which include (cross-sectional dependence, endogeneity, and heterogeneity) using distinct empirical approaches, thereby producing consistent and robust outcomes for policy designs. Likewise, Mean Group (*MG*) **Pesaran & smith (1995)**, Augmented Mean Group (*AMG*) (**Bond & Eberhardt, (2009)**). The study also uses the common correlated effect (*CCE*)

estimation technique proposed by **Pesaran (2006)**, and the dynamic CCE (*DCCE*) estimator developed by **(Chidik & Pesaran, 2015)**. The **Dumitrescu & Hurlin (2012)** causality test will be used to examine the causality among the variables.

The descriptive statistics of the variables are presented in Table 1. Every economy has a different level of emissions. The maximum value of CO₂ emissions in D-8 countries is 661710.2 kt in Iran in 2016 and the minimum is 7638.361 kt in 1980 in Bangladesh. In the case of G-7 economies in 2005 the highest level of emissions recorded in the United states 5789727. and minimum value in France 303275.6 kt in 2014. Moreover, the findings of the correlation matrix are presented in table 2. All the study variables are correlated as expected.

Table 1 Descriptive Statistics

D-8					
Variables	Mean	Median	Maximum	Minimum	Std. Dev.
CO₂	185341.5	149371.6	661710.2	7638.361	150563.1
GDP	3880.868	2641.154	15190.10	359.4563	3423.746
TR	98173.01	46885.00	465057.0	2889.000	116970.1
CC	7.912965	1.628328	61.55799	0.029489	12.66427
OC	31.56721	26.66520	99.88875	1.508813	23.58642
GC	25.66150	17.48450	193.9434	0.029227	30.83025
ENG	1009.207	808.1769	3060.387	104.8616	794.1035
G-7					
CO₂	1268177.	546300.5	5789727.	303275.6	1609945.
GDP	37614.37	37316.41	55753.14	21684.69	7278.636
TR	-4.685168	-4.610	-3.535	-5.993	0.592
CC	106.7910	38.934	545.740	7.600	149.034
OC	224.4586	99.799	972.722	58.512	264.211
GC	122.8966	63.857	702.600	21.132	164.085
ENG	4686.120	3946.357	8455.547	-3523.025	2020.121

Table 2 Correlation Matrix

D-8 (Model 1)						
Correlation	CO2	GDP	TR	PCC	POC	PGC
CO₂	1.000000					
GDP	0.705751	1.000000				
TR	0.257015	0.586160	1.000000			
PCC	0.625522	0.800763	0.571116	1.000000		
POC	0.695571	0.876339	0.480805	0.624072	1.000000	
PGC	0.572578	0.514499	0.535804	0.268481	0.592322	1.000000
G-7 (Model 2)						
CO₂	1.000000					
GDP	0.303563	1.000000				
TR	-0.292804	0.693358	1.000000			
PCC	0.705349	0.055085	-0.222874	1.000000		
POC	0.589361	0.239650	-0.230546	0.584300	1.000000	
PGC	0.322109	0.433350	0.354559	0.407371	0.583979	1.000000
D-8 (Model 1.1)						
	CO2	GDP	TR	ENG		
CO₂	1.000000					
GDP	0.710737	1.000000				
TR	0.628541	0.879787	1.000000			
ENG	0.754987	0.909515	0.836946	1.000000		
G-7 (Model 2.1)						
CO₂	1.000000					
GDP	0.302555	1.000000				
TR	-0.293099	0.694813	1.000000			
ENG	0.506441	0.355734	0.060423	1.000000		
Note: Here model 1 & 2 includes disaggregate and 1.1 & 2.1 aggregate energy usage.						

4. Results And Discussion

LLC and IPS unit root tests are used initially to examine the stationarity of data. Some variables are stationary at the level and some at the level. Results are presented in appendix table 1(a). cross-sectional dependence (CD) of the variables and model was also checked, and results are presented in Table 3. All test statistics are significant, confirms the presence of CD and analysis can proceed second generation unit root test.

Table 3 Cross-sectional dependence Test D-8 and G-7 Countries

Variables	BP LM	PS LM	BCS LM	Pesaran CD
D-8				
	Statistics	Statistics	Statistics	Statistics
LCO ₂	811.615***	121.994***	121.904***	28.488***
LGDP	716.445***	107.309***	107.219***	26.646***
LTR	670.777***	100.262***	100.173***	25.795***
LPCC	322.478***	46.519***	46.419***	6.232***
LPOC	375.064***	54.633***	54.543***	15.161***
LPGC	730.792***	109.492***	109.402***	26.999***
G-7				
LCO ₂	317.764***	45.791***	45.702***	12.351***
LGDP	745.981***	111.867***	111.777***	27.271***
LTR	823.558***	123.837**	123.747***	28.697***
LPCC	410.451***	60.093***	60.003***	8.536***
LPOC	446.896***	65.717***	65.627***	18.452***
LPGC	467.854***	68.951***	68.861***	19.919***
CD Test for Models				
	D-8		G-7	
	Model 1	Model 2	Model 1	Model 2
BP LM	175.837***	867.299***	176.351***	165.5672***
PS LM	23.892***	112.156***	23.971***	22.30721***
Pesaran CD	7.527***	28.779***	9.389***	9.254269***
Note: BP <i>Breusch-Pagan</i> , PS <i>Pesaran scaled</i> , BCS <i>Bias-corrected scaled</i> . Model 1 & 2 have disaggregate & aggregate energy use indicators respectively. *10% level, ** 5% level, ***1% level of significance				

Second-generation unit root tests have been used as CD is confirmed because it allows CD and heterogeneity across the panel. CIPs and CADF tests were used to examine the stationarity of data at both level and first difference. Mostly, Variables are stationary at first difference. Most of the variables are stationary at first difference.

Table 4 Panel Unit Root Test

D-8				
Variables	CADF		CIPS	
	Level	1st Difference	Level	1st Difference
LCO₂	-2.399***	-7.038 ***	-2.773 ***	-6.010 ***
LGDP	-0.598	-3.538***	-1.789	-4.154 ***
LTR	-0.743	-6.119***	-1.948	-5.328***
LPCC	-2.569 ***	-5.541 ***	-2.618 ***	-5.928 ***
LPOC	-1.323*	-6.017 ***	-1.988	-5.557 ***
LPGC	-0.933	-5.857***	-2.066	-5.036 ***
LENG	-1.174	-8.530 ***	-2.470**	-5.938 ***
G-7				
LCO₂	-0.218	-10.239 ***	-1.913	-6.021***
LGDP	-0.343	-5.424***	-1.712	-3.941***
LTR	-2.256***	-9.119***	-2.695***	-6.037***
LPCC	0.436	-8.925***	-1.672	-4.851***
LPOC	-2.730***	-6.859***	-3.327 ***	-5.122 ***
LPGC	-0.696	-7.726***	-2.250**	-5.262***
LENG	-0.819	-8.887***	-2.195	-6.064***
*10% level, ** 5% level, ***1% level of significance				

Here this study uses two prominent panel cointegration tests and the results of Pedroni, Kao cointegration tests are presented in appendix table 1(b). All the tests confirm the presence of cointegration. The Results of the Westerlund cointegration are presented in table 5. In both regions study variables are cointegrated. Panel and group test confirm the existence of cointegration. The null hypothesis is rejected.

Table 5 Westerlund cointegration Test D-8 Countries

D-8 Model 1				
Statistics	Value	Z-value	P-value	Robust P-value
G _t	-3.641	-2.18	0.013	0.000***
G _a	-15.992	0.320	0.625	0.000***
P _t	-8.904	-1.939	0.026	0.000***
P _a	-15.721	-0.706	0.240	0.000***
D-8 Model 2				
G _t	-2.540	-0.262	0.397	0.000***
G _a	-11.474	-0.512	0.696	0.000***
P _t	-5.492	0.177	0.570	0.000***
P _a	-9.110	0.068	0.527	0.000***
G-7 Model 1				
G _t	-3.874	-2.857	0.002	0.050
G _a	-15.555	0.450	0.673	0.000
P _t	-10.470	-3.394	0.000	0.000
P _a	-16.298	-0.876	0.191	0.000
G-7 Model 2				
G _t	-2.991	-1.512	0.065	0.050
G _a	-12.530	0.147	0.559	0.050
P _t	-8.477	-2.579	0.005	0.050
P _a	-13.290	-1.390	0.082	0.000
Note: Model 1 & 2 have disaggregate & aggregate energy use indicators, respectively. *10% level, ** 5% level, ***1% level of significance				

Table 7 column 1-2, & 3-4 explains the findings of Fully modified OLS and dynamic OLS in D-8 and G-7 countries, respectively., the coefficient of GDP per capita is positive and significant in the case of D-8 economies as 1% increase in GDP causes CO₂ emissions to escalate by 3.721%, 5.320% as results shown by FMOLS and DOLS respectively. Moreover, the coefficient of square of GDP per capita, as shown by both estimators are negative and significant. As 1% increase in square of GDP per capita causes CO₂ emissions to decrease by -0.515%, and -0.703%. Result confirms the existence of the EKC hypothesis in the case of D-8 countries as the initial phases of development are associated with ecological degradation but after a certain threshold level ecological degradation tends to decrease (**Hanif *et al.*, 2019; Ozturk & Acaravi, 2013; Grossman & Krueger, 1991**). On the other side, GDP per capita coefficient is negatively and statistically significant associated with CO₂ emissions in the case of G-7 countries as 1 percent increase in GDP Causes improvements in ecological quality by -2.913, -9.730% respectively (results of FMOLS, DOLS). Here GDP per capita has a negative and significant link with CO₂ emissions and square of GDP per capita is positive and significant which supports U-shaped curve similar to the findings of (**Destek & Sarkodie, 2019**).

Secondly, the findings of disaggregate energy consumption suggest that in the case of D-8 economies, the coefficients of coal, oil, gas consumption are positive and significant implying that 1 percent surge in oil, coal, gas consumption leads to elevate emissions by 0.04, 0.32, 0.31 percent respectively. Though the magnitude of oil consumption is higher out of the aforementioned non-renewable resources. The findings of DOLS are same but differs in magnitude. According to a report published by the *European Union Joint*

Research Centre, elaborated that the combustion of fossil fuel accounted for about 90 percent of total worldwide CO₂ emissions (Oliver *et al.*, 2012). However, the outcomes of the present study are similar to the outcomes of (Valadkhani *et al.*, 2019). In the case of G-7 countries, the findings are similar as a rise by 1 percent raises in coal, oil, and gas consumption escalates emissions by 0.14, 0.05, 0.52 percent respectively and findings of DOLS estimator is same. The findings are consistent with the outcomes of (Ahmad *et al.* 2016). In G-7 economies gas and oil consumption is more detrimental for the environment but lower magnitude than D-8 confirms that G-7 economies are also using green technologies to curb the level of emissions.

Thirdly, estimates obtained from shows that in column 1 & 2, the coefficient of trade is positive and significant suggesting that 1% increase in trade causes a surge in the level of emissions by 0.04%, 0.06%. This result is in the line with the results of (Ozturk & Acaravi, 2013; Al-Mulali & Ozturk, 2015; Van Tran, 2020). In developing economies trade can affect ecological quality through various channels like if trade increases, energy demand will also increase, furthermore it will escalate the energy consumption repercussion will be a resurgence in emissions. Contrary to this, the findings of trade in the case of G-7 are as trade shows negative and significant association with CO₂ emissions. Both estimators confirm that one percent surge in trade slackens the emissions by -0.01 percent. In the case developed economies, trade cannot be a source of boosting emissions because they usually use advance and eco-friendly technologies. Strick rules and regulations are also a hurdle in these economies in polluting environment. our findings are supported by (Ahmed *et al.* 2016; Jalil & Mehmood, 2011; Managi *et al.* 2009; Aller *et al.* 2015).

Table 7 FMOLS and DOLS Results

Variable	D-8		G-7	
	1	2	3	4
	ICO2	ICO2	ICO2	ICO2
LGDP	3.721*** (2.556)	5.320*** (14.173)	-2.913*** (-2.498)	-9.730** (2.054)
LGDP²	-0.515*** (-2.529)	-0.703*** (-9.642)	0.332*** (2.582)	1.084** (2.099)
LTR	0.049*** (4.458)	0.062*** (3.898)	-0.014*** (-2.767)	-0.018** (-2.136)
LPCC	0.041** (2.322)	0.086*** (2.829)	0.147*** (17.718)	0.231*** (5.942)
LPOC	0.321*** (6.022)	0.269*** (3.523)	0.054*** (3.775)	0.228*** (4.033)
LPGC	0.314*** (9.753)	0.286*** (7.627)	0.520*** (17.326)	0.130* (1.588)
*10% level, ** 5% level, ***1% level of significance				

FMOLS and DOLS Results with Aggregate Energy Consumption

In Table 8 column 1-2, 3-4 explain the estimates of the same model with aggregate energy consumption. Results obtained from FMOLS and DOLS, in this case, show that in D-8 countries coefficient of GDP per capita is also positive and significant highlighting that, 1% increase in GDP per capita causes CO₂

emissions to escalate by 3.19, 2.03%. However, the result reveals are the same as the findings of (Zoundi, 2017). The square of GDP per capita confirm the presence of the EKC hypothesis in D-8 countries. The result supports the existence of the EKC hypothesis in the case of D-8 countries (Hanif *et al.*, 2019). However, aggregate energy consumption is a second significant contributor that enhances CO₂ emissions by 1.25, 0.91% if there is 1 percent surge in the usage of energy consumption as examined by (Alam *et al.*, 2016). Trade is positively associated with CO₂ emissions concludes that one percent increase in trade elevates CO₂ emissions by 0.05%, 0.11%.

In G-7 economies, according to the estimates of FMOLS, the sign of parameter of GDP per capita is negative highlighting that 1% surge in GDP per capita leads to a decline in emissions by -2.99% and -1.08%. Furthermore, Square GDP per capita coefficient is positive and significant supporting the U-shaped EKC hypothesis. The finding of the current study, in this case, are supported by (Destek & Sarkodie, 2019). Moreover, aggregate energy consumption in G-7 has positive and significant coefficient associated with CO₂ emissions. As 1% increment in energy usage leads to boost CO₂ emissions by 0.60%, 0.27%. According to existing literature more energy usage is a significant factor in boosting environmental pollution. Thus, the result of the present study are consistent with the findings of (kasman & Duman, 2015; Acheampong, 2018). The coefficient of trade is negative and significant implying that 1 percent increase in decline CO₂ emissions by -0.54and -0.38 percent. Trade findings in the case G-7 countries show that trade is not a significant factor in escalating CO₂ emissions (Jalil & Mehmood, 2009).

From the above discussion, it can be concluded that, the major contributor in escalating carbon emissions include economic growth, disaggregate and aggregate energy use. Trade is also a factor boosting the level of carbon emissions in D-8 economies, but trade is not a major contributor. EKC is valid in D-8 countries. In the case of G-7 economies, trade, growth is not a significant factor elevating carbon emissions. But both aggregate and disaggregate energy usage in economies are the major contributor in boosting carbon emissions

Table 8 FMOLS and DOLS Results with Aggregate Energy Consumption

	D-8		G-7	
	1	2	3	4
Variable	ICO2	ICO2	ICO2	ICO2
LGDP	3.194 ^{***} (7.623)	2.036 ^{***} (4.791)	-2.992 ^{***} (-153.055)	-1.084 ^{***} (-3.744)
LGDP²	-0.380 ^{***} (-6.395)	-0.308 ^{***} (-4.865)	0.709 ^{***} (177.491)	0.382 ^{***} (7.127)
LTR	0.055 ^{***} (2.122)	0.115 ^{***} (2.921)	-0.542 ^{***} (-225.214)	-0.385 ^{***} (-10.996)
LENG	1.125 ^{***} (9.933)	0.914 ^{***} (5.168)	0.608 ^{***} (90.493)	0.274 ^{**} (1.977)
*10% level, ** 5% level, ***1% level of significance				

To check further robustness of the results study used heterogeneous static and dynamic estimators. The results of MG, AMG, CCEMG, and DCCEMG are presented in table 9, which will elaborate the findings in the

case of both D-8 and G-7 countries. Tables 9, column 1-4 explaining the findings of MG, AMG, CCEMG, and DCCEMG. In the case of D-8 countries, column 1 elaborates the findings of MG. The results of columns 1 and 4 show that GDP per capita is a positive factor in deteriorating ecological quality. It also confirms the existence of the EKC hypothesis as discussed in the findings of previous estimators.

Coal consumption has positive but statistically significant as shown in columns 3 and four of table 11. Similarly, the findings of columns 1,2, and 3 highlights that oil consumption is also a significant factor in boosting carbon emissions. Lastly, the results explain that gas consumption is also contributing to emissions. Trade coefficient is positive and significant, and findings are similar in columns 2, 3 and 4 as well. On contrary, column 5-8 present findings in the case of G-7 economies as However, the findings of GDP, the square of GDP, and the results of disaggregated energy consumptions are robust and similar as discussed in previous results (FMOLS, DOLS). Trade is a negative but statistically insignificant factor in escalating CO₂ emissions and the same results drawn in the study of (Jalil & Mehmood, 2011).

Table 9: Static and Dynamic Heterogeneous Estimators Results

	D-8				G-7			
	1	2	3	4	5	6	7	8
Variables	MG	AMG	CCEMG	DCCEMG	MG	AMG	CCEMG	DCCEMG
LGDP	5.45*	3.23***	5.004*	5.28**	-11.40*	-0.11	7.57	7.25
	(2.83)	(0.79)	(2.733)	(2.32)	(6.47)	(4.79)	(8.38)	(8.13)
LGDP ²	-0.74*	-0.43***	-0.705*	-0.75**	1.28*	0.03	-0.86	-0.81
	(0.42)	(0.13)	(0.375)	(0.32)	(0.71)	(0.53)	(0.93)	(0.90)
LTR	0.04**	0.02***	0.0461*	0.05*	-0.01	0.01	-0.01	-0.00
	(0.02)	(0.01)	(0.0286)	(0.03)	(0.01)	(0.01)	(0.03)	(0.04)
LPOC	0.30***	0.14**	0.136***	0.10	0.39***	0.27***	0.34***	0.35***
	(0.06)	(0.07)	(0.0442)	(0.06)	(0.03)	(0.04)	(0.09)	(0.10)
LPCC	0.05	0.07	0.0942**	0.09*	0.14***	0.16***	0.18***	0.16***
	(0.05)	(0.05)	(0.0458)	(0.05)	(0.03)	(0.02)	(0.04)	(0.04)
LPGC	0.28***	0.08*	0.113*	0.10*	0.20***	0.18***	0.16***	0.14***
	(0.08)	(0.05)	(0.0691)	(0.05)	(0.03)	(0.02)	(0.03)	(0.03)
L.LCO ₂	-	-	-	-0.00	-	-	-	0.09*
				(0.06)				(0.05)
Constant	-0.58	0.70	5.54	-	35.39**	9.57	-5.87	-
	(5.33)	(1.57)	(5.01)		(14.72)	(11.00)	(9.10)	
RMSE	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
CD Statistics				-3.00				-3.80
Observations	280	280	280	273	280	280	280	273
R ²	-	-	-	0.518				0.388
Adjusted R ²	-	-	-	0.006				0.044

Standard Errors in Parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Somehow to further clarify the results, table 10 presents country-specific analysis, as in the case of D-8 economies the relationship of trade with emissions in Malaysia, Pakistan, Turkey, and Indonesia is positive, negative in Egypt but insignificant in the case of Iran and Bangladesh. The association of GDP with CO₂ emissions is positive and significant in Bangladesh, Egypt, Malaysia, Pakistan, Turkey, and in Iran,

Indonesia it is negative and insignificant. EKC hypothesis is confirmed in Bangladesh, Egypt, Malaysia, Pakistan, Turkey but not supported in Indonesia and Iran. Oil, coal, and gas consumption have a positive and statistically significant on emissions in all D-8 countries.

The results of country-specific analysis in G-7 countries indicate that trade has a negative relation in the UK, USA, and positive in Canada and Italy. GDP has a negative and statistically significant indicator and confirms the presence of a U-shaped curve in all G-7 countries except Canada. All the indicators of disaggregate energy consumption are damaging environment in G-7 countries. Our findings to some extent are consistent with the outcomes of (Ike *et al.*, 2020).

Table 10 FMOLS Country Specific Analysis D-8 and G-7 Countries

D-8						
Country	LGDP	LGDP²	LTR	LPCC	LPOC	LPGC
BGD	12.85*** (22.12)	-2.12*** (-22.53)	0.01 (1.26)	0.03*** (9.33)	0.12*** (7.78)	0.47*** (33.11)
EGY	0.81 (0.65)	0.10*** (0.53)	-0.03*** (-4.42)	-0.02*** (-2.58)	0.77*** (5.59)	0.16*** (6.21)
IRN	-9.83*** (5.94)	1.32*** (5.91)	-0.00 (-0.33)	0.15*** (6.47)	1.10*** (2.96)	0.53*** (75.88)
IND	1.41 (0.25)	-0.15 (-0.19)	0.11*** (2.85)	0.04 (1.06)	0.39* (1.67)	0.19 (0.89)
MYS	3.29** (1.98)	-0.35* (-1.70)	0.11*** (4.67)	0.06*** (4.10)	1.70*** (14.58)	0.16*** (5.44)
PAK	12.72*** (18.22)	-1.89*** (-16.43)	0.03*** (5.06)	-0.90*** (-15.12)	2.80*** (20.27)	2.46*** (29.40)
TUR	7.27*** (11.41)	-0.84* (-11.10)	0.06*** (12.89)	0.26*** (19.21)	0.12*** (5.88)	0.02*** (11.07)
G-7						
CAN	-9.57 (-5.95)	1.07*** (6.11)	0.04*** (9.75)	0.16*** (18.39)	0.38*** (19.51)	0.35 (18.58)
FRA	-36.40*** (-10.63)	4.02*** (10.79)	-0.01 (-1.42)	0.17*** (6.98)	0.34 6.78	0.19*** (4.98)
DEU	5.52 2.81	-0.59 -2.75	-0.03 -3.93	0.16 7.18	0.50 8.43	0.11 3.48
ITA	-20.03*** (-3.66)	2.23*** (3.67)	-0.00 (-0.31)	0.01 (0.18)	0.40 8.62	0.24 (2.51)
JPN	-13.30*** (-9.38)	1.49*** (10.15)	0.02 (3.80)	0.14*** (6.30)	0.54 37.55	0.07*** (4.57)
UK	-3.80*** (-1.55)	0.44* (1.61)	-0.04*** (-2.63)	0.12*** (10.36)	0.45*** (6.63)	0.13*** (5.01)
USA	-3.75*** (-3.29)	0.46*** (3.61)	0.01 (1.03)	0.29*** (14.54)	0.33*** (7.67)	0.21*** (7.62)

BGD Bangladesh, EGY Egypt, IRN Iran, IND Indonesia, MYS Malaysia, PAK Pakistan, TUR Turkey, CAN Canada, FRA France, DEU Germany, ITA Italy, JPN Japan, UK United Kingdom, USA United States of America. *10% level, ** 5% level, ***1% level of significance

The study used a second-generation panel causality test to investigate the causality among variables. The result of **Dumitrescu and Hurlin, (2012)** are presented in table 11. The results reveal that there is unidirectional causality from CO₂ to GDP, CO₂ to trade, CO₂ to PGC, CO₂ to POC, GDP to PCC and bidirectional causality from PCC to CO₂, in D-8 countries while in the case of G-7 economies findings are as follows: there is an existence of unidirectional causality from GDP to CO₂, TR to CO₂, PGC to CO₂ and PCC to CO₂, bidirectional causality from POC to CO₂.

Table 11 Dumitrescu Hurlin Causality Test Result

Null Hypothesis:	W-Stat.	Findings	W-Stat.	Findings
LGDP does not homogeneously cause LCO ₂	2.149	GDP≠CO ₂	3.392	GDP≠CO ₂
LCO ₂ does not homogeneously cause LGDP	3.968**	CO ₂ →GDP	2.582	CO ₂ ≠GDP
LTR does not homogeneously cause LCO ₂	2.285	TR≠CO ₂	4.564***	TR → CO ₂
LCO ₂ does not homogeneously cause LTR	8.624***	CO ₂ →LTR	2.122	CO ₂ ≠LTR
LPCC does not homogeneously cause LCO ₂	4.691***	PCC↔CO ₂	3.425	PCC≠CO ₂
LCO ₂ does not homogeneously cause LPCC	3.600*		4.704***	PCC→CO ₂
LPGC does not homogeneously cause LCO ₂	2.684	PGC≠CO ₂	2.542	PGC≠CO ₂
LCO ₂ does not homogeneously cause LPGC	4.434***	CO ₂ →PGC	2.257	CO ₂ ≠PGC
LPOC does not homogeneously cause LCO ₂	3.037	POC≠CO ₂	5.359***	POC↔CO ₂
LCO ₂ does not homogeneously cause LPOC	3.408	CO ₂ ≠POC	4.569***	
LTR does not homogeneously cause LGDP	3.360	TR≠GDP	3.043	TR≠GDP
LGDP does not homogeneously cause LTR	2.708	GDP≠TR	4.098***	GDP→TR
LPCC does not homogeneously cause LGDP	1.931	PCC≠GDP	2.940	PCC≠GDP
LGDP does not homogeneously cause LPCC	5.417***	GDP→PCC	4.919***	GDP→PCC
LPGC does not homogeneously cause LGDP	2.840	PGC≠GDP	1.254	PGC≠GDP
LGDP does not homogeneously cause LPGC	1.285	GDP≠PGC	3.232	GDP≠PGC
LPOC does not homogeneously cause LGDP	2.177	POC≠GDP	4.334***	POC↔GDP
LGDP does not homogeneously cause LPOC	2.312	GDP≠POC	4.213***	
LPCC does not homogeneously cause LTR	2.806	PCC≠TR	2.494	PCC≠TR
LTR does not homogeneously cause LPCC	4.424***	TR→PCC	4.200***	TR→PCC
LPGC does not homogeneously cause LTR	7.936***	PGC→TR	3.810**	PGC→TR
LTR does not homogeneously cause LPGC	1.616	LTR≠PGC	2.708	LTR≠PGC
LPOC does not homogeneously cause LTR	2.271	POC≠LTR	2.742	POC≠LTR
LTR does not homogeneously cause LPOC	4.410***	TR→POC	6.374***	TR→POC
LPGC does not homogeneously cause LPCC	3.15717	PGC≠PCC	1.830	PGC≠PCC
LPCC does not homogeneously cause LPGC	2.06720	PCC≠PGC	2.796	PCC≠PGC
LPOC does not homogeneously cause LPCC	3.30178	POC≠PCC	4.438***	POC↔PCC
LPCC does not homogeneously cause LPOC	2.68295	PCC≠POC	3.841**	
LPOC does not homogeneously cause LPGC	1.87901	POC≠PGC	4.585***	POC↔PGC
LPGC does not homogeneously cause LPOC	5.18516***	PGC→POC	4.729***	
*10% level, ** 5% level, ***1% level of significance				

5. Conclusion

Ecological degradation is a very pressing topic that has been under discussion since the 20th century. This study examines the dynamics links among CO₂ emissions, trade, GDP, aggregate, and disaggregate energy consumption for D-8 and G-7 countries utilizing the annual data between 1980 and 2019. The empirical analysis is based on both first and second-gen panel time series analysis. The study takes care of different econometric concerns such as endogeneity, heterogeneity, and cross-sectional dependence using static and dynamic panel estimators.

The results of both Pedroni, Kao, and Westerlund cointegration test confirm the long-run association among all the study variables. The findings of FMOLS, DOLS and heterogenous dynamic panel estimators conclude that the GDP per capita, aggregate and disaggregate energy consumption (i-e oil, coal, gas consumption), trade are the significant factors of CO₂ emissions in the panel of D-8 countries. The results accept the EKC hypothesis for the panel D-8 economies implying that the existing development policy framework in these countries has the potential to recover the environmental loss caused by growth-oriented policies in the long run. However, a better and improved policy framework can shorten the transitional spell between for- and pro-environment growth periods.

The results for G-7 countries reveal that GDP and trade have a negative effect on CO₂ emissions. Besides, the existence of a U-shaped curve is validated in G-7 economies. G-7 countries are following strict environmental rules and regulations but at the same time due to economies of scale and large-scale production, they are also facing the challenge of high emissions. The findings validate that aggregate and disaggregate energy consumption, and GDP are highly emission intensive. Trade deleterious for the environment in D-8 countries.

Findings of the study suggest that D-8 economies need to adopt green strategies, green technologies and must ensure sustainable patterns for production and consumption. Renewable energy has the potential to meet the growing demands of energy with improving ecological quality. The integration of more effective, advanced and green, and clean technologies is mandatory for an effective transition from fossil fuel usage while attaining a decarbonized economy. Public, private sectors should substitute conventional sources with advance, clean and green resources.

Declarations

Authors' contributions This idea was given by Muhammad Tariq Majeed. Muhammad Tariq Majeed supported in all sections of this work and completed the final write up of the paper. Naveed Asghar analysed the data and discussed the results and drafted initial versions of the other sections. All authors have read and approved the manuscript.

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