JMBE | Journal Of Management and Business Environment
ISSN 2685-5992 (media online) Vol. 7 (1) July 2025

Concentration and Determinants of Carbon Dioxide (CO_2) Emissions in 25 Asian Countries from 2015 to 2021

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Abstract

This study analyzes the concentration of carbon dioxide (CO_2) emissions and its determinants in 25 Asian countries from 2015 to 2021. Carbon dioxide (CO_2) is a greenhouse gas produced by human activities, such as fossil fuel combustion. The study utilizes secondary data and employs two analytical tools: the concentration index to identify countries with the highest CO_2 emissions and panel data regression to analyze its determinants. The findings reveal that 13 of 25 countries have a concentration index greater than one. Japan, Russia, and Azerbaijan are ranked as the top three countries with the highest CO_2 emission concentrations, while Vietnam has the lowest concentration index with a value of less than one. Oil consumption, natural gas consumption, coal consumption, and population size have a positive and significant effect on CO_2 emissions in the 25 Asian countries. On the other hand, economic growth does not have a significant impact on CO_2 emissions. These findings highlight the urgency of implementing energy transition policies in high-emission countries as a strategic measure to reduce dependence on fossil fuels. Furthermore, the development of population-based policies oriented toward sustainability is deemed crucial to effectively reducing carbon emissions across the Asian region.

Keywords: concentration index, carbon dioxide emissions, oil consumption, natural gas consumption, coal consumption

INTRODUCTION

Environmental issues have become a global concern due to environmental degradation triggering climate change and global warming, primarily caused by greenhouse gas emissions (Osobajo et al., 2020). The Intergovernmental Panel on Climate Change (IPCC) reports that the rise in global average temperatures since the mid-20th century has been driven by

anthropogenic greenhouse gas concentrations, such as carbon dioxide (CO_2), methane, and water vapor, which absorb infrared radiation and cause the greenhouse effect (Solomon et al., 2007). Carbon dioxide (CO_2) is the main contributor due to its role in fossil fuel combustion in the energy, industrial, and transportation sectors (Begum et al., 2020).

The IPCC's Sixth Assessment Report estimates that greenhouse gas concentrations have increased global temperatures by 1.4°C since the industrial era, with adverse impacts on human health, such as respiratory and mental disorders caused by poor air quality (Yang et al., 2021). International efforts, such as the Kyoto Protocol and UNFCCC, have not effectively curbed the rising CO_2 emission trends, particularly in developing countries experiencing rapid economic growth. Carbon emissions from fossil fuel combustion increased from 1.1% between 1990–1999 to 3% between 2000–2004 (Raupach, 2007). Dependency on fossil-based energy, including coal, oil, and natural gas, remains the primary driver of the surge in CO_2 emissions (Kasman & Dusman, 2015).

Energy consumption that produces CO_2 emissions has shown significant fluctuations in recent years, driven by human activities heavily reliant on fossil-based energy sources such as oil, natural gas, and coal. China and India rank highest among carbon emitters in Asia, releasing 11.4 and 2.83 billion metric tons of CO2 ($GtCO_2$), respectively, in 2022 (Hannah et al., 2022). To understand the determinants of CO_2 emissions across 25 Asian countries, a comprehensive study is essential, given the significant variations in oil, natural gas, and coal consumption, as well as economic growth and population size. Massive fossil fuel use, especially in industrial and transportation sectors, has substantially contributed to global climate change, which poses serious threats to the environment and human health (Commer et al., 2020).

Globally, developed and developing countries in Asia contribute approximately 80% of anthropogenic CO_2 emissions, with ten of the world's largest emitters in 2012 originating from Asia (Poku, 2016). Increased consumption of oil, natural gas, and coal, alongside economic and population growth, are the main drivers of CO_2 emissions. Studies by Nasir and Rehman (2011) reveal that countries with large populations tend to have higher emission levels, particularly as developing countries are not required to comply with the Kyoto Protocol. Additionally, urban expansion driven by population growth often leads to deforestation, reducing the environment's ability to absorb carbon. Voumik (2022) and Khan et al. (2021) also emphasize the significant relationship between population and rising CO_2 emissions. Therefore, this study aims to analyze the concentration and determinants of CO_2 emissions in 25 Asian countries during the period of 2015–2021 and focuses on oil, natural gas, and coal consumption, economic growth, and population as the primary influencing factors.

LITERATURE REVIEW

Research conducted by Muhammad and Khamran (2021) across 170 countries (1990–2018) and used the generalized method of moments (GMM) and fixed effect model indicated that CO_2 emissions decrease due to natural resources, fuel resource exports, ore and metal resource exports, urbanization, economic globalization, and political globalization. However, energy consumption, social globalization, foreign direct investment, and economic growth increase CO_2 emissions.

The study by Goswami et al (2023) in India (1980–2021) that applied the autoregressive distributed lag (ARDL) method concluded that in the long term, energy consumption, urbanization, and trade openness positively influence CO_2 emissions, while economic growth

has a negative impact. In the short term, economic growth and trade openness reduce CO_2 emissions, whereas energy consumption and urbanization increase them.

Research by Belucio et al (2022) in 16 European countries (1993–2018) used the ARDL method evidently found that natural gas consumption positively affects CO_2 emissions in the short term, while oil consumption increases emissions in both the short and long term. In contrast, renewable energy and hydroelectric energy consumption reduce CO_2 emissions in both time frames. GDP negatively impacts CO_2 emissions in the long term.

The study by Adinew (2020) in Ethiopia (1990–2017) employing the ARDL bound testing model resulted in renewable energy consumption negatively impacts CO_2 emissions, while economic growth positively influences emissions in both short and long terms.

Mahmood et al (2022) who researched the GCCC countries (Saudi Arabia, Kuwait, UAE, Qatar, Bahrain, and Oman) during 1980–2019 with ARDL method found different impacts on CO_2 emission in the GCCC countries. Economic growth increases CO_2 emissions in Kuwait, Oman, Qatar, and Saudi Arabia, while economic decline positively impacts emissions in Bahrain, Kuwait, Qatar, and the UAE. Rising oil prices increase CO_2 emissions in Oman, Qatar, and Saudi Arabia, while falling oil prices have mixed effects. Urbanization generally contributes to increased CO_2 emissions in Bahrain, Oman, Qatar, and the UAE.

METHODS

This study is a quantitative research that uses numerical data to analyze information, characterized by logical reasoning, deductive approaches, and a focus on cause-and-effect relationships (Djollong, 2014). The type of data utilized in this study is secondary data comprising a combination of cross-sectional and time-series data that were processed using EViews 13. The data analysis employed two methods: the concentration index that is used to

determine the concentration of carbon dioxide (CO_2) emissions in 25 Asian countries in the period of 2015 to 2021 and panel data regression analysis that were applied to identify the determinants of carbon dioxide (CO_2) emissions.

1. Air pollution concentration analysis

$$IK = \frac{ECO_{2n}/GRK_n}{ECO_{2a}/GRK_a}$$

in which IK = Concentration Index, ECO_2n = Carbon Dioxide Emissions in 25 Asian Countries, GRKn = Greenhouse Gases in 25 Asian Countries, ECO_2a = Carbon Dioxide in Asia, and GRKa = Greenhouse Gases in Asia.

The resulted concentration index is categorized into three groups as follows:

a. IK > 1: The country in question plays a larger role in producing carbon dioxide emissions compared to other countries in Asia and serves as a CO_2 emission base.
b. IK = 1: The country in question has an equal role with other Asian countries in producing carbon dioxide (CO_2) emissions.
c. IK < 1: The country in question plays a smaller role in producing carbon dioxide (CO_2) emissions compared to other countries in Asia and is not a CO_2 emission base.

2. Analysis of determinants of air pollution concentration

To analyze the determinants of air pollution concentration, panel data regression was utilized. The panel data regression equation is as follows:

in which ECO2: carbon dioxide emissions, β0: constant, KMB: oil consumption, KGA: natural gas consumption, KBB: coal consumption, PE: economic growth, PDD: population, βi: regression coefficient of independent variables, t: year, i: country, ε: error term.

To estimate the results of panel data regression, three approaches were employed: the Common Effect Model, the Fixed Effect Model, and the Random Effect Model. The best

model for this study was selected using three stages of testing: the Chow Test, the Hausman Test, and the Lagrange Multiplier Test. Once the appropriate model for panel data regression is identified, a classical assumption test was necessarily conducted. If the Fixed Effect Model (FEM) is chosen during data processing, only the multicollinearity and heteroscedasticity tests are assumed to be sufficient. Subsequently, statistical tests were also conducted which include t-test, F-test, and goodness-of-fit test.

RESULTS AND DISCUSSION

Results

Based on the results of the carbon dioxide (CO_2) emission concentration index analysis, the findings reveal that 13 countries have a concentration index above 1, no country has a concentration index equal to 1, and 12 countries have a concentration index below 1.

Japan recorded the highest average carbon dioxide (CO_2) emissions among the 25 Asian countries during the 2015–2021 period, averaging 3.079, with a peak of 3.2347 in 2020. Japan's reliance on fossil fuels increased following the Fukushima nuclear disaster in 2011 which led to the shutdown of many nuclear power plants. To meet its energy needs, Japan significantly increased its imports and usage of coal, oil, and liquefied natural gas (LNG), which are high-emission energy sources. Although Japan is recognized as a leader in energy-efficient technologies, such as electric vehicles, high urbanization levels, industrial and transportation sectors, and large household energy consumption remain significant contributors to its national carbon emissions.

Meanwhile, Vietnam recorded the lowest average carbon emissions at 0.38 million tons, attributed to its lower industrialization level and the growing adoption of renewable energy sources, such as solar and wind power, which have helped reduce dependence on fossil fuels.

Discussion

Based on the concentration index calculations, from the 25 Asian countries analyzed between 2015–2021, Japan, Russia, and Azerbaijan had the highest CO_2 emission concentration with an index value of IK > 1. Meanwhile, Vietnam had the lowest CO_2 emission concentration with an IK < 1. This indicates that Japan, Russia, and Azerbaijan play a larger role than other countries in contributing to air pollution, making them the basis of air pollution among the top ten most polluted countries globally.

From the panel data regression results, oil consumption has a positive and significant impact on CO_2 emission concentration. The regression coefficient value is 6,348,201, meaning that an increase of 1 TWh in oil consumption would result in a rise of 6,348,201 tons of CO_2 emissions. In Asia, significant CO_2 emission increases due to oil consumption are influenced by the high energy demand driven by rapid economic growth, massive urbanization, and intensive industrialization. According to Shahbaz et al. (2019), oil consumption significantly contributes to CO_2 emissions, particularly in developing countries reliant on fossil energy for economic growth.

Panel data regression also shows that natural gas consumption has a positive and significant effect on CO_2 emission concentration. The regression coefficient is 16,695,693, meaning that an increase of 1 TWh in natural gas consumption leads to a 16,695,693-ton rise in CO_2 emissions. Natural gas contributes to CO_2 emissions in Asia due to its widespread use as a primary energy source for electricity generation, industry, and transportation amid rapid economic growth and urbanization, coupled with limited transitions to renewable energy. Shahbaz et al. (2019) note that while natural gas has a lower carbon intensity, high consumption volumes offset its benefits, particularly in countries heavily dependent on it for energy.

Coal consumption also has a positive and significant influence on CO_2 emissions, with a regression coefficient of 5,417,308. This indicates that a 1 TWh increase in coal consumption results in a 5,417,308-ton increase in CO_2 emissions. Coal contributes to CO_2 emissions in Asia due to its dominant role in electricity generation and heavy industry, particularly in countries with high energy demands, low production costs, and limited adoption of low-carbon technologies or renewable energy. Friedlingstein et al. (2020) found that coal combustion has been responsible for a substantial portion of global carbon emissions growth over recent decades, especially in Asia and Africa, where economic growth and industrialization drive coal consumption.

Population size positively and significantly affects CO_2 emissions, with a regression coefficient of 90.43939, meaning an increase of one person would result in an additional 90.43939 tons of CO_2 emissions. Population growth contributes to CO_2 emissions in Asia by increasing energy demand for household needs, transportation, and the consumption of goods and services, most of which rely on fossil fuels. Bongaarts (2019) emphasized that besides population size, consumption patterns and lifestyles also play a critical role in determining carbon emission levels. In countries with large populations, high per capita energy and carbon-based product consumption exacerbate environmental impacts. Without advancements in green technology and effective mitigation policies, rapid population growth will lead to faster emission increases compared to countries with slower population growth.

Economic growth variables showed no significant effect on CO_2 emissions in the 25 Asian countries between 2015–2021. This could be attributed to the implementation of environmentally friendly policies and the role of clean technologies in these countries. Hao et al. (2019) found that the relationship between economic growth and CO2 emissions is not always linear or significant, especially in countries with strong carbon mitigation policies. In

many developed countries, economic growth is often associated with improved energy efficiency and the adoption of green technologies, reducing carbon intensity in economic activities. Conversely, in developing countries, although economies are growing, advancements in environmentally friendly technologies may not be sufficient to significantly reduce carbon emissions due to the dominance of fossil energy use.

CONCLUSION AND IMPLICATIONS

Conclusion

This study analyzes the concentration of carbon dioxide (CO_2) emissions and the impact of oil, natural gas, coal consumption, economic growth, and population in 25 Asian countries from 2015 to 2021. The findings can be summarized as the following:

a. Among the 25 countries, 13 countries are major emitters, with Japan recorded as the highest concentration, while 12 other countries have the lowest concentrations.
b. Oil consumption positively affects CO_2 emissions, proving that the higher the oil consumption, the greater the emissions produced.
c. Natural gas consumption positively affects CO_2 emissions, indicating that increased natural gas consumption contributes to higher carbon emissions.
d. Coal consumption positively affects CO_2 emissions, indicating that its use remains a significant contributor to carbon emissions in the region.
e. Population size positively affects CO_2 emissions, showing that population growth drives increased carbon emissions due to higher energy demands and consumption activities.
f. Economic growth has a negative effect on CO_2 emissions, contradicting the initial hypothesis that economic growth would increase carbon emissions.

Recommendations

The results indicate that oil, natural gas, coal consumption, and population in 25 Asian countries have a significant impact on CO_2emissions. Therefore, it is important for governments in Asian countries to develop policies that support the transition to be more environmentally friendly energy sources, such as renewable energy, and promote energy efficiency in industry and transportation sectors. Investments in low-carbon technologies, such as electric vehicles and carbon capture technologies, should be prioritized to reduce the negative impacts of fossil fuel consumption. Restricting coal usage, especially in power plants, is also an important step to reduce emissions. Additionally, population control policies and sustainable urban planning should be implemented to reduce the per capita carbon footprint. An integrated approach involving governments, the private sector, and society is essential in achieving ambitious emission reduction targets. Further research is also needed to explore other factors influencing CO_2emissions and to better understand the dynamics between energy consumption, the economy, and carbon emissions.

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