SUYANTO • Muhammad Afdha Alif ALMUGHNI • Jajuk SUPRIJATI • Rahmawati Erma STANDSYAH • Sayekti Suindyah DWININGWARNI

INSTITUTIONAL QUALITY AND GOVERNMENT EXPENDITURE: AN EMPIRICAL STUDY OF THE ENVIRONMENTAL KUZNETS CURVE (EKC) IN G20 COUNTRIES

Suyanto (ORCID: 0000-0002-5954-6046) – *Faculty of Economics and Business, University of Dr. Soetomo, Indonesia*

Muhammad Afdha Alif **Almughni** (ORCID: 0009-0003-8971-8624) – *Faculty of Economics and Business, Airlangga University, Indonesia*

Jajuk **Suprijati** (ORCID: 0009-0003-8929-7305) – *Faculty of Economics and Business, University of Dr. Soetomo, Indonesia*

Rahmawati Erma **Standsyah** (ORCID: 0000-0001-6211-5696) – *Faculty of Mathematics and Natural Sciences, State University of Surabaya, Indonesia*

Sayekti Suindyah **Dwiningwarni** (ORCID: 0000-0003-0638-057X) – *Faculty of Economics and Business, University of Dr. Soetomo, Indonesia*

Correspondence address:
Taman Pondok Jati blok AP No. 4, Sidoarjo, Indonesia
e-mail: suyanto_fe@unitomo.ac.id

ABSTRACT: G20 member countries are forced to reduce carbon dioxide emissions from the global community as well as economic development constraints from domestic resources and the environment. Literature related to institutional quality and government expenditure is still limited, especially in G20 countries. To provide empirical evidence to support the theoretical argument, the study investigated the effects of institutional quality and government expenditure on CO2 emissions using a balanced panel dataset of nineteen countries that were members of the G20 between 1995 and 2015. Empirical results show that institutional quality is able to reduce carbon emissions. A good government can formulate strict environmental regulations and ensure transparency, which allows investment in green technologies and renewable energy. Other findings suggest that government spending can increase carbon emissions. The findings show that government spending in G20 countries still does not consider environmental impacts. Several policy recommendations are suggested.

KEYWORDS: carbon emissions, institutional quality, government expenditure, environmental Kuznets curve

Introduction

The use of fossil fuels has ushered in an era of unprecedented prosperity and well-being, but carbon dioxide (CO_2) emissions that are the result of the increased use of fossil fuels could negatively impact global temperatures and ocean acidity (Jiang et al., 2020). According to statistics from the World Bank (2024), The last few decades have shown a rapid increase in carbon dioxide (CO_2) emissions worldwide, with a strong increase from 21284042.79 kt in 1990 to 33566427.59 kt in 2020. G20 member countries, comprising the G7 developed countries and BRICS developing countries, are forced to reduce carbon dioxide emissions from the global community as well as economic development constraints from domestic resources and the environment (Chen et al., 2020). The drastic increase in CO_2 concentrations is causing serious global warming and climate instability, leading to unwanted natural disasters, melting glaciers, and extreme weather patterns (Gao et al., 2020). In an effort by the global community to start paying attention to environmental problems related to increasing CO_2 emissions, many countries have taken various actions to address the increase in CO_2 emissions (Dong et al., 2020a; Dong et al., 2020b).

One of the causes of the increase in CO_2 emissions is economic activity. This is explained in the study of Sinha and Shahbaz (2018), which explains that when the economy moves in line with its growth, during the early stages of economic growth, the environment deteriorates rapidly due to air pollution, deforestation, soil and water pollution, and other factors. Then, when income increases, and the economy begins to develop, the rate of damage slows down to a certain point in income, environmental degradation begins to decrease, and environmental quality begins to improve (Galeotti, 2007). The relationship between economic growth and CO_2 emissions has been formulated in the Environmental Kuznets Curve (EKC) hypothesis. The hypothesis explains that the phenomenon of economic growth and CO_2 emissions is Inverted U-shaped (Wang et al., 2024).

EKC describes the development of pollution and income generated from economic development over time of an economy (Tenaw & Beyene, 2021). Therefore, EKCs are usually divided into three stages: the initial economic development stage, the turning point stage, and the final economic development stage (Leal & Marques, 2022). Briefly taking into account the course of economic growth, the first phase is characterised by intensive use of resources and a rapid increase in environmental degradation. The second phase, the turning point, occurs when a certain level of income is reached and the trajectory of pollution changes, leading to the third phase, where environmental degradation is reduced. The inextricable relationship mentioned earlier represents the initial stage of economic development. However, when the turning point is reached, revenues begin to be distinguishable from environmental damage and emissions. This will lead to the final stage of economic development, where innovation and clean technology are widespread (Gill et al., 2017).

The idea of EKC was first initiated by Beckerman (1992), who stated that "too poor to be green", meaning that the least developed countries have fewer resources to protect the environment. From this thought, empirical studies of EKC such as Shafik and Bandyopadhyay (1992) began to emerge. In its development, empirical studies on EKC have taken into account other explanatory variables such as energy consumption and several others (Shahbaz & Sinha, 2019).

In an effort to address the climate challenges facing humanity, the United Nations recommends that countries work together. Governments must urgently use existing instruments, such as fiscal policy (with government spending playing a key role), to address climate change and move towards sustainable development. (Fernández et al., 2018). Government spending, direct taxes, and indirect taxes are some of the fiscal tools used to protect the environment (Postula & Radecka-Moroz, 2020). Taxes are implemented with the aim of limiting consumption by raising prices, while government spending on environmental protection includes biodiversity protection, pollution reduction, and wastewater and waste management. Governments in developing countries must specifically reform and improve the quality of their organisations and governance to ensure that government spending on environmental protection is allocated and used correctly (Nguyen, 2024). Therefore, this study considers government spending as an explanatory variable in the EKC model.

Research on how government spending helps protect the environment is abundant in academia, and this topic is considered a school of research in economics. According to almost all research, government spending can improve the quality of the environment by reducing harmful emissions. However, there are still few studies that examine the relationship between institutional quality, govern-

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ance, and government spending and carbon dioxide emissions, especially in G20 countries. One of the important factors in dealing with environmental problems is institutional quality. Institutional improvement is the right tool to control carbon dioxide emissions (Salman et al., 2019; Wawrzyniak & Doryń, 2020). Through regulations and policies, institutional quality (good bureaucracy, corruption control, law and order, government stability, and democracy) can serve as a good catalyst to improve the quality of the environment (Uzar, 2021). A recent study by Sadik-Zada and Loewenstein (2020). It also revealed that several factors that are often heavily influenced by the level of institutional quality, such as political rights and civil liberties, can have a negative impact on per capita carbon emissions.

Due to the importance of the role of institutional quality and government expenditure in reducing carbon emissions, this study aims to investigate the influence of institutional quality and government expenditure on CO2 in G20 countries. Policymakers need to understand the concept of renewable energy production and consumption in order to create effective policies that can increase sustainable development, especially in G20 countries. To deepen the analysis and distinguish other literature, this study also analyses the Environmental Kuznets Curve (EKC) to determine the condition of carbon emissions and economic growth in G20 countries, which then adds the combined effect of institutional quality and government expendency with the control variables of renewable energy consumption and fossil energy to the EKC argument. This is done for G20 countries, which have recorded little documentation in the relevant literature.

The rest of this paper is organised as follows: Part 2 presents a literature review, while Part 3 presents a description of the model and data. The interpretation and discussion of the results are presented in Part 4. Finally, Part 5 presents conclusions and policy recommendations.

An overview of the literature

The impact of economic activities on environmental pollution has been of great concern to researchers, and much empirical literature has been published. Pata and Karlilar Pata (2024a) found that economic growth effectively reduces the ecological footprint of African countries, but renewable energy does not contribute to ecological progress. The study used the general correlation effects of the new regularisation and a half-panel jackknife approach on data from five countries in Africa from 2006 to 2020. Eweade et al. (2023) used the Autoregressive Distributed Lag (ARDL) and Nonlinear ARDL (NARDL) approach on Mexico data from 1975 to 2020 to investigate the asymmetric effects of fossil fuels, foreign direct investment, and globalisation on the ecological footprint. Empirical results show that economic growth and fossil fuel consumption lead to ecological degradation, while foreign direct investment improves environmental conditions. Pata and Karlilar (2024b) examined the impact of energy security, green innovation, economic policy firmness, and income on the fossil fuel material footprint for 24 OECD countries during the period 1995–2018 using the Augmented Mean Group (AMG) and Half Panel Jackknife (HPJ) methods. Empirical results show that the energy security risk index reduces the material footprint, while green innovation and economic policy firmness have no impact on environmental degradation.

The influence of investment and renewable energy technology on carbon emissions in G7 countries was analysed by Erdogan et al. (2023). Using the Augmented Mean Group method on data for the period 2004-2018, empirical results show that renewable energy investments and technologies help reduce carbon emissions in various models. Pata et al. (2023b) analysed the impact of economic growth, globalisation, foreign direct investment, and fossil energy intensity on ecological efficiency in China using dynamic autoregressive distributed lag (DARDL) and kernel-based regularised least squares (KRLS) methods for the period 1990 to 2018. Empirical results show that globalisation and economic growth improve ecological efficiency in China, while foreign direct investment and fossil fuel intensity have a negative impact on environmental quality. Pata et al. (2023a) examined how the intensity of renewable energy and the share of renewable energy improved the environmental sustainability load capacity factor (LCF) in Germany from 1970 to 2018. Using the autoregressive distributed lag model method, the empirical results show that renewable energy intensity has no statistically significant effect on LCF. In addition, the share of renewable energy & capital increases LCF, and urbanisation decreases LCF.

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Aytun et al. (2024) examined the effects of human capital, technological innovation, and financial development on the ecological footprint of 19 middle-income countries from 1980 to 2016. Using the cross-sectional augmented autoregressive distributed lag (CS-ARDL) method, empirical results show that the increase in technological advancement does not contribute to the achievement of the sustainable development goals (SDGs) for middle-income countries, while human capital and financial development play an environmentally friendly role. Pata and Caglar (2021) examined the ecological outcomes of income, human capital, globalisation, renewable energy consumption, and trade openness for China within the framework of the EKC hypothesis for the period 1980-2016 using the ARDL method. Empirical results show that globalisation, trade openness, and income drive environmental pollution while increasing human capital reduces the ecological footprint in the long run. No impact was found on renewable energy consumption. The EKC hypothesis does not apply to China.

Pata (2018) analysed the dynamic relationship between GDP per capita, carbon dioxide (CO2) emissions per capita, financial development, total renewable energy consumption per capita, hydropower consumption, alternative energy consumption and urbanisation investigated using ARDL, FMOLS, and CCR testing approaches for Turkey during 1974-2014. Empirical results show that economic growth, financial development, and urbanisation increase environmental degradation, while total renewable energy consumption, hydropower consumption, and alternative energy consumption have no effect on CO2 emissions.

Studies have shown that the EKC hypothesis shows mixed results. In certain empirical studies, the EKC hypothesis was not found to be valid (Neve & Hamaide, 2017; Rehman & Rashid, 2017; Zoundi, 2017). Other research shows empirical findings of the validity of the EKC hypothesis but in various forms, i.e., monotonically increasing (Dong et al., 2016; López-Menéndez et al., 2014), monotonically decreasing (Yaduma et al., 2015), U-Shaped (Ben Jebli & Ben Youssef, 2015; Sapkota & Bastola, 2017), Inverted U-Shaped (Apergis & Ozturk, 2015; Dogan & Seker, 2016; Iwata et al., 2011), N-Shaped (Lorente & Álvarez-Herranz, 2016; Sinha et al., 2017), and Inverted N-Shaped (Musolesi et al., 2010).

Zheng et al. (2024) investigated the relationship between higher education, institutional quality, and CO2 emissions, taking into account the role of R&D for the E-7 countries for the period 1995-2020. The study found that better education and improved institutional quality significantly lowered emissions. Amin et al. (2022) examined the influence of financial development, institutional quality, foreign direct investment, trade openness, urbanisation, and renewable energy consumption on CO2 emissions during the period 1996–2020 in China using the dynamic ARDL method. The study found that indicators of governance, trade, financial development, and renewable energy consumption negatively impacted CO2 emissions, while urbanisation and foreign investment directly contributed to environmental degradation. Bletsas et al. (2022) examined the relationship between fiscal and monetary policy, institutional quality, central bank characteristics, and carbon dioxide and greenhouse gas emissions of 95 countries during the period 1998 to 2019 using the static panel method. The study found that economic growth is a factor that significantly worsens the state of the environment. On the contrary, institutional and bureaucratic quality is a factor that improves because these factors reduce emissions.

Petrović and Lobanov (2020) tested the effect of public spending on research and development on CO2 emissions. They used estimation methods such as fixed-effect models, MGs, and general correlated effects collected. The results show that these countries are reducing CO2 emissions through public spending on research and development. Adewuyi (2016) examines the impact of household, corporate and government spending on CO2 emissions. Estimators used include PMG, MG, and fixed-effect models. The results show that public spending reduces CO2 emissions globally. Shao et al. (2022) applied an estimator to examine the impact of public spending on entertainment, culture, and society on CO2 emissions. The results reported that this spending reduced CO2 emissions. The researchers argued that governments could use this spending to raise public awareness of how responsible consumption and social responsibility relate to society, health, the environment, and ecology. However, in the research, Moshiri and Daneshmand (2020) did not find any evidence regarding the impact of public spending on environmental protection.

The main conclusions drawn from these previous studies seem to suggest that, first, the EKC hypothesis has mixed findings depending on the location of the study. Second, institutional quality

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can reduce carbon emissions. Third, many studies show that government expenditure can reduce carbon emissions, but few of them show such an effect.

Research methods

Theoretical framework and model specification

This study follows the general EKC model, where the squared effect of income and GDP on CO2 emissions is assumed to explore hypothetical EKCs while examining the determinants of CO2 emissions. Considering that economic growth, institutional quality, and government expenditure as well as control variables (renewable energy consumption and fossil energy), can have an impact on CO2 emissions, referring to the research of Khan et al. (2021), Nguyen (2024), and Shahbaz and Sinha (2019), the framework per Equation (1) is expressed as:

$$CO2 = f(GDP, GDP2, IQ, GEXP, Z) \tag{1}$$

where:
CO2 – represents CO2 per capita (metric ton),
GDP – represents GDP per capita and GDP2 is the square (constant 2015 US$),
IQ – represents Institutional Quality, GEXP represents Government Expenditure (% of GDP),
Z – represents control variables consisting of renewable energy consumption (% of total final energy consumption) and fossil energy (% of total).

Then, the control variables in the substitution and simple form of this model are presented in Equation (2):

$$\begin{aligned} CO2_{it} = \alpha + \beta_1\, GDP_{it} + \beta_2\, GDP^2{}_{it} + \beta_3\, IQ_{it} \\ + \beta_4\, GEXP_{it} + \beta_5\, REN_{it} + \beta_6\, NREN_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

Taking into account the natural logarithm (ln), Equation (2) is converted into a linear logarithm square parameter to obtain a meaningful interpretation (Bekhet & Othman, 2018) in Equation (3):

$$\begin{aligned} \ln(CO2_{it}) = \alpha + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(GDP_{it})^2 + \beta_3 \ln(IQ_{it}) \\ + \beta_4 \ln(GEXP_{it}) + \beta_5 \ln(REN_{it}) + \beta_6 \ln(NREN_{it}) + \varepsilon_{it} \end{aligned} \tag{3}$$

where:
α – is intecept,
ε – is the error term,
parameters β_1 – β_6 – denote the estimated coefficients,
i and *t* – denote country and year.

The value of β1 and β2 determines the different shapes of the EKC hypothesis. For example, where β1=β2=0, economic growth has no relationship with emissions; where β1>0 and β2=0, the association between income and emissions is positive and monotonic; where β1<0 and β2=0, income has a negative relationship with emissions and linearly decreases them; where β1<0 and β2>0, the link between emissions and income is described by a U-shaped curve; and where β1>0 and β2<0, the association of income and emissions is represented by an inverted U-shaped curve, which validates the EKC hypothesis (Shahbaz & Sinha, 2019).

Data Source

To investigate the effects of institutional quality and government expenditure on CO2 emissions, we used balanced panel data for 19 countries that are members of the G20 (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Korea, Turkiye, United Kingdom, and United States) for the period 1995-2015. The data analysis period was limited in 2015 due to data limitations, especially on the Fossil Fuel Energy Consump-

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tion (NREN) variable which at the time of this study, the latest data was still in 2015. The data of CO2 emissions (notated as CO2), GDP (notated with GDP), Institutional Quality (notated with IQ), Renewable Energy Consumption (notated with REN), and Fossil Fuel Energy Consumption (notated with NREN) were obtained from the World Bank (2024). Furthermore, the variable Government Expenditure (notated with GEXP) is obtained from the International Monetary Fund (2024). The IQ variable is a variable based on the results of the Principal Component Analysis (PCA) on the indicator data. IQ has 6 indicators, namely Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption.

Results of the research

Descriptive Analysis

This section is done with a preliminary analysis that includes summary statistics. Summary data from all countries is presented in Table 1. Descriptive statistics are presented in Table 1 to show the nature of the data used during the period 1995 to 2015. The results show that, on average, CO2 emissions (CO2), GDP (GDP), Institutional Quality (IQ), Government Expenditure (GEXP), Renewable Energy Counsumption (REN), and Fossil Fuel Energy Consumption (NREN) are 8.168278, 21620.89, -6.16e-10, 33.79754, 14.21053, and 81.04421 respectively.

Table 1. Summary Statistic

Variable	Obs	Mean	Std. dev.	Min	Max
CO2	399	8.168278	5.295057	0.765189	20.46980
GDP	399	21620.89	16642.98	618.1393	57040.21
IQ	399	-6.16e-10	2.297621	-3.973208	3.384350
GEXP	399	33.79754	10.91064	11.09503	57.22779
REN	399	14.21053	13.88714	0	50.70000
NREN	399	81.04421	12.84527	46.22592	99.99677

Source: authors' work based on data processing by Stata MP 17.

While the minimum and maximum values for these variables are as follows: the minimum and maximum values for CO2 are 0.765189 and 20.46980. The minimum and maximum values for GDP are 618.1393 and 57040.21. The minimum and maximum values for IQ are – 3.973208 and 3.38435. The minimum and maximum values for GEXP are 11.09503 and 57.22779. The minimum and maximum values for REN 0 and 50.7. Finally, NREN varies from 46.22592 to 99.99677 across the G20 countries during the period under consideration.

Diagnostic Test & Estimation

We estimate the model using the Stata MP 17. The selection of the estimation model is made between a fixed effect model (FEM) and a random effect model (REM), as they are two alternative methods in our solution to estimate static panel models. We lack a predicate to use the Pooled OLS method because it does not take into account the heterogeneity of each country observed, and on the other hand, the FEM and/or REM estimators are able to overcome this (Baltagi, 2005). However, we still test Pooled OLS for robustness. Therefore, the Hausman and LM tests have been used to select the best model.

Based on Table 2, the LM Test using the Breusch Pagan method has a probability value of 0.0000, which is smaller than the real level of 5 percent (prob < 0.05) which means rejecting H0, and the model chosen is a random effect. Then the probability of the Hausman Test is greater than the real level of 5 percent (prob > 0.05), which means that the selected model is a random effect. Based on the results of the two tests, it can be concluded that the best model used in this paper is the Random Effect Model.

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Table 2. Best Model Selection Estimation

	Prob.	Conclusion	
LM Test	0.0000	Not Reject H_0	REM
Hausman Test	0.1397	Reject H_0	REM

Source: authors' work based on data processing by Stata MP 17.

Table 3. Estimation Result

Variables	Result
CONSTANT	-9.986***
	(0.690)
LnGDP	1.231***
	(0.151)
$LnGDP^2$	-0.0433***
	(0.00866)
LnIQ	-0.0733**
	(0.0328)
LnGEXP	0.0934***
	(0.0266)
LnREN	-0.128***
	(0.0110)
LnNREN	0.942***
	(0.101)
Observations	374
R-Square	0.8658
Prob. F	0.0000
Number of code	18

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: authors' work based on data processing by Stata MP 17.

After obtaining the best model, namely using a random effect model, the interpretation of the estimated results presented in Table 3 is carried out.

Discussion/Limitation and Future Research

Based on Table 2, the findings are obtained. The results of GDP estimation show a coefficient of 1,231, and statistically, in the GDP estimation model, it has a positive effect on the level of carbon dioxide emissions. The results of this estimate show that every 1 percent increase in GDP will cause an increase in carbon dioxide emissions by 1,231 percent. Due to the increasing demand for fossil fuels, which causes temperatures to rise, the increase in economic activity puts significant pressure on the environment. As a result, the quality of the environment in some countries has become worse, along with rapid economic growth. We can say that carbon dioxide emissions are the result of economic activity. The results of the GDP^2 estimate show a coefficient of -0.0433, and statistically, in the GDP^2 estimation model, it has a negative effect on the level of carbon dioxide emissions. The results

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of this estimate show that every 1 percent increase in GDP^2 will cause a decrease in carbon dioxide emissions by 0.0433 percent. The results show that $\beta_1 > 0$ and $\beta_2 < 0$ can be concluded that the EKC curve in G20 countries is in the form of an Inverted U-shaped curve according to the theory.

These results are in line with the research of Chang et al. (2021), which concluded that the Kuznets curve of the environment is inverted U-shaped in China, with peaks occurring earlier due to the effect of spatial overflow. Khan et al. (2022) similarly concluded the inverted U-shaped relationship between economic growth and environmental sustainability (Environmental Kuznets Curve) for APEC countries. Consistent with the research of Gyamfi et al. (2021), an inverted U-shaped environmental Kuznets curve for E-7 countries. According to Chang et al. (2021), For some areas, the inverted U-shaped relationship between GDP and pollution holds true, but it breaks down for other places. For example, areas that have greater GDP percentages of secondary industry and higher income levels.

The results of the Institutional Quality estimate show a coefficient of -0.0733, and statistically, the Institutional Quality estimation model has a negative effect on the level of carbon dioxide emissions. The results of this estimate show that every 1 percent increase in Institutional Quality will cause a decrease in carbon dioxide emissions by 0.0733 percent. The results of this finding are in line with the results of the research of Safi et al. (2022), which concluded that institutional quality reduces carbon emissions and improves environmental quality in developing countries. Consistent with Xaisongkham and Liu's (2024) research, Institutional qualities, such as the effectiveness of governance and the rule of law, reduce CO2 emissions in developing countries. Amin et al. (2022) concluded that institutional quality has a negative impact on CO2 emissions in China. The most important institutional dimensions are (i) the rule of law, (ii) citizens' political voice, (iii) corruption control, (iv) regulatory quality, and (v) government effectiveness. Effective climate change policies must also be associated with improvement in at least three main institutional dimensions: the protection of property rights (rule of law), citizens' participation in elections and freedom of expression (voice), and control of corruption (Stef et al., 2023). Effective government can also increase public awareness of the importance of environmental sustainability through education programs and awareness campaigns, which can encourage changes in people's behaviour towards more environmentally friendly practices. All of these factors contribute to the reduction of carbon emissions by encouraging more efficient use of energy, reducing reliance on fossil fuels, and accelerating the transition to a sustainable economy.

The results of the Government Expenditure estimate show a coefficient of 0.0934, and statistically, the Government Expenditure estimation model has a positive effect on the level of carbon dioxide emissions. The results of this estimate show that every 1 percent increase in Government Expenditure will cause an increase in carbon dioxide emissions by 0.0934 percent. These results show that government spending in G20 countries has not taken into account environmental factors. Although the empirical results of government expenditure on CO2 emissions in this study are not in line with most of the results of previous studies, the results of this study are in line with the research of Kamal et al. (2021), which states that government spending has a positive impact on CO2 emissions. Pirgaip et al. (2023) concluded similarly that Government spending has a positive impact on CO2 emissions in the US and Canada. Yang et al. (2018) also concluded that the level of public expenditure is positively correlated significantly with regional CO2 emissions in China. Yilanci and Pata (2022) explain that fiscal expansion without taking into account environmental sensitivity can lead to an increase in CO2 emissions, which is seen as a major cause of climate change and an obstacle to sustainable growth. Increased government spending can lead to increased carbon emissions as larger spending is often directed at large infrastructure projects and energy-intensive economic activities.

The control variables, Renewable Energy consumption and Fossil Fuel Energy Consumption, have coefficient values of -0.128 and 0.942, respectively. This shows that Renewable Energy consumption has a negative impact, and Fossil Fuel Energy Consumption has a positive impact on carbon dioxide emissions. The results of the estimate show that when Renewable Energy Consumption increases by 1 percent, crowdsourcing carbon dioxide emissions will be 0.128 percent, and when Fossil Fuel Energy Consumption increases by 1 percent, carbon emissions will also increase by 0.942 percent. The results show that G20 countries have made a transition to start consuming renewable energy but still rely on fossil energy sources. This can be seen from the greater value of the NREN coefficient compared to REN. The results of this study also show an R2 value of 0.8658. This result explains that the proportion of the influence of GDP, GDP2, Institutional Quality, Government Expend-

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iture, Renewable Energy Counsumption, and Fossil Fuel Energy Consumption to CO2 Emissions is 86.58 percent. So the remaining 13.32 percent was influenced by other variables that were not the focus of this study.

Conclusions

Using a balanced panel of data for 19 G20 countries covering 1995–2015, the study aims to investigate the influence of Institutional Quality and Government Expenditure on CO2 emissions worldwide. This paper finds empirical findings, namely that Institutional Quality has a negative effect on carbon dioxide emission levels. A better government can formulate and enforce strict environmental regulations that are free from corruption so that resources are allocated efficiently for green technology. They also raise public awareness of sustainability through education and campaigns. All of this contributes to the reduction of carbon emissions by driving energy efficiency, reducing dependence on fossil fuels, and accelerating the transition to a sustainable economy.

Other findings also show that Government Expenditure has a positive effect on carbon dioxide emission levels. Government spending in G20 countries often does not take environmental factors into account, so large infrastructure projects and energy-intensive economic activities increase carbon emissions. Despite the economic benefits, without proper management and regulation, government spending can contribute to an increase in carbon emissions.

Based on empirical evidence found in this article, it shows that G20 countries have an institutional quality that is able to reduce CO2 emissions but has Government Expenditure that does not consider environmental effects in its implementation. We recommend policies that can be implemented by G20 countries. First, the government can carry out development by prioritising cooperation with organisations that have environmental management systems like ISO 14001 certification. This policy will also encourage other organisations to carry out environmental management systems. Second, G20 countries can consider investing in research and development for renewable energy with the aim that renewable energy can compete with fossil fuels. Third, the government must reconsider implementing a carbon tax, especially for China and the United States, which are G20 members who contribute the largest amount of CO2 emissions compared to other countries. It is hoped that by considering these policies, government expenditure will be able to reduce CO2 emissions in the future.

The contribution of the authors

Conceptualization, S. and M.A.A.A.; literature review, J.S. and S.S.D.; methodology, R.E.S. and S.S.D.; formal analysis, S., M.A.A.A. and R.E.S.; writing, M.A.A.A. and J.S.; conclusions and discussion, S., J.S. and S.S.D.

The authors have read and agreed to the published version of the manuscript.

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