

Effects of Energy Consumption on GDP: New Evidence of 24 Countries on Their Natural Resources and Production of Electricity

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Abstract. Because of rapid economic expansion, China, the USA, and India have become the largest energy producers and sources of CO₂ emissions in the world. They burned over 45% of global fuels in 2016. Meanwhile, the developing strategies of 24 polluted states to decrease fossil energy consumption without additional economic output. This paper explores the effect of world top polluted countries' CO₂ emission, their GDP and production of electricity by potential indicators and identifies the basic factors that contribute to changes in an environment where petroleum, natural gas, coal, nuclear, biomass, and other renewable energy and hydroelectric sources are examined with GDP per capita. We estimate our data for the period from 1968 to 2017 and use the GLM model. The results show that more production of electricity is causing abnormal CO₂ emissions. The Granger causality test shows that there is a unidirectional relationship between energy consumption and economic advancement. Also, there is a short-run bidirectional causality that exists among the energy indicators. We find a unilateral causality between energy consumption and economic growth. Therefore, the consumption of energy might be conducive of 24 (polluted) countries and better economic development; the consumption of energy may be failsafe and guaranteed, while we should limit the resources of countries.

Keyword: CO₂ emission; energy consumption; production of electricity; GDP

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1. Introduction

Fossil fuels, like petroleum, natural gas, and coal, are estimated at 80% of energy consumption in the United States, and highest value recorded 101 quadrillion British thermal units (Btu) only in 2018, which was 81(Btu) of fossil fuel. Increases in natural gas consumption and petroleum drove the fossil fuel flow in 2018, while coal consumption fell by 4.3%. In 2005 in the USA, consumption peaked and since then declined by 42%. The onset of petroleum, coal, renewable energy, and nuclear power plants was a major energy indicator of energy consumption in the USA in the 18th to 21st centuries. We reached the natural gas consumption at a turning point with a value of 82.1 billion feet per day in 2018, and consumption has only increased by 37% in the last 8 to 10 years. In 2018, the petroleum product supplied reached 20.5 million barrels per day to 2005. Furthermore, the renewable energy consumption (hydroelectricity, wind, biomass, and solar energy) was 11.4% and it increased from the previous year.

China's coal production has increased tenfold since 1960 and because of fossil-fuel CO₂ emissions more than doubled alone in 2000. China's emissions of CO₂ have increased in the period of 1950 to 1997, and it became the world's largest emitter of CO₂ because of fossil-fuel. It recorded an annual 5.4% and growing with huge development. Almost half of the world's cement had been produced in China; in 2008, it amounted to 1.38 billion metric tons. The per capita emission rate now stands at 1.34 metric tons of carbon (Boden, G.Marland, & R.J.Andres, 2011; Etemad, J.Luciani, P.Bairoch, & J.C.Toutian, 1991). China is the third largest natural gas consumption market and significantly relies on it for economic growth; among other primary energy sources, natural gas has been the optimal choice to resource energy transition, because it produces fewer CO₂ emissions. The annual natural gas consumption was 16.26% in 2000 to 2007 with a 10.5% average annual economic growth (Fadiran, Adebusuyi, & Fadiran, 2019; Li, Cheng, & Gu, 2019). We recorded China's natural gas consumption at 27.381 Cub ft/Day bn in 2018, and it increased in 1.17% from 2017. The petroleum consumption of coke (CO₂, N₂O and CH₄) in China is exploding and had increased by 18.9% from 2010 to 2016. The petroleum related-CO₂, N₂O, and CH₄ emissions reached 28, 143, and 870 million tonnes in 2016, respectively (Shan et al., 2018; X. Xu et al., 2018).

China's renewable energy is comprised of hydroelectric, solar, wind, biofuel, biomass, and geothermal power. Pertaining to electricity, China is one of the leading country's in form of renewable energy sources and who derive double its electricity from the USA. In 2013, the country had produced 378 GW of renewable power, from hydrochloric and wind power. Fig 1 signifies the energy difference between production and consumption in the period of 2010–2016. China, the USA, and India's production of energy and consumption was developing faster than that of Russia, Saudi Arabia, and Australia. The renewable energy sector of China is growing faster than its fossil fuels and nuclear power energy sources. The largest rise of CO₂ emissions grew by 3% in China since 2013. Hence, in 2013 to 2016, China's CO₂ emissions fell and shifted away from smokestack industries; also, renewable energy is a source of booming power generation, and policies are being implemented to

tackle air pollution. China started another construction boom using its coal resources and increased its production by 4.5% in 2018 and by 3.3% in 2017. With the world's largest population and fastest growing economy, China is by far the world's top country among the 25 highest CO₂ emitters. China's CO₂ emission rates are growing because of its huge economic development. In 2017, the CO₂ emissions from fossil fuel were 46.44% and 74.92% higher than those of the USA and India (See Table 1 for a comparative analysis).

Carbon dioxide emissions of India have increased from 7.1% to 10.1% in 2011 to 2014, which has been stemming from the burning of fossil fuel and cement manufacture. The overall growth of energy consumption will be higher for future industries and economic development in India. The non-conventional sources of energy have reduced the CO₂ emissions by 11.8% (Gupta, Jain, & Bansal, 1995; Kumar & Sinha, 1995). The fourth largest country is Russia. We have declared the Russian Federation as contributing in CO₂ emissions after India, and we record an overall 14% increase with 0.99 kg in 2010 (\$GDP). We have declared that the Russian Federation has increased and will increase in the level of greenhouse (GHG) emissions by 20 to 30% in the period of 1990 to 2030 (Ketenci, 2018; Pao & Tsai, 2011).

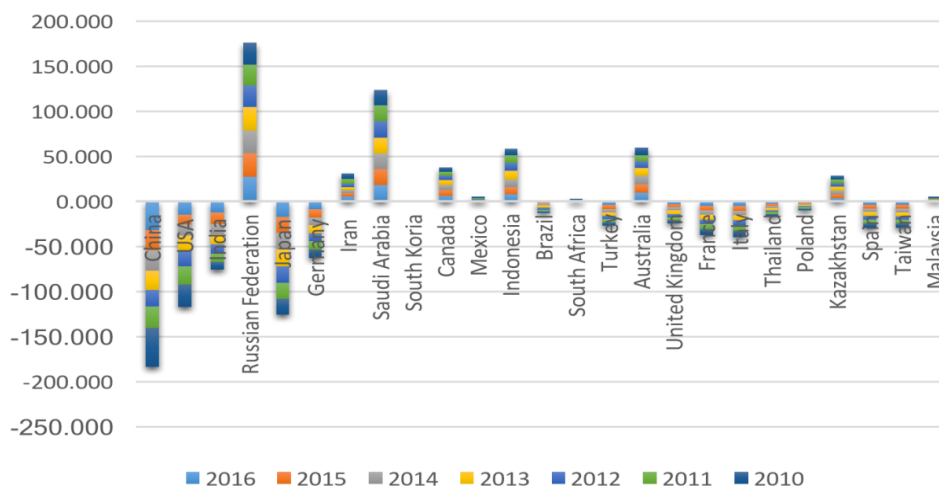


Fig. 1. Difference b/w energy production and consumption.

Source: US. Energy Information Administration

The world's 15 top countries are responsible for 72% CO₂ emissions. According to the rankings of the CEOWORLD magazine, 25 countries were listed based on regional CO₂ emissions from fossil fuel, methane emissions, CO₂ emissions, and the changes were published in the 2018 Global Carbon Project (Table 1). We base this research paper on the rapid increase in CO₂ emissions from petroleum, natural gas, coal, nuclear, biomass, other renewable energy and hydroelectric power, and its effects on the GDP of the top 24 polluted countries. Electricity production by natural resource results of carbon emissions in developing and developed countries. We can address this question through factors

that cause the CO₂ emission change and individual territory economic development and identify the force that changes the CO₂ emissions.

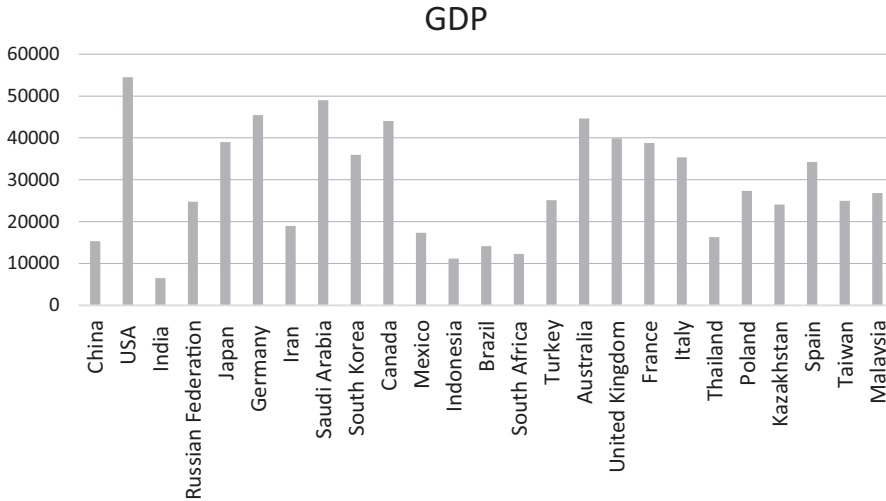


Fig. 2. GDP per capita 2017 (\$)

The monetary terms of economic data, Gross Domestic Product (GDP) and per capita GDP, used in early studies to compare energy intensity were not examined in the top 24 countries of the high-ranking CO₂ emissions and economic development. However, energy efficiency indicators were influenced by petroleum, natural gas, coal, nuclear, biomass, other renewable energy and hydroelectric with per capita of GDP, therefore leading to misleading efficiency conclusions. If, such as the economic growth of the 24 countries will increase, the energy use of the economic efficiency indicator will rise, although the energy use per unit output will not change.

Table 1. 25 highest CO₂-emitting countries

Countries		
China	Canada	Italy
USA	Mexico	Thailand
India	Indonesia	Poland
Russian Federation	Brazil	Kazakhstan
Japan	South Africa	Spain
Germany	Turkey	Taiwan
Iran	Australia	Malaysia
Saudi Arabia	United Kingdom	
South Korea	France	

Sources: Author compiling by the World's Top 25 countries CO₂ Emission.

According to the environmental Kuznets's Curve, rapid economic growth has an influence on the environment. Advanced technology can reduce the impact of CO₂ emissions on economic growth. Developed and civilized people prefer to live in zones free of CO₂ and protect nature from the harmful gasses with the help of modified technology and primary energy sources (Kong & Khan, 2019). If population and the poverty control by economic development policies, through its effect on rural and urban population for timber and fuel, lead to an increase in CO₂, it will therefore cause air pollution. By doing so, we eliminate the possibility of a bias in study results (Baek, 2017).

This study used the GLM method to identify the basic factors that contribute to changes in an environment in the 24 top polluted countries. Eight indicators – petroleum, natural gas, coal, nuclear, biomass, other renewable energy and hydroelectric power – were examined with GDP per capita. We organize the rest of the paper as follows. Section 2 discusses the relevant literature; Section 3 presents the research methodology. Section 4 discusses the results, and Section 5 concludes the paper.

2. Literature review

In a recent study, the researchers examined the effects of CO₂ emissions by oil, gas, and renewable energy of 79 different countries in the period of 1965–2017 but did not classify the contribution of the top 24 countries' economic development and CO₂ emission levels by petroleum, natural gas, coal, nuclear, biomass, other renewable energy and hydroelectric power. We investigate the changes in the primary energy production and consumption in the panel data of 24 countries. The World Bank database is a reliable source for CO₂ emissions, and we used it in the current analysis. We have elaborated on the effect of the CO₂ emissions by primary energy consumption under optimal thresholds without nuclear and coal emissions. Energy consumption classifies on the basis of income and emission levels (Valadkhani, Nguyen, & Bowden, 2019). The climate change policies have been examined, and the results showed that transport carbon emission increased in top 7 countries (Solaymani, 2019). With the EU-27 aggregated energy consumption with LMDI at 3 levels, the research showed the R&D and efficiency technologies are the main showing elements of low CO₂ emissions (Fernández González et al. 2014). We analyze the BRICS countries results, the use of biomass in energy consumption for a sustainable environment, and showed an energy dependency along a rapid economic growth (Aydin, 2019). The 17 emerging countries were examined and the results showed the change in economic growth and renewable energy consumption with economic growth. The results show the conservation policies of energy do not have any adverse effect on the economic development of 16 countries; some strengths of the current analysis in earlier applications are as follows.

Table 2. Literature by different states

Countries	Study	Database	Econometric techniques	Periods	Outcomes
China	(Kang, Islam, & Kumar Tiwari, 2019; B. Xu & Lin, 2019; G. Xu, Schwarz, & Yang, 2019)	International Energy Agency (IEA)	Non parametric regression model, NARX and VAR model.	2000-2015 1965-2015 2017-2050	Natural gas consumption has effect in the eastern region. The coal consumption adds huge emissions. Impact of CO ₂ on GDP and a positive shock to CO ₂ .
USA	(Chen, Shi, Shen, Huang, & Wu, 2019; Jiang, Wang, & Li, 2018)	World Input-Output Database (WIOD)	Geographical Detector Model	1995-200	45% global CO ₂ emission produced from China and USA and production structure effect on environment.
India	(Anandarajah & Gambhir, 2014)	The Energy Resources Institute (TERI)	TIAM-UCL model	2030-2050	34% energy consumption by renewable energy and 52% in 2050
Russian	(C. Cheng, Ren, Wang, & Yan, 2019)	Organization for Economic Cooperation and Development (OECD)	OLS regression	2000-2012	GDP has created negative impacts on CO ₂ emission in EU-28 countries.
Japan	(Cai, Sam, & Chang, 2018)	World Development Indicators (WDI)	ARDL	1965-2015	As a dependent variable the integration exists in Japan
Germany	(González, Marrero, Rodríguez-López, & Marrero, 2019)	EU-13	Dynamic panel data	1990-2105	CO ₂ emission have been given positive implementation to technological progress and changes.
Iran	(Hosseini, Saifoddin, Shirmohammadi, & Aslani, 2019)	WDI	multiple linear regression (MLR)	1971-2014	Iran include top CO ₂ emitted country and 30% increase in 2030.
Saudi Arabia	(Alkathlan & Javid, 2015)	BP Statistical Review of World Energy	Structural Time Series Models (STSMs)	1971-2013	The CO ₂ emission grow by oil consumption
South Korea	(Jeong, Hong, & Kim, 2018)	MFHC Multi-family housing complex	Quartile	CO ₂ emission reduction target by 2030	The results indicated CO ₂ emission benchmark for MFHCs can be applied.
Canada	(Cai et al., 2018)	WDI	ARDL	1970-2015	Canada use energy efficiency to reduce CO ₂ emission.

Sources: Author literature review about the top ten CO₂ emission countries.

3. Methodology

3.1. Generalized Linear Models (GLMs)

GLM model is used to analyze the extended linear regression to non-linear systematic and non-normal stochastic components (McCullagh, 1989). The GLM approach shows the response of the energy, natural gas, coal rent, nuclear energy, oil gas and coal, and renewable energy consumption in the six groups of carbon emissions. CO2 emission hypothesis, we followed the approach (K. Dong, Sun, & Dong, 2018; Kang et al., 2019; Ohashi et al., 2017). The relationship between GDP, energy, natural gas, coal rent, nuclear energy oil, gas, coal renewable energy consumption and total population Eq. 1 and GDPG Eq. 2.

$$GDP_{it} = \alpha_{it} + \gamma_{1t} + \beta_{1t}CO2_A_{it} + \beta_{2t}CO2_B_{it} + \beta_{3t}CO2_C_{it} + \beta_{4t}TGGE_{it} + \beta_{5t}CO2_INT_{it} + \beta_{6t}CO2_F_{it} + \beta_{7t}PT_{it} + \epsilon_{it} \dots \quad (1)$$

$$GDPG_{it} = \alpha_{it} + \gamma_{2t} + \beta_{8t}CO2_A_{it} + \beta_{9t}CO2_B_{it} + \beta_{10t}CO2_C_{it} + \beta_{11t}TGGE_{it} + \beta_{12t}CO2_INT_{it} + \beta_{13t}CO2_F_{it} + \beta_{14t}PT_{it} + \epsilon_{it} \dots \quad (2)$$

Where GDP and GDPG shows the growth rate and growth rate per capita and $i=1, \dots, 24$ and $t=1968, \dots, 2017$ divulge the country and time, where the GDP and GDPG effects, which we take from the CO2 emission from Energy, Natural Gas, Coal Rent, Nuclear Energy, Oil Gas and Coal, and Renewable energy consumption. α_{it} shows country fixed effect and $\beta_{1t} - \beta_{14t}$ are parameters for elasticities in Eq 1 and Eq 2, which are showing each explanatory variable of the panel ϵ_{it} , shows estimated residual further in each group of variables. The research intention based on causal link between Energy, Natural Gas, Coal Rent, Nuclear Energy, Oil Gas and Coal, and Renewable Energy Consumption with GDP and GDPG. The GLM yield sturdy and useful tool to estimate in a regression and estimated variables are not exogenous, autocorrelation and heteroscedasticity within exist. (Chong et al., 2019; Hosseini et al., 2019). We apply the GLM on an individual group to analyze the impact of the explanatory variable in each group on CO2 emission.

The Energy consumption was analyzed by energy use and natural resources Eq. 3-5. and cause of CO2 emission. Natural gas consumption was analyzed by the production of electricity and natural gas Eq. 6-8. and cause of CO2 emission. Coal rent consumption was analyzed by production of electricity and coal rents with causes of CO2 from solid fuel Eq. 9-11. Nuclear energy consumption was analyzed by production of electricity of nuclear resources and nuclear energy with causes of green gas emission Eq. 12-14. Oil gas and coal consumption was examined by electricity access and the production of electricity from oil gas and coal with causes of intensity of CO2 Eq. 15-17. Renewable energy consumption was analyzed by renewable and waste combustion and net saving includes emission damages with causes of CO2 from manufacturing industries Eq. 18-20.

Group A: Energy consumption

$$CO2_A_{it} = a_{it} + \mu_{1i}t + \eta_{1t}EG_{it} + \eta_{2t}ANRD_{it} + \gamma it \quad (3)$$

$$\begin{aligned} \Delta EG_{it} = & a_{2s} + \sum_{k=1}^q \mu_{4ik} \Delta CO2_A_{it-k} + \sum_{k=1}^q \mu_{5ik} \Delta EG_{it-k} + \\ & + \sum_{k=1}^q \mu_{6ik} \Delta ANRD_{it-k} + \vartheta_{2i}\varepsilon_{it-k} + \tau_{2i} \end{aligned} \quad (4)$$

$$\begin{aligned} \Delta ANRD_{it} = & a_{3s} + \sum_{k=1}^q \mu_{7ik} \Delta CO2_A_{it-k} + \sum_{k=1}^q \mu_{8ik} \Delta EG_{it-k} + \\ & + \sum_{k=1}^q \mu_{9ik} \Delta ANRD_{it-k} + \vartheta_{3i}\varepsilon_{it-k} + \tau_{3i} \end{aligned} \quad (5)$$

Group B: Natural gas consumption

$$CO2_B_{it} = a_{it} + \mu_{2t} + \eta_{3t}EPNG_{it} + \eta_{4t}NGR_{it} + \gamma it \quad (6)$$

$$\begin{aligned} \Delta EPNG_{it} = & a_{4s} + \sum_{k=1}^q \mu_{10ik} \Delta CO2_B_{it-k} + \sum_{k=1}^q \mu_{11ik} \Delta EPNG_{it-k} + \\ & + \sum_{k=1}^q \mu_{12ik} \Delta NGR_{it-k} + \vartheta_{2i}\varepsilon_{t-k} + \tau_{4i} \end{aligned} \quad (7)$$

$$\begin{aligned} \Delta NGR_{it} = & a_{5s} + \sum_{k=1}^q \mu_{13ik} \Delta CO2_B_{it-k} + \sum_{k=1}^q \mu_{14ik} \Delta EPNG_{it-k} + \\ & + \sum_{k=1}^q \mu_{15ik} \Delta NGR_{it-k} + \vartheta_{3i}\varepsilon_{t-k} + \tau_{5i} \end{aligned} \quad (8)$$

Group C: Coal rent consumption

$$CO2_C_{it} = a_{it} + \mu_{3t} + \eta_{5t}EPCS_{it} + \eta_{6t}CR_{it} + \gamma it \quad (9)$$

$$\begin{aligned} \Delta EPCS_{it} = & a_{6s} + \sum_{k=1}^q \mu_{16ik} \Delta CO2_C_{it-k} + \sum_{k=1}^q \mu_{17ik} \Delta EPCS_{it-k} + \\ & + \sum_{k=1}^q \mu_{18ik} \Delta CR_{it-k} + \vartheta_{2i}\varepsilon_{t-k} + \tau_{6i} \end{aligned} \quad (10)$$

$$\begin{aligned} \Delta CR_{it} = & a_{7s} + \sum_{k=1}^q \mu_{19ik} \Delta CO2_C_{it-k} + \sum_{k=1}^q \mu_{20ik} \Delta EPCS_{it-k} + \\ & + \sum_{k=1}^q \mu_{21ik} \Delta CR_{it-k} + \vartheta_{3i}\varepsilon_{t-k} + \tau_{7i} \end{aligned} \quad (11)$$

Group D: Nuclear energy consumption

$$TGGE_{it} = a_{it} + \mu_{4t} + \eta_{7t}EPNS_{it} + \eta_{8t}ANE_{it} + \gamma it \quad (12)$$

$$\begin{aligned} \Delta EPNS_{it} = & a_{8s} + \sum_{k=1}^q \mu_{22ik} \Delta TGGE_{it-k} + \sum_{k=1}^q \mu_{23ik} \Delta EPNS_{it-k} + \\ & + \sum_{k=1}^q \mu_{24ik} \Delta ANE_{it-k} + \vartheta_{2i}\varepsilon_{t-k} + \tau_{8i} \end{aligned} \quad (13)$$

$$\begin{aligned} \Delta ANE_{it} = & a_{9s} + \sum_{k=1}^q \mu_{25ik} \Delta TGGE_{it-k} + \sum_{k=1}^q \mu_{26ik} \Delta EPNS_{it-k} + \\ & + \sum_{k=1}^q \mu_{27ik} \Delta ANE_{it-k} + \vartheta_{2i}\varepsilon_{t-k} + \tau_{9i} \end{aligned} \quad (14)$$

Group E: Oil, Gas and Coal consumption

$$CO2_INT_{it} = a_{it} + \mu_{5t} + \eta_{9t}AE_{it} + \eta_{10t}EPOGC_{it} + \gamma it \quad (15)$$

$$\Delta AE_{it} = a_{10s} + \sum_{k=1}^q \mu_{28ik} \Delta CO2_INT_{it-k} + \sum_{k=1}^q \mu_{29ik} \Delta AE_{it-k} + \sum_{k=1}^q \mu_{30ik} \Delta EPOGC_{it-k} + \vartheta_{2i} \varepsilon_{t-k} + \tau_{10i} \quad (16)$$

$$\Delta EPOGC_{it} = a_{11s} + \sum_{k=1}^q \mu_{31ik} \Delta CO2_INT_{it-k} + \sum_{k=1}^q \mu_{32ik} \Delta AE_{it-k} + \sum_{k=1}^q \mu_{33ik} \Delta EPOGC_{it-k} + \vartheta_{2i} \varepsilon_{t-k} + \tau_{11i} \quad (17)$$

Group F: Renewable Energy consumption

$$CO2_F_{it} = a_{it} + \mu_{6t} + \eta_{11t}CRW_{it} + \eta_{12t}ANSE_{it} + \gamma it \quad (18)$$

$$\Delta CRW_{it} = a_{12s} + \sum_{k=1}^q \mu_{34ik} \Delta CO2_F_{it-k} + \sum_{k=1}^q \mu_{35ik} \Delta CRW_{it-k} + \sum_{k=1}^q \mu_{36ik} \Delta ANSE_{it-k} + \vartheta_{2i} \varepsilon_{t-k} + \tau_{12i} \quad (19)$$

$$\Delta ANSE_{it} = a_{13s} + \sum_{k=1}^q \mu_{37ik} \Delta CO2_F_{it-k} + \sum_{k=1}^q \mu_{38ik} \Delta CRW_{it-k} + \sum_{k=1}^q \mu_{39ik} \Delta ANSE_{it-k} + \vartheta_{2i} \varepsilon_{t-k} + \tau_{13i} \quad (20)$$

All above six groups data of each country. In addition, we identify the parameter and a_i and μ_i effect with a deterministic trend. All above six groups Granger with F-test among them. Where the first difference specifies by as Δ , lag of length showed by at q one conferring to likelihood ratio-test and show τ uncorrelated serial error term.

3.2. Data Description

This paper investigates the relationship among CO2 in six groups of individual variables. The economic growth and per-capita growth shows the dynamic relationship with CO2_A, CO2_B, CO2_C, TGGE, CO2_INT and CO2_F. The level of CO2 emission was and its effects on the GDP of the top 24 polluted countries with a huge production of electricity by different resources in the period of 1968–2017 were analyzed and selected as the research samples given in Table 3. The research variables were constructed as follows with the meaningful statistics tools in Table 4.

4. Empirical estimation results and discussions

Table 4 shows the Energy, Natural Gas, Coal rent, Nuclear Energy Oil, Gas and Coal Renewable Energy consumption, variables mean in the period of 1968–2017, and countries analyzed by the CO2 emission. In each group, CO2_A, CO2_B, CO2_C, TGGE, CO2_INT and CO2_F have tested on an individual basis with explanatory variables. We applied the descriptive statistics tests to judge whether the explanatory variable works with response to the variables. The China (CO2_C), USA (CO2_A, CO2_B, TGGE), Saudi Arabia (CO2_INT) and Korea (CO2_F) register the highest mean, while Korea, Malaysia, Indonesia (CO2_A, CO_B), the Iran Islamic Republic, Malaysia, Mexico (CO2_C, TGGE), Indonesia, Brazil, and the Russian Federation (CO2_F) register the lowest mean. The

Table 3. Variables descriptions

Variables	Symbol	Description	Data Source
Natural resources	ANRD	Natural resource depletion and mineral depletion	NY.ADJ.DRES.GN. ZS
Energy use	EG	Primary energy before transformation	EG.USE.PCAP.KG. OE
Energy consumption	CO2_A	CO2 produced during consumption of solid, liquid and gas	EN.ATM.CO2E.KT
Natural gas	NGR	Natural gas rents and total costs of production	NY.GDP.NGAS. RT. ZS
Production of electricity from natural gas	EPNG	Electricity sources and natural gas	EG.ELC.NGAS.ZS
Natural gas consumption	CO2_B	CO2 emission from liquid fuel consumption	EN.ATM.CO2E.GF. KT
Coal rents	CR	Coal rent value and their costs of production.	NY.GDP.COAL. RT. ZS EG.ELC.COAL. ZS
Production of electricity from coal sources	EPCS	Sources of electricity used to generate electricity	EG.ELC.COAL. ZS
Carbon emission from solid fuel	CO2_C	CO2 emissions from consumption of solid fuel	EN.ATM.CO2E.SF. KT
Nuclear Energy	ANE	Non carbohydrate energy does not produce CO2, when generated	EG.USE.COMM.CL. ZS
Production of electricity from nuclear sources	EPNS	Electricity produced by nuclear power plants	EG.ELC.NUCL. ZS
Greenhouse gas emission	TGGE	CO2 excluding burning of short cycle biomass	EN.ATM.GHGT. KT. CE
Production of electricity from oil, gas, and coal sources	EPOGC	Oil, gas and liquids is source of electricity	EG.ELC.FOSL. ZS
Electricity access	AE	Electrification data collected from industries	EG.ELC.ACCS. ZS
Intensity of Carbon dioxide	CO2_INT	CO2 emission from use of coal as source of energy	EN.ATM.CO2E.EG. ZS
Net saving includes emission damages	ANSE	Natural savings and particular emissions damage.	NY.ADJ.SVNG.GN. ZS
Renewable and waste combustion	CRW	Combustible renewable as percentage of energy use	EG.USE.CRNW. ZS
Carbon emission from manufacturing industries	CO2_F	CO2 emissions from combustion of fuels industry	EN.CO2.MANF. ZS
Total population	PT	De facto population	SP.POP.TOTL
Growth of domestic product	GDP	Annual percentage growth on local currency	NY.GDP.MKTP.KD. ZG
Per-capita growth (GDP)	GDPG	Annual percentage growth rate of GDP	NY.GDP.PCAP.KD. ZG

Sources: Selection based on accessibility of database of World Bank. Variable's definition indicated in Table 3.

Table 4. Descriptive statistics

Descriptive analysis		Mean	Median	Std. Dev.	Observations
Energy consumption	ANRD	2.848	1.236	4.516	1030
	EG	2848.151	2512.106	2080.778	1059
	CO2_A	754203.900	346876.200	1336399.000	1021
Natural gas consumption	NGR	0.370	0.068	0.771	1032
	EPNG	16.525	8.180	20.226	1071
	CO2_B	121734.000	46985.270	248984.800	1021
Coal rent consumption	CR	0.411	0.048	0.901	1028
	EPCS	35.664	27.698	30.069	1071
	CO2_C	308747.000	72293.070	768653.000	1044
Nuclear energy consumption	ANE	6.312	2.941	8.429	1058
	EPNS	8.005	0.316	14.958	1059
	TGGE	1160331.000	550135.800	1649953.000	997
Oil, Gas and Coal consumption	EPOGC	68.787	75.064	24.639	1071
	AE	95.263	100.000	12.024	559
	CO2_INT	2.703	2.623	0.955	993
Renewable energy consumption	ANSE	9.260	8.738	7.136	600
	CRW	9.802	3.880	14.474	1059
	CO2_F	23.270	21.289	11.517	1047
GDP effects	PT	153000000.000	57000451.000	281000000.000	1195
	GDP	3.846	3.707	4.809	1075
	GDPG	2.483	2.544	4.602	1075

Sources: Calculated by the authors. Variable's definition indicated in Table 3.

highest mean value concludes that all predictors with CO2_A, CO2_B, CO2_C, TGGE, and CO_F integrated countries of economic development (Fig 3). The results were computed by a Generalized Linear Model (GLM) and, to remove any inconvenience, considered using a stationary test by a 1st generation unit root test and individual intercept in level. Most of the statistics test rejects the null hypothesis, including the variables stationary at the level in individual groups.

4.1. Unit root and co-integration

Before analysis, the unit root test applied so ADF, PP, LLC, IPS and BR whether the variables in group A (ANRD, EG, CO2_A), group B (NGR, EPNG, CO2_B), group C (CR, EPCS, CO2_C), group D (ANE, EPNS, TGGE), group E (EPOGC, AE, CO2_INT), group F (ANSE, CRW, CO2_F) and group G (PT, GDP, GDPG) have unit-root or not. The test results rejected the null hypothesis and concluded that the selected variables are not stationary, whether the cointegration exists among the variables. In the 1st stage, VAR was estimated and the model proved to stable as shown in Table 5.

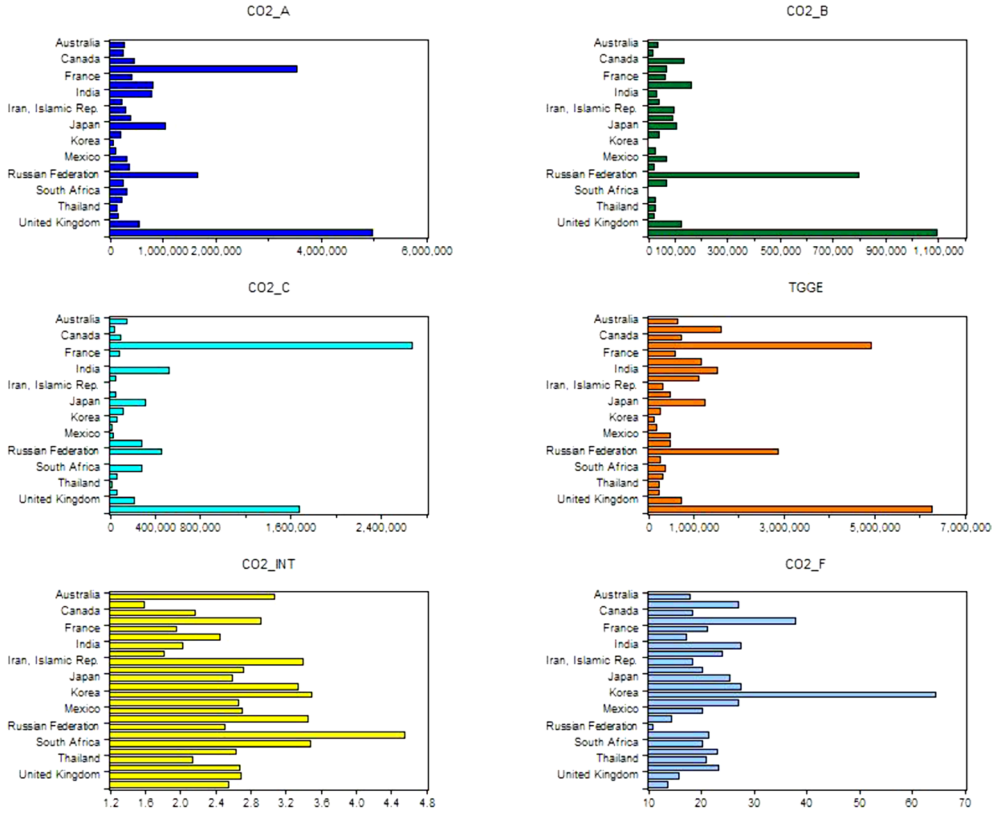


Fig. 3. Countries distribution by mean

4.2. Pair wise Granger causality test

We applied a Granger causality test to confirm whether endogenous variables were treated as exogenous in individual groups. Ahead, selected variables co-integrated, we assessed to perform the Granger Causality Test (GCT) among variables as presented in Table 6. We accept the null hypothesis that CO2_A does not granger cause EG and ANRD and EG does not granger cause of ANRD and vice versa found in Energy consumption. In the Natural Gas, Coal rent, Nuclear Energy Oil, Gas and Coal Renewable Energy consumption, CO2_B, CO2_C, TGGE, CO2_INT and CO2_F does not granger cause of EPNG, EPCS, TGGE, EPOGC and CRW. (Emirmahmutoglu & Kose, 2011; Hao, Wang, Zhu, & Ye, 2018; Pao & Tsai, 2011). The Padroni Co-integration modified by Weighted Level Table 7. All the six group variables tested by co-integration methods rejected the null hypothesis and there is no co-integration relationship among variables. Table 8 (Kao C, 1995; P., 2004).

Table 5: Estimation by VAR

Group A [t-test]	ANRD (-1)	ANRD (-2)	EG (-1)	EG (-2)	CO2_A (-1)	CO2_A (-2)
ANRD	0.841[25.502]	0.072[2.206]	0.000[-0.032]	0.000[-0.003]	0.000[0.796]	0.000[-0.821]
EG	3.676[1.525]	3.525[1.470]	1.028[27.910]	-0.028[-0.763]	0.000[2.291]	0.000[-2.311]
CO2_A	(755.402)[-0.767]	1446.458[1.475]	(81.432)[-5.407]	77.684[5.110]	1.700[58.061]	(0.692)[-22.764]
Group B [t-test]	NGR (-1)	NGR (-2)	EPNG (-1)	EPNG (-2)	CO2_B (-1)	CO2_B (-2)
NGR	1.029[30.557]	(0.128)[-3.739]	(0.002)[-0.660]	0.004[1.312]	0.000[2.103]	0.000[-2.019]
EPNG	0.317[0.852]	(0.406)[-1.073]	1.150[33.597]	(0.154)[-4.444]	0.000[-0.010]	0.000[-0.032]
CO2_B	(2363.177)[-1.640]	2431.678[1.664]	176.159[1.331]	(157.399)[-1.174]	1.133[32.576]	(0.129)[-3.695]
Group C [t-test]	CR (-1)	CR (-2)	EPSC (-1)	EPSC (-2)	CO2_C (-1)	CO2_C (-2)
CR	0.670[20.059]	0.142[4.279]	(0.001)[-0.217]	0.005[0.774]	0.000[0.964]	0.000[-0.979]
EPSC	0.039[0.211]	0.261[1.437]	0.990[29.446]	(0.004)[-0.105]	0.000[0.093]	0.000[-0.091]
CO2_C	(2224.419)[-0.828]	3786.855[1.421]	(1644.893)[-3.335]	1645.273[3.355]	1.676[58.142]	(0.666)[-21.959]
Group D [t-test]	ANE (-1)	ANE (-2)	EPNS (-1)	EPNS (-2)	TGGE (-1)	TGGE (-2)
ANE	0.977[17.483]	0.016[0.276]	0.164[5.353]	(0.155)[-5.043]	0.000[0.400]	0.000[-0.332]
EPNS	0.087[0.871]	(0.099)[-0.980]	1.284[23.492]	(0.277)[-5.032]	0.000[-0.071]	0.000[0.106]
TGGE	(19665.7)[-1.065]	22779.000[1.226]	8362.019[0.828]	(10844.630)[-1.066]	0.696[21.843]	0.333[10.166]
Group E [t-test]	EPOGC (-1)	EPOGC (-2)	AE (-1)	AE (-2)	CO2_INT (-1)	CO2_INT (-2)
EPOGC	0.924[17.984]	0.077[1.483]	(0.054)[-0.725]	0.050[0.702]	1.602[1.263]	(1.967)[-1.553]
AE	0.036[1.478]	(0.023)[-0.963]	0.529[15.075]	0.404[12.162]	0.112[0.187]	(0.716)[-1.207]
CO2_INT	(0.001)[-0.565]	0.002[0.795]	(0.003)[-1.097]	0.003[0.961]	0.866[17.336]	0.096[1.934]
Group F [t-test]	ANSE (-1)	ANSE (-2)	CRW (-1)	CRW (-2)	CO_F (-1)	CO_F (-2)
ANSE	0.840[18.716]	0.027[0.631]	(0.394)[-1.751]	0.378[1.716]	0.116[1.785]	(0.048)[-0.754]
CRW	0.006[0.747]	(0.014)[-1.678]	1.160[25.769]	(0.179)[-4.068]	(0.022)[-1.741]	0.012[0.975]
CO_F	(0.026)[-0.877]	0.031[1.067]	(0.131)[-0.859]	0.142[0.948]	0.764[17.195]	0.199[4.554]

Sources: Calculated by the authors. Variable's definition indicated in Table 3. VAR estimation were estimated with individual group restrictions and provide first lag coefficients of each group with t-test.

Table 6. Pairwise Granger Causality Test

Consumption	Null Hypothesis	F-Statistics
Energy	EG does not Granger Cause CO2_A	22.529***
	CO2_A does not Granger Cause EG	2.026*
	ANRD does not Granger Cause CO2_A	0.695*
	CO2_A does not Granger Cause ANRD	1.098*
	ANRD does not Granger Cause EG	25.303***
	EG does not Granger Cause ANRD	0.899*
Natural gas	EPNG does not Granger Cause CO2_B	1.486*
	CO2_B does not Granger Cause EPNG	0.576*
	NGR does not Granger Cause CO2_B	1.478*
	CO2_B does not Granger Cause NGR	4.00***
	NGR does not Granger Cause EPNG	0.820*
	EPNG does not Granger Cause NGR	8.860***
Coal rent	EPCS does not Granger Cause CO2_C	5.198***
	CO2_C does not Granger Cause EPCS	0.101*
	CR does not Granger Cause CO2_C	1.214*
	CO2_C does not Granger Cause CR	0.508*
	CR does not Granger Cause EPCS	3.583***
	EPCS does not Granger Cause CR	12.524***
Nuclear energy	EPNS does not Granger Cause TGGE	1.516*
	TGGE does not Granger Cause EPNS	0.059*
	ANE does not Granger Cause TGGE	0.94*
	TGGE does not Granger Cause ANE	0.280*
	ANE does not Granger Cause EPNS	0.392*
	EPNS does not Granger Cause ANE	16.941***
Oil, Gas and Coal	AE does not Granger Cause CO2_INT	1.031***
	CO2_INT does not Granger Cause AE	1.802*
	EPOGC does not Granger Cause CO2_INT	14.266***
	CO2_INT does not Granger Cause EPOGC	0.648*
	EPOGC does not Granger Cause AE	2.659**
	AE does not Granger Cause EPOGC	0.161*
Renewable Energy	CRW does not Granger Cause CO2_F	2.492*
	CO2_F does not Granger Cause CRW	0.756*
	ANSE does not Granger Cause CO2_F	0.655*
	CO2_F does not Granger Cause ANSE	7.376***
	ANSE does not Granger Cause CRW	7.148***
	CRW does not Granger Cause ANSE	3.148***

Sources: Calculated by the authors. Variable's definition indicated in Table 3 ***, **, * indicates significance levels at 1%, 5% and 10%.

Table 7. Padroni Residual Co-Integration Modified table by Weighted level

Consumption	Dimensions	Panel v-Statistic	Panel rho-Statistic	Panel PP-Statistic	Panel ADF-Statistic
Energy	Within	5.283***	(1.833)***	(4.157)***	(1.744)***
	Between		0.224**	(3.088)***	(1.595)***
Natural gas	Within	1.749**	1.711**	1.199**	2.562**
	Between		1.262**	(0.851)**	1.103**
Coal rent	Within	(0.291)**	2.488**	(0.433)**	2.41**
	Between		0.373**	(2.122)***	(0.148)**
Nuclear energy	Within	5.562***	(1.261)**	(4.168)***	(2.712)***
	Between		0.028**	(4.701)***	(1.761)***
Oil, Gas and Coal	Within	(1.705)**	0.192**	(2.803)***	(4.354)***
	Between		1.027**	(2.716)***	(1.284)***
Renewable energy	Within	(2.366)**	1.191**	(3.486)***	(0.250)**
	Between		1.329**	(4.620)***	(1.905)***

Note: Variable's definition indicated in Table 3, *** specifies the significance levels at 1%, ** specifies the significance levels at 5%, * specifies the significance levels, at 1%, 5% and 10%.

Sources: Calculated by the authors.

Table 8. Covariance of GLM by GDPG

Variables	GDPG	CO2_A	CO2_B	CO2_C	TGGE	CO2_INT
GDPG		(2.238)***	(0.436)***	2.277***	2.435***	2.953***
CO2_A	(2.239)***		32.626***	36.245***	11.833***	2.681***
CO2_B	(0.437)**	32.620***		(46.465)***	6.660***	1.295**
CO2_C	2.277***	36.245***	(46.465)***		7.438***	3.591***
TGGE	2.243***	11.833***	6.660***	7.438***		(9.354)***
CO2_INT	2.954***	11.833***	1.295**	3.591***	(9.354)***	
CO2_F	1.604**	2.681***	(10.871)***	(2.592)***	7.546***	(0.529)***

Note: Variable's definition indicated in Table 3 ***, **, *, at 1%, 5% and 10%.

Sources: Calculated by the authors.

Although an excessive number of researchers examine the relationship of energy consumption with economic growth, very few do so on the group consumptions. No agreement has been reached on China's energy consumption between economic development. Furthermore, the USA and India are also listed among the highest levels of energy consumption. Changes in economic growth and CO2 emissions have been examined in six-different comparisons. In contrast, the literature examined a unidirectional causality running from output to Energy, Natural Gas, Coal rent, Nuclear Energy Oil, Gas and Coal Renewable Energy consumption (Z. Cheng et al., 2017; Herrerias, Joyeux, & Girardin, 2013; Liang, Chai, Zhang, & Zhang, 2019; Lin, Fridley, Lu, Price, & Zhou, 2018; McGee & Greiner, 2019; Wolde-Rufael & Menyah, 2010). We should also note that in many

countries except China the bulk of natural resources are still used, including Natural gas, Coal rent, Nuclear energy and renewable energy in a different group consumption.

The offered literature has already confirmed that the use of coal rent, natural gas, nuclear energy and renewable energy would impede economic development (F. Dong, Wang, Su, Hua, & Zhang, 2019; Jin & Kim, 2018). Natural gas to electricity causality and vice versa (Uribe, Guillen, & Mosquera-López, 2018). USA and China play an important role in the production of electricity from Coal and is a crucial factor for economic growth (Morales Pedraza, 2019; Wang et al., 2019). The USA provided substantial electricity by nuclear power and a meaningful increase in its capacity of production (Karney, 2019). The production of electricity from different fuel sources (oil, coal, and water) and prices of coal and oil are similar, it was found in the long run (Kharbach & Chfadi, 2018).

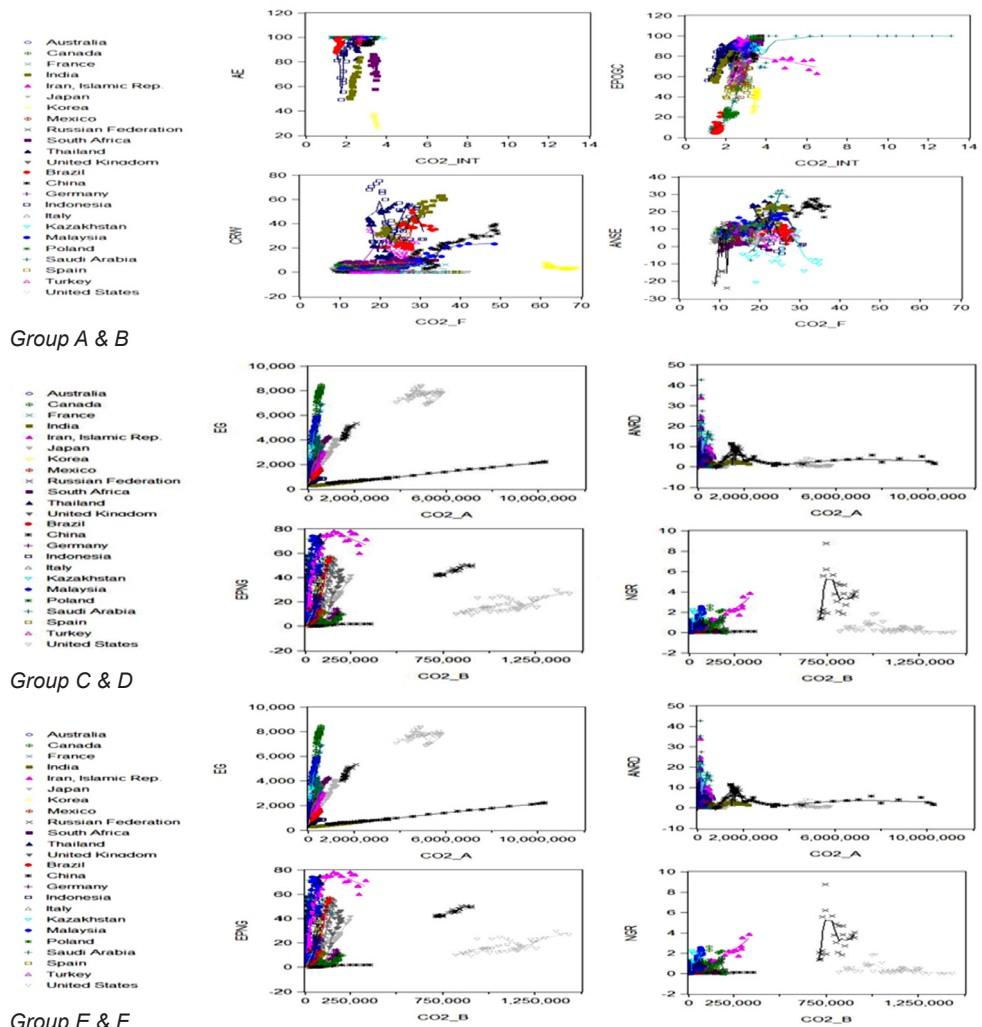


Fig. 4. Groups distribution by indicators

The results of estimation may be the reason for Granger causality for natural gas, coal rent, nuclear energy oil, gas and coal renewable energy consumption. The conclusion that ANRD, EG, NGR, EPNG, CR, EPCS, ANE, EPNS, EPOGC, AE, ANSE and CRW are not a Granger cause of CO2_A, CO2_B, CO2_C, TGGE, CO2_INT and CO2_F differs from the earlier study, some prior research using a mass of macro data, as most of earlier research found a positive effect on ANRD, CR, EPCS and ANSE on CO2_A, CO2_B, CO2_C (Acheampong, 2018; Mezghani & Ben Haddad, 2017). However, one reason for disparity may be that this study emphasizes the 25 polluted countries except Taiwan, while most of the previous studies have already discussed the environmental causes of GDP, but this study determined the six different groups of emission and individual effect of each variable with CO2_A, CO2_B, CO2_C, TGGE, CO2_INT and CO2_F. (Fig 4)

The Granger causality existence from energy consumption to ANRD, EG, NGR, EPNG, CR, EPCS, ANE, EPNS, EPOGC, AE, ANSE and CRW specifies the level of growth. Energy consumption precedes to increase of ANRD, EG, NGR, EPNG, CR, EPCS, ANE, EPNS, EPOGC, AE, ANSE and CRW in 24 top polluted countries, which can be assumed to be a feature of each individual country's economic growth. There is some caution that the co-existent casualty in the coherent might not occur though the calculated results – this suggests the Granger causality. It shows test results significant causality among the variables. Almost a uni-directional causality could run from energy consumption and its effected-on GDP. In fact, however, if CO2_A, CO2_B, CO2_C, TGGE, CO2_INT and CO2_F is mismanaged into barren economic sectors, then the economic growth of an individual state is insignificant or cannot occur at all and may create big problems for nations.

4.3. Particular analysis by GLM

After computing the Granger causality among the variables, specifying the relationship and that needed by the Generalized Linear Model (GLM), it was seen that linear regression permits non-linear systematic components with non-normal stochastics in each group of energy consumption (Hardin, 2007; McCullagh, 1989). We get the conclusions of covariance of GLM by GDP. We estimate the covariance of reliant variables with GDPG in Ordinary and Huber-White.

We can observe that CO2_A, CO2_B, CO2_C, TGGE, CO2_INT and CO2_F affect GDPG at the significant level of 1% in the long term and that the 1% increase in energy consumption CO2_A, will cause of a GDPG increase with a 2.238. A 1% increase in CO2_B, CO2_C, TGGE, CO2_INT and CO2_F will cause a 0.436, 2.277, 2.435 and 2.953 increase in GDPG. The impact of CO2_A, CO2_B, CO2_C, TGGE, CO2_INT, CO2_F and GDPG is also positive at a significant level of 1%, and that a 1% rise is related to an increase in the GDPG results Table 8. We state the individual state consumption in Fig 5. The group covariance computed with Wald test. The impact of CO2_A, TGGE and CO2_INT is showing negative significant level of 1% in ANRD, ANE and AE with 11.248, 3.145 and 0.913 Wald test Table 9.

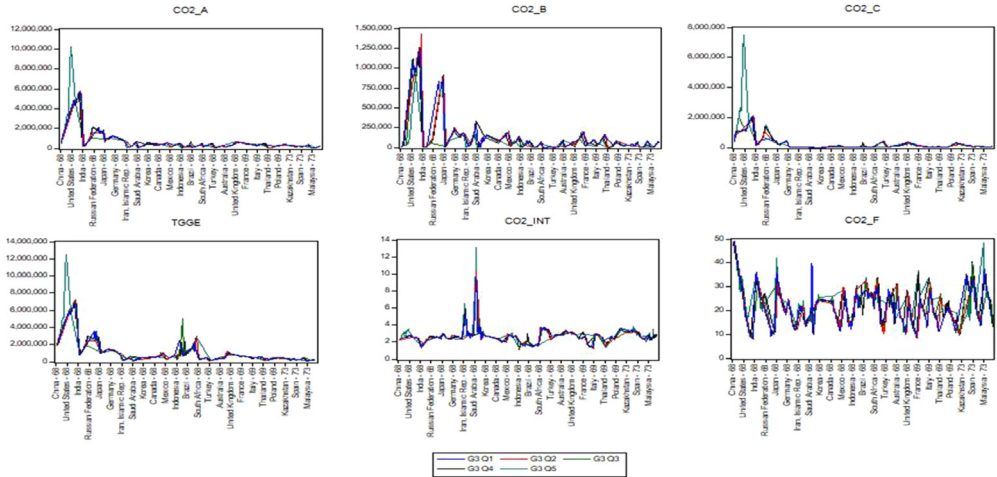


Fig. 5. Consumption level by individual state

Table 9. Stepwise regression

Consumption	Variables	Periods					Wald-test
		1st	2nd	3rd	4th	5th	
		1968-1977	1978-1987	1988-1997	1998-2007	2008-2017	
Energy	ANRD	4.800***	(0.379)**	3.655***	8.222***	4.744***	2.831***
	EG	3.332***	(0.631)**	(0.628)**	0.610**	(2.124)***	(2.253)***
	CO2_A	(0.933)**	2.997***	3.161***	6.277***	6.318***	11.248***
Natural gas	NGR	0.502**	1.789**	(2.631)***	4.360***	0.784**	7.804***
	EPNG	3.059***	(2.936)***	6.181***	2.858***	1.367**	9.984***
	CO2_B	(0.918)**	1.144**	(0.256)**	1.557**	0.848**	1.228**
Coal rent	CR	(1.347)**	(0.376)**	(5.083)**	1.886**	0.434**	0.554**
	EPCS	2.802***	1.701***	5.996***	5.834***	3.358***	3.125***
	CO2_C	0.837**	2.919***	2.575***	3.947***	4.274**	7.795***
Nuclear energy	ANE	4.394***	1.118**	1.322**	1.842**	0.946**	16.684***
	EPNS	(0.906)**	(0.360)**	(0.848)**	(1.345)**	(1.325)**	(2.535)***
	TGGE	1.783**	3.463***	4.092***	8.350***	5.601***	3.145***
Oil, Gas and Coal	EPOGC	-	-	0.411**	(1.883)**	(1.444)**	11.681***
	AE	-	-	(1.126)**	(2.845)***	(3.019)***	24.442***
	CO2_INT	-	-	0.986**	4.862***	3.485***	(0.913)**
Renewable energy	ANSE	-	-	6.378***	(0.122)**	3.568***	36.042***
	CRW	-	-	0.496**	(1.436)**	1.359**	8.198***
	CO2_F	-	-	1.109**	7.257***	0.974**	10.542***

Note: Variable's definition indicated in Table 3, ***, **, *, represent significance level at 1%, 5% and 10%.
Sources: Calculated by the authors.

4.4. Additional analysis

The above analysis implies the influence of each group and uses it on the other variables. The result does not specify the 10 years' period of Energy, Natural gas, Coal rent, Nuclear energy, Oil and gas and Coal, and Renewable energy consumption. The stepwise regression shows five periods and each consists of 10 years' duration.

Energy consumption of the 1st period shows negative at a significant level of 1% and uses that 1% increase CO₂_A to decrease 1% in ANRD and EG. The Natural gas consumption 1st and 3rd periods are negative at a significant level and denote a 1% increase in CO₂_B related to the decrease of NGR and EPNG. However, the 4th and 5th period positive at the significant level of 1% that a 1% rise in CO₂_A, CO₂_B, CO₂_C, TGGE, CO₂_INT and CO₂_F used that 1% used of ANRD, NGR, EPNG, CR, EPCS, and ANE. The estimated results are the influence of a shock of specific periods on a group of the variables. This paper uses individual states' energy consumption and their impact, the computation of results shown in Fig 6 with high and low levels of consumption.

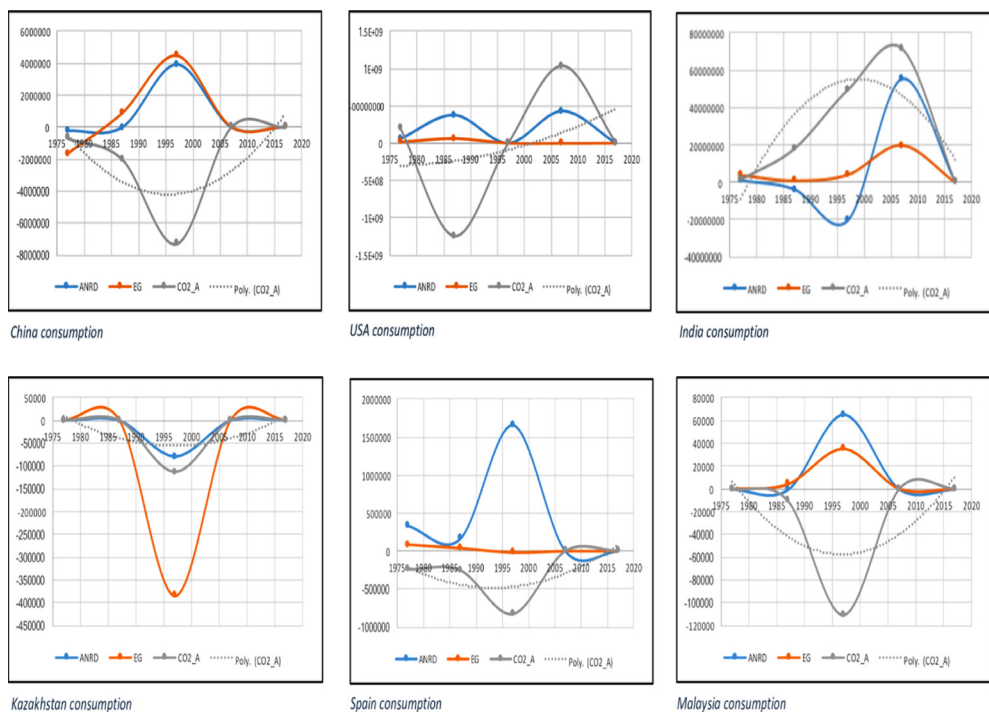


Fig. 6. High and low level of consumption. Note: high level consumption (China, USA and India) and low level (Kazakhstan, Spain and Malaysia)

5. Conclusions and policy implications

This research study assesses the relationship between the energy computation by Energy, Natural Gas, Nuclear Energy, Oil Gas and Coal, Renewable Energy and its effect on GDP in the period of 1968 and 2017 using a panel data set. The co-variance of GLM and stepwise regression were applied to investigate the relationship among an individual group of explanatory variables. After the Granger causality, variance analysis was used on the energy consumption and contribution of a relevant factor of production of electricity by the difference in sources and the intensity of CO₂ emission in 24 (polluted) countries. It is significant that in each group there is a sign for a unidirectional relationship of the Granger causality in the energy consumption.

That Natural resources, use of energy, natural gas, electricity production by natural gas, coal rent, electricity production by coal rent, nuclear energy, production of electricity by nuclear energy, production of electricity by oil, gas and coal, electricity access, net saving and waste combustion, are not a Granger cause of energy; natural gas, carbon emission from solid fuel, green gas emission, intensity of CO₂ and emission by manufacturing industries differed from earlier studies and specify that the level of growth of energy consumption precedes in polluted countries, which can be comprehended as a feature of economic growth. The negative results on economic sectors might be the cause of misused energy resources. The unidirectional causality runs from economic growth to energy consumption. The analysis estimation results show that the huge production of electricity from different sources that causes CO₂ emissions and influences economic growth and validity has decreased after a continuous increase and steadying period. However, a positive unidirectional causality from 24 (polluted) countries' energy consumption to economic development was detected, while a short-run bidirectional casualty exists among the above six groups of variables. These estimated results also showed some valuable strategy and implications as follows.

First, energy and natural gas intake policies should revised and changed in China, the USA, India, Russia, and Japan to reduce energy, natural gas and green gas consumption in the 6th (Next ten years) period and control the production of electricity by natural resources in group A, B, C, and D. However, the oil, gas and renewable energy consumption in Saudi Arabia, Iran, Korea, and China changed with new equipments and policies to control the CO₂ emissions and the production of electricity. Second, the Granger causality test results suggest a unidirectional causality from Energy, Natural Gas, Coal rent, Nuclear Energy Oil, Gas and Coal Renewable Energy consumption to economic growth. And the consequences of results impulsive a response, the impact of 24 (polluted) countries energy consumption would at first increase then decrease, and the upcoming 6th and 7th periods would stabilize more with new changed strategies for control energy consumption. Third, a clean energy consumption role should endorsed in the above countries, so that energy environmental quality and affordability is enhanced and the ecosystem is secured in an upcoming period. Fourth, renewable energy by alternative means emits less carbon elements and controls the release of harmful gasses to the environment. Fifth, high-polluted

countries should avoid high quantities of oil and gasses for development and introduce safe and controllable natural resources like solar and wind power. We find a unilateral causality in between energy consumption and economic growth. Therefore, the consumption of energy might be conducive of 24 (polluted) countries and better economic development, the consumption of energy face lifted and guaranteed, while we should limit the resources of countries. Thus, varying current consumption of the energy mix in above countries, and likewise promoting clean energy, is necessary for the coming generations.

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