Article Type: Research Paper

The Nexus Between Economic Demography and Carbon Emission: A Case Study in South American Region

Yahya Mahda Vikia*, Valeriana Sekar Adhianti Wibowo, Faizal Maulana, and Dwi Rahmayani

AFFILIATION:
Department of Development Economics, Faculty of Economics, Universitas Negeri Semarang, Central Java, Indonesia

***CORRESPONDENCE:**
yahyamahdavikia10@students.unnes.ac.id

THIS ARTICLE IS AVAILABLE IN:
http://journal.umy.ac.id/index.php/jerss

DOI: 10.18196/jerss.v7i1.15893

CITATION:
Vikia, Y. M., Wibowo, V. S. A., Maulana, F., & Rahmayani, D. (2023). The Nexus Between Economic Demography and Carbon Emission: A Case Study in South American Region. *Journal of Economics Research and Social Sciences*, 7(1), 49-59.

Abstract: One of the world community's current challenges is determining how to achieve the SDGs goals on environmental quality before 2030. This study aims to determine how the massive population and economic growth affect the emission of carbon dioxide (CO2) gas in the six South American countries with the largest population and use the Environmental Kuznets Curve (EKC) hypothesis approach. The data used is panel data from 2011 to 2021 in six countries based on the average population of the largest population over 11 years in South America. The results of the study explain that the total population has a significant positive effect on CO2 emissions. In addition, trade openness through imports has a significant positive effect and this study was unable to validate the Environmental Kuznets Curve (EKC) hypothesis in six South American countries from 2011 to 2021.

Keywords: Emission; CO2; Import; Population; Environmental Kuznets Curve (EKC)
JEL Classification: F10; J10; O10; O44

Introduction

One of the challenges of the world community today is how to achieve the SDGs goals before 2030 regarding the problem of worsening environmental quality. Global warming and climate change are problems faced by all people in the world today. One of the causes of rising global temperatures is the emission of carbon dioxide (CO2) (Candra, 2018). The next problem is when the population is already massive, causing each country to continue to try to suppress the population so that it can be absorbed in the labor market.

With the optimal absorption of labor, it is hoped that it can improve the level of the domestic economy and that the welfare of the domestic community can be achieved. However, not a few jobs created due to the massive population can create problems in the quality of the surrounding environment. Then population density, industrialization, activities, and the expansion of economies of scale, have the potential and main determinants in increasing CO2 emissions, especially in developing countries (Aslam et al., 2021; Hang & Yuan-sheng, 2011).

According to Mendonça et al. (2020) explained that in the 50 largest economies, population growth was a contributing factor to the increase in carbon dioxide emissions from 1995 to 2015. With the creation of jobs and economic activity caused by the massive population, the externalities created from these economic activities could potentially damage nature either directly or indirectly. Based on data taken from British Petroleum, the emission level of carbon dioxide gas pollution on the South American continent tends to increase and the growth of carbon dioxide gas pollution has increased each year amid a decline in population growth from 2011 to 2021.

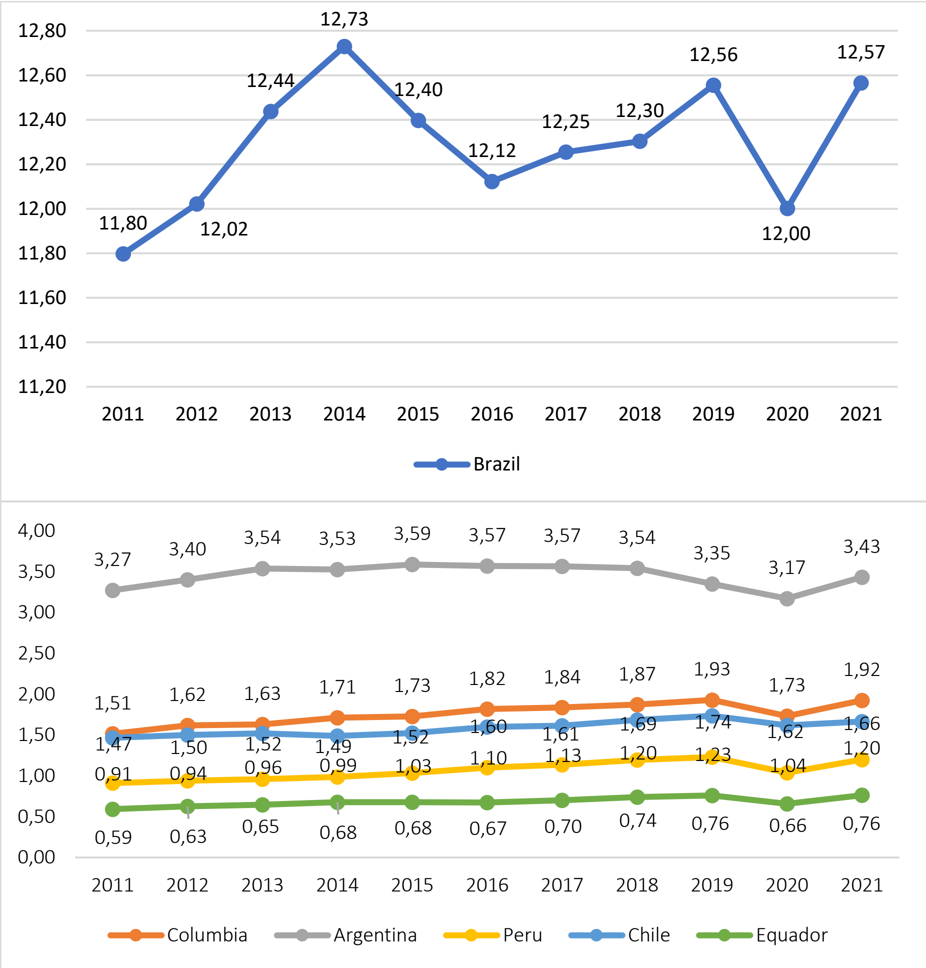

Figure 1 Carbon dioxide (CO2) Emission Levels in 6 South American Continental Countries 2011-2021 (m/t)
Source: British Petroleum, 2022

Based on Figure 1, it can be seen that the level of pollution of carbon dioxide gas emissions with units of metric tons in six countries has an increasing trend from 2011 to 2021. Meanwhile, if we look further, the growth of pollution levels in each of the six countries tends to increase from 2011 to 2021. Sampling from the six countries is based on the average number of the largest populations over 11 years, from 2011 to 2021 on the South American continent.

In addition, the population and community activities also influence the issue of increasing carbon dioxide (CO2) emissions. This is then examined in the research of Wang and Li (2021) and Xie et al. (2017) which states that humans are the main source of global warming, urbanization, and transportation infrastructure have contributed to the increase in CO2 emissions. Indirectly, the human population in a country has an important role in dealing with emissions problems. Carbon emissions are increasingly becoming an issue of global concern, not least for developing countries where population and economic growth factors have an impact on carbon emissions (Yeh & Liao, 2017).

Known as a country with a large population, Brazil is a country with potential for economic development. As a developing country, the total human population in Brazil and other countries in South America has the largest human population in the world. Nevertheless, the trend of population growth in the six countries with the largest average population continues to decline until the end of 2021. The following is data on population growth in six countries on the South American continent compiled from the World Bank.

Based on Figure 2, it is explained that although six countries have a massive total population, the trend of population growth in six countries has decreased. The phenomenon of the downward trend in population growth is inversely proportional to the level of carbon dioxide gas emissions which is experiencing an increasing trend from 2011 to 2021. This is contrary to previous findings which stated that population growth is the main contributor to carbon emissions in India and population growth is increasing. unsustainability is a direct cause of environmental damage (Rehman & Rehman, 2022).

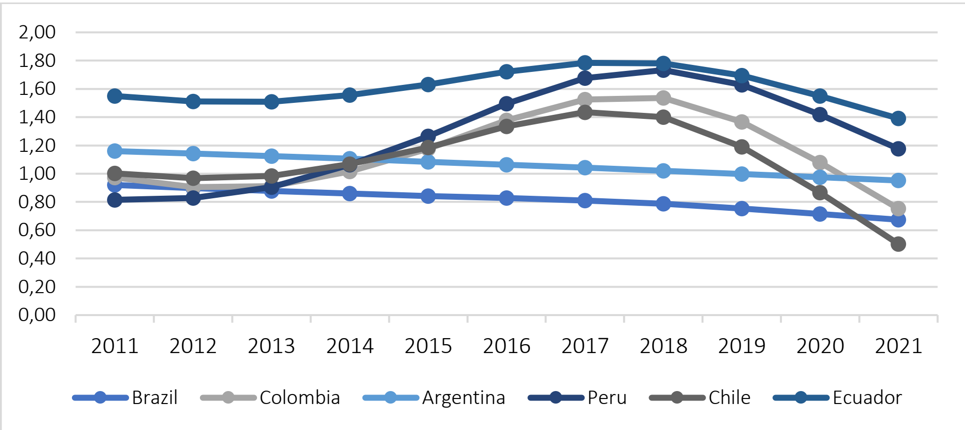

Figure 2 Population Growth of 6 Countries in South America
in 2011-2021 (Percent)
Source: World Bank, 2022

The human population will be directly proportional to the individual needs of the population and is closely related to energy consumption and carbon emissions in a country (Bu et al., 2022). With this high level of consumption, it has the potential for an increase in environmental degradation. In their research, Shao et al. (2020) explained that consumption-based emissions in Shanghai City have increased by 32.82% since 2007, which is growing much faster than production-based carbon. This resulted in goods and services in the country must be met to meet the needs through import activities. These international trade activities through imports have a negative effect on CO2 emissions (Salman et al., 2019).

In addition, according to research conducted by Zhang and Zhang (2018), it explains that domestic trade activities in developing countries such as China have a negative impact on the level of carbon dioxide (CO2) emissions. However, there are concrete steps to overcome emissions caused by import activities. Hu et al. (2020) explained that by diversifying imported products and consuming renewable energy. And the research was conducted in 35 developed countries and 93 developing countries. Then, based on the data in Figure 3, it is explained that the trend of imports of goods and services in six countries tends to fluctuate from 2011 to the end of 2021. The following is import data that we collect from the World Bank in 2011-2021.

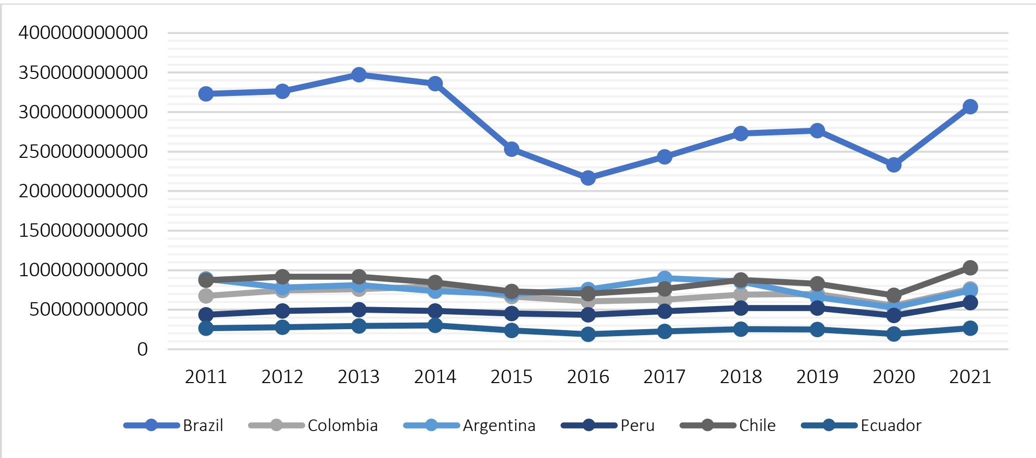

Figure 3 Value of Imports of Goods and Services from 6 Countries in South America in 2011-2021 (USD)
Source: World Bank, 2022

Then we try to describe this phenomenon using the Environmental Kuznets Curve (EKC) hypothesis. The Environmental Kuznets Curve (EKC) hypothesis states that economic growth will be continuously higher, but at a point, the policies implemented are more concerned with aspects of environmental conservation, as evidenced by the turning point or turning point that will be achieved when a country is in a state of crisis. a certain level of economic growth (Todaro & Smith, 2006). The following is a hypothetical curve of the Environmental Kuznets Curve (EKC).

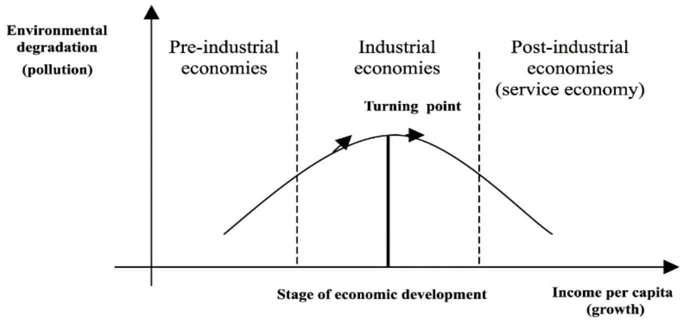

Figure 4 Environmental Kuznets Curve (EKC)

According to Nikensari et al. (2019), the EKC curve hypothesis explains how economic growth can lead to an increase in environmental degradation. This is because countries, especially developing countries, focus on increasing production and domestic economic activities without paying attention to environmental aspects, whether in the form of water, air, or land. Although the EKC approach is often used to describe economic activity with environmental quality, the EKC hypothesis modeling is not statistically strong enough (Stern, 2018).

Economic activity (proxied by GDP), population, and renewable energy generation have a positive impact and become a solution to reduce CO2 emissions in developed countries (Mendonça et al., 2020). Meanwhile, the EKC approach cannot be answered in developing countries instead the EKC approach takes the form of a bell (Al-Mulali et al., 2015; Sasana & Aminata, 2019). From the explanation, it is clear that there are still gaps in previous research regarding the use of the EKC hypothesis. Therefore, research on the relationship between economics and environmental quality can still be done. In addition, research using EKC modeling is still rarely carried out on the South American continent. .

Research Method

This study uses secondary data with quantitative and descriptive approaches sourced from the World Bank and British Petroleum. The data used is panel data from 2011 to 2021 in six countries based on the average of the largest population over six years in South America. The six countries are Brazil, Colombia, Argentina, Peru, Chile, and Ecuador. This study uses two types of variables, namely the dependent variable and the independent variable. This study uses carbon dioxide (CO2) emissions as the dependent variable and demographics as a proxy for the total population, total GDP per capita, GDP per capita squared, and the value of imports of goods and services as independent variables.

This study uses multiple linear regression analysis with the help of software as a data processing tool. Economically, the socio-economic relationship that is proxied from the total population, total GDP per capita, GDP per capita squared, and the value of imports of goods and services on carbon dioxide (CO2) emissions in six countries on the South American continent in 2011-2021 can be analyzed using the equation the following:

$$CO2it = \beta 0 + \beta 1TP1it + \beta 2PDB2it + \beta 3PDB23it + \beta 4IMPOR4it + eit$$

Information:

CO2	=	Carbon Dioxide Emissions (m/t)
Pop	=	Population
GDP	=	Gross Domestic Product Per Capita (USD)
GDP^2	=	Gross Domestic Product Per Capita squared (USD)
Import	=	Value of Imported Goods and Services (USD)
E	=	Standard error

Result and Discussion

The descriptive statistics in Table 1 are used to see several indicators that are predicted to have an impact and contribution to environmental degradation. Environmental degradation is proxied by CO2 emissions, economic activity is proxied by Gross Domestic Product (GDP). Environmental degradation has an average value of 3,47 with a variability of 4,07. CO2 emissions can reach a maximum value of 12,73 with a minimum value of 0,59. Then when viewed from the economic activity which is proxied by the GDP value, it has an average value of 8919,98 with a variability value of 3330,39. GDP reached 14322,29 for the maximum point and 5315,52 for the minimum point. In addition, other variables such as population have an average value of 60.638.443 and a variability value of 66.620.921. The maximum value for the population variable is 214.000.000 with a minimum value of 15.243.885. Meanwhile, the import variable has an average value of 97.800.000.000 with a variability value of 88.700.000.000.

Table 1 Summary Statistic Descriptive

Variables	Unit of Measurements	Obs	Mean	Std. Dev	Min	Max
CO2	Metric Tonnes (M/t)	66	3.47	4.07	0.59	12.73
Pop	Number of Population	66	60638443	66620921	15243885	2.14E+08
GDP	Constant 2015 (US Dollars)	66	8919.98	3330.39	5315.52	14322.29
GDP2	Constant 2015 (US Dollars)	66	90489602	65200205	28254716	2.05E+08
Import	Value of Imported Goods and Services (US Dollars)	66	9.78E+10	8.87E+10	1.90E+10	3.47E+11

The Chow test is a test method aimed at determining the right model between the Common Effect Model (CEM) and the Fixed Effect Model (FEM). The null hypothesis states that the Common Effect Model (CEM) is the best. The common Effect Model (CEM) becomes the best model when the probability value is more than 5%. Meanwhile, H1 states that the best model is FEM if the probability value is less than 5%.

Table 2 Best Model Selection Estimation Results

Chow Test		
Effects Test	**Statistic**	**Prob.**
Cross-section F	100,917769	0,000
Cross-section Chi-square	152,039979	0,000
Hausman Test		
Test Summary	Chi-Sq. Statistic	Prob.
Cross-section random	5,993215	0,1997
LM Test		
Cross-section Breusch-Pagan	220,7785	0,000

The results of the Chow test in Table 2 show that the probability is 0,0000, so H1 is accepted, and H0 is rejected. This is because the probability has a value of less than 0,05 or a critical value, so the Fixed Effect Model (FEM) is the right model to use. Hausman test is a test carried out to determine the right model between the Fixed Effect Model (FEM) and the Random Effect Model (REM). The Hausman test has the condition that H0 the REM model is the best model by looking at the probability of more than 5%. Meanwhile, H1 states that the best model is the FEM model with a probability value of less than 0,05 or 5%. The Hausman test results in Table 2 show that the probability value is more than 0,05, which means H0 is accepted and H1 is rejected.

The Lagrange Multiplier (LM) test is a test carried out to determine the right model between the Common Effect Model (CEM) and Random Effect Model (REM). In the LM test, Table 2 shows that the probability value is less than 0,05. So that the right model is used for panel data estimation by using the Random Effect Model (REM) model. Based on the results of the Chow Test, Hausman Test, and Lagrange Multiplier (LM) Test, it can be concluded that the appropriate model used for panel data estimation is the Random Effect Model (REM).

According to Melati & Suryowati (2018), the application of the Random Effect Model (REM) does not require a classical assumption test. This is because the Generalized Least Square (GLS) model can overcome the problems of autocorrelation and heteroscedasticity. To avoid other classical assumption problems, the GLS Random Effect Model (REM) model needs to be tested, including the normality test and multicollinearity test. Jarque-Bera Test and Partial Correlation Test are some of the classical assumption tests used in the GLS model.

Table 3 Classic Assumption Test Results

	Jarque-Bera	Partial Correlation
Indicator	0,137898	0,981516
Threshold	>alpha 0,5	<0,8
Results	Free from normality's problem	Having multicolinearity's problem

The results of the normality test that has been carried out, show that the Jarque-Bera probability has a value of 0,137898 and is more than the critical value of 5%. These results indicate that H1 is rejected and H0 is accepted so it can be said that the residuals are normally distributed. Then a multicollinearity test was carried out to see whether there was a linear relationship between the independent variables. Based on the results of the multicollinearity test, it shows that the partial correlation value is more than 0,8. This number means that the model is affected by the multicollinearity problem. This is due to the use of GDP and GDP squared variables in proving the Environmental Kuznets Curve (EKC) hypothesis. The following is the estimation result of the Random Effect Model (REM). The estimation results in Table 3 show that the total population has a significant positive effect on CO_2 emissions, this can be seen with a probability value that is less than the critical value of 0,05, which is 0,0000.

The coefficient of the total population is 5,1 which means that if the population increases by 1 population, then CO_2 emissions increase by 5,1 metric tons. These results are in line with and support previous research by Dong et al. (2018) which states that population size has a positive and significant effect. In addition, the population has the potential and influence other surrounding regions and countries so that it will increase the barriers to reducing carbon emissions (Bu et al., 2022; Gao et al., 2021).

Table 4 Random Effect Model (REM) Estimation Results

Variable	Coefficient	t-Statistic	Prob.
C	-1,930169	-3.151553	0,0025
Population	5,15E-08	16.97615	0,0000
GDP	0,00028	2.606796	0,0115
GDP^2	-6,24E-09	-1.331498	0,1880
Import	3,59E-12	4.940832	0,0000
R-squared	0,847462	F-statistic	84,725
Adjusted R-squared	0,837459	Prob (F-statistic)	0,0000

In addition, the estimation results in Table 3 show that CO_2 emissions are positively and significantly influenced by GDP per capita. This can be seen through the probability value of GDP, which is 0.0115 (less than the critical value of 5% or 0,05). The coefficient value of GDP is 0,000280, meaning that if GDP per capita increases by 1 USD, it will affect and increase CO_2 emissions by 0,000280 metric tons. On the other variable, GDP per capita squared (GDP2) has a coefficient of -6,24. This value indicates that GDP per capita squared has a negative relationship with CO_2 emissions.

This inconsistent result is similar to the EKC hypothesis which explains that CO_2 emissions will increase in line with an increase in GDP per capita until it reaches a turning point, and then CO_2 emissions will decrease with increasing GDP per capita. However, when viewed from the level of significance, the estimation results cannot explain the Environmental Kuznets Curve (EKC) hypothesis, so the EKC hypothesis is invalid in the six South American countries with the largest population levels. This is in accordance with previous findings in developing countries such as Malaysia which found that the EKC hypothesis could not describe the existing phenomenon (Begum et al., 2015).

The import variable in the estimation results means that the imported variable has a positive and significant effect. This can be seen from the probability value of the imported variable which is less than the critical value of 5%. So, it can be said that if imports increase by 1 USD, it will affect and increase CO2 emissions by 3,59 metric tons. These results are in line with previous findings by Mahmood et al. (2020) and Salman et al. (2019) which confirmed that countries with trade openness and import influence have negative effects on neighboring countries in North African states and seven ASEAN countries. Based on the results of the F test, the probability value is 0,0000 which means that all the independent variables in the model have a significant impact on the CO2 emission variable together. Then the estimation results also show that the R-squared value is 0.847462 which means that the use of the independent variable in the model can explain the dependent variable, namely CO2 emissions of 84,7%.

Conclusion

The results of the study found that the total population in the six countries of the South American continent with the largest population had a significant positive effect on CO2 emissions. This finding strengthens the previous research conducted by Dong et al. (2018) that population size has a positive and significant effect. Then in this study, it was not possible to validate the Environmental Kuznets Curve (EKC) hypothesis in the six countries that have the largest population on the South American continent. This study is also in line with previous research conducted by Begum et al. (2015) which could not explain the Environmental Kuznets Curve (EKC) hypothesis in developing countries such as Malaysia.

Furthermore, the import of goods and services shows a positive and significant effect. This finding further strengthens previous findings which explain that trade openness, namely imports, has a negative effect on countries, especially spillovers to neighboring countries (Mahmood et al., 2020). After knowing the results of these findings, the suggestions that can be given include: First, to reduce the level of CO2 emissions, it is necessary to reduce the use of non-renewable energy and the conversion of the use of renewable energy needs to be carried out. Second, there is a need to diversify imports of environmentally friendly goods and services (Hu et al., 2020). Third, need for government intervention in each country in reducing the conversion of rainforest land and implementing a green economy.

References

Al-Mulali, U., Solarin, S. A., & Ozturk, I. (2015). Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: an autoregressive distributed lag (ARDL) approach. *Natural Hazards, 80*(3), 1729–1747. https://doi.org/10.1007/s11069-015-2050-x

Aslam, B., Hu, J., Shahab, S., Ahmad, A., Saleem, M., Shah, S. S. A., Javed, M. S., Aslam, M. K., Hussain, S., & Hassan, M. (2021). The nexus of industrialization, GDP per capita and CO2 emission in China. *Environmental Technology & Innovation, 23*, 101674. https://doi.org/10.1016/j.eti.2021.101674

Begum, R. A., Sohag, K., Abdullah, S. M. S., & Jaafar, M. (2015). CO2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews, 41*, 594–601. https://doi.org/10.1016/j.rser.2014.07.205

British Petroleum. (2022). BP Statistical Review of World Energy June 2022. Retrieved from http://www.bp.com/statisticalreview

Bu, Y., Wang, E., Qiu, Y., & Möst, D. (2022). Impact assessment of population migration on energy consumption and carbon emissions in China: A spatial econometric investigation. *Environmental Impact Assessment Review, 93*, 106744. https://doi.org/10.1016/j.eiar.2022.106744

Candra, K. A. (2017). Analisis Pengaruh Pertumbuhan Ekonomi dan Penanaman Modal Asing Terhadap Emisi Karbondioksida di Delapan Negara ASEAN Periode 2004-2013. *Undergraduate Thesis*. Universitas Surabaya.

Dong, K., Hochman, G., Zhang, Y., Sun, R., Li, H., & Liao, H. (2018). CO2 emissions, economic and population growth, and renewable energy: Empirical evidence across regions. *Energy Economics, 75*, 180–192. https://doi.org/10.1016/j.eneco.2018.08.017

Gao, C., Tao, S., He, Y., Su, B., Sun, M., & Mensah, I. A. (2021). Effect of population migration on spatial carbon emission transfers in China. *Energy Policy, 156*, 112450. https://doi.org/10.1016/j.enpol.2021.112450

Hang, G., & Yuan-sheng, J. (2011). The Relationship between CO2 Emissions, Economic Scale, Technology, Income and Population in China. *Procedia Environmental Sciences, 11*, 1183–1188. https://doi.org/10.1016/j.proenv.2011.12.178

Hu, G., Can, M., Paramati, S. R., Doğan, B., & Fang, J. (2020). The effect of import product diversification on carbon emissions: New evidence for sustainable economic policies. *Economic Analysis and Policy, 65*, 198–210. https://doi.org/10.1016/j.eap.2020.01.004

Mahmood, H., Alkhateeb, T. T. Y., & Furqan, M. (2020). Exports, imports, Foreign Direct Investment and CO2 emissions in North Africa: Spatial analysis. *Energy Reports, 6*, 2403–2409. https://doi.org/10.1016/j.egyr.2020.08.038

Melati, P. M., & Suryowati, K. (2018). Aplikasi Metode Common Efect, Fixed Effect, dan Random Effect Untuk Menganalisis Faktor-faktor yang Mempengaruhi Tingkat Kemisikinan Kabupaten/Kota di Jawa Tengah dan Daerah Istimewa Yogyakarta. *Jurnal Statistika Industri dan Komputasi, 3*(1), 41-51. Retrieved from https://ejournal.akprind.ac.id/index.php/STATISTIKA/article/view/1079

Mendonça, A. K. de S., de Andrade Conradi Barni, G., Moro, M. F., Bornia, A. C., Kupek, E., & Fernandes, L. (2020). Hierarchical modeling of the 50 largest economies to verify the impact of GDP, population and renewable energy generation in CO2 emissions. *Sustainable Production and Consumption, 22*, 58–67. https://doi.org/10.1016/j.spc.2020.02.001

Nikensari, S. I., Destilawati, S., & Nurjanah, S. (2019). Studi Environmental Kuznets Curve di Asia: Sebelum dan Setelah Millennium Development Goals. *Jurnal Ekonomi Pembangunan, 27*(2), 11–25. https://doi.org/10.14203/jep.27.2.2019.11-25

Rehman, E., & Rehman, S. (2022). Modeling the nexus between carbon emissions, urbanization, population growth, energy consumption, and economic development in Asia: Evidence from grey relational analysis. *Energy Reports, 8,* 5430–5442. https://doi.org/10.1016/j.egyr.2022.03.179

Salman, M., Long, X., Dauda, L., Mensah, C. N., & Muhammad, S. (2019). Different impacts of export and import on carbon emissions across 7 ASEAN countries: A panel quantile regression approach. *Science of The Total Environment, 686*, 1019–1029. https://doi.org/10.1016/j.scitotenv.2019.06.019

Sasana, H., & Aminata, J. (2019). Energy Subsidy, Energy Consumption, Economic Growth, and Carbon Dioxide Emission: Indonesian Case Studies. *International Journal of Energy Economics and Policy, 9*(2), 117–122. Retrieved from https://www.econjournals.com/index.php/ijeep/article/view/7479

Shao, L., Geng, Z., Wu, X. F., Xu, P., Pan, T., Yu, H., & Wu, Z. (2020). Changes and driving forces of urban consumption-based carbon emissions: A case study of Shanghai. *Journal of Cleaner Production, 245*, 118774. https://doi.org/10.1016/j.jclepro.2019.118774

Stern, D. I. (2018). *The Environmental Kuznets Curve*. Reference Module in Earth Systems and Environmental Sciences. https://doi.org/10.1016/b978-0-12-409548-9.09278-2

Todaro, M. P., & Smith, S. C. (2006). *Ekonomi Pembangunan. (9th Ed)*. Jakarta: Erlangga.

Wang, Q., & Li, L. (2021). The effects of population aging, life expectancy, unemployment rate, population density, per capita GDP, urbanization on per capita carbon emissions. *Sustainable Production and Consumption, 28*, 760–774. https://doi.org/10.1016/j.spc.2021.06.029

World Bank. (2022). The World Bank Annual Report 2022. Retrieved from https://data.worldbank.org/

Xie, R., Fang, J., & Liu, C. (2017). The effects of transportation infrastructure on urban carbon emissions. *Applied Energy, 196*, 199–207. https://doi.org/10.1016/j.apenergy.2017.01.020

Yeh, J.-C., & Liao, C.-H. (2017). Impact of population and economic growth on carbon emissions in Taiwan using an analytic tool STIRPAT. *Sustainable Environment Research, 27*(1), 41–48. https://doi.org/10.1016/j.serj.2016.10.001

Zhang, Y., & Zhang, S. (2018). The impacts of GDP, trade structure, exchange rate and FDI inflows on China's carbon emissions. *Energy Policy, 120*(2), 347-353. https://doi.org/10.1016/j.enpol.2018.05.056