INVESTIGATING THE DETERMINANTS OF CARBON EMISSIONS IN THE UNITED STATES: A STATE-LEVEL ANALYSIS

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ABSTRACT:

The present study investigates the significant determinants of carbon emissions, namely GDP, energy consumption, energy price, and energy expenditure, utilizing data of 50 American states from 2005 to 2016. Results obtained from application of OLS with fixed effects and Panel Quantile Regression revealed that the effect of GDP on carbon emissions is negative but significant at all quantiles, energy consumption and energy price have a positive and significant effect on carbon emissions, while the effect of energy expenditure is negative but significant at the upper and lower quantiles, implying that high energy expenditures do not reduce carbon dioxide emission at the US state level. Policymakers should introduce further initiatives, so all the states would implement the climate legislations.

KEYWORDS: Carbon Emission, Energy Consumption, State-Level Analysis, OLS fixed effects, Panel Quantile Regression

1. INTRODUCTION

Climate change is one of the most challenging issues faced by humanin the past few decades.. According to the Intergovernmental Panel on Climate Change (IPCC), CO2 emissions contribute 76.7% of green-house gases (GHG) emissions generatedby numerous developed and developing nations around the globein order to accelerate their economic growth (Gökmenoğlu and Taspinar, 2016), and it is also the major reason for the current environmental degradation crisis. . There have been several international attempts, such as the Paris Agreement, to limit the increase in global temperature below 2°C, and to try lowering it to 1.5°C (Li et al., 2020); hence, it is essential for researchers and policymakers to understand the determinantal factors of CO2 emissions, as it is a

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threat to human and economic development (Acheampong et al., 2021). Therefore, investigating the determinants of CO_2 emissions is imperative and decisive in solving global warming and climate change problems (Muhammad and Long, 2021).

Among many pollutants, energy consumption (especial utilization of traditional energy resources) is generally recognized as the major cause of global warming and climate change(Shao et al., 2021). Reviewing past studies revealed that energy consumption, energy price, and economic growth are the main determinants of CO_2 emissions, but their impact found to be controversial. For instance, some researchers found a positive relationship between energy consumption and CO_2 emissions (Eluwole et al., 2020; Rahman, 2020; Lai et al., 2019), while others failed to find enough evidence on the impacts of energy consumption on CO_2 emissions (Ehigiamusoe et al., 2020; Nazirah Wahid et al., 2013).

Energy has a pivotal role in facilitating countries' development, and fluctuations in energy prices cause major disturbances in the world economy; it puts development and growth at risk and jeopardy. This variable is important as income fluctuation as a result of changes in energy prices can affect pollution and might cause an inverted U-shaped EKC (Al-Mulali and Ozturk, 2016).Some studies have indicated a positive impact of energy prices on carbon emissions (McCollum et al., 2016; Zhang et al., 2017; Ju et al., 2017). Based on the neoclassical economics theory, increasing energy prices will cause lower energy consumption, and it will lead to a reduction in CO_2 emissions. On the other hand, it also highlights the significance of energy scarcity, which eventually encourages consumption of cheaper alternatives such as coal and hence, results in further carbon dioxide emissions (Li et al., 2020).

Many researchers have investigated the relationship between CO_2 emissions and economic growth, using four hypotheses, including the growth-led CO_2 hypothesis (Aydoğan and Vardar, 2020; Wasti and Zaidi, 2020; Shahbaz et al., 2017); CO_2-led growth hypothesis (Adedoyin et al., 2020b; Wang et al., 2016, a); feedback hypothesis (Tong et al., 2020; Acheampong, 2018); and neutrality hypothesis (Wang et al., 2016, b). In terms of the GDP-CO_2 emission nexus, which is known by the environmental Kuznets curve (EKC), researchers (Ozcan and Ozturk, 2019; Agboola and Bekun, 2019; Kotroni et al., 2020) claimed that there is an inverted U-shaped curve between the environmental quality and economic growth; however, other researchers (Onafowora and Owoye, 2014) found a cubic (or N-shaped) relationship and Pata and Aydin (2020) and Wang (2012) stated that the environmental Kuznets curve hypothesis is not true.

The current research focuses on 50 states of the United States (US), as the United States has a significant role in accelerating climate change, and has contributed over 13% to the global CO2 emissions by 2020, while it only represents less than 5% of global population (Tiseo, 2022) This study contributes to the literature by using state-level data in studying carbon emissions. .. What makes this study's contribution valuable is the focus on American states, which is not covered by the current literature. The level of the US greenhouse gases varies among states due to the physical size, types of energy system, energy consumption, energy expenditure, energy price, and economic growth. For example, Columbia contributes in the CO2 emissions by 3.8 million tons, while this amount is 105.4 million tons for Wyoming. In addition, renewable and non-renewable energy consumption is 176 million British thermal units (MBTU) in Rhode Island and 897.4 MBTU in Louisiana. Moreover, GDP per capital differs among states and Washington, D.C. has the highest rank by USD 159219 and Mississippi has the lowest rank by USD 32,338. Therefore, investigating the determinants of carbon emissions using panel data of different states has been found pivotal for policymakers (Salari et al., 2021).

Currently the US is aiming to meet the net-zero greenhouse emission goal or carbon neutrality latest by 2050. To achieve this target, the state level governments are keen to take some measurable actions against climate change. Most recently almost fifteen states including territories have taken legislative actions, to progress towards the path of clean electricity polices and pollution reduction programs to achieve clean energy future (Podesta et al, 2019). Virginia has passed Clean Economy Act to reduce carbon emissions particularly in power sector by wind energy usage. Washington state has passed sector specific polices for transportation, buildings, power, and industrial sectors. New York, Colorado, and Maine have structured comprehensive policies for a reduction in gas pollution to support workers and front-line communities in the energy transition sectors (Washington state governor office, 2019). The state of California has been in the frontline in contracting bilateral climate partnerships with other nations across the world, such as India and China (California Energy Commission, 2020). Pennsylvania and North Carolina are ready to begin their regulatory procedure for combating climate change issues (North Carolina Clean Energy Technology Center, 2019).

Around 26 states have already passed standard policies to decarbonize power generations and for the enforcement of energy efficiency resource standards (EERS), which help in reducing total energy usage demand, and ultimately, help in achieving clean electricity generation (American Council for an Energy Efficient Economy, 2019). Besides, almost 17 state governments are using corresponding policies like tax incentives and aggregate metering program for distributing renewable energy (National Conference of State Legislatures,2017). More specifically, state actions towards climate-smart transportation policy are somehow very effective, as 43 states including Washington DC taken measures to enhance electric vehicles (EVs) and charging infrastructure during 2019 all alone. California and 12 other states also implementing zero emission vehicle standards and invest in charging infrastructure taxes to encourage purchase of EVs including public vehicle fleets. The city of New York has emphasized on large-scale energy proficiency developments, and has legally bound the carbon pollution to certain limits from large and new buildings, with heavy penalties imposed in case of noncompliance (Neuman, 2019). In the same way California, is planning to implement climate-smart building standards and introducing anti-displacement policy. In 2018, Hawaii has launched a Greenhouse Gas Sequestration Task Force to find ideas to stock carbon in state farms and in forests (State of Hawaii Office of Planning, 2020). California was considered as the primary state to introduce CalEnviroScreen program to provide statewide assessment of pollution and environmental effects (California Environmental Justice Alliance, 2018). All these state level policy measures are usually supported by cities, and can be a pathway to provide bases to formulate federal policies. A table describing state-specific characteristics affecting the determinates of CO_2 emissions has been established and provided in the Appendix A.

This study examines various determinants of carbon emissions such as energy price, energy consumption, energy expenditures, and economic growth on CO_2 emissions using the state-level panel data of the United States for the period from 2005 to 2016, and by utilizing the panel quantile regression technique. The study is organized as follows. Section 2 provides the relevant literature review. Section 3 discusses the data and the methodology approach. The results and discussions are presented in section 4, and finally, section 5 derives conclusions and policy recommendations.

2. LITERATURE REVIEW

Recent decades have witnessed two major issues of global warming and climate change, and CO2 emissions are the main causes of these problems (Esso and Keho, 2016). Therefore, many researchers have investigated the effects of different factors affecting carbon emissions. The studies can be classified into four groups, as presented in the following sub-sections.

2.1. GDP AND CARBON DIOXIDE EMISSIONS

The first group contains studies that examined the impact of GDP on the quality of the environment. For instance, using the panel quantile regression model, Salehnia et al. (2020) indicated that the impact of economic growth on CO2 emissions was positive in MENA countries for the period from 2004 to 2016. According to the study by Udemba et al. (2020) that focuses on China over the 1955Q1- 2016Q4, a positive relationship exists between CO2 emissions and economic growth. In addition, Liu et al. (2020) explored the interaction between renewable energy consumption, income, and CO2 emissions using annual data from 1999 to 2014 for BRICS countries by utilizing the 3SLS approach. The results were found to be heterogeneous at the country level, and no causal relationships were found in India and China.

Chen et al. (2019) investigated the link between CO2 emissions, foreign trade, GDP, and renewable and non-renewable energies in China from 1980 to 2014 using ARDL and VECM approaches. They found that the consumption of renewable energy and foreign trade, decrease CO2 emissions, while consumption of non-renewable energy sources and GDP, increase CO2 emissions. Analyzing the impact of energy consumption and national output on CO2 emission in 20 Organization of Islamic Cooperation (OIC) nations by implementing the ADRL model. Shaari et al. (2020) stated that GDP leads to further environmental degradation in the long-run; however, there is no impact on CO2 emissions in the short-run. Bekun et al. (2019) investigated the nexus between energy use and economic growth for the data from 1960 to 2016 in South Africa, and found a long-run association among investigated variables.

Sheng et al. (2020) studied the relationship between economic growth and CO2 emissions in Chinese provinces. Their research focused on both the short-run and long-run horizons, and found a positive effect in the short-run, when they are in low stage or high stage of development, and a negative effect in the intermediate economic development stage. In addition, Adedoyin et al. (2020a) investigated the impact of coal rent, consumption of coal, and economic growth on carbon dioxide emissions in BRICS nations by using PMG-ARDL approaches, and found that consumption of coal has a negative impact on CO2 emissions. Another empirical research by Boubellouta and Kusch-Brandt, (2020) investigated the EKC in selected 30 economies of Europe over the 2000-2016 period by using the GMM approach. Their findings support the EKC in the region.

2.2. ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS

The second group's studies examined the effect of energy consumption on carbon emissions. For instance, Muhammad and long (2021) studied BIR (belt and road initiative) courtiers over the 2000-2016 period, and showed that energy consumption causes environmental pollution and increases CO2 emissions across all income groups. Acheampong et al. (2021) examined the linkage between CO2 emissions, economic growth, and energy consumption among different regions using the PVAR method from 1990 to 2014. They found that energy consumption increases carbon dioxide emissions in MENA, but there is a negative impact in Caribbean-Latin America and sub-Saharan Africa. Another study was conducted by Danish et al. (2019) on the relationship between ICT and energy consumption across various income groups, such as high-income countries, middle-income countries, and low-income countries from 1990 to 2015. The results showed that energy consumption is the main reason for increasing in CO2 emissions.

Sarkodie and Strezov (2019) studied the impact of economic development, foreign direct investment inflows, and consumption of energy on CO2 emissions in developing countries from the year 1982 to 2016 by using panel quantile regression. The findings revealed a strong positive relationship between energy consumption and greenhouse gas emissions. Behera and Dash (2017) addressed the energy consumption and the carbon dioxide emission nexus problem in South and Southeast Asian countries from 1980 to 2012. The results confirmed that energy consumption increases CO2 emissions.

2.3. ENERGY PRICES AND CARBON DIOXIDE EMISSIONS

The third group of investigations reviewed the role of energy price in environmental quality. For example, Li et al. (2020) tested China's energy prices and CO_2 emissions using an extended STIRPAT. They used Chinese provincial data over 2002 to 2016 period and utilized the spatial panel data techniques. The results revealed the negative impact of energy prices on CO_2 emissions. Li et al. (2019) also studied the effect of population and energy price on CO_2 emissions in 30 Chinese provinces from 2001 to 2016 through two channels, residential and industrial. The study employed neoclassical growth theory and showed that a decrease in energy price would increase environmental pollution. In addition, Li et al. (2018) studied the effects of energy investment, economic development, energy consumption, energy prices, and energy intensity on CO_2 emissions in China from 1997 to 2014 using the GWR model and quantile regression. They realized that energy prices could increase carbon emissions.

Zhao et al. (2012) investigated the impact of energy price and showed that the price of energy facilitates the reduction in energy use. Several studies have examined energy prices and energy consumption, but the results are controversial. For instance, Yuan et al. (2010) investigated energy prices and energy consumption in China using the national data from 1993 to 2007. The study showed that higher energy prices decrease energy consumption over the long run; however, the impact is the opposite in the short run. Ferreira et al. (2005) examined the data from the UK for the period 1968–2005 and found a significant connection between the energy prices and energy consumption.

2.4. ENERGY EXPENDITURES AND CARBON DIOXIDE EMISSIONS

Finally, the fourth group of investigations studied the effect of energy expenditures on CO_2 emissions. For instance, Rehman et al. (2021) explored the dynamic effects of CO_2 emissions on expenditures, trade, foreign direct investment, and renewable energy in Pakistan from 1975 to 2017 using nonlinear autoregressive distributed lag (NARDL). The study results showed that expenditures have a positive relationship with CO_2 emissions.

3. METHODS AND MATERIAL

This section discusses the method of the study, and the model and its variables. The study models carbon dioxide emission against its determinants for 50 American states, and utilizes Panel Quantile Regression Method for the purpose of model estimation.

3.1. PANEL QUANTILE REGRESSION METHOD AND OLS WITH FIXED EFFECTS

Panel quantile regression method was introduced by Koenker and Bassett (1978). This method tolerates the individual effect to affect the whole distribution in place of fluctuating means between the others. The model also has endogenous independent variables and roots with individual effects (Canay, 2011; Koengkan et al., 2022). The present study uses the Method of Moments Quantile Regression with fixed effects (MMQR). Machado and Silva (2019) developed this method. The equation of MMQR is as follows:

$$Y_{it} = a_i + X'_{it}\beta + (\rho_i + Z'_{it}\gamma)U_{it} \, , \qquad (1)$$

Where $P\{\rho_i + Z'_{it}\gamma > 0\} = 1$ and Y_{it}, X'_{it} are a panel of N individuals (i=1, 2, …, N) over T periods.

For a group of observations, the OLS estimates slope and intercepts. In addition, this method is able to estimate the fixed predictors utilizing the conditional mean function. Moreover, the results of OLS with fixed effects are comparable to the 50th quantile of simultaneous quantile regression as discussed by Koengkan et al. (2022).

3.2. MODELS AND VARIABLES

This study utilizes data from 50 American states from 2005 to 2016 in order to model CO2 emissions at the state level. Table 1 summarizes the variables of the study, their definition, and the sources, from which the relevant data that have been captured. As it can be seen from Table 1, this study models states' CO2 emissions against their significant determinants, including GDP by state, energy consumption by state, energy price by state, and energy expenditure by state. For the purpose of a better interpretation of the results, all the variables have been transformed into a logarithm format. In addition, Table 2 represents the descriptive statistics of the variables of this study.

Table 1 Definition of variables

Variable	Symbol	Definition	Source
CO_2 emission by State	CO_2	Million metric tons of carbon dioxide	EIA
GDP by state	GDP	Real GDP by state 2012 dollars	EIA
Energy consumption by state	EC	Total energy average energy consumption -Million Btu	EIA
Energy prices by state	EAP	Total energy average price by State - Dollars per Million	EIA
Energy expenditure by state	EX	Total energy expenditures per capita by State – Dollars	EIA

Notes: The estimation period is 2005-2016. All variables are in natural logarithms.

Table 2 Summary of descriptive statistics (before logarithm)

Variables	CO_2	GDP	EC	EAP	EX
Mean	109.074	319512.9	1942696	19.598	4395.813
Std. Dev.	106.356	37949.9	2037019	4.013	1459.229
Skewness	2.453	2.933	2.870	0.859	2.530
Kurtosis	11.164	13.081	13.623	4.960	10.580
Minimum	2.700	26793	129223	9.330	2594.900
Median	78.550	186403	1471148	19.215	4033.150
Maximum	657.400	2519134	12994812	38.840	13046.70
Jarque-Bera	2268.412^{***}	3401.457^{**}	3645.315^{***}	169.928^{***}	2076.968^{***}
Observations	600	600	600	600	600

Notes: (1) ***significance at the 1% level, **significance at the 5% level

The following equation represents the carbon dioxide emissions model defined by the present study, where i indicates the state, and t denotes the year. For the purpose of better interpretation of results, all variables are transformed to their logarithm form in this study.

$$LnCO2_{it} = f\ (LnGDP_{it}, LnEC_{it}, LnEAP_{it}, LnEX_{it})$$

$$i = 1 \dots 50 \quad and\ t = 2005 \dots 2016$$

4. RESULTS AND DISCUSSION

Table 3 shows the correlation matrix for the variables of the model, and Table 4 represents the Variance Inflation Factor or VIF, which measures the multicollinearity between the explanatory variables. High multicollinearity will result in unstable parameter estimates. As the results show, there is no significant correlation or multicollinearity issue between the variables of the study.

Table 3 Correlation matrix (after logarithm)

Variables	CO_2	GDP	EC	EAP	EX
CO_2	1.000				
GDP	0.393^{***}	1.000			
EC	0.538^{***}	0.902^{***}	1.000		
EAP	-0.209^{***}	-0.001	-0.262^{***}	1.000	
EX	-0.056	-0.208^{***}	-0.018	0.075^{*}	1.000

Notes: (1) ***significance at the 1% level, *significance at the 10% level.

Table 4 VIF statistics

Variables	VIF	1/VIF
GDP	4.50	0.222
EC	4.41	0.226
EAP	1.18	0.847
EX	1.10	0.908
Mean VIF	**2.80**	

Panel unit root test is utilized to examine the stationarity characteristic of the data. The test's null hypothesis is based on the assumption that the series is non-stationary. It is substantially important to check the series order of integration, because using non-stationary variables can lead to a spurious regression issue. For the purpose of checking the stationary, this study applies Fisher-ADF, Fisher-PP, and Im–Pesaran–Shin (IPS) tests, with the null hypothesis of non-stationarity. These tests have the advantage of allowing as much heterogeneity across units as possible (Apergis and Payne, 2012). In addition, cointegration has been tested among variables of the study using the Kao cointegration test introduced by McCoskey & Kao (1998), which is a residual-based panel cointegration test. Cointegration helps in avoiding the spurious regression problem, and leads to more consistent parameter estimations. Table 5 represents the results of panel unit root tests and panel cointegration tests. All variables found to be integrated of order one or I(1), and all are cointegrated according to the Kao residual cointegration test result.

Table 5 Panel unit root tests and cointegration test of variables

Variables		Fisher ADF		Fisher PP		IPS	
		Constant	TC	Constant	TC	Constant	TC
Levels	CO_2	56.055	91.712	119.832*	137.051***	2.638	0.787
	GDP	45.524	84.191	56.856	72.525	5.971	1.304
	EC	143.969***	107.039	238.514***	204.838***	-3.161***	-0.820
	EAP	142.805***	20.126	143.831***	22.331	-1.807**	7.813
	EX	139.563***	42.381	119.933*	28.238	-3.736***	3.246
First differences	CO_2	251.005***	230.417***	482.358***	498.841***	-7.914***	-4.520***
	GDP	186.092***	190.334***	311.698***	398.572***	-5.041***	-3.249***
	EC	305.561***	276.941***	555.278***	538.687***	-10.350***	-6.053***
	EAP	267.193***	251.709***	270.533***	440.609***	-10.196***	-9.103***
	EX	287.736***	228.706***	318.742***	462.385***	-11.048***	-6.956***

Kao Residual Cointegration Test: -4.151 (0.000)

Notes: (1) ***significance at the 1% level, **significance at the 5% level, *significance at the 10% level. (2) TC represents a trend and constant.

Hausman test (Hausman, 1978) compares and evaluates the fixed effects and random effects estimators. The null hypothesis implies that the random effects estimator is efficient and consistent. However, in case unobserved effects are correlated with the covariates, the null hypothesis will not be holding, and the fixed effects estimator should be selected. The result of the Hausman test (chi2(4) = 18.228 ***)[2] indicates the rejection of the null hypothesis that the random effects estimator is consistent. As a result, we decide to apply the fixed effects estimator, as it is more consistent, while it may not be efficient when the null hypothesis holds. If we select the random effects, biased estimates would be the consequence, which is a more significant issue.

Finally, the study reports the full sample estimation results. Results from the fixed effects estimation show a negative impact of GDP on carbon emissions, with the elasticity of higher than one. This indicates that as the economies grow, their carbon intensity increases. The estimation results from the quantile regression reveal that the impact of economic growth on carbon emissions is increased moving towards higher quantiles. The negative coefficient of GDP in carbon

[2] *** significance at the 1% level. (2) Hausman results for H0: difference in coefficients not systematic.

emissions model implies that the higher level of economic growth is associated with lower carbon emissions, which is in line with the findings of Baek and Pride (2014), Dogan and Aslan (2017), and Mirziyoyeva and Salahodjaev (2022). In the case of the present study, further growth of the economy leads to higher provision of services and moving away from polluting manufacturing economic activities; hence, further growth does not cause higher carbon emissions. In addition, the findings demonstrate that the lowering impact on emissions as a result of utilizing modern technologies and implementing environmental policies, has exceeded the increasing impact on emissions, due to the intense economic activities. This means that the environmental policies and the advancements in technology in the US states have had a significant impact in lowering CO2 emissions, and the magnitude of their impact had been higher than the rising CO2 emissions as a result of economic activities in industries for instance.

Consumption of energy shows a positive and significant impact on carbon emissions in both fixed effects and quantile regression results; however, its impact decreases moving towards higher quantiles. This result is in line with the findings of Sharif et al. (2019), Chontanawat (2020) and Salari et al. (2021).

The contribution of energy consumption in generating CO2 emissions is mainly due to the higher share of nonrenewable sources of energy in the United States energy consumption structure. To illustrate, according to the US Energy Information Administration, coal, petroleum, and natural gas shape 79% of primary energy consumption in the United States. To point out, about 61% of electricity generation in the United States in 2021 was from fossil fuels sources such as coal, petroleum, natural gas, and other gases, and only 19% was from nuclear energy, and 20% was from renewable sources (EIA, 2021). Hence, the increase in the consumption of energy has led to the increase in carbon emissions in the US states.

Table 6 Panel quantile regression results and OLS fixed effects[3]

	Quantiles					
Variable	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**	**OLS fixed**
GDP	-1.042***	-1.096***	-1.134***	-1.170***	-1.194***	-1.125***
EC	1.874***	1.757***	1.675***	1.598***	1.547***	1.696***
EAP	0.904	1.201**	1.410***	1.606***	1.737***	1.357***
EX	-0.962**	-0.980***	-0.993***	-1.005***	-1.013***	-0.990***
Observations	600	600	600	600	600	600
Post-estimation test for the panel quantile model						
F/Wald test	Chi2(4) = 90.91***		Chi2(4) = 273.64***		Chi2(4) = 67.70***	

Notes: (1) ***significance at the 1% level, **significance at the 5% level. (2) The Stata commands xtqreg, xtreg, testparm.

Energy price and energy expenditure represent the similar behavior to the GDP across quantiles, meaning that their magnitude of impacts on carbon dioxide emissions increases in the higher quantiles. While energy prices positively impact carbon emissions, energy expenditure's impact is negative. When energy prices increase, there will be a shift towards lower cost and hence, more carbon-intensive fuels (i.e., a shift from natural gas to coal). While a surge in energy prices is expected to result in further energy conservation practices and higher investments in renewable energy sources it also imposes changes to energy structure of a state, moving towards the types of fuel, which emit more carbon dioxide (Ari et al., 2022). In the case of the current study, the latter have had higher magnitude and have offset the expected conservation impact. Other studies, such as Valizadeh et al. (2017) and Linn (2009), also suggest positive effects of energy prices on consumption of energy, which will lead to further carbon emissions.

The higher energy expenditure has led to lower carbon emissions, as the higher expenditure will cause further energy savings by households and firms. Due to the higher energy expenditures, firms and households have moved towards more energy conservation and utilization of renewable energy sources, which consequently have led to lower carbon emissions.

Figure 1 illustrates the estimation results using panel quantile regression.

[3] The financial crisis is statistically significant in the OLS, with fixed effects, but it only provokes slightly changes in the estimated coefficient; therefor, the authors opt not to include the model with dummies in the manuscript.

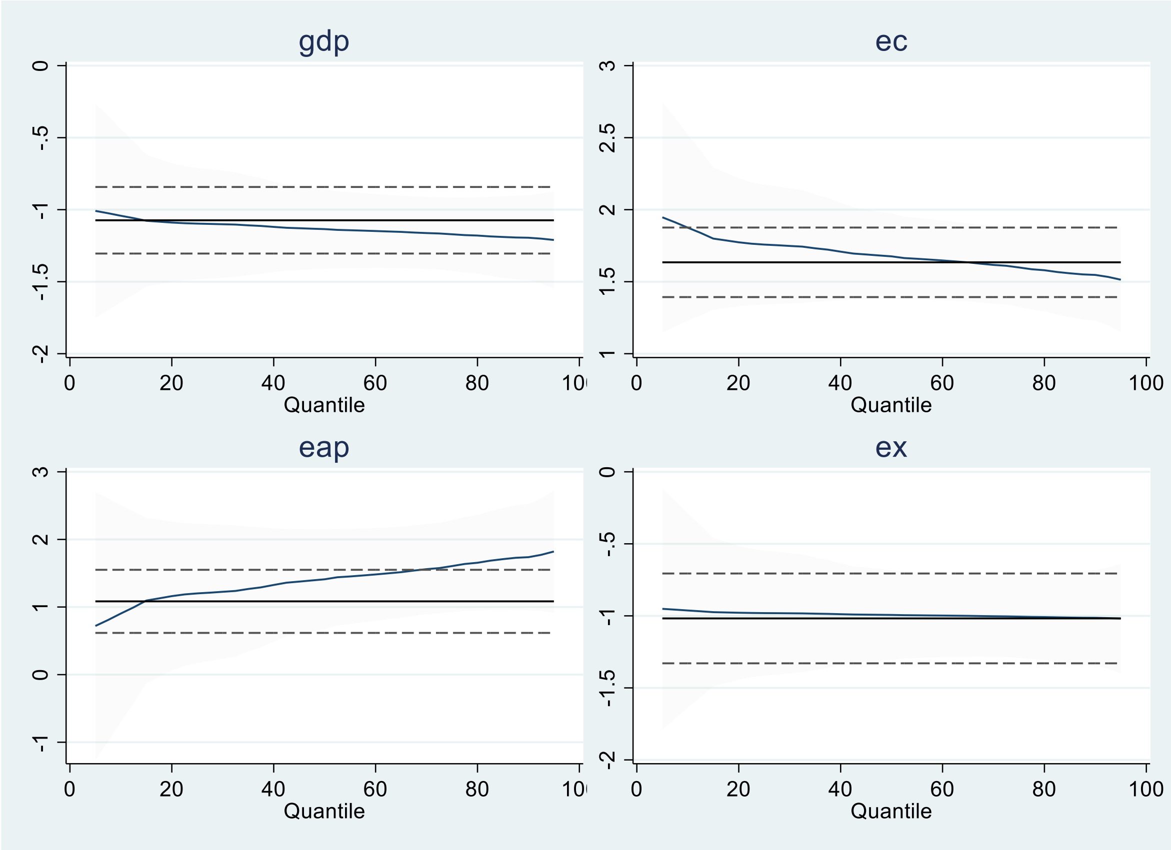

Fig 1. Panel quantile regression estimation results illustration

4.1. Robustness Check

In this subsection, an alternative model is designed to survey the robustness and the validity of model results (Cheng et al., 2018; Salehnia et al., 2022). Hence, in the additional robustness check, EAP is dropped, and the findings are shown in Table 8. As indicated in Table 8, the GDP, EC, and EX results are almost consistent with the findings shown in Table 6, and support the previous findings.

Table 7 Robustness analysis: excluding EAP

			Quantiles			
Variable	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**	**OLS fixed**
GDP	-0.603**	-0.710***	-0.782***	-0.850***	-0.912***	-0.766***
EC	1.393***	1.326***	1.281***	1.238***	1.200***	1.291***
EAP	-	-	-	-	-	-
EX	-0.784**	-0.863***	-0.916***	-0.966***	-1.011***	-0.904***
Observations	600	600	600	600	600	600
Post-estimation test for the panel quantile model						
F/Wald test	Chi2(3) = 84.47***	Chi2(3) = 289.13***		Chi2(3) = 62.27***		

Notes: (1) ***significance at the 1% level, **significance at the 5% level.
(2) The Stata commands xtqreg, testparm.

5. CONCLUSIONS AND POLICY IMPLICATIONS

When it comes to global greenhouse gas emissions since the industrial revolution, US emerged as one of the biggest emitters globally. With this amount of CO2 emissions, the United States has an essential responsibility to reduce the impact of climate change. Hence, to get a comprehensive and deepened understanding of determinants of carbon emission, this study explores the state-level investigation of the US state, covering the time period of 2005 till 2016.

In the present study, we studied the various determinants of carbon emissions with relevant parameters debated in the literature, such as energy price, consumption of energy, energy expenditures, and economic growth, by analyzing 50 states of the US from 2005 to 2016.

The contribute of the study is the utilization of a panel quantile regression technique for the state-level data. The combination of this technique and the US state-level dataset have not been used previously to examine the determinants of carbon dioxide. Therefore, this confirms that the empirical outcomes of this study provide a strong theoretical basis that leads to an actual realization of the climate change crisis, and helps in formulating better environment policies.

The results obtained from panel quantile regression show that the various factors' effects on carbon dioxide emissions, are clearly heterogeneous. More specifically, the effect of GDP on carbon dioxide emissions is negative but significant over all quantiles, meaning that a high level of GDP will mitigate the rise in carbon emissions, considering the US state-level emissions. The investigation also finds out that parameter consumption of energy has a positive and significant effect on carbon emissions in US states. This parameter raises carbon dioxide emissions, with the greatest impacts found at all quantiles. Similarly, the effect of energy price is also found to be significant at all quantiles, which suggests that high energy prices can reduce the rise in carbon emissions. Also, the effect of energy expenditure is negative but significant at the upper and lower quantile, implying that high energy expenditures do not reduce carbon dioxide emission at the US state-level. Finally, the findings indicate the robustness of the diverse values when alternative model specifications are adopted.

Considering the urgency of reducing carbon dioxide emissions in countries such as the US, which has a significant role in the current trend of carbon emissions, the study suggests some policy approaches. As the findings suggest, energy prices positively impact carbon emissions. The increase in the energy prices will lead to a shift towards lower cost and hence, more carbon-intensive fuels such as coal that ultimately contributes to higher CO2 emissions. Authorities should enhance carbon pricing policies when global fossil fuel prices fluctuate. In addition, as the economic growth has a mitigating impact, which is due to the huge share of services in the country’s income, there should be an emphasis on providing further financial incentives to the services sector to ensure the sustainable growth of each state.

While the US is planning to be net-zero carbon dioxide emitter by 2050, for many years, the US states have been adopting climate change initiatives in the absence of effective federal actions and by implementing different approaches during different regimes. Despite these actions, most of the states are way behind their targeted carbon emissions level, as they need full support from the federal government. There is a need for more progressive policy beyond carbon footprints and cap-and-trade schemes. The introduction of energy portfolio standards is quite interesting in reducing emissions that numerous states have already implemented. However, policymakers should bound all the states to implement the climate legislation.

The major non-carbon-generating energy forms have been hydroelectric and nuclear and neither of these energy forms have practiced substantially in the United States in the recent years. Recently, renewable energy forms such as solar and wind have showed significant development, which has absolutely transformed the non-carbon generation position of several states.

Future research can focus on other big nations, such as Russia, China, Brazil etc., and perform state or provincial level investigations for a more comprehensive understanding and comparisons among different nations at state levels. Future research can also focus on empirically examining the different determinants of carbon emission like water pollution, industrial water, and income inequality in different countries, particularly developing nations.

REFERENCES

Acheampong, A. O. (2018). Economic growth, CO2 emissions and energy consumption: What causes what and where? Energy Economics, 74, 677–692. https://doi.org/10.1016/j.eneco.2018.07.022

Acheampong, A. O., Dzator, J., & Savage, D. A. (2021). Renewable energy, CO2 emissions and economic growth in sub-Saharan Africa: Does institutional quality matter? Journal of Policy Modeling, 43(5), 1070–1093. https://doi.org/10.1016/j.jpolmod.2021.03.011

Adedoyin, F. F., Gumede, M. I., Bekun, F. V., Etokakpan, M. U., & Balsalobre-lorente, D. (2020a). Modelling coal rent, economic growth and CO2 emissions: Does regulatory quality matter in BRICS economies? Science of the Total Environment, 710, 136284. https://doi.org/10.1016/j.scitotenv.2019.136284

Adedoyin, F., Ozturk, I., Abubakar, I., Kumeka, T., Folarin, O., & Bekun, F. V. (2020b). Structural breaks in CO2 emissions: Are they caused by climate change protests or other factors? Journal of Environmental Management, 266(December 2019), 110628. https://doi.org/10.1016/j.jenvman.2020.110628

Agboola, M. O., & Bekun, F. V. (2019). Does agricultural value added induce environmental degradation? Empirical evidence from an agrarian country. Environmental Science and Pollution Research, 26(27), 27660–27676. https://doi.org/10.1007/s11356-019-05943-z

Al-Mulali, U., & Ozturk, I. (2016). The investigation of environmental Kuznets curve hypothesis in the advanced economies: The role of energy prices. Renewable and Sustainable Energy Reviews, 54, 1622–1631. https://doi.org/10.1016/j.rser.2015.10.131

American Council for an Energy-Efficient Economy (2019). State Energy Efficiency Resource Standards (EERS). https://www.aceee.org

Apergis, N., & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. Energy economics, 34(3), 733-738. https://doi.org/10.1016/j.eneco.2011.04.007

Ari, A., Arregui, N., Black, S., Celasun, O., Iakova, D., Mineshima, A., ... & Zhunussova, K. (2022). Surging energy prices in europe in the aftermath of the war: How to support the vulnerable and speed up the transition away from fossil fuels. https://ssrn.com/abstract=4184693

Aydoğan, B., & Vardar, G. (2020). Evaluating the role of renewable energy, economic growth and agriculture on CO2 emission in E7 countries. International Journal of Sustainable Energy, 39(4), 335–348. https://doi.org/10.1080/14786451.2019.1686380

Baek, J., & Pride, D. (2014). On the income–nuclear energy–CO2 emissions nexus revisited. Energy Economics, 43, 6-10. https://doi.org/10.1016/j.eneco.2014.01.015

Behera, S. R., & Dash, D. P. (2017). The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. Renewable and Sustainable Energy Reviews, 70(October 2016), 96–106. https://doi.org/10.1016/j.rser.2016.11.201

Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Science of the Total Environment, 657, 1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Boubellouta, B., & Kusch-Brandt, S. (2020). Testing the environmental Kuznets Curve hypothesis for E-waste in the EU28+2 countries. Journal of Cleaner Production, 277, 123371. https://doi.org/10.1016/j.jclepro.2020.123371

Burnett, J. W., & Bergstrom, J. C. (2010). U. S. State-Level Carbon Dioxide Emissions: A Spatial-Temporal Econometric Approach of the Environmental Kuznets Curve U.S. http://dx.doi.org/10.22004/ag.econ.96031

Canay, I. A. (2011). A simple approach to quantile regression for panel data. *The econometrics journal*, *14*(3), 368-386. https://doi.org/10.1111/j.1368-423X.2011.00349.x

Chen, Y., Wang, Z., & Zhong, Z. (2019). CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renewable Energy, 131, 208–216. https://doi.org/10.1016/j.renene.2018.07.047

Cheng, C., Ren, X., Wang, Z., & Shi, Y. (2018). The impacts of non-fossil energy, economic growth, energy consumption, and oil price on carbon intensity: evidence from a panel quantile regression analysis of EU 28. *Sustainability*, *10*(11), 4067. https://doi.org/10.3390/su10114067

Chontanawat, J. (2020). Relationship between energy consumption, CO2 emission and economic growth in ASEAN: Cointegration and causality model. Energy Reports, 6, 660-665. https://doi.org/10.1016/j.egyr.2019.09.046

Danish, Zhang, J., Wang, B., & Latif, Z. (2019). Towards cross-regional sustainable development: The nexus between information and communication technology, energy consumption, and CO2 emissions. Sustainable Development, 27(5), 990–1000. https://doi.org/10.1002/sd.2000

Dogan, E., & Aslan, A. (2017). Exploring the relationship among CO2 emissions, real GDP, energy consumption and tourism in the EU and candidate countries: Evidence from panel models robust to heterogeneity and cross-sectional dependence. Renewable and Sustainable Energy Reviews, 77, 239-245. https://doi.org/10.1016/j.rser.2017.03.111

Ehigiamusoe, K. U., Lean, H. H., & Smyth, R. (2020). The moderating role of energy consumption in the carbon emissions-income nexus in middle-income countries. Applied Energy, 261(July 2019), 114215. https://doi.org/10.1016/j.apenergy.2019.114215

US Energy Information Administration (2021). What is U.S. electricity generation by energy source? www.eia.govEluwole, K. K., Akadiri, S. Saint, Alola, A. A., & Etokakpan, M. U. (2020). Does the interaction between growth determinants a drive for global environmental sustainability? Evidence from world top 10 pollutant emissions countries. Science of the Total Environment, 705, 135972. https://doi.org/10.1016/j.scitotenv.2019.135972

Esso, L. J., & Keho, Y. (2016). Energy consumption, economic growth and carbon emissions: Cointegration and causality evidence from selected African countries. Energy, 114, 492–497. https://doi.org/10.1016/j.energy.2016.08.010

Ferreira, P., Soares, I., & Araùjo, M. (2005). Liberalisation, consumption heterogeneity and the dynamics of energy prices. Energy Policy, 33(17), 2244–2255. https://doi.org/10.1016/j.enpol.2004.05.003

Gökmenoğlu, K., & Taspinar, N. (2016). The relationship between Co2 emissions, energy consumption, economic growth and FDI: the case of Turkey. Journal of International Trade and Economic Development, 25(5), 706–723. https://doi.org/10.1080/09638199.2015.1119876

Hausman, J. A. (1978). Specification Tests in Econometrics. Econometrica, 46(6), 1251-1271. https://doi.org/10.2307/1913827

Ju, K., Su, B., Zhou, D., & Wu, J. (2017). Does energy-price regulation benefit China's economy and environment? Evidence from energy-price distortions. Energy Policy, 105(May 2016), 108–119. https://doi.org/10.1016/j.enpol.2017.02.031

Koengkan, M., Fuinhas, J. A., Kazemzadeh, E., Alavijeh, N. K., & de Araujo, S. J. (2022). The impact of renewable energy policies on deaths from outdoor and indoor air pollution: Empirical evidence from Latin American and Caribbean countries. *Energy*, 123209. https://doi.org/10.1016/j.energy.2022.123209

Koengkan, M., Fuinhas, J. A., Teixeira, M., Kazemzadeh, E., Auza, A., Dehdar, F., & Osmani, F. (2022). The Capacity of Battery-Electric and Plug-in Hybrid Electric Vehicles to Mitigate CO2 Emissions: Macroeconomic Evidence from European Union Countries. World Electric Vehicle Journal, 13(4), 58. https://doi.org/10.3390/wevj13040058

Koenker R, Bassett G Jr (1978) Regression quantiles. *Econometrica*: 33–50.

Kotroni, E., Kaika, D., & Zervas, E. (2020). Environmental kuznets curve in Greece in the period 1960-2014. International Journal of Energy Economics and Policy, 10(4), 364–370. https://doi.org/10.32479/ijeep.9671

Lai, X., Lu, C., & Liu, J. (2019). A synthesized factor analysis on energy consumption, economy growth, and carbon emission of construction industry in China. Environmental Science and Pollution Research, 26(14), 13896–13905. https://doi.org/10.1007/s11356-019-04335-7

Li, K., Fang, L., & He, L. (2019). How population and energy price affect China' s environmental pollution? Energy Policy, 129(September 2018), 386–396. https://doi.org/10.1016/j.enpol.2019.02.020

Li, K., Fang, L., & He, L. (2020). The impact of energy price on CO2 emissions in China: A spatial econometric analysis. Science of the Total Environment, 706, 135942. https://doi.org/10.1016/j.scitotenv.2019.135942

Li, W., Sun, W., Li, G., Jin, B., Wu, W., Cui, P., & Zhao, G. (2018). Transmission mechanism between energy prices and carbon emissions using geographically weighted regression. Energy Policy, 115(August 2017), 434–442. https://doi.org/10.1016/j.enpol.2018.01.005

Linn, J. (2009). Why do energy prices matter? The role of interindustry linkages in US manufacturing. Economic Inquiry, 47(3), 549-567. https://doi.org/10.1111/j.1465-7295.2008.00168.x

Liu, J.-L., Ma, C.-Q., Ren, Y.-S., & Zhao, X.-W. (2020). Do Real Output and Renewable Energy Consumption BRICS Countries. Energies, 1–18. https://doi.org/10.3390/en13040960

Machado, J. A., & Silva, J. S. (2019). Quantiles via moments. *Journal of Econometrics, 213(1),* 145-173. https://doi.org/10.1016/j.jeconom.2019.04.009

McCoskey, S., & Kao, C. (1998). A residual-based test of the null of cointegration in panel data. Econometric reviews, 17(1), 57-84. https://doi.org/10.1080/07474939808800403

McCollum, D. L., Jewell, J., Krey, V., Bazilian, M., Fay, M., & Riahi, K. (2016). Quantifying uncertainties influencing the long-term impacts of oil prices on energy markets and carbon emissions. Nature Energy, 1(7). https://doi.org/10.1038/nenergy.2016.77

Mirziyoyeva, Z., & Salahodjaev, R. (2022). Renewable energy and CO2 emissions intensity in the top carbon intense countries. Renewable Energy, 192, 507-512. https://doi.org/10.1016/j.renene.2022.04.137

Muhammad, S., & Long, X. (2021). Rule of law and CO2 emissions: A comparative analysis across 65 belt and road initiative (BRI) countries. Journal of Cleaner Production, 279, 123539. https://doi.org/10.1016/j.jclepro.2020.123539

National Council of State Legislators (2017). State Net Metering Policies. https://www.ncsl.org/

Nazirah Wahid, I., Abd Aziz, A., & Hashim Nik, M. N. (2013). Energy Consumption, Economic Growth and CO2 emissions in Selected ASEAN Countries. Prosiding Perkem Viii, Jilid, 2, 758–765. https://www.ukm.my/fep/perkem/pdf/perkemVIII/PKEM2013_3D2.pdf

Neuman, W. (2019). Big Buildings Hurt the Climate. New York City Hopes to Change That. The New York Times. https://www.nytimes.com/

North Carolina Clean Energy Technology Center (2019). The 50 States of Electric Vehicles: States Focus on Transportation Electrification Planning, Charging Station Regulation in Q2 2019, Press release https://nccleantech.ncsu.edu

Onafowora, O. A., & Owoye, O. (2014). Bounds testing approach to analysis of the environment Kuznets curve hypothesis. Energy Economics, 44, 47–62. https://doi.org/10.1016/j.eneco.2014.03.025

Ozcan, B., & Ozturk, I. (2019). Renewable energy consumption-economic growth nexus in emerging countries: A bootstrap panel causality test. Renewable and Sustainable Energy Reviews, 104(November 2018), 30–37. https://doi.org/10.1016/j.rser.2019.01.020

Pata, U. K., & Aydin, M. (2020). Testing the EKC hypothesis for the top six hydropower energy-consuming countries: Evidence from Fourier Bootstrap ARDL procedure. Journal of Cleaner Production, 264, 121699. https://doi.org/10.1016/j.jclepro.2020.121699

Rahman, M. M. (2020). Environmental degradation: The role of electricity consumption, economic growth and globalisation. Journal of Environmental Management, 253(July 2019), 109742. https://doi.org/10.1016/j.jenvman.2019.109742

Rehman, A., Ma, H., Ahmad, M., Ozturk, I., & Işık, C. (2021). An asymmetrical analysis to explore the dynamic impacts of CO2 emission to renewable energy, expenditures, foreign direct investment, and trade in Pakistan. Environmental Science and Pollution Research, 28(38), 53520–53532. https://doi.org/10.1007/s11356-021-14537-7

Roy Cooper (2019). Governor Cooper and North Carolina Move Forward with Clean Energy Plan, Press release. https://governor.nc.gov

Salari, M., Javid, R. J., & Noghanibehambari, H. (2021). The nexus between CO2 emissions, energy consumption, and economic growth in the US. Economic Analysis and Policy, 69, 182-194. https://doi.org/10.1016/j.eap.2020.12.007

Salari, M., Javid, R. J., & Noghanibehambari, H. (2021). The nexus between CO2 emissions, energy consumption, and economic growth in the U.S. Economic Analysis and Policy, 69, 182–194. https://doi.org/10.1016/j.eap.2020.12.007

Salehnia, N., Karimi Alavijeh, N., & Hamidi, M. (2022). Analyzing the impact of energy consumption, the democratic process, and government service delivery on life expectancy: evidence from a global sample. Environmental Science and Pollution Research, 1-18. https://doi.org/10.1007/s11356-021-18180-0

Salehnia, N., Karimi Alavijeh, N., & Salehnia, N. (2020). Testing Porter and pollution haven hypothesis via economic variables and CO2 emissions: a cross-country review with panel quantile regression method. Environmental Science and Pollution Research, 27(25), 31527-31542. https://doi.org/10.1007/s11356-020-09302-1

Sarkodie, S. A., & Strezov, V. (2019). Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Science of the Total Environment, 646, 862–871. https://doi.org/10.1016/j.scitotenv.2018.07.365

Shaari, M. S., Karim, Z. A., & Abidin, N. Z. (2020). The effects of energy consumption and national output on CO2 emissions: New evidence from OIC countries using a panel ARDL analysis. Sustainability (Switzerland), 12(8), 1–12. https://doi.org/10.3390/SU12083312

Shahbaz, M., Shafiullah, M., Papavassiliou, V. G., & Hammoudeh, S. (2017). The CO2–growth nexus revisited: A nonparametric analysis for the G7 economies over nearly two centuries. Energy Economics, 65, 183–193. https://doi.org/10.1016/j.eneco.2017.05.007

Shao, X., Zhong, Y., Liu, W., & Li, R. Y. M. (2021). Modeling the effect of green technology innovation and renewable energy on carbon neutrality in N-11 countries? Evidence from advance panel estimations. Journal of Environmental Management, 296(June), 113189. https://doi.org/10.1016/j.jenvman.2021.113189

Sharif, A., Raza, S. A., Ozturk, I., & Afshan, S. (2019). The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: a global study with the application of heterogeneous panel estimations. Renewable energy, 133, 685-691. https://doi.org/10.1016/j.renene.2018.10.052

Sheng, P., Li, J., Zhai, M., & Huang, S. (2020). Coupling of economic growth and reduction in carbon emissions at the efficiency level: Evidence from China. Energy, 213, 118747. https://doi.org/10.1016/j.energy.2020.118747

State of Hawaii Office of Planning (2020). Greenhouse Gas Sequestration Task Force. https://planning.hawaii.gov/

Tiffany Eng, Amy Vanderwarker, & Marybelle Nzegwu (2018). CalEnviroScreen. Huntington Park, CA: California Environmental Justice Alliance. https:// caleja.org/

Tiseo, I. (2022). Emissions in the U.S. – statistics & facts. Statista. www.statista.com

Tong, T., Ortiz, J., Xu, C., & Li, F. (2020). Economic growth, energy consumption, and carbon dioxide emissions in the E7 countries: A bootstrap ARDL bound test. Energy, Sustainability and Society, 10(1), 1–17. https://doi.org/10.1186/s13705-020-00253-6

Udemba, E. N., Magazzino, C., & Bekun, F. V. (2020). Modeling the nexus between pollutant emission, energy consumption, foreign direct investment, and economic growth: new insights from China. Environmental Science and Pollution Research, 27(15), 17831–17842. https://doi.org/10.1007/s11356-020-08180-x

Valizadeh, J., Sadeh, E., Javanmard, H., & Davodi, H. (2018). The effect of energy prices on energy consumption efficiency in the petrochemical industry in Iran. Alexandria Engineering Journal, 57(4), 2241-2256. https://doi.org/10.1016/j.aej.2017.09.002

Wang, K. M. (2012). Modelling the nonlinear relationship between CO2 emissions from oil and economic growth. Economic Modelling, 29(5), 1537–1547. https://doi.org/10.1016/j.econmod.2012.05.001

Wang, K., Zhu, B., Wang, P., & Wei, Y. M. (2016a). Examining the links among economic growth, energy consumption, and CO2 emission with linear and nonlinear causality tests. Natural Hazards, 81(2), 1147–1159. https://doi.org/10.1007/s11069-015-2124-9

Wang, S., Li, Q., Fang, C., & Zhou, C. (2016b). The relationship between economic growth, energy consumption, and CO2 emissions: Empirical evidence from China. Science of the Total Environment, 542, 360–371. https://doi.org/10.1016/j.scitotenv.2015.10.027

Wasti, S. K. A., & Zaidi, S. W. (2020). An empirical investigation between CO2 emission, energy consumption, trade liberalization and economic growth: A case of Kuwait. Journal of Building Engineering, 28, 101104. https://doi.org/10.1016/j.jobe.2019.101104

Yuan, C., Liu, S., & Wu, J. (2010). The relationship among energy prices and energy consumption in China. Energy Policy, 38(1), 197–207. https://doi.org/10.1016/j.enpol.2009.09.006

Zhang, N., Yu, K., & Chen, Z. (2017). How does urbanization affect carbon dioxide emissions? A cross-country panel data analysis. Energy Policy, 107(October 2016), 678–687. https://doi.org/10.1016/j.enpol.2017.03.072

Zhao, X., Li, N., & Ma, C. (2012). Residential energy consumption in urban China: A decomposition analysis. Energy Policy, 41, 644–653. https://doi.org/10.1016/j.enpol.2011.11.027

Appendix A

Determinants of Emissions	State Specific Characteristics
Emission by Coal	From 2005 till 2016, the energy-related CO2 releases dropped in 41 states and grew in 9 states. For instance, In Ohio, during 2005 to 2016 coal-related CO2 releases from the electric power sector showed drop of almost 62 MMmt while the Ohio state economy raised by less than 8% in total. In the same year in Texas state, coal related Co2 releases from the electric power sector shows drop of 23 MMmt while the economy raised by almost 42%. Mostly this growth came from petroleum refining and energy-intensive industries. Within six states, coal related Co2 emissions contributed almost half of overall emissions. These six states mostly rely on coal to generate electric power. In the year 2015 till 2016, almost 36 states showed drop in energy-related CO2 emissions, whereas almost 14 states showed an increased sign. During the same years, however, national emissions dropped by nearly 2%. In 2016, coal consumption accounted for 75% of energy-related CO2 emissions in West Virginia (71 MMmt) and 71% of Wyoming's energy-related CO2 emissions (43 MMmt).
Fuel/Petroleum	Petroleum contributed for almost more than half of emissions within 17 states. Most of these states are specified as a result of petroleum emissions particularly from the transport sector, though states like Louisiana have a substantial industrial part contributed in petroleum emissions. Similarly, natural gas contributed about half of emissions particularly in state of Alaska from industrial production and in the District of Columbia from buildings/constructions. Alabama for instance, have energy-related CO2 releases that are relatively equally distributed through fuels. California, Rhode Island, Hawaii's, Vermont' and Maine showed an emission of 66% (239 MMmt), 52%(5 MMmt (239 MMmt) 92% (17 MMmt) 89% (5 MMmt) and 81% (13 MMmt) from petroleum respectively.
Emissions by sector	Vermont state during 2016 has shown the major share of emissions resulting from the transport sector almost 57%, (3 MMmt), particularly from petroleum, whereas the electric power sector contributes to 0.0% as Vermont had shown no signs of utilizing fossil fuels. Vermont's residential sector contribute to 22%, (1 MMmt), because of comparatively cold climate where petroleum usage is the major heating fuel. In contrast, Hawaii, had a zero contribution of residential sector, which was the lowermost in the United States due of its nominal heating fuel need. Though, unlike Vermont, Hawaii's electric power sector contribution was relatively high almost 36%, (7 MMmt) as the use of petroleum is the major fossil fuel to generate electricity in Hawaii state. Interestingly, in the District of Columbia the combined commercial and residential sector building releases contributed almost half of the overall emissions. Louisiana is considered as the only state where emission from industrial sector contributes more than half of the total emission because of having high energy consuming petrochemical plants and refineries. The other 15 states are equally distributed in contributing more than half of the emission from electric power and transport sector respectively. The states that shows largest share of Co2 emission came from electric power through coal, and the states that shows the highest contribution in Co2 emission from transport sector incline to usage low-carbon fuels to generate electricity and petroleum in the transportation.
Per capita carbon dioxide emissions	During 2016, Wyoming was the third-largest energy producer in the United States. Unlike the largest energy producer, Texas with a population of 28 million and the second-largest energy producer, Pennsylvania—with a population of 13 million—Wyoming state has less than 600,000 people, declaring Wyoming state as the lowest population density within the Lesser 48 states. One of the reason is its cold winters, temperature ranges from 5 degrees to 10 degrees Fahrenheit and hence raises Wyoming state 's per capita energy-related CO2 releases in comparison to the rest of the states. North Dakota at 72 mt per capita. West Virginia (52 mt percapita), Alaska (47 mt per capita), and Louisiana (45 mt per capita) stood as second, third, fourth and fifth highest states per capita CO2 emitters. In contrast, New York state consisting of a population of nearly 20 million people, showed the lowest per capita CO2 emissions of almost 8 mt per capita. A big portion of the population living in the metropolitan area of New York City where organized mass transit is freely accessible and most of the dynasties are based on multi-family units that give proficiencies of scale by means of using energy for cooling and heating. and cooling. The New York state economy is inclined toward less energy-consuming practices such as and hence contributed almost 6% of the U.S. population during 2016, but utilized 1% only of the nation's industrial energy. Also the energy price in New York city is comparatively high almost 14.47 cents per kWh in comparison to country s average use of 10.27 cents per kWh during 2016, consequently, boosts energy efficiency.
Energy intensity	The states with comparatively higher energy intensities incline in cold weathers and rural or having a big industrial area as compared to the whole economy. The states with the high rates of energy-related CO2 releases per capita during 2016 also inclined to possess high energy-intensity values such as Wyoming (24,000 Btu per chained 2009 dollar of GDP), West Virginia and Louisiana both 19,000 Btu per dollar, North Dakota (16,000 Btu per dollar), and Montana and Alabama both about 14,000 Btu per dollar. California, Connecticut, Maryland, Massachusetts, and New York were ranked the lowest and each at around 3,000 Btu per dollar.

Carbon intensity of the energy supply	With respect to energy intensity, the states possess a high carbon-intensive energy supply incline to be the states having higher per capita emissions such as West Virginia (79 kg CO2/MMBtu), Wyoming (76 kg CO2/MMBtu), Kentucky (72 kg CO2/MMBtu), Utah (69 kg CO2/MMBtu), Indiana, Missouri, and North Dakota all about 68 kg CO2/MMBtu. In all the above mentioned states, coal was the major emitting source of CO2. Similarly, the states possessing a lesser carbon-intensive energy supply incline to be the states with comparatively considerable non-carbon electricity generation from hydropower or nuclear. These states comprised of Washington and Oregon (both 35 kg CO2/MMBtu), New Hampshire (36 kgCO2/MMBtu), Vermont (39 kg CO2/MMBtu) Maine, South Carolina, and South Dakota (all 41 kg CO2/MMBtu).
Electricity trade	Wyoming has had an index value of 2.5 or higher since 2005 which means supplementary electricity generated and consumed in the state was trade across states. Idaho, Instead, generated almost 60% of its own electricity in 2012till 2016. The states with high per emission such as capita Alaska, Louisiana, and Oklahoma use natural gas as a main source to generate electricity. The states use coal as the major fuel. The states with lower per capita CO2 emission doesn't show any sign of using coal as their main fuel to generate electricity but use natural gas and non-carbon sources except Vermont who has been an important exporter of electricity in current years..
Non-carbon energy	California state has increased its electricity generation through solar and wind during 2005 till 2016, but generation from nuclear and hydropower dropped during 2005 and 2016. Illinois state has increased its nuclear output from present nuclear volume by combining wind capacity in the year 2016. Pennsylvania has practiced a same pattern of Illinois. Whereas, Texas state has increased twofold its non-carbon generation from nuclear and wind capacity within the same period from 44 billion kWh during 2005 till 102 billion kWh during 2016. Likewise, Washington has always depended on hydropower generation and after adding wind capacity the state has achieved 96 billion kWh of non-carbon electric generation in the year 2016.

Author ‘s Compilation
Source: U.S. Energy Information Administration (EIA),2019

Statements and Declarations

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