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Investigating the environmental Kuznets curve (EKC) hypothesis: does government effectiveness matter? Evidence from 170 countries

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Abstract

The lack of studies that examined the influence of government effectiveness on environmental pollution and whether it formulates the environmental Kuznets curve (EKC) hypothesis motivated this research. Therefore, this research examines the role of government effectiveness on CO_2 emission in 170 countries. To achieve the research aims, the system generalized method of moment model is applied while categorizing the countries into three groups: namely high, moderate, and low government effectiveness countries. The major results of this research revealed that government effectiveness reduces CO_2 emission significantly in the overall sample, high and the moderate government effectiveness countries while it is not significant in the low government effectiveness countries. Moreover, the EKC hypothesis is present in the overall sample high and moderate government effectiveness countries while the hypothesis does not exist in the low government effectiveness countries. Therefore, the outcome of this research shows clearly that effectiveness of the government in terms of independence from political pressures, the quality of policy preparation and application, and the reliability of the government's commitment to such policies is an important element that determines the EKC hypothesis. From the outcome of this research, a number of policy implications were provided for the investigated countries.

Keywords CO_2 Emissions · Government effectiveness · Environmental Kuznets Curve · Panel Data

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1 Introduction

The Paris Agreement of 2015 has increased the pressure on governments to find solutions to environmental damage while minimizing harm to economic growth and development. Therefore, a considerable number of strategies have been implemented which include environmental regulations, information programmers, innovation policies, environmental subsidies and environmental taxes especially (Organization for Economic Co-operation and Development (OECD, 2021). Consequently, governments play a vital role in eliminating environmental damage in their countries (Department of Economic & Social Affairs, 2021). However, to make environmental policies successful for each country, government effectiveness is essential. In other words, government independence from political pressures, the quality of policy preparation and application, and the reliability of the government's commitment to such policies (World Bank, 2021) might be key elements to help reduce countries' environmental degradation.

Therefore, the focus of this study is to examine whether government effectiveness (measured by the World Bank' government effectiveness index) is vital to mitigate CO_2 emission (as a main measure of environmental pollution). Moreover, this research categorizes the countries into three groups based on the level of government effectiveness: high (37 countries), moderate (45 countries), and low (87 countries). The countries listed in high government effectiveness countries are mostly developed and strong emerging economies. The countries listed in the moderate group comprise both emerging and developing economies. However, the least developed countries are listed in the low government effectiveness group. Hence, countries with higher scores on the government effectiveness index have more politically independent governments with a higher quality of policy formulation and are more committed to implement the policies (including environmental policies). So, we expect that countries with more effective governments are more likely able to mitigate pollution in comparison with countries with low government effectiveness. The main contribution of this study is to evaluate the impact of government effectiveness on air pollution at different levels of government effectiveness using recent data from a large sample country.

The remainder of this article is structured as follows. Section 2 briefly reviews the relevant literature. Section 3 describes the methodology and data. The estimation results are presented and discussed in Sect. 4. Section 5 concludes the paper.

2 A brief literature review

As environmental pollution is a rising global concern, many studies have been implemented to examine the main contributing factors of environmental pollution. Most of the research implemented the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis explains that in the early stage of economic development, gross domestic product (GDP) tends to increase environmental damage until the GDP reaches certain level trend reverses. Thus, high income level and higher economic growth tends to lower environmental damage, forming an inverted U-shaped relationship between GDP and pollution. Most of these studies have confirmed the existence of the EKC hypothesis in contexts such as Australia (Churchill et al., 2020), Jamaica (Brown et al., 2020), highly globalized OECD countries (Leal & Marques, 2020), Middle East and North Africa (MENA) (Cheikh et al., 2020; Amirnejad et al., 2021), resource-based countries (Badeeb et al., 2020), China (Ahmad et al., 2021; Pata & Caglar, 2021; Xie et al., 2019; Xu et al., 2020), European countries (Boubellouta & Kusch-Brandt, 2020) and several African countries (Mahmood et al., 2020; Ekeocha, 2021). The majority of these studies utilized CO_2 emission as an indicator of pollution (Churchill et al., 2020; Badeeb et al., 2020; Cheikh et al., 2020; Pata & Caglar, 2021; Ahmad et al., 2021; Abokyi et al., 2021). From the literature above it is clear that the EKC hypothesis is present not only in developed countries, but also in emerging and developing countries.

In addition to income level, previous studies show that that energy consumption (excluding renewable energy sources), trade openness, globalization, urban population, population, industrial and manufacturing output are also the main determinants of environmental pollution.

In terms of openness, Churchill et al. (2020), Mahmood et al. (2020), Abokyi et al. (2021), Leal and Marques (2020), and Pata and Caglar (2021) found that trade openness and globalization increases the environmental pressure. However, studies such as Malumfashi et al. and Uddin (2020) have reached the conclusion that trade openness and globalization are able to mitigate environmental pollution. Energy consumption, especially from fossil fuels (Leal & Marques, 2020; Mahmood et al., 2020; Uddin, 2020; Ben Cheikh et al. 2021), energy consumption in commercial and residential buildings (Chen et al., 2020; Ma et al., 2018), urban populations and populations in general (Boubellouta & Kusch-Brandt, 2021; Churchill et al., 2020; Danish et al., 2021; Uddin, 2020), foreign direct investment (Ahmad et al., 2021; Ekeocha, 2021), industrial and manufacturing output (Abokyi et al., 2021; Boubellouta & Kusch-Brandt, 2021; Xie et al., 2019), oil rents (Sadik-Zada & Gatto, 2021) and institutional quality (Tang et al., 2021) are important drivers of environmental pollution. However, the use of renewable energy (Gatto & Drago, 2021; Leal & Marques, 2020; Tang et al., 2021) and better human capital (Pata & Caglar, 2021 and Tang et al., 2021) are able to mitigate environmental pollution.

Increases in population (including urban population), a country's output of goods and services, and trade levels increases the demand for energy—which chiefly comes in the form of fossil fuels (63% of the world energy generation) and is the main source of environmental pollution. Therefore, governments potentially play a vital role in implementing policies to mitigate environmental pollution at the national level. Several studies have extended the research and examined government variables such as institutional quality (e.g., Gholipour & Farzanegan, 2018; Goel et al., 2013; Khan & Rana, 2021; Nair et al., 2021). The overall outcome of existing studies revealed that better institutional quality plays an important role in reducing pollution.

In terms of government effectiveness, Yameogo et al. (2021) found government effectiveness reduces environmental pollution (air and land) in Sub-Saharan Africa (SSA). Similarly, Gani and Scrimgeour (2014) find that government effectiveness reduces water pollution across the industries among the OECD countries. To justify the negative relationship between government effectiveness and water pollution, they argued that "bureaucratic inefficiency can delay the development and implementation of sound environmental and resource management policies with damaging consequences" (p. 366). Specifically, they noted that "countries that maintain effective governments characterized by efficient public service, financial integrity and better management of public processes and resources can gain confidence from a wide cross-section of population in managing natural resources with prompt actions in terms of enforcement of governmental rules and regulations where damage is evident" (p. 366). Dadgara and Nazari (2016) also showed that government effectiveness is an important factor in reducing pollution in South West Asian Countries.

Peng et al. (2021) found that government air pollution prevention and control policies (which are the components of government effectiveness) have positive impacts on urban air quality in China. On the other hand, Halkos and Tzeremes (2013) show that the government effectiveness has no impact on pollution in G-20 countries.

However, including countries with different levels of government effectiveness might not reveal its true effects on pollution. Numerous contexts and countries with different levels of government effectiveness should be investigated. Therefore, to cover the gap in the literature, our study examines the effect government effectiveness on pollution and whether it helps to formulate the EKC in 170 countries. We categorize the countries in three main groups namely high, moderate, and low government effectiveness countries.

The government effectiveness index captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies (WGI, 2021). Therefore, countries with higher government effectiveness are more likely to have the EKC (inverted U-shaped relationship between GDP and CO_2 emission) while countries with low government effectiveness are less likely to have the EKC. Our argument relies on the fact that when governments are dedicated to high quality environmental policies, they more likely have a significant effect on mitigating environmental pollution. However, countries with governments that are less committed to even lower quality environmental policies might be unsuccessful in mitigating environmental pollution.

3 Methodology and data

3.1 Dynamic panel regression model of the EKC hypothesis

Our objective is to test the relationship between government effectiveness and air pollution. The majority of previous studies found that the hypothesis is present when there is an inverted U-shaped relationship between GDP and pollution. Following past research, CO_2 emission is utilized as an indicator of environmental pollution. Moreover, GDP per capita, the square term of GDP per capita, renewable electricity consumption, non-renewable electricity consumption, urban population as an indicator of urbanization, trade openness, and government effectiveness index are used as major determinants of CO_2 emission. The model of this study is presented below:

$$\begin{aligned} \mathrm{CO2}_{it} = \beta_0 + \beta_1 \mathrm{CO2}_{it-1} + \beta_2 \mathrm{GDP}_{it} + \beta_3 \mathrm{GDP}^2_{it} + \beta_4 \mathrm{REN}_{it} \\ + \beta_5 \mathrm{FOS}_{it} + \beta_6 \mathrm{UR}_{it} + \beta_7 \mathrm{TO}_{it} + \beta_8 \mathrm{GEX}_{it} + \varepsilon_{it} \end{aligned} \tag{1}$$

where CO_2 represents CO_2 emission measured in millions of tones; $CO2_{it-1}$ is 1-year lag of CO_2; GDP and GDP^2 represent the gross domestic product per capita (measured in constant 2010 US dollars) and its square term; REN represents renewable electricity consumption measured in billions of kilowatts per hour which includes all sources of renewable energy generation (utilized by Gatto & Drago, 2021; Leal & Marques, 2020; Tang et al., 2021); FOS represents fossil fuels electricity consumption measured in billions of kilowatts per hour (utilized by Mahmood et al., 2020; Uddin, 2020; Cheikh et al., 2020); UR represents the urban population as an indicator or urbanization (utilized by Boubellouta &

Kusch-Brandt, 2021; Churchill et al., 2020; Danish et al., 2021; Uddin, 2020); TO represents the trade of goods and services as a percentage of total GDP as an indicator of trade openness (utilized by Abokyi et al. (2021), Leal and Marques (2020), and Pata and Caglar (2021); and GEX represents the government effectiveness index (utilized by Gani and Scrimgeour, (2014) and Yameogo et al. (2021)). The index ranges from low, approximately −2.5, to high, about 2.5. Lastly ε_{it}, the error disturbance term.

3.2 Data description

This research utilized nine years of data from 170 countries over the 2010–2018 period. Due to some missing values for variables, our panel data are an unbalanced data set. Moreover, the countries are categorized based on 2018 government effectiveness index. Since there are no classifications from the World Bank that rank the countries based on the size government effectiveness index; the presented classification is based on our own preference. Neither the less based on the data description the index starts from very low which is a negative −2.5 to very high + 2.5. Therefore, we classified the countries with the range of + 2.23 to + 0.92 (close to + 1) as high government effectiveness countries while the countries with moderate government effectiveness are within the range of + 0.87 to + 0.11 (the smallest positive value in the index). The countries with the range of −0.003 to −2.44 (completely ineffective governments) are categorized as low government effectiveness countries. Moreover, The World Bank collect data from more than 30 sources to compute the Government Effectiveness index. Some of the components of this measures are "Quality of bureaucracy/institutional effectiveness", "Quality of budgetary and financial management", "Allocation & management of public resources for rural development", "Efficiency of revenue mobilization".[1]

There are 37 high government effectiveness index countries (within the rage of 2.23–0.92), these countries are namely Singapore, Switzerland, Denmark, Finland, Norway, Sweden, Netherlands, Hong Kong SAR, China, Luxembourg, Canada, New Zealand, Japan, Germany, Australia, Iceland, Austria, United States, United Kingdom, France, United Arab Emirates, Korea, Rep., Bermuda, Israel, Brunei Darussalam, Ireland, Macao SAR, China, Portugal, Latvia, Slovenia, Chile, Lithuania, Belgium, Aruba, Spain, Malaysia, and Cyprus, Czech Republic.

Moreover, 45 moderate government effectiveness index countries (within the range of 0.87 to 0.11), these countries are Mauritius, Malta, Georgia, Virgin Islands (U.S.), Greenland, Qatar, Uruguay, Slovak Republic, Barbados, Poland, American Samoa, China, Seychelles, Jamaica, Hungary, the Bahamas, Italy, Samoa, Botswana, Costa Rica, Croatia, Greece, South Africa, Thailand, Bulgaria, Bhutan, Saudi Arabia, Bahrain, Cabo Verde, Oman, St. Vincent and the Grenadines, Fiji, Rwanda, Indonesia, India, Tonga, Russian Federation, Kazakhstan, Jordan, Namibia, Colombia, Panama, Philippines, Turkey, and Serbia.

Lastly 87 low government effectiveness countries (within the range of −0.003 to −2.44), which are Vietnam, Kuwait, North Macedonia, Antigua and Barbuda, Senegal, Albania, Armenia, Peru, Argentina, Tunisia, Sri Lanka, Morocco, Grenada, Azerbaijan, Mexico, Cuba, Belarus, Brazil, Maldives, Mongolia, Ghana, Kiribati, Dominica, Romania, Ukraine, Dominican Republic, Kenya, Moldova, Ecuador, Egypt, Arab Rep., Benin,

[1] For more details about other components of this index, see https://info.worldbank.org/governance/wgi/

El Salvador, Mauritania, Uzbekistan, Algeria, Paraguay, Vanuatu, Iran, Islamic Rep., Cambodia, Uganda, Honduras, Gambia, Bosnia and Herzegovina, Ethiopia, Zambia, Belize, Guatemala, Pakistan, Eswatini, Kyrgyz Republic, Bolivia, Bangladesh, Malawi, Burkina Faso, Nicaragua, Lao PDR, Niger, Cameroon, Mozambique, Lesotho, Lebanon, Tanzania, Gabon, Togo, Solomon Islands, Nepal, Tajikistan, Mali, Nigeria, Angola, Sierra Leone, Madagascar, Turkmenistan, Zimbabwe, Burundi, Iraq, Equatorial Guinea, Liberia, Guinea-Bissau, Chad, Sudan, Venezuela, RB, Comoros, Central African Republic, Libya, Haiti, and South Sudan.

The data for GDP per capita, trade openness and urbanization were retrieved from the World Development Indicator (WDI) of the World Bank. The government effectiveness index data was retrieved from the Worldwide Governance Indicators (WGI) of the World Bank. The data for renewable and fossil fuels electricity consumption were from the Energy Information Administration (EIA).

3.3 The dynamic panel system-generalized method of moments (System GMM)

Since our panel data contains large cross-sections (*N*) and small time series (*T*), the System GMM is utilized in this research. This method basically contains stronger instruments than the difference GMM which is considered to be problematic as including lagged level variables are weak instruments if the variables in the question perform obstinately (Blundell & Bond, 1998). The System GMM was developed by Blundell and Bond (1998) by adding the assumption of the first differences of instrument variables that are uncorrelated with the fixed effects by removing the country-specific effects and to control endogeneity constraints. Thus, including more instruments in the equation can dramatically improve the efficiency and reliability of our estimation results. Therefore, our EKC model can be written as follows:

$$\Delta \mathrm{CO2}_{it} = \Delta\delta \mathrm{CO2}_{it-1} + \Delta\delta \mathrm{GDP}_{it-1} + \Delta\delta \mathrm{GDP}^2_{it-1} + \delta\Delta V_{it} + \Delta\varepsilon_{it} \tag{2}$$

where CO_2 represents CO_2 emission, V_{it} represent the vector of the independent variables, $\mathcal{E}_{it}$ is the error term, Δ represents the first difference, *i* represents the cross sections and *t* represents time. Including the lagged first difference of the lagged variables is not only successful in eliminating the country-specific effects, but also to avoid endogeneity problems due to the inclusion of the lagged dependent variable in the equation.

4 Empirical results and discussion

Before applying the System GMM model, we utilized Bond's (2002) approach which uses three based models: the ordinary least square (OLS), fixed effect, and the first difference GMM estimator. Essentially, if the value of the coefficient of $\mathrm{CO2}_{\mathrm{it-1}}$ in the first difference GMM falls within the range the coefficient values of $\mathrm{CO2}_{\mathrm{it-1}}$ in the OLS model and the fixed effect model, then the difference GMM is a good fit for our model. However, if the value of the coefficient $\mathrm{CO2}_{\mathrm{it-1}}$ in the first difference GMM is not within the range values of $\mathrm{CO2}_{\mathrm{it-1}}$ coefficient of the OLS and the fixed effects models, the first difference GMM indicates a bias and inefficiency.

The outcome of the ordinary least square (OLS), fixed effect, and the first difference GMM estimator (reported in Appendix 1) revealed that for all sample countries the size of the coefficient of $CO2_{it-1}$ in the first difference GMM (0.100031 for overall countries sample, 0.322976 for high government effectiveness index group, 0.228779 for moderate government effectives index group, and 0.0844557 for low government effectiveness index group) is lower than size of the coefficient of $CO2_{it-1}$ in the fixed effects models (0.144291 for overall countries sample, 0.525377 for high government effeteness index group, 0.600278 for moderate government effectives index group, and 0.116564 for low government effectiveness index group). This means that the first difference GMM estimation is biased downward and the method is not efficient for our utilized panel data. Therefore, the System GMM is the ideal method for the study's analysis.

Table 1 below shows the estimation results of the system GMM for overall countries sample and the three country groups samples. The results for the overall sample revealed that electricity generated from renewable energy decreases CO_2 emission while electricity generated from fossil fuel increases CO_2 emission significantly. Moreover, trade openness has a significant positive relationship with CO_2 emission. The results also showed that government effectiveness index reduces CO_2 emission significantly. However, urbanization has no significant effect on CO_2 emission. Lastly, an inverted U-shaped is present indicating that the EKC hypothesis is present for the overall sample countries.

However, the results of the high and moderate government effectiveness index group countries are not consistent with the low government effectiveness group countries. The results show that the government effectiveness index significantly mitigates CO_2 emission in the full sample countries, high and the moderate government effectiveness countries while it is statistically insignificant for the low government effectiveness index countries. Moreover, the EKC is confirmed in the full sample countries, high and the moderate government effectiveness countries while the EKC was not confirmed in the low government effectiveness countries. The results also show that electricity consumption generated from fossil fuels increases CO_2 emission for all country groups including the full sample which is similar to the outcome of Leal and Marques (2020), Mahmood et al. (2020), Uddin (2020), Cheikh et al. (2020), Abokyi et al. (2021) and Amirnejad et al. (2021). However, electricity consumption generated from renewable energy sources mitigate CO_2 emission in all country groups including the full sample which is within the line of Leal and Marques (2020) and Tang et al. (2021). Moreover, urbanization increases CO_2 emission in full sample countries, high and moderate government effectiveness index countries; Xie et al. (2019) Churchill et al. (2020), Xu et al. (2020), Boubellouta and Kusch-Brandt (2020) and Uddin (2020) reached the same outcome. Interestingly, urbanization has no significant effect on CO_2 emission in the low government effectiveness index countries. Meanwhile, trade openness has no significant effect on CO_2 emission for both high and moderate government effectiveness index countries while its effect is significantly positive for the low government effectiveness group countries (Churchill et al., 2020; Mahmood et al., 2020; Abokyi et al., 2021; Leal & Marques, 2020; and Pata & Caglar, 2021 found similar outcomes). Regarding the fit of our estimation models, the results indicate that the Wald test is significant at the 1% level for all the estimation models, indicating that the system-GMM models fitted our panel dataset well. Furthermore, we find that the Arellano-Bond test for second order of autocorrelation and the Sargan test for the validity of instruments did not reject the null hypothesis at the 5% significance level. Moreover, AR2 and the Wald test

Table 1 Results of System GMM Estimator CO_2 as the dependent variable

Variables	(1) All countries	(2) High government effectiveness index countries	(3) Moderate government effectiveness index countries	(4) Low government effectiveness index countries
$CO2_{it-1}$	0.122870*** (0.0395220)	0.938537*** (0.00555929)	0.662352*** (0.108359)	0.388772*** (0.105440)
GDP	1.94849*** (0.119661)	0.207369*** (0.0263226)	0.507475** (0.203612)	1.37921* (0.698019)
GDP^2	−0.0206540 (0.00225936)	−0.00352467*** (0.000412191)	−0.00382495* (0.00229243)	−0.0130229 (0.0141780)
REN	−0.000706460*** (0.000104259)	-0.00601933* (0.0033099)	−0.000795334*** (0.000257508)	−0.00111927** (0.000443773)
FOS	0.000728487*** (0.0000642595)	0.00325946*** (0.000774144)	0.000555509*** (0.000179810)	0.00315981* (0.00177093)
UR	0.00481930 (0.0182477)	0.0336857** (0.00904609)	0.0284190* (0.0156370)	0.0268094 (0.0566896)
TO	0.000890494*** (0.000227147)	−0.00117826 (0.00660268)	−0.0111942 (0.0321951)	0.00714946*** (0.00168461)
GEX	−0.262488*** (0.0219426)	−0.0435162*** (0.00845022)	−0.155963*** (0.0517359)	−0.0400387 (0.0852336)
Constant	−32.9634*** (1.54495)	−3.23050*** (0.304360)	−9.51237*** (3.47070)	−25.0586*** (8.38447)
AR(2) test (*p*-values)	-0.305283 (0.7602)	-1.27908 (0.2478)	1.47947 (0.1390)	1.36416 (0.1725)
Diagnostic tests Wald test [*p*-values]	43,643.9 [0.0000]	1,004,660*** [0.0000]	111,227*** [0.0000]	4845.01*** [0.0000]
Sargan test [*p*-values]	31.7928 [1.0000]	33.2685 [0.5033]	26.1918 [0.8285]	11.9734 [0.9913]
Number of instruments	85	43	42	35

Figure in the parenthesis [.] indicates the robust standard errors

***$p<0.01$, **$p<0.05$ and * $p<0.10$.

can thus be concluded that the estimated models are free from autocorrelation along with no endogeneity issues.

The estimation results provide evidence that electricity consumption generated from renewable energy reduces environmental pollution in all country groups including the full sample. This outcome is expected as renewable or clean energy sources are proven to mitigate air pollution and greenhouse gas emissions. Yet, electricity generated from fossil fuels increases air pollution for all country groups that includes the full sample as well; again, unsurprisingly, as this energy source is documented as a major polluter. The outcome for urbanization increases air pollution in both high and moderate GE levels while it is also positive but statistically insignificant for the low GE level. The results may attribute to the fact that urban population in developed and emerging countries mostly in high- and moderate-income group countries are far higher than the low-income group countries which mostly come from the least developed countries. However, the results from the overall sample revealed that urbanization increases air pollution in general. Our results also show that trade openness has no significant effects on pollution in both high and moderate groups while it has a significant and positive effect on air pollution in the full sample and low group countries. This outcome indicates that the environmental policies in adopting trade-related procedures aimed at environmental protection are fulfilled in the high and moderate government effectiveness countries while it is not in the low government effectiveness countries. This shows that trade policies to protect and preserve the environment are more effective in countries with governments that are committed to high quality policy formulation than countries with lesser dedication to lower quality policy formulation.

The estimation results clearly showed that the government effectiveness index is a significant tool in mitigating CO_2 emission in high, moderate government effectiveness and overall sample countries. However, it is not significant in affecting CO_2 emission in countries with a low level of government effectiveness. Moreover, the EKC hypothesis is present in the high, moderate government effectiveness and overall sample countries while it is not present in countries with lower government effectiveness. It is clear that countries that are categorized in low government effectiveness group basically have governments with low quality of public services, low quality of the civil service and low degree of independence from political pressures, low quality of policy formulation and implementation, and low credibility of the government's commitment to such policies. Therefore, countries with governments that creates low quality in formulating and implanting policies including environmental policies and are less committed to such polices make these policies less effective to mitigate air pollution in these countries. Therefore, the EKC hypothesis is most likely to be present in countries with high government effectiveness than the countries with low government effectiveness.

5 Conclusion and policy implication

The aim of this research is to examine the effect of the government effectiveness on environmental pollution and to validate the EKC hypothesis utilizing system GMM for 170 countries. The countries are categorized into three groups based on the government effectiveness levels of high, moderate, and low. Moreover, overall sample countries were also included in analysis of this research.

The most important outcome of this research revealed the EKC hypothesis is linked with the significance of the government effectiveness index. Therefore, the hypothesis exists in overall country sample, high and moderate government effectiveness country group in which the government effectiveness index is significant in reducing CO_2 emission. However, the EKC hypothesis does not exist in low government effectiveness group in which the government effectiveness index is statistically not significant in effecting CO_2 emission.

From the outcome of this research, government commitment to policy formulation and implementation is essential to minimize environmental pollution. Moreover, the EKC hypothesis only exists in countries where the government effectiveness index is high and moderate as the variable is statistically significant and negative toward CO_2 emission. However, the low government effectiveness index country group have a negative but statistically insignificant impact on mitigating CO_2 emission. Therefore, low government effectiveness countries need to introduce measures to improve the quality of public services, civil service, policy formulation, policy implementation and integrity to achieve more sustainable environments. Moreover, the overall country sample revealed that the government effectiveness is significant to mitigate CO_2 emission. This outcome shows that including overall government effectiveness together plays a major rule to reduce the world CO_2 emission. Since pollution in general is a global problem, nations should conduct international cooperation to address pollution problems at the scientific and the policy level. Therefore, implementing international environmental policies might be the key to mitigate global environmental pollution in general.

As urbanization increases, so does CO_2 emission in high and moderate government effectiveness countries. Hence, urban areas need to be re-planned, re-designed, and re-developed to reduce their impact on the environment and be determined to the climate change effects. Therefore, government policies are important to transform dense cities into well-made services and infrastructure, and effectively lessen the cost of energy provision, transport, and so forth for businesses. This will increase the cities productivity and efficiency and encourages private investment for economic growth and development.

This research shows that fossil fuels electricity generation increases CO_2 emission while renewable electricity generation mitigates it in all country groups. Thus, it is important to formulate government policies that increase the use of renewable energy which is proven by the outcome of this research and the vast majority of the previous studies that renewable energy sources play a significant rule to mitigate CO_2 emission. Increasing the rule of renewable energy in the energy mix is important reduce fossil fuel use which represent the major source of CO_2 emission globally. Therefore, policies that includes a minimum carbon price floor for emissions trading, renewable energy tariff incentive schemes, better regulating emissions limits for power plants, lessening planning restrictions for renewable energy farms, and loans intensives for renewable energy equipment purchases.

Lastly, trade openness increases CO_2 emission for low government effectiveness index countries. Therefore, imposing taxes on traded goods that are relative to CO_2 emission pairing climate change policy with a tariff on CO_2-intensive traded goods has the potential to address pollution levels.

Future research may utilize other air pollution indicators such as Particulate Matter, Sulfur Dioxide, Nitrogen Oxides in their investigation of the EKC hypothesis. Moreover, it is important to utilize other governance indicators such as voice and accountability, political stability and absence of violence/terrorism, regulatory quality, and the rule of law in future research. Finally, despite the robustness of system GMM it is important for future research to implement new method for panel date that are more capable to control cross-sectional dependents (such as panel mean group) to obtain a more robust outcome.

Appendix

See Tables 2, 3, 4 and 5

Table 2 OLS, Fixed effects and first difference GMM Estimator CO2 as the dependent variable for all countries

Variables	(1) OLS	(2) Fixed effects	(3) First difference GMM
$CO2_{it-1}$	0.299148*** (0.0132970)	0.144291*** (0.0117526)	0.100031*** (0.0141988)
GDP	1.65665*** (0.152560)	1.75462*** (0.184370)	1.82499*** (0.203557)
GDP^2	−0.0182717*** (0.00304933)	−0.0174523*** (0.00376786)	−0.0174602*** (0.00415111)
REN	−0.000550266*** (0.000137026)	−0.000931678*** (0.000189401)	−0.000859949*** (0.000174735)
FOS	0.000636785*** (0.0000775735)	0.000643734*** (0.000109302)	0.000600840*** (0.000107269)
UR	−0.00273090*** (0.0244979)	0.0412544 (0.0259380)	0.0652775** (0.0286483)
TO	0.000926711*** (0.000310477)	0.000368047 (0.000340041)	0.00003958 (0.000355191)
GEX	−0.231298*** (0.0293530)	−0.297833*** (0.0674014)	−0.214171*** (0.0662624)
Constant	−27.6369*** (1.82567)	−30.6936*** (2.19148)	0.00632182*** (0.00265238)
Adjusted R-squared	0.947310	0.974427	–
AR(2) test (*p*-values)	–	–	-0.793992 [0.4272]
Diagnostic tests Wald test [*p*-values]	–	–	17,991.8 [0.0000]
Sargan test [*p*-values]	–	–	56.5064 [0.7645]
Number of instruments	–	–	74

Figure in the parenthesis [.] indicates the robust standard errors

***$p < 0.01$, **$p < 0.05$ and * $p < 0.10$.

Table 3 OLS, Fixed effects and first difference GMM Estimator CO2 as the dependent variable for high government effectiveness index countries

Variables	(1) OLS	(2) Fixed effects	(3) First difference GMM
$CO2_{it-1}$	0.967352*** (0.0108979)	0.525377*** (0.0457768)	0.322976*** (0.114037)
GDP	0.269304*** (0.0970106)	−0.488870 (1.39451)	−0.502735 (1.79664)
GDP^2	−0.00478551*** (0.00180466)	0.00732011 (0.0272203)	0.00314381 (0.0375435)
REN	0.00544216	0.000119432 (0.000400535)	0.00672472 (0.000523034)
FOS	0.00304022 (0.00212791)	0.000523126 (0.000394833)	0.00555191*** (0.000219342)
UR	0.0119965 (0.0155431)	0.236976 (0.227203)	1.08230 (0.794792)
TO	0.00953071 (0.00725853)	0.00960499 (0.00461991)	0.00144103 (0.00894249)
GEX	−0.0592819 (0.0212724)	0.0368425 (0.0444950)	0.0929392 (0.0934022)
Constant	−3.74487*** (1.20745)	5.88462 (18.9547)	−0.00722814 (0.0102537)
Adjusted R-squared	0.997643	0.998492	–
AR(2) test (*p*-values)	–	–	-1.62156 (0.1049)
Diagnostic tests Wald test [*p*-values]	–	–	44.6924 [0.0000]
Sargan test [*p*-values]	–	–	73.3072 [0.0000]
Number of instruments	–	–	36

Figure in the parenthesis [.] indicates the robust standard errors

***$p < 0.01$, **$p < 0.05$ and * $p < 0.10$.

Table 4 OLS, Fixed effects and first difference GMM Estimator CO2 as the dependent variable for moderate government effectiveness index countries

Variables	(1) OLS	(2) Fixed effects	(3) First difference GMM
$CO2_{it-1}$	0.994157*** (0.00879625)	0.600278*** (0.0438678)	0.228779* (0.139980)
GDP	−0.0819973 (0.0583804)	0.880751 (0.697710)	3.40506** (1.45366)
GDP^2	0.00121143 (0.00112585)	−0.0142484 (0.0141088)	−0.0534645 (0.0288786)
REN	−0.0046858 (0.00744564)	−0.00191861 (0.00121543)	−0.00143447 (0.00181245)
FOS	0.00330307 (0.00470332)	0.00161806 (0.00181681)	0.00160901 (0.00303047)
UR	0.0247560** (0.00969599)	0.153002 (0.154260)	0.233039 (0.252321)
TO	−0.005.90639 (0.00100958)	0.00452262 (0.00167092)	−0.00379402 (0.00145072)
GEX	−0.0137550 (0.0191810)	0.100753*** (0.0347807)	0.00973253 (0.0572537)
Constant	0.994157 (0.717889)	−14.0942 (8.60264)	−0.0118720* (0.00677158)
Adjusted R-squared	0.998846	0.999231	–
AR(2) test (*p*-values)	–	–	1.5334 (0.1252)
Diagnostic tests Wald test [*p*-values]	–	–	77.9559 [0.0000]
Sargan test [*p*-values]	–	–	32.0249 [0.2312]
Number of instruments	–	–	36

Figure in the parenthesis [.] indicates the robust standard errors

***$p < 0.01$, **$p < 0.05$ and * $p < 0.10$.

Table 5 OLS, Fixed effects and first difference GMM Estimator CO2 as the dependent variable for low government effectiveness index countries

Variables	(1) OLS	(2) Fixed effects	(3) First difference GMM
$CO2_{it-1}$	0.208876*** (0.324718)	0.116564*** (0.0136690)	0.0844557*** (0.0306351)
GDP	1.60277*** (0.324718)	1.60277*** (0.398980)	1.72317* (1.03762)
GDP^2	−0.0102724*** (0.00692735)	−0.0102724 (0.00855665)	−0.0126094 (0.0217604)
REN	−0.00135184*** (0.000288451)	−0.00135184*** (0.000447989)	−0.00154826* (0.000845793)
FOS	0.00455832*** (0.000796221)	0.00368223*** (0.000991124)	0.00289810 (0.00224123)
UR	0.0397808 (0.0302484)	−0.0679054* (0.0373108)	−0.0307423 (0.0943160)
TO	0.00869939*** (0.000794262)	0.00699732*** (0.000999916)	0.00663260** (0.00260670)
GEX	0.00584352 (0.0466926)	−0.170156** (0.0829823)	−0.146428 (0.154281)
Constant	−30.5368*** (3.67374)	−29.9129*** (4.48086)	−0.0103841 (0.0104631)
Adjusted R-squared	0.942074	0.982974	–
AR(2) test (*p*-values)	–	–	−0.186064 (0.8524)
Diagnostic tests Wald test [*p*-values]	–	–	2351.86 [0.0000]
Sargan test [*p*-values]	–	–	9.72663 [0.9729]
Number of instruments	–	–	29

Figure in the parenthesis [.] indicates the robust standard errors

***$p<0.01$, **$p<0.05$ and * $p<0.10$.

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