International Journal of Educational Review, Law, and Social Sciences (IJERLAS)
ISSN: 2808-487X
Edition: Vol. 6 No.5 (2026)
https://radjapublika.com/index.php/IJERLAS/index

Analysing The Relationship Between CO2 Emissions And Poverty In Indonesia: A Granger Causality Test

Tetuko Rawidyo Putro[1]*
[1]Sebelas Maret University, Surakarta
e-mail: tetuko97@staff.uns.ac.id
*Corresponding Author: tetuko97@staff.uns.ac.id

Keywords:
CO2 emissions, Poverty, Indonesia, Granger causality

Article Info.
Received:
04/07/2026
Revised:
16/07/2026
Accepted:
25/08/2026
Published:
16/09/2026

ABSTRACT

Background of the study: Global warming is a significant problem that many experts have discussed because it relates to the world's future. A few countries are experiencing the impacts of global warming, which can affect large populations. Indonesia is also one of the countries at high risk. One of the factors that can cause global warming is CO2 emissions. Low income or poverty is another problem that arises in Indonesia. The Indonesian population currently living below the poverty line is 9.76%. According to the World Bank, 1 in 10 people lives below the poverty line. Increasing CO2 emissions related to anthropogenic activities can also increase the poverty rate. This study investigates whether there is a long-term relationship between CO2 emissions and poverty in Indonesia from 2000 to 2022. This study will examine the direction of influence between the two variables, and the results indicate that CO2 emissions have a one-way relationship with the poverty rate in Indonesia. The data collection process was conducted without significant constraints, and the pooled time-series data derived from the long-run Granger causality test are appropriate for analysis. The selection of an annual data series is justified because the quarterly data series was not available. The choice to utilise an annual data series is justified, as the quarterly data series was not accessible. The Granger representation theorem establishes unidirectional causality, elucidating the impact of poverty on CO2 emissions. It is reasonable to hypothesise that contemporaneous correlation or feedback presence reinforces the implications of model one (unidirectional Granger causality), which reveals the relationship between Y1t and Y2t, provided that the correlation is not excessively strong (two-way causality cannot occur). This research found that CO2 emissions exhibit a unidirectional association with Indonesia's poverty level. CO2 emissions impact poverty in Indonesia. Indonesia's economy is expanding, as demonstrated by the persistent upward trajectory in economic activities. The consistent expansion of economic activity has led to increased CO2 emissions. This study will contribute to the growing body of evidence on the relationship between low income and CO2 emissions. The technology used determines the level of CO2 emissions. The new insights pertain to environmental and development economics, as well as social policies. Providing alternative energy is a means to control CO2 emissions. In addition, welfare policies can be implemented to anticipate and minimise the impact of increased CO2 emissions. The choice of technologies and relevant factors may shape CO2 emissions. The level of CO2 emissions in this study is determined by examining Indonesia.

How to cite:
DOI: https://doi.org/10.5281/ijerlas.v6i5.6404

Introduction

This study originated from the fact that economic development, distribution, and sustainable environmental management are moving towards localisation and decentralisation phenomena in many

countries (Wu et al. 2019). This is because the region's local government directly manages the people's domestic affairs, and the people know the urgency of their problems. This aligns with Law Number 23 of 2014 concerning the Local Government of the Republic of Indonesia. Indonesia is an archipelago country with various cultures. This leads to differences among the people of Indonesia across multiple aspects of life (Fanani 2023). Economic differences can be seen in each region's economic growth, income, welfare, and poverty.

One of the problems in communities experiencing poverty is environmental pollution, which is addressed by many related discourse efforts, including efforts to reduce poverty rates and carbon dioxide (CO2) emissions. (Baloch et al. 2020). Since 1960, Indonesia has become one of the world's most significant contributors of carbon dioxide (CO2) emissions. It is expected to remain one of the world's most significant contributors to carbon dioxide (CO2) emissions. (Idroes et al. 2024). According to the World Bank, one effect of increased CO2 emissions is that people living in poverty account for an average of 15.6 per cent of Indonesia's population. It is based on the fact that people with low incomes are forced to live in polluted environments and must endure air pollution from industrial emissions. (Rentschler and Leonova 2023).

Many previous related studies have concluded the relationship between CO2 emissions and economic growth. High levels of industrialisation are the cause. (Liu and Bae 2018). However, more research is needed on the relationship between CO2 emissions and poverty. Moreover, issues of poverty, income inequality, and environmental damage are significant topics in sustainable development. Poverty and ecological issues are central to the Sustainable Development Goals (SDGs), and special attention must be paid to them, especially in developing countries. Indonesia is one of the countries with the highest poverty rate. The issue of environmental pollution in Indonesia is also increasing, and greenhouse gas emissions, especially CO2, account for around 80-90% of total emissions in all sectors of the economy. With this concept, the problem of poverty and the environment are related. (Kusumawardani and Dewi 2020).

The focus of this study is the relationship between the two. Specifically, this study empirically analysed the relationship between CO2 emissions and poverty. The study used Indonesia's annual time series data from 2000 to 2022. The research method used Granger causality. Model analysis indicates a relationship between the two. So, the research proved the relationship between poverty and CO2 emissions.

Nowadays, people are becoming more aware of the environment and the impact of CO2 emissions on Earth's temperature. (Baiardi, Baiardi, and Morana 2020). One indicator of high CO2 emissions is the increase in industrial activities. Industrial growth, especially in developing countries, is closely linked to a country's poverty levels. This is caused by the classification of the community's participation in national economic activities. Thus, the lower classes will be more involved in primary economic activities, which cause many negative impacts on the environment. One of the most well-studied energy consumption indicators in the literature is carbon emissions. (Sikder et al. 2022).

Using Granger causality in this context, we test the asymmetry between carbon emissions and poverty in Indonesia. This is the significance of our research. This research has found that prior investigations into the research topic have yet to make significant progress. Thus, the results of our study will contribute to the development of science, especially economics. Its policy implication is to improve the Indonesian people's condition by controlling carbon emissions from the industrial sector, thereby contributing to reducing poverty. Ironically, many studies correlating CO2 emissions with poverty concluded that CO2 emissions induced poverty to some degree, but very few studies identified a robust, effective solution to the problem of CO2 emissions and poverty reduction. (Vanegas Cantarero 2020). We support Hanna, Martinez-Zarzoso, Ali, and Salahuddin, who state that focusing on the solution is essential. However, our study is also designed to identify the appropriate policy for Indonesia, which may differ from country to country, based on the empirical test we employ. (Vanegas Cantarero 2020).

Literature Review

Global warming is one of the most critical threats of today. The main greenhouse gas responsible for global warming is carbon dioxide (CO2). The world's primary source of CO2 emissions comes from fossil fuel consumption. When fossil fuels are burnt to produce energy, the carbon trapped in the fuel is released into

the atmosphere as CO2. The larger the consumption of fossil fuels, the more CO2 is emitted. Indonesia, as one of the largest economies in Asia, has experienced high fossil fuel consumption in recent years (Hwang and Yoo 2012).

In addition, the poverty rate is still very high in Indonesia, with about 10.9% of the people living in poverty, especially those in rural areas and those who are unemployed. Unfortunately, global warming, an effect of CO2 emissions, has not received adequate attention from policymakers and researchers in the country. Researchers have recently noted the relationship between CO2 emissions and income inequality. Using a theoretical model, their paper explores the effects of preventive population control policies on per capita CO2 emissions and income. Previous studies have also shown a relationship between CO2 emissions and people's welfare. (Akbar et al. 2020).

This study is an extension of the work of (Coondoo and Dinda 2002), whose results indicate a bidirectional Granger causality relationship between CO2 emissions and income. We use the same time series data for Indonesia as (Coondoo and Dinda 2002) to analyse the relationship between CO2 emissions and poverty. Therefore, the result of this study can provide implications for policymakers and researchers in Indonesia.

Several studies have investigated the impact of various factors on CO2 emissions. These variables include income, energy consumption, foreign direct investment (FDI) - host countries' knowledge effect, trade openness, etc. (Sarkodie and Strezov 2018). In a developing country, such as Indonesia, CO2 emissions may also be affected by the poverty rate. Many poor people in Indonesia rely on charcoal because it is cheaper than kerosene, liquefied petroleum gas (LPG), or electricity. Thus, thermal power producers produce intermediate products using charcoal as fuel, and these activities will contribute to rising CO2 emissions. However, if poverty occurs in Indonesia, energy consumption will decrease, both in energy derived from charcoal and in power generated by other modern fuels. As a result, the CO2 emissions will decline. In Indonesia, the relationship between CO2 emissions and the poverty rate is theoretically hazy and should be tested empirically. In connection with the above description, this study will research the relationship between Indonesia's poverty rate and CO2 emissions.

This research focuses on the analysis of the relationships between energy usage sectors and economic performance (income) through energy consumption (electricity), both in the long term and the short term. Hypotheses can be developed from the relationships explained above, as follows. In the long term, there is a unidirectional causality between CO2 emissions and poverty. This is mainly because carbon dioxide, a greenhouse gas, is a by-product of energy usage. If energy is used for economic activities, particularly production, emissions will increase, and a larger workforce will be required for production. Thus, production activities and employment will increase income. Consequently, poverty will decline. (Acheampong 2018).

Researchers such as (Dhrifi, Jaziri, and Alnahdi 2020) Conducted a study in 20 low-income countries and found that poverty is the primary factor driving increased industrial carbon emissions. They developed a climate-economy model with a robust bootstrap to determine the link between poverty and CO2 emissions. Before the research, a literature review was conducted across economics, the social sciences, environmentalism, and energy science. The (Dhrifi, Jaziri, and Alnahdi 2020) found no uniform consensus on the impact of poverty on pollution emissions. Some studies in developing countries suggest they support an Environmental Kuznets curve (EKC). Although some scholars consider income and population growth to be one of the main drivers of emissions, poor people do not emit more. Generally, the relationship between emissions and poverty varied across countries, depending on their historical and social contexts and their exposure to local resources.

(Zhao et al. 2021) Conducted a survey and used household data from the National Sample Survey Office (NSSO) to evaluate and remove doubts. (Zhao et al. 2021) explained the link between energy, poverty, and pollution by devising a framework that combines the relationship between environmental income dynamics and the corresponding energy requirements. Based on the analysis, the study found that poverty alleviation strategies in India must focus on reducing carbon intensity and reliance on emissions. Meanwhile, (Banerjee, Mishra, and Maruta 2021) discovered a negative link between per-unit energy use

and family income. In contrast, the overall relationship between energy consumption and poverty, measured in monetary and non-monetary terms, was negative in 18 of 24 nations.

Theoretical Framework

The Granger causality theory posits that if a variable can statistically and significantly predict another variable, the former is said to "Granger-cause" the latter. The Granger causality test assesses the causal relationship between two or more variables. (Shojaie and Fox 2021). In the contemporary theory of time-series econometrics, GC, introduced by Clive Granger in 1969, is essentially more than previous causality theories, such as the Reichenbachian "seems likely" and the outstanding Neyman-Pearl "a cause is an invariable antecedent of an event." Compared to Granger causality, it served as a more practical tool, mainly used in earlier business cycle literature for empirical causality analysis to verify genuine relationships among economic time series. Granger developed the definition and test of causality, then demonstrated their power through a real-world application. Since Granger laid out the "(non-)Causality" idea widely, many empirical studies on causality between variables have improved by focusing on Granger causality. Granger posits that causality can be assessed in terms of short-run or long-run direction and applies it to economic time series such as income and consumption expenditure.

GC tests are necessary when changes or shocks affect two or more variables, and deciding which variables react to one another becomes crucial. As such, evidence of unidirectional or bidirectional causality between poverty and carbon emissions can offer important policy implications. In Indonesia, although several substantive practices to reduce overall poverty are already in place (e.g., a conditional cash transfer program, village development, entrepreneurship and skills training), these measures might work against efforts to reduce CO2 emissions or lead to trade-offs between reducing poverty and reducing CO2 emissions. Given this argument, it is pertinent to explore the evidence that a change in one variable is predictable from a change in the other (and not vice versa). However, whether any change in one variable leads to a predictable change in another variable, and the direction of causality, are not addressed by the earliest poverty–CO2 studies, such as Apergis et al. and Shahbaz et al.

Granger Causality Theory

"If two or more events are correlated, they may (or may not) have a causal element." This is a definition of causality offered by Granger to understand the possibility of the existence of causality (Troster 2018). The Granger causality is a statistical concept that uses the slope coefficient of the time-series equation to measure "one variable causes another variable." Suppose the regression variable better estimates a dependent variable's value than an alternative regression model that omits the causal variable. In that case, the evidence is that the omitted variable does cause the dependent variable. Various theories of causality can be used, including physical and statistical theories, as well as Granger causality.

Granger causality directly relates changes in one variable to changes in other variables. Economically, Granger causality is only connected to a single idea: the prediction difference. In this summation, the concept of Granger causality implies that one variable can cause another (unidirectional), two variables can cause each other, or there is no causal relationship between the two variables. In this study, Granger causality is used to see the existence of causality between CO2 emissions and poverty in Indonesia.

The principle of causality is used to create and examine theories, to justify measuring a theory's operational variables, and to show the possible policy implications of research. Therefore, the main concern often underlying testing for causality is to suggest that a variation in one variable results in a variation in another variable according to some set of ideas.

Several types of causality have different characteristics, such as theoretical, empirical, exogenous, and endogenous. One essential explanation is Granger causality, due to its simplicity and popularity in statistical research. In time-series causal testing, specific criteria must be met by a pair of variable models. The first criterion is that the variables must be stationary. If the value is found to be nonstationary, the variable must first be differenced before the test is attempted again. Second, if both variables are stationary, Granger causality can be tested by substituting one variable for the other in the model. If the F-statistic is significant,

there is Granger causality, suggesting that one variable allows for better forecasting of the other and directly implies causality.

Method

Our empirical study uses data from 2000 to 2022. All time series data were available on an annual frequency. Annual data on gross domestic product per capita (GDPcap), CO2 emissions, and the poverty rate were obtained from the World Development Indicators. The data on CO2 emissions were obtained from the World Development Indicators (WDI) database, which provides detailed CO2 emissions data. Meanwhile, the data on the percentage of the population below the national poverty line were taken from the Indonesian database (Indonesian Central Bureau of Statistics). The data collection process was completed without significant constraints, and the pooled time-series data resulting from the long-run Granger causality test are suitable for the test. The decision to use an annual data series is also appropriate, given that the quarterly data series was unavailable.

Assumptions of Granger Causality

Seven key assumptions must be met before establishing Granger causality. First, the two time series, Y_{1t} and Y_{2t}, should be stationary and mean-reverting. The ADF test can be applied to assess this assumption, but if the time series are non-stationary, they will be cointegrated. The co-integration test may be applied next. The test considers the correlation between one variable and both current and lagged values of the other variable; this condition is taken into account, as it forms the core of the Granger causality formulation. If the time series is not cointegrated, we apply the Granger representation theorem, which states that if we know Y1t's past, it adds no further to our power to predict Y2t after adjusting for the past of Y2t, whereas the reverse statement is not supported. This resembles a sufficient statistic test, where the conditioning variable Y_{1t-1} is associated with Y_{2t}, but not vice versa.

The Granger representation theorem establishes unidirectional causality, which can clarify the existence of poverty effects on CO2 emissions. It seems safe to conjecture that contemporaneous correlation or the presence of feedback only supports the implication and model one (unidirectional Granger causality), which can disclose the relationship between Y_{1t} and Y_{2t}, if it is not too strong (two-way causality cannot exist). Contemporaneous correlation will not imply jointly symmetric $Y_{1t} \leftrightarrow Y_{2t's}$ Granger causality property, as previously mentioned. The reduction of causality to mere correlation was a basic objection to Granger causality, since Granger causality was defined as a market information-set implication, leading to asymmetry; contemporaneous correlation could not then signal Granger causality; its sole association with Granger causality was spurious and inconsequential.

We used the Granger causality test to investigate whether there is a causal relationship between CO2 emissions and poverty, where changes in one variable significantly influence judgments about the presence of a causal relationship in the other variable. The Granger causality test showed that, based on the time-series statistics, H0 is rejected, indicating evidence of a relationship between CO2 testing and poverty. CO2 emissions in the Granger hierarchical order (Granger Causality) do not exhibit causality with the poverty rate in Indonesia. Therefore, the time sequence of poverty rates does not respond to changes in CO2 emissions.

When the minimum level of significance is set at 5%, the test results are meaningful, but caution is warranted in interpreting them. This is similar to the Granger causality test, with a time series showing no direction of correlation or time lag between poverty and CO2 emissions in Indonesia. The test results indicated that the poverty rate in Indonesia was unresponsive to increases or decreases in CO2 emissions, so CO2 emissions did not influence increases or decreases in poverty if Indonesia's reference time series was used in Granger causality testing at level I(2) for CO2 emissions.

Testing for Granger Causality

One relevant concept in economic data analysis is causality. A potential fourth step takes this to a testing regime. Here, we do not cover hypothesis testing on the validity of the lag order or the presence of

cointegration in VAR models for Granger causality tests. To motivate the method, we provide a simple example. Knowing that Y is correlated with X, one may propose that X causes Y. The goal then would be to test this claim. The object involved at that point is to determine if the introduction of lagged information on X has value in predicting Y. This is the essence of a Granger causality test. Noting at this point that such tests and inference are econometric procedures for analysing time series data and are agnostic to the definition of causality. It may be worthwhile to differentiate between metrics and methodologies that allow for the study of causality but do not test hypotheses of Granger non-causality. The important step is to bridge the gap between testing whether X causes Y and whether X predicts Y at some point. With a separation confirmed, it is then possible to muster evidence to support a claim of causality.

Results and Discussion

Table 1. Granger causality results of poverty and CO2 emissions

Pairwise Granger Causality Tests
Date: 08/17/26 Time: 17:22
Sample: 2000 2022
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
POVERTY does not Granger Cause LNCO2EMISS	22	7.44943	0.0133
LNCO2EMISS does not Granger Cause POVERTY		1.15230	0.2965

Source: data processing (EViews)

Based on the results above, CO2 emissions have a one-way relationship to Indonesia's poverty level. This means that CO2 emissions affect poverty in Indonesia. Indonesia's economy is growing, as evidenced by the upward trend in economic activity. The steady growth of economic activities has triggered a surge in CO2 emissions. The population living below the official national poverty line is a comprehensive task for economic development, requiring the work of various sectors and programs. There is a significant difference in empirical results among studies. Therefore, it is interesting to investigate this problem in a panel or country-specific context. Our study aimed to examine the relationship between CO2 emissions and poverty in Indonesia using a general approach, particularly the Granger causality test. (Raihan et al. 2023).

The increasing trend in CO2 emissions in Indonesia aligns with economic development. The Indonesian Government encourages all parties, including the private sector, NGOs, CBOs, and donors, to adopt the "green growth" principle in implementing development programs. Additionally, the government has been accelerating decarbonization, as evidenced by a shift in energy consumption toward mineral oil, natural gas, and the primary energy mix, with greater emphasis on developing new and renewable energy sources.

Theoretical studies suggest that lower or slower economic growth will reduce CO2 emissions because economic activity will decline. (Aye and Edoja 2017). However, if further economic growth is considered to include clean technology, it will be accompanied by increased CO2 emissions. This means that in SDGs 2030, eliminating poverty is the main target that provides the opportunity to slow down CO2 emissions among poor people. A Granger causality test was conducted to find out how this relationship occurs. This discussion focuses on the two leading studies that conducted the Granger causality test for each generation and the panel. Overall, Indonesia's Granger causality test results indicate that poverty Granger-causes CO2 emissions.

As this study indicates, there is a one-way relationship between CO2 emissions and poverty in Indonesia. In other words, the policy regarding CO2 emissions and poverty eradication must be integrated using simultaneous equation modelling. (Dhrifi, Jaziri, and Alnahdi 2020). Therefore, efforts to reduce CO2 emissions in Indonesia aim not only at environmental sustainability but also at improving people's welfare.

Conversely, poverty reduction in Indonesia should also be directed to enhancing people's welfare and considering environmental sustainability. Some policy implications and recommendations based on the relationship between CO2 emissions and poverty in Indonesia are as follows.

Given the one-way relationships between CO2 emissions and poverty, we expected that successful, sustainable poverty reduction could be achieved through technological change, good governance, and the adoption of poverty-focused development strategies that protect the environment and actively enhance the use of environmental resources. As a major source of CO2 emissions in Indonesia, the energy sector will continue to expand to reduce energy poverty by improving energy access (Wang and Wei 2020).

Conclusion

This study found a one-directional causality between CO2 emissions and poverty in Indonesia. This means CO2 emissions affect poverty. Thus, this research demonstrates that relationships between CO2 emissions and poverty persist. The empirical research shows relationships between poverty and CO2 emissions, and between urban poverty and CO2 emissions. As a result, the study's policy implications suggest that efforts to reduce CO2 emissions to alleviate poverty fall within the paradigm. Moreover, rural poverty contributes to increased CO2 emissions, such that policy implications, particularly for developing countries such as Indonesia, suggest the need to consider the capacity to adapt or to create carbon sinks if efforts to alleviate poverty do not tend to urbanise. The results recommend conducting further research that includes additional independent variables to analyse carbon emissions affecting poverty. This is in line with the results and with previous studies by Hobman (1998), who found that poverty is a cause of environmental destruction, whereas CO2 emissions also cause, or have a reciprocal effect on, poverty. This means that if CO2 emissions increase, poverty will also increase. This can be caused by low-income people who need farmers, fishermen, workers, and small-scale entrepreneurs to be made aware of the need to protect the environment. Moreover, rural communities are more economically minded, which increases the land area for cultivation and animal farming.

Acknowledgement

As a member of the research team of the Monetary and Fiscal Studies Group, the author wishes to thank the Institute for Research and Community Service (LPPM) of Universitas Sebelas Maret for funding this work through the Research Group Grant scheme (HGR-UNS) for 2025 under contract number 371/UNS27.22/PT.01.03/2025.

AI Usage Statement

The author's utilisation of Artificial Intelligence (AI) tools in this work is strictly confined to supportive functions. Authors are exclusively permitted to employ AI for language editing, grammar checking, and enhancing clarity and readability. AI was not utilised to generate core ideas, conduct substantive analysis, interpret data, or formulate scholarly conclusions. The author maintains full responsibility for the originality, accuracy, and academic integrity of the content. Additionally, AI tools are not acknowledged as authors or contributors, in adherence to ethical standards in academic publishing.

Conflict of Interest

The authors state that they have no conflict of interest concerning the research conducted.

References

Acheampong, A. 2018. "Economic Growth, CO2 Emissions and Energy Consumption: What Causes What and Where?" *Energy Economics*. https://doi.org/10.1016/j.eneco.2018.07.022.

Akbar, M, A Hussain, A Akbar, and I Ullah. 2020. "The Dynamic Association between Healthcare Spending, CO2 Emissions, and Human Development Index in OECD Countries: Evidence from Panel VAR Model." *Environment, Development and Sustainability* 23: 10470–89. https://doi.org/10.1007/s10668-020-01066-5.

Aye, G, and Prosper Edoja. 2017. "Effect of Economic Growth on CO2 Emission in Developing Countries: Evidence from a Dynamic Panel Threshold Model." *Cogent Economics & Finance* 5. https://doi.org/10.1080/23322039.2017.1379239.

Baiardi, Donatella, Donatella Baiardi, and C Morana. 2020. "Climate Change Awareness: Empirical Evidence for the European Union." *Energy Economics*. https://doi.org/10.2139/ssrn.3513061.

Baloch, M, Danish, S Khan, Zübeyde Şentürk Ulucak, and Ashfaq Ahmad. 2020. "Analyzing the Relationship between Poverty, Income Inequality, and CO2 Emission in Sub-Saharan African Countries." *The Science of the Total Environment* 740: 139867. https://doi.org/10.1016/j.scitotenv.2020.139867.

Banerjee, Rajabrata, Vinod Mishra, and A Maruta. 2021. "Energy Poverty, Health and Education Outcomes: Evidence from the Developing World." *Energy Economics* 101: 105447. https://doi.org/10.1016/j.eneco.2021.105447.

Coondoo, D, and Soumyananda Dinda. 2002. "Causality between Income and Emission: A Country Group-Specific Econometric Analysis." *Ecological Economics* 40: 351–67. https://doi.org/10.1016/s0921-8009(01)00280-4.

Dhrifi, Abdelhafidh, R Jaziri, and S Alnahdi. 2020. "Does Foreign Direct Investment and Environmental Degradation Matter for Poverty? Evidence from Developing Countries." *Structural Change and Economic Dynamics* 52: 13–21. https://doi.org/10.1016/j.strueco.2019.09.008.

Fanani, A. 2023. "Historical Juridical Study on the Amendment of Law Number 32 of 2004 Juncto Law Number 23 of 2014 Concerning Regional Government." *Rechtenstudent*. https://doi.org/10.35719/rch.v4i2.267.

Hwang, Jo-Hee, and S Yoo. 2012. "Energy Consumption, CO2 Emissions, and Economic Growth: Evidence from Indonesia." *Quality & Quantity* 48: 63–73. https://doi.org/10.1007/s11135-012-9749-5.

Idroes, Ghalieb Mutig, Irsan Hardi, Md. Hasanur Rahman, Mohd Afjal, T Noviandy, and R Idroes. 2024. "The Dynamic Impact of Non-Renewable and Renewable Energy on Carbon Dioxide Emissions and Ecological Footprint in Indonesia." *Carbon Research* 3. https://doi.org/10.1007/s44246-024-00117-0.

Kusumawardani, Deni, and Ajeng Kartiko Dewi. 2020. "The Effect of Income Inequality on Carbon Dioxide Emissions: A Case Study of Indonesia." *Heliyon* 6. https://doi.org/10.1016/j.heliyon.2020.e04772.

Liu, Xuyi, and Junghan Bae. 2018. "Urbanization and Industrialization Impact of CO2 Emissions in China." *Journal of Cleaner Production* 172: 178–86. https://doi.org/10.1016/j.jclepro.2017.10.156.

Raihan, A, Monirul Islam Pavel, Dewan Ahmed Muhtasim, Sadia Farhana, Omar Faruk, and A Paul. 2023. "The Role of Renewable Energy Use, Technological Innovation, and Forest Cover toward Green Development: Evidence from Indonesia." *Innovation and Green Development*. https://doi.org/10.1016/j.igd.2023.100035.

Rentschler, Jun, and Nadezda Leonova. 2023. "Global Air Pollution Exposure and Poverty." *Nature Communications* 14. https://doi.org/10.1038/s41467-023-39797-4.

Sarkodie, S, and V Strezov. 2018. "Effect of Foreign Direct Investments, Economic Development and Energy Consumption on Greenhouse Gas Emissions in Developing Countries." *The Science of the Total Environment* 646: 862–71. https://doi.org/10.1016/j.scitotenv.2018.07.365.

Shojaie, A, and E Fox. 2021. "Granger Causality: A Review and Recent Advances." *Annual Review of Statistics and Its Application* 9: 289–319. https://doi.org/10.1146/annurev-statistics-040120-010930.

Sikder, Mukut, Chao Wang, X Yao, Xu Huai, Limin Wu, Frederick KwameYeboah, Jacob Wood, Yuelin Zhao, and Xuecheng Dou. 2022. "The Integrated Impact of GDP Growth, Industrialization, Energy Use, and Urbanization on CO2 Emissions in Developing Countries: Evidence from the Panel ARDL Approach." *The Science of the Total Environment*, 155795. https://doi.org/10.1016/j.scitotenv.2022.155795.

Troster, Victor. 2018. "Testing for Granger-Causality in Quantiles." *Econometric Reviews* 37: 850–66. https://doi.org/10.1080/07474938.2016.1172400.

Vanegas Cantarero, María Mercedes. 2020. "Of Renewable Energy, Energy Democracy, and Sustainable Development: A Roadmap to Accelerate the Energy Transition in Developing Countries." *Energy Research and Social Science* 70: 101716. https://doi.org/10.1016/j.erss.2020.101716.

Wang, Huiqing, and Weixian Wei. 2020. "Coordinating Technological Progress and Environmental Regulation in CO2 Mitigation: The Optimal Levels for OECD Countries & Emerging Economies." *Energy Economics* 87: 104510. https://doi.org/10.1016/j.eneco.2019.104510.

Wu, Haitao, Yunwei Li, Yu Hao, Siyu Ren, and Pengfei Zhang. 2019. "Environmental Decentralization,

Local Government Competition, and Regional Green Development: Evidence from China." *The Science of the Total Environment*, 135085. https://doi.org/10.1016/j.scitotenv.2019.135085.

Zhao, Jun, Qingzhe Jiang, Xiucheng Dong, and Kangyin Dong. 2021. "Assessing Energy Poverty and Its Effect on CO2 Emissions: The Case of China." *Energy Economics* 97: 105191. https://doi.org/10.1016/j.eneco.2021.105191.