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The Role of Demographic, Economic, and Technological on Carbon Emissions in ASEAN

Alma Aurellia Amanda✉

Development Economic Study Program, Economics Faculty, Universitas Negeri Semarang

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Abstract

ASEAN as a region with rapid economic growth and a large population. This study aims to analyze the factors affecting CO_2 emissions in ASEAN member countries using the STIRPAT model and Panel FMOLS in the period 2014-2021. The results show that population, GDP per capita, tourism and ICT have a significant and positive influence on emissions in the long run. Meanwhile, renewables energy consumption also contributes to the reduction of CO_2 emissions in the long term. However, there is a difference between CO_2 emissions produced before and during the Covid-19 pandemic.

Keywords: STIRPAT Model, ASEAN, FMOLS, CO_2 Emissions, Covid-19

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✉ Correspondence Address :
Address: Gedung L2 Lantai 2 FE Unnes
Kampus Sekaran, Gunungpati, Semarang, 50229
E-mail : almaurlm@students.unnes.ac.id

INTRODUCTION

Global climate change is a complex phenomenon with significant impacts on various aspects of life. Some observable impacts of climate change include rising temperatures and sea levels, diminishing polar ice caps, and increased surface temperatures of the earth (Merzdorf, 2020). Global warming occurs as a result of increased carbon dioxide (CO_2) emissions, caused by both natural factors and human activities (Liu et al., 2017).

Human activities, particularly the utilization of goods and services, can lead to the emission of carbon, which in turn can have adverse impacts on environmental conditions, including pollution of water, soil, and air. Among the greenhouse gases, carbon dioxide plays a significant role in contributing to the

observed changes in global climate (NASA's Global Climate Change, 2020).

Global carbon emissions have been increasing over time, although experiencing a drastic decline in 2020 due to the COVID-19 pandemic. However, carbon emissions have rebounded in 2021 due to economic recovery following the pandemic-induced recession.

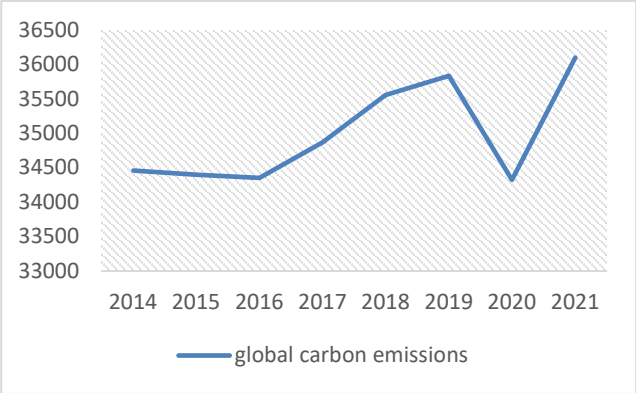

Figure 1. Global CO_2 Emissions in 2014-2021 ($MtCO_2$)
Source : World Bank, 2021

ASEAN, or the Association of Southeast Asian Nations, comprises ten Southeast Asian countries including Indonesia, Malaysia, Thailand, Philippines, Vietnam, Singapore, Laos, Cambodia, and Brunei). The association was established with the aim of fostering economic advancement, social progress, cultural development, and promoting regional peace and stability.

However, ASEAN also faces the challenges posed by climate change. The region has witnessed a continuous increase in CO_2 emissions due to rapid population and economic growth. Historically, ASEAN countries have exhibited a growing consumption and reliance on fossil fuels. Consequently, the region is considered vulnerable to the impacts of climate change (Khan et al., 2019).

The total population in the 10 ASEAN countries reached 673.9 million people in 2021, with an average annual growth rate of 1.3 percent. More than 380 million working-age population in ASEAN, accounting for 58 percent of the total population or about 20 percent larger than the entire population of the United States (US-ASEAN Business Council, 2019).

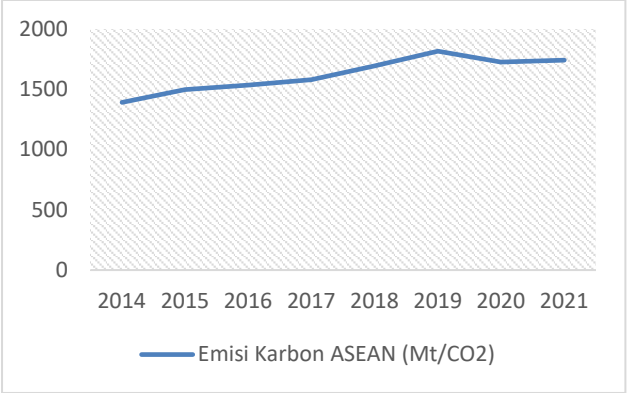

Figure 2. ASEAN CO_2 Emissions in 2014-2021 ($MtCO_2$)
Source : Global Carbon Atlas, 2021

The population in ASEAN countries is experiencing faster growth compared to the population in the United States and China. In the last 8 years, population growth in ASEAN countries has outpaced growth in the United States (4.2%) and China (2.9%). The average population growth in ASEAN is 7 percent.

According to the Asian Development Bank in ASEAN Briefing (2023), the ASEAN region is one of the fastest-growing economic regions in the world. ASEAN's economic growth from 2014 to 2021 averaged 3.8 percent, which is higher than the global average economic growth of 2.9 percent annually measured over the period of 2014 to 2021.

The IPAT (Impact, Population, Affluence, and Technology) model is a mathematical equation used to analyze the relationship

between anthropogenic factors and the environment. (Yu et al., 2016). However, the main problem of the IPAT model is that factors are not independent between variables due to multiplication relationships. York et al., (2003) developed a stochastic model by reformulating the IPAT model. In this way, they introduced STIRPAT model that could estimate the disproportionate impact of population, affluence, and technology on the environment (Dietz & Rosa, 1997).

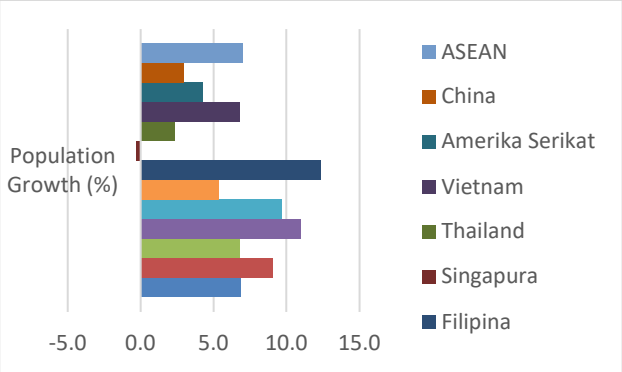

Figure 3. Population Growth in the Last 8 Years, 2014-2021
Source : World Bank, data processed 2023

Populations, or the number of people, can have an impact on the environment. In recent years, rapid population growth has been linked to increased CO_2 emissions (Liddle, 2015). The population size has a positive and significant influence on carbon emissions (Ghazali & Ali, 2019) (Rahman et al., 2022). Therefore, it is undeniable that as the population increases, environmental issues arise, such as the rise in atmospheric CO_2 emissions.

Considering that only the local population contributes to CO_2 emissions is not sufficient because economic activities involve not only the local residents but also nomadic populations or tourists. (Arbulu et al., 2017). These transient populations, including nomads and tourists, can have a significant impact on the environment through their consumption patterns, transportation, and energy use.

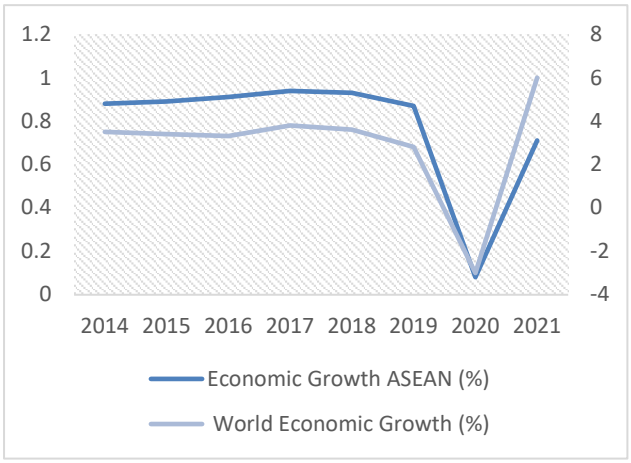

Figure 4. Economic Growth from 2014 to 2021
Source : International Monetary Fund, data processed 2023

The increase in the number of foreign individuals, including tourists, has the potential to harm the environment (Rahman et al., 2022). High levels of affluence can lead to increased resource consumption and emissions generated by individuals, including international tourists. The variable of the number of international tourist visits has a positive and significant impact on environmental degradation (Eyuboglu & Uzar, 2019) (Zafar, et al., 2022) (Fethi & Senyucel, 2021). Affluence is one of the hopes of every country, because it will be followed by an increase in life and social welfare (Rapanna &; Sukarno, 2017).

In pursuing prosperity, a high gross domestic product (GDP) per capita is accompanied by choices, as income is one of the primary factors that can increase environmental impact. There is a positive long run effect influence between economic growth and CO_2

(Pratama, 2022). The higher the income of a country, the higher the environmental emissions it generates (Zafar et al., 2022).

Economic prosperity is accompanied by an increased development of technology that is effective in reducing environmental damage alongside economic growth (Kongbuamai et al., 2020). The role of Information and Communication Technology (ICT) can influence the environment through its subtle nature in reducing the use of non-renewable energy by replacing traditional goods or services with modern ones, leading to a decrease in environmental damage (Shah et al., 2022).

Innovation and technology also have a correlation with energy use as they can enhance energy efficiency (H. Khan et al., 2021). Therefore, the integration of sustainable technologies and innovative solutions is crucial in promoting a more environmentally friendly and efficient economic development. With rapid development, ICT development may have a positive impact that cannot be ignored on the development of environmental quality. Therefore, ICT will be treated as a technology in the STIRPAT model equation (Zheng &; Wang, 2021).

The STIRPAT model is used as a frame of reference to understand how economic growth and changes in energy consumption relate to technological advances (Song, et al., 2011). In recent years, the use of renewable energy has emerged as an alternative to fossil fuels, offering benefits that extend beyond economic advantages and contribute to improved environmental quality (Kongbuamai et al., 2020).

The utilization of renewable energy sources has a significant positive impact on reducing environmental degradation and supports the mitigation of environmental hazards (Shah et al., 2022) (Zandi & Haseeb, 2019). By shifting to renewable energy sources, communities can decrease their dependency on fossil fuels, mitigate greenhouse gas emissions, and promote a more sustainable and environmentally friendly ecosystem.

Embracing renewable energy technologies is crucial for addressing climate change and preserving the planet for future generations. Renewable energy can be used to represent technology (T) since renewable energy production requires technological progress and it can be easily increased as the level of technology increases (Dogan et al., 2020).

Based on the background described above, it is fascinating to investigate the factors influencing CO2 emissions in ASEAN through variables such as population, tourism, GDP per capita, ICT, renewable energy consumption, and the COVID-19 dummy variable. Understanding the relationships between these factors can provide valuable insights into the environmental dynamics of the ASEAN region and guide policy-making decisions towards achieving sustainable development goals.

RESEARCH METHODS

Based on the analysis of data, this research adopts a quantitative approach. The data utilized in the study is secondary data, which is obtained indirectly or through intermediary sources such as books, archival documents, or the web. We set up the empirical model using ASEAN regional panel data for 10 countries from 2014 to 2021.

The study uses as dependent variable carbon dioxide emission (CO2) in Millions Tonnes from Global Carbon Atlas, and the independent variables are population (POPU),

tourism arrival (TOURISM) from the World Tourism Organization, income per capita (GDPP) from World Bank, Information and communication technologies (ICT) is total sum of fixed telephone subscriptions, mobile subscriptions, and fixed broadband subscriptions per 100 people from ITU HUB, consumption renewable energy (RENEWABLES) in quadratic BTU from Energy Information Administration (EIA), and dummy variable COVID-19 (COVID).

Table 1. Desciptive Variables

Variable	Abbreviation	Proxi	Data Range	Source
CO_2 (Million Tonnes per CO_2)	CO_2	Environment	2014-2021	Atlas Carbon Project
Population (person)	POPULATION	Population	2014-2021	World Bank
Tourist arrival (thousand person)	TOURISM	Affluence	2014-2021	World Tourism Organization
Gross domestic product per capita (Current USD)	GDPP	Affluence	2014-2021	World Bank
Information and communication technologies (is total sum of fixed telephone subscriptions, mobile subscriptions, and fixed broadband subscriptions per 100 people)	ICT	Technology	2014-2021	ITU HUB
Renewables consumption (quad BTU)	RENEWABLES	Technology	2014-2021	Energy Information Administration
Covid-19	COVID19	-	2014-2021	-

Note: The dummy variable used in this study is the number of years since the Covid-19 pandemic. Before Covid = 0 for 2014-2018. Covid = 1 for 2020-2021
Source : Data processed, 2023

Regarding the empirical strategy, we employ the panel cointegration method due to the characteristics of our dataset, which consists of a relatively small time series and a long cross-section. Additionally, FMOLS is recognized as a dependable estimation technique for small sample sizes, and it is specifically designed to address issues such as residual autocorrelation and endogeneity. The macro and regional panel data we utilize exhibit robust cross-sectional properties. However, numerous earlier and recent studies fail to tackle the time-series problem, resulting in concerns over the reliability of statistical inference.

To tackle this challenge, we employ the FMOLS approach to produce estimates that are asymptotically unbiased and standard normal distributions that are not affected by irrelevant parameters (Pedroni, 2001). All variables are expressed in logarithmic form. Considering the studies of Rahman et al. (2021) and Zaman et al. (2021) the following function is used:

$logCO2_{it} = \alpha_i + \beta_1 logPOPULATION_{it} + \beta_2 logTOURISM_{it} + \beta_3 logGDPP_{it} + \beta_4 logICT_{it} + \beta_5 RENEWABLES_{1it} + \beta_6 DUMMY_{it} + \varepsilon_{it}$

Here, logCO2it was the logarithm of CO2 emission at time t, and for the specific country it was represented by i; logPOPULASIit was the logarithm of population at time t, and for the specific country it was represented by i; β2logTOURISMit was the logaritm tourism arrival at time t and for the specific country it was represented as i; logGDPPit was the logaritm income per capita at time t and for the specific country it was represented as i; logICTi was the logaritm Information and communication technologies at time t and for the specific country it was represented as i; RENEWABLES1it was the renewable consumption at time t and for the specific country it was represented as i; DUMMYit was the dummy variable at time t and for the specific country it was represented as i and *εit* was the residual at time t and for the specific country it as represented as i.

The estimation procedures employed in this study consisted of three main steps. The initial step involved examining the stationarity of each variable using the Levin-Lin-Chu (LLC) and ADF-Fisher panel unit root tests. If the variables demonstrated stationarity at the first difference, the second step entailed investigating the existence of a cointegrating relationship between the variables in bivariate models using the panel Kao cointegration test.

Finally, to estimate the bidirectional long-run elasticity coefficients in the bivariate models, the third step involved estimating the cointegrating regression equation through the FMOLS method. This approach was utilized considering the established cointegrating relationship between the variables in each bivariate model.

RESULTS AND DISCUSSION

Data must have a stationary assumption the mean and variance do not vary systematically over time (Gujarati & Porter, 2009). Data that is not stationary will cause spurious regression problems (Andrei & Andrei, 2015). The panel unit root test suggested by levin Lin & Chu and phillips-perron is reported in table 3. The results show that all variables are stasionary at level.

The outcomes of the Kao residual cointegration test are depicted in Table 3. The statistical findings reveal that a significant majority of the tests reject the null hypothesis of no cointegration. Consequently, it can be concluded that the variables under investigation are co-integrated in the long run at significant levels (Khan et al, 2019).

Based on the findings, it can be concluded that the variables employed in this study exhibit long-run cointegration. The findings indicate that the variables utilized in this study exhibit cointegration in the long run. Table 4 presents the long-run outcomes of the FMOLS estimation for the model under consideration in this research.

The variable of population (L_POPULATION) presents a positive impact on carbon dioxide emissions, proving that population stimulates sustainable development. Thus, an increase at 1% of population (L_POPULATION) encourages and increases carbon dioxide emissions of 5.65% in the long term. this results is compatible with severan researches Rahman et al. (2022), Namahoro et al. (2021) and Chandra Voumik & Ridwan (2023) also found a positive correlation between

population (L_POPULATION) and carbon dioxide emissions (CO_2). The main reason for that is the increase in population contributes to the demand and supply of goods and services. The demand for energy in fulfilling the needs of goods and services from a growing population leads to an increase in CO_2 emissions.

Table 2. Panel Unit Root Test Results

Variable	Level	
	Levin, Lin & Chu	**PP-Fisher**
L_CO2	-7.82966	64.6891
	0.0000***	0.0000***
L_POPULATION	-13.5502	142.296
	0.0000***	0.0000***
L_TOURISM	-11.1709	18.6757
	0.0000***	0.5430
L_GDPP	-13.550	142.296
	0.0000***	0.0000***
L_ICT	-4.6563	25.685
	0.0000***	0.1765
RENEWABLES	-5.49013	15.9122
	0.0000***	0.7221

Note: All variables are presented in logarithm form. *** denotes the significance level at 1%. * stands for level.
Source : Data processed, 2023

The correlation between the variable of tourist arrivals (L_TOURISM) and carbon dioxide emissions is positive. The statistical analysis shows a significant relationship at a 1% level, indicating that the tourism can increases carbon dioxide emissions of 0.01% in the long term. The empirical studies of Ehigiamusoe (2020), Eyuboglu & Uzar (2019), and Zafar, et al. (2022) give support to our result.

Table 3. Cointegration Test

	t-Statistic	**Prob.**
ADF	-3.462546	0.0003
Residual variance	0.004305	
HAC variance	0.003961	

Note: Statistically significant at 1% (***) and 5% level (**)
Source : Data processed, 2023

The resulting of tourism that is small may come from the tourism sector that has begun to transform towards a sustainable tourism sector in the ASEAN region that pays attention to

environmental issues to help reduce CO_2 emissions. The variable of income per capita (L_GDPP) has a positive impact on carbon dioxide emissions in the long term, and this relationship is statistically significant at a 1% level. The empirical studies of Pratama (2022), Kartiasih & Setiawan (2020), Zafar et al. (2022), and Perwithosuci et al. (2020) also found a positive effect of income per capita on carbon dioxide emissions, showing that the higher environmental emissions resulting from increased production of goods and services by industrial sectors that utilize energy consumption from environmentally unfriendly fossil fuels in their manufacturing processes and consequently, is associated with growth activities. Nevertheless, an increase in carbon dioxide emissions also stimulates environmental damage.

Table 4. Long-run elastisity results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
L_POPULATION	5.652435	0.212009	26.66124	0.0000***
L_TOURISM	0.010219	0.044302	20.07575	0.0000***
L_GDPP	0.889391	0.001692	6.038983	0.0000***
L_ICT	0.321134	0.027927	11.49888	0.0000***
RENEWABLES	-0.422207	0.018613	-22.68299	0.0000***
COVID19	-0.040175	0.003742	-10.73560	0.0000***

Note: Statistically significant at 1% (***) and 5% level (**)
Source : Data processed, 2023

The variable of Information and communication technologies (L_ICT) presents a positive effect ($\beta 3 > 0$) on carbon dioxide emissions in the long term. Thus, an increase at 1% Information and communication technologies (L_TIK) represents a carbon dioxide emission increased (0.32%) respectively. Besides, the empirical studies of Batool et al., (2022) and Raheem et al. (2020) also found a positive association between information and communication technologies and carbon dioxide emissions, mentioning that ICT causes a increased in climate change and greenhouse gas. ICT use as measured by telephone and internet use can significantly increase CO_2 emissions and have a direct and indirect positive impact on energy consumption that increased emissions (Avoma et al., 2020).

The variable representing renewable energy consumption (RENEWABLES) demonstrates a negative impact on carbon dioxide emissions, and this effect is statistically significant at a 1% level. The empirical study of Batool et al., (2022), Shah et al. (2022) dan Zandi & Haseeb (2019) also found a negative effect of renewables energy on carbon dioxide emissions in the long term. The increasing dependence on renewable energy sources can reduce the use of fossil energy and effectively reduce environmental damage. This is a positive step towards transitioning to a more sustainable and environmentally friendly sector of the economy.

Finally, the dummy variable (COVID19) respectively has a differences before and during the Covid-19 pandemic on CO_2 emissions in the ASEAN region, where the Covid-19 pandemic in

2020 and 2021 reduced CO_2 emissions by 0.04 percent compared to before the pandemic took place. The empirical study of Iqbal et al. (2021) regarding the role of the Covid-19 pandemic in reducing energy consumption and carbon emissions.

According to Saadat et al. (2020), one of the striking impacts of the Covid-19 pandemic on environmental quality is caused by a decrease in energy consumption. The rapid implementation of lockdowns has resulted in a sharp decline in world energy demand, especially for coal, oil, and gas (McGrath, 2020).

However, while these impacts are positive in terms of environmental quality, the fact that ASEAN region is still heavily dependent on conventional energy sources such as fossil fuels demonstrate the need for changes in energy production and consumption to achieve sustainability goals the implications of Covid-19 only have a temporary impact on reducing CO_2 emissions (Gillingham et al., 2020). After some time, the trend before the pandemic will resume.

CONCLUSION

This paper investigated the relationship between population, tourist arrival, income per capita, Information and communication technologies (ICT), renewables energy, and dummy variable Covid-19 on carbon dioxide emissions for the case of ASEAN using the panel data covering the 10 countries during the period 2014-2021. The FMOLS analysis were undertaken to examine whether, in the long run, population, tourist arrival, income per capita, Information and communication technologies (ICT), renewables energy, dummy variable Covid-19 and carbon dioxide were co-integrated or not.

The FMOLS results suggest that population, income per capita, tourism and communication technologies (ICT) was positive and significant into carbon dioxide emissions, whereas there was a negative and significant relationship between renewables energy consumption on carbon dioxide emmisions. There is a difference between CO_2 emissions produced before and during the Covid-19 pandemic.

To achieve environmental sustainability in ASEAN, sustainable steps are needed, including adopting environmentally friendly patterns of economic growth, developing renewable energy, drive increased energy efficiency in the ICT sector, and implementing consistent policies to support sustainable tourism. With these measures, it is expected that CO_2 emissions can be reduced, and environmental sustainability can be achieved in the ASEAN region.

REFERENCES

Arbulu, I., Lozano, J., & Rey-Maquieira, J. (2017). Waste Generation Flows and Tourism Growth: A Stirpat Model for Mallorca. *Journal of Industrial Ecology, 21*(2), 272–281. https://doi.org/10.1111/jiec.12420

ASEAN Briefing. (2023). *ASEAN Economic Outlook 2023*. ASEAN Briefing. https://www.aseanbriefing.com/news/asean-economic-outlook-2023/

Avoma, D., H. N., H. K., & A. T. (2020). ICT and environmental quality in Sub-Saharan Africa: Effects and transmission channels. *Technological Forecasting & Social Change* (155). doi: https://doi.org/10.1016/j.techfore.2020.120028

Batool, Z., Raza, S. M., Ali, S., & Abidin, S. Z. (2022). ICT, renewable energy, fnancial development, and CO_2 emissions in developing countries of East and South Asia. *Environmental Science and Pollution Research* (29), 35025–35035. doi: https://doi.org/10.1007/s11356-022-18664-7

Dietz, T., & Rosa, E. A. (1994). Rethinking the Environmental Impacts of Population, Affluence and Technology. *Human Ecology Review, 1*(2), 277-300. Retrieved from https://www.jstor.org/stable/24706840

Dogan, E., Ulucak, R., Kocak, E., & Isik, C. (2020). The use of ecological footprint in estimating the Environmental Kuznets Curve hypothesis for BRICST by considering cross-section dependence and heterogeneity. *Science of The Total Environment* (723). doi: https://doi.org/10.1016/j.scitotenv.2020.138063

Dogan, E., Ulucak, R., Kocak, E., & Isik, C. (2020). The use of ecological footprint in estimating the Environmental Kuznets Curve hypothesis for BRICST by considering cross-section dependence and heterogeneity. *Science of The Total Environment* (723). doi: https://doi.org/10.1016/j.scitotenv.2020.138063

Ehigiamusoe, K. U. (2020). Tourism, growth, and environment: analysis of non-linear and moderating effects. *Journal of Sustainable Tourism, 28*(8), 1174–1192. https://doi.org/10.1080/09669582.2020.1729164

Eyuboglu, K., & Uzar, U. (2019). The impact of tourism on CO2 emission in Turkey. *Current Issues in Tourism*, 1-15. doi:10.1080/13683500.2019.163600

Fethi, S., & Senyucel, E. (2021). The role of tourism development on CO2 emission reduction in an extended version of the environmental Kuznets curve: evidence from top 50 tourist destination countries. *Environment, Development and Sustainability, 23*(2), 1499–1524. https://doi.org/10.1007/s10668-020-00633-0

Ghazali, A., & Ali, G. (2019). Investigation of key contributors of CO 2 emissions in extended STIRPAT model for newly industrialized countries: A dynamic common correlated estimator (DCCE) approach. *Energy Reports, 5*, 242–252. https://doi.org/10.1016/j.egyr.2019.02.006

Gillingham, K. T., Knittel, C. R., Li, J., Ovaere, M., & Reguant, M. (2020). The Short-run and Long-run Effects of Covid-19 on Energy and the Environment. *Joule, 4*(7), 1337–1341. https://doi.org/https://doi.org/10.1016/j.joule.2020.06.010

Godil, D. I., Sharif, A., Agha, H., & Jermsittiparsert, K. (2020). The dynamic nonlinear influence of ICT, financial development, and institutional quality on CO2 emission in Pakistan: new insights from QARDL approach. *Environ Sci Pollut Res, 27*, 24190–24200. https://doi.org/10.1007/s11356-020-08619-1/Published

Hashmi, R., & Alam, K. (2019). Dynamic relationship among environmental regulation, innovation, CO2 emissions, population, and economic growth in OECD countries: A panel investigation. *Journal of Cleaner Production, 231*, 1100–1109. https://doi.org/10.1016/j.jclepro.2019.05.325

Kartiasih, F., & Setiawan, A. (2020). [*Aplikasi Error Correction Mechanism Dalam Analisis Dampak Pertumbuhan Ekonomi, Konsumsi Energi Dan Perdagangan Internasional Terhadap Emisi Co2 di Indonesia*]. *Media Statistika, 13*(1), 104–115. https://doi.org/10.14710/medstat.13.1.104-115

Khan, H., Weili, L., Khan, I., & Oanh, L. thi K. (2021). Recent advances in energy usage and environmental degradation: Does quality institutions matter? Worldwide evidence. *Energy Reports, 7*, 1091–1103. https://doi.org/10.1016/j.egyr.2021.01.085

Kongbuamai, N., Bui, Q., Yousaf, H. M. A. U., & Liu, Y. (2020). The impact of tourism and natural resources on the ecological footprint: a case study of ASEAN countries. *Springer; In Environmental Science and Pollution Research, 27*(16), pp. 19251–19264. https://doi.org/10.1007/s11356-020-08582-x

Liddle, B. (2015). What are the carbon emissions elasticities for income and population? Bridging STIRPAT and EKC via robust heterogeneous panel estimates. *Global Environmental Change, 31*, 62–73. https://doi.org/10.1016/j.gloenvcha.2014.10.016

Liu, X., Zhang, S., & Bae, J. (2017). The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries. *Journal of Cleaner Production, 164*, 1239–1247. https://doi.org/10.1016/j.jclepro.2017.07.086

McGrath, M. (2020). *Climate change and coronavirus: Five charts about the biggest carbon crash*. bbc.com: https://www.bbc.com/news/science-environment-52485712

Merzdorf, J. (2020). *Climate Change Could Trigger More Landslides in High Mountain Asia*. NASA's Global Climate Change. https://climate.nasa.gov/news/2951/climate-change-could-trigger-more-landslides-in-high-mountain-asia/

Namahoro, J. P., Wu, Q., Zhou, N., & Xue, S. (2021). Impact of energy intensity, renewable energy, and economic growth on CO2 emissions: Evidence from Africa across regions and income levels. *Renewable and Sustainable Energy Reviews, 147*(January). https://doi.org/10.1016/j.rser.2021.111233

NASA's Global Climate Change. (2020). *Earth Will Continue to Warm and the Effects Will Be Profound*. NASA's Global Climate Change. https://climate.nasa.gov/effects/

Pedroni, P. (2001). Fully modified OLS for heterogeneous cointegrated panels. *In Advances in Econometrics, 15*. https://doi.org/10.1016/S0731-9053(00)15004-2

Pratama, A. (2022). [*Pengaruh Industrialisasi Terhadap Emisi CO2 Di Indonesia*]. *Ecodemica: Jurnal Ekonomi, Manajemen dan Bisnis, 6*(1). http://ejournal.bsi.ac.id/ejurnal/index.php/ecodemica

Rahman, A. R. A., Shaari, M. S., Masnan, F., & Esquivias, M. A. (2022). The Impacts of Energy Use, Tourism and Foreign Workers on CO2 Emissions in Malaysia. *Sustainability (Switzerland), 14*(4). https://doi.org/10.3390/su14042461

Saadat, S., Rawtani, D., & Hussain, C. M. (2020). Environmental perspective of COVID-19. *Science of The Total Environment* (728). doi: https://doi.org/10.1016/j.scitotenv.2020.138870

Shah, M. I., AbdulKareem, H. K. K., Zulfiqar khan, & Abbas, S. (2022). Examining the agriculture induced Environmental Kuznets Curve hypothesis in BRICS economies: The role of renewable energy as a moderator. *Renewable Energy*, 198, 343–351. https://doi.org/10.1016/j.renene.2022.08.052

Shah, S. A. R., Balsalobre-Lorente, D., Radulescu, M., Zhang, Q., & Hussain, B. (2022). Revising the tourism-induced environment Kuznets curve hypothesis in top 8 Asian economies: the role of ICT and renewable energy consumption. *Journal of Hospitality and Tourism Technology*. https://doi.org/10.1108/JHTT-02-2022-0064

Smith, L. V., Tarui, N., & Yamagata, T. (2021). Assessing the impact of COVID-19 on global fossil fuel consumption and CO2 emissions. *Energy Economics, 97*. https://doi.org/10.1016/j.eneco.2021.105170

The ASEAN Secretariat. (2023). *ASEAN launches framework on sustainable tourism development post-COVID-19*.

US-ASEAN Business Council. (2019). *Growth Projections*. https://www.usasean.org/why-asean/growth

Voumik, L. C., & RIdwan, M. (2023). Impact of FDI, Industrialization, and Education on The Environment in Argentina: ARDL Approach. *Heliyon, 12872*. doi: https://doi.org/10.1016/j.heliyon.2023.e12872

Wibowo, W. (2023). The Effect of Economic Variables on CO2 Emissions in 7 Asian Countries. *Efficient: Indonesian Journal of Development Economics, 6*(1), 84-95. https://doi.org/10.15294/efficient.v6i1.57683

Yu, X., Geng, Y., Dong, H., Ulgiati, S., Liu, Z., Liu, Z., Ma, Z., Tian, X., & Sun, L. (2016). Sustainability assessment of one industrial region: A combined method of emergy analysis and IPAT (Human Impact Population Affluence Technology). *Energy, 107*, 818–830. https://doi.org/10.1016/j.energy.2016.04.092

Zafar, S. Z., Zhilin, Q., Mabrouk, F., Ramirez-Asis, E., Alzoubi, H. M., Hishan, S. S., & Michel, M. (2022). Empirical Linkages Between ICT, Tourism, and Trade Towards Sustainable Environment: Evidence from BRICS Countries. *Economic Research-Ekonomska Istrazivanja*. https://doi.org/10.1080/1331677X.2022.2127417

Zandi, G., & Haseeb, M. (2019). The importance of green energy consumption and agriculture in reducing environmental degradation: Evidence from sub-Saharan African countries. *International Journal of Financial Research, 10*(5), 215–227. https://doi.org/10.5430/ijfr.v10n5p215

Zheng, C. (2022). *Which ASEAN countries will be the front-runners to decarbonize their power sectors? S&P Global*. https://www.spglobal.com/commodityinsights/en/ci/research-analysis/which-asean-countries-will-be-the-frontrunners-to-decarbonize.html.