THE IMPACT OF ENVIRONMENTAL SUSTAINABILITY AND ECONOMIC GROWTH ON CARBONDIOXIDE EMISSIONS IN D-8 COUNTRIES FROM 2012 TO 2021

THESIS

SUBMITTED TO THE FACULTY OF ISLAMIC ECONOMICS AND BUSINESS

SUNAN KALIJAGA STATE ISLAMIC UNIVERSITY YOGYAKARTA

AS ONE OF THE REQUIREMENTS FOR OBTAINING A BACHELOR'S DEGREE IN ECONOMICS

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ISLAMIC ECONOMICS STUDY PROGRAM

FACULTY OF ISLAMIC ECONOMICS AND BUSINESS

SUNAN KALIJAGA STATE ISLAMIC UNIVERSITY

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Acc munaqasyah

29-12-2025

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AS ONE OF THE REQUIREMENTS FOR OBTAINING A BACHELOR'S DEGREE
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yang dipersiapkan dan disusun oleh:

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THESIS APPROVAL LETTER

THESIS APPROVAL LETTER

To:
Dear Dean of the Faculty of Islamic Economics and Business
UIN Sunan Kalijaga Yogyakarta
In Yogyakarta
Assalamualaikum wr.wb.

After reading, researching, providing clues and correcting and making corrections as necessary, I as a supervisor am of the opinionn that your thesis:

Name : Irma Novandari
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Thesis Title : **The Impact of Environmental Sustainability and Economic Growth on CO_2 Emissions in D-8 Countries from 2012 to 2021**

It can be submitted to the Faculty of Islamic Economics and Business, Departmen Sharia Economics Study Program, UIN Sunan Kalijaga Yogyakarta as one of the requirements to obtain a Bachelor of Science degree in the field of Islamic Economics.

With this, I hope that the thesis mentioned above can be submitted soon. I thank you for your attention.

Yogyakarta, 07 Januari 2026

Acknowledged,

Supervisor	Head of Program Studi
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STATEMENT OF AUTHENTICITY OF THESIS

STATEMENT OF AUTHENTICITY OF THESIS

The undersigned:

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Faculty : Islamic Economics and Business

I declare truthfully, that my thesis entitled: **"The Impact of Environmental Sustainability and Economic Growth on CO_2 Emissions in D-8 Countries from 2012 to 2021"** is a personal work and as far the author's knowledge does not contain material published or written by others, except for certain parts that the author takes as a reference.

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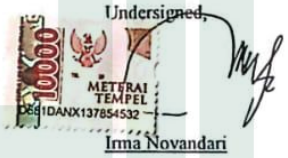

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22108010042

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As one of the academic sateis of Sunan Kalijaga Yogyakarta State Islamic University, I am the undersigned:

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No. HP	: 085715356711

Menyatakan bahwa saya menyerahkan diri dengan mengenakan jilbab untuk dipasang pada ijazah saya. Atas segala konsekuensi yang timbul di kemudian hari sehubungan dengan pemasangan pasfoto berjilbab pada ijazah saya tersebut adalah menjadi tanggung jawab saya sepenuhnya.

Demikian surat pernyataan ini saya buat dengan sebenar-benarnya.

Yogyakarta, 07 Januari 2026

Irma Novandari

MOTTO

"Surely, with every difficulty there is relief."

(QS. Al-Insyirah: 6)

ACKNOWLEDGMENT SHEET

With all gratitude, I dedicate this thesis to:

The two most amazing people in my life Ayah and Ibu. Thank you for your unending prayers, your tireless love, and your often unspoken sacrifices. Without you, I would not be where I am today. I Love You.

LITERACY GUIDELINES

In preparing this thesis, the transliteration of Arabic words follows the guidelines set forth in the Joint Decree of the Minister of Religious Affairs and the Minister of Education and Culture of the Republic of Indonesia No. 158 of 1987 and No. 0543b/U/1987.

A. Single Consonant

Arabic script	Name	Latin script	Explanation
ا	alif	not represented	not represented
ب	bā’	b	be
ت	tā’	t	te
ث	ṡā’	ṡ	es (with a dot above)
ج	jim	j	je
ح	ḥā’	ḥ	ha (with a dot below)
خ	khā’	kh	ka and ha
د	dāl	d	de
ذ	żāl	ż	zet (with a dot above)
ر	rā‘	r	er
ز	zāi	z	zet
س	sīn	s	es
ش	syīn	**sy**	es and ye
ص	ṣād	ṣ	es (with a dot below)
ض	ḍād	ḍ	de (with a dot below)

ط	ṭā’	ṭ	te (with a dot below)
ظ	ẓā’	ẓ	zet (with a dot below)
ع	‘ain	‘	inverted comma above
غ	gain	g	ge
ف	fā‘	f	ef
ق	qāf	q	qi
ك	kāf	k	ka
ل	lām	l	el
م	mīm	m	em
ن	nūn	n	en
و	wāwu	w	w
ه -	hā’	h	ha
ء	hamza h	’	apostrof
ي	yā'	Y	ye

B. Double Consonants due to Syaddah are Written as Double Letters

ممتعّددة	written	*muta’addidah*
عدّة	written	*‘iddah*

C. *Tā' Marbutāh* at the End of a Sentence

a. Written with *h* if pronounced *Sukun.*

حكمة	written	*ḥikmah*
جزية	written	*jizyah*

b. When followed by the definite article *'al'* and the two words are read separately, it is written with an *h.*

كرامة االولياء	written	*karāmah al-auliyā'*

c. When *Tā'marbutāh* is followed by *fathāh, kasrah*, or *dāmah*, it is written as *ny t* or *h*.

زكاة الفطرة	written	*ẓakatā al-fitrāh*

D. Short Vowels and Their Application

Every *tā' marbūṭah* letter is transliterated into the letter 'h', both when it is at the end of a single word and when it is in the middle of a series of words (for example, when followed by the article 'al-'). However, this rule does not apply to words borrowed from Arabic that have become part of the Indonesian vocabulary, such as shalat, Zakah, and so on, unless the original spelling is explicitly desired.

---َ---	fatḥah	written	a
---ِ---	kasrah	written	i
---ُ---	ḍammah	written	u
فعَل	fatḥah	written	fa'ala
ذكِر	kasrah	written	ẓukira
يذهبُ	ḍammah	written	yaẓhabu

E. Long Vowels

1	fatḥah + alif جاهلية	written	ā *jāhiliyah*
2	fatḥah + yā'mati تنسى	written	ā *tans* ā
3	kasrah + yā'mati كريم	written	*i* *karim*
4	ḍammah + wāwu mati فروض	written	*ū* *furūḍ*

F. Double Vowels

1	fatḥah + yā'mati بينكم	written	*ai* *bainakum*
2	fatḥah + wāwu mati قول	written	*au* *qaul*

G. Consecutive short vowels in a single word are separated by an apostrophe

أأنتم	written	*a'antum*
أُعدّت	written	*u'iddat*
لئن شكرتم	written	*la'in syakartum*

H. The definite article alif + Lam

a. If followed by a *Qamariyyah* letter, it can be written using the initial letter "al".

القرآن	written	*al-Qur'ān*
القياس	written	*al-Qiyās*

b. If followed by a *Syamsiyyah* letter, it is written according to the first letter of that *Syamsiyyah.*

السماء	written	*al-Samā'*
الشمس	written	*al-Syams*

I. Writing Words in Sentences

Written according to their spelling

ذوى الفروض	written	*ẑawi al-furūḍ*
أهل السّنّة	written	*ahl as-sunnah*

PREFACE

All praise be to Allah, the Most Gracious, the Most Merciful. The grateful author offers thanks to Allah SWT for His abundant mercy and guidance, which enabled the successful completion of this thesis entitled **"-".** May peace and blessings be upon our Prophet Muhammad SAW, his family, companions, and all his followers until the end of time.

Thanks to the support of various parties, this thesis has finally been completed successfully. Therefore, on this occasion, the author would like to express her deepest gratitude to:

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2. Prof. D.r. Misnen Ardiansyah, S.E., M.Si., K.CA., ACPA., as Dean of the Faculty of Islamic Economics and Business, Sunan Kalijaga Yogyakarta State Islamic University.
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5. Dr. Muhammad Ghafur Wibowo, S.E., M.Sc., as author's Thesis Advisor, who has patiently provided guidance, direction, and valuable input so that this thesis could be well-structured and organized.
6. All lecturers of the Sharia Economics Study Program, Faculty of Islamic Economics and Business, who have shared their knowledge and insights during my studies.
7. All employees and administrative staff of the Faculty of Islamic Economics and Business, Sunan Kalijaga Yogyakarta State Islamic University.

8. Basiran, my beloved Dad, who has given me his full support, both morally and materially, as well as his unceasing prayers. My dad's sincerity, hard work, and sacrifice have been the main source of motivation for me in pursuing my education and writing this thesis.
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other together has become an unforgettable memory and has given me great motivation to complete this thesis.

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ABSTRACT

This study aims to analyze the effect of GDP per capita, energy consumption, renewable energy, and trade openness on carbon dioxide (CO_2) emissions in the Developing Eight (D-8) countries using panel data consisting of 80 observations. The analysis method used is panel data regression with a Fixed Effect Model approach. The results show that energy consumption has a positive and significant effect on CO_2 emissions, while renewable energy has a negative and significant effect. Meanwhile, GDP per capita and trade openness have a positive but insignificant effect on CO_2 emissions, thus requiring energy transition policies to support sustainable development.

Keywords: CO_2 emissions, energy consumption, renewable energy, GDP per capita, international trade.

ABSTRAK

Penelitian ini bertujuan menganalisis pengaruh GDP per kapita, konsumsi energi, energi terbarukan, dan keterbukaan perdagangan terhadap emisi karbon dioksida (CO_2) di negara-negara Developing Eight (D-8) menggunakan data panel sebanyak 80 observasi. Metode analisis yang digunakan adalah regresi data panel dengan pendekatan Fixed Effect Model. Hasil penelitian menunjukkan bahwa konsumsi energi berpengaruh positif dan signifikan terhadap emisi CO_2, sedangkan energi terbarukan berpengaruh negatif dan signifikan. Sementara itu, GDP per kapita dan keterbukaan perdagangan berpengaruh positif namun tidak signifikan terhadap emisi CO_2, sehingga diperlukan kebijakan transisi energi untuk mendukung pembangunan berkelanjutan.

Kata kunci: emisi CO_2, konsumsi energi, energi terbarukan, GDP per kapita, perdagangan internasional.

CHAPTER I

INTRODUCTION

A. Background

Climate change is one of the most crucial global issues of the 21st century due to its widespread impact on economic, social, and environmental stability. The increase in average global temperatures, changes in rainfall patterns, rising sea levels, and the increasing intensity and frequency of natural disasters are clear indications of the deteriorating global environment. Reports from various international institutions show that human activities are the main cause of climate change, particularly through increased greenhouse gas emissions. Among the various types of greenhouse gases, carbon dioxide (CO_2) is the largest contributor because it is released on a massive scale through economic activities, particularly the burning of fossil fuels in the industrial, transportation, and energy generation sectors.

The scale of global carbon emissions is becoming increasingly alarming. According to the Global Carbon Project (2023), humans are estimated to have released around 10.9 billion tons of CO_2 into the atmosphere throughout 2023, an increase of around 1.1 percent compared to 2022. When added to emissions from land use change, including deforestation and forest degradation, global carbon dioxide emissions reached around 45 billion tons that year. The data shows that global dependence on fossil fuels remains very high and

continues to be the main cause of increased carbon emissions worldwide, even though many countries have been striving to move towards clean energy.

In recent decades, the increase in CO_2 emissions has gone hand in hand with the acceleration of global economic growth. Developing countries tend to experience a significant increase in energy demand to support industrialization, urbanization, and improved community welfare. However, this increase in economic activity is often not balanced with the use of environmentally friendly technologies, resulting in increased environmental degradation. This situation creates a dilemma between achieving economic growth and environmental conservation efforts, which has become a major concern in the discourse on sustainable development.

The issue of climate change is increasingly relevant in the context of developing countries because these countries generally have higher levels of environmental vulnerability than developed countries. Dependence on the primary sector, limited adaptation capacity, and high population pressure make the impact of climate change more pronounced. Therefore, understanding the economic factors that influence CO_2 emissions is important as a basis for formulating environmentally-friendly development policies.

The global commitment to environmental sustainability has been institutionalized through the Sustainable Development Goals (SDGs) adopted by the United Nations (Nations, 2015). SDG 13 emphasizes the importance of immediate action to address climate change and its impacts, while SDG 7

affirms the importance of access to clean and affordable energy as a key element of sustainable economic growth. On the other hand, SDG 8 promotes inclusive and sustainable economic growth with an emphasis on creating decent jobs and improving energy efficiency. This shows that the agendas of economic growth and environmental sustainability must be integrated simultaneously.

In the context of developing countries, the Developing Eight (D-8) group of countries, consisting of Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan, and Turkey, represents developing countries with economic and environmental characteristics that are interesting to study. These countries have large populations, relatively high economic growth rates, and an increasingly important role in the global economy. Geographically and environmentally, most D-8 countries have extensive coastal areas, tropical or semi-tropical climates, and high vulnerability to natural disasters caused by climate change, such as floods, droughts, and heat waves.

These natural and geographical conditions make environmental quality a significant development challenge for the D-8 countries. On the one hand, these countries are striving to promote economic growth in order to improve the welfare of their people and reduce poverty. On the other hand, increased economic activity has the potential to increase pressure on the environment through increased energy consumption and carbon emissions. Therefore, the dynamics of the relationship between economic activity and environmental quality in the D-8 countries is an issue that is relevant for further study.

One of the main indicators used to measure the impact of economic activity on the environment is carbon dioxide (CO_2) emissions. Per capita CO_2 emissions describe the average amount of carbon emissions produced by each individual in a country and are often used to assess the pressure of economic activity on the environment.

Based on CO_2 emissions per capita data for the Developing Eight (D-8) countries, there are significant variations between countries. Countries such as Malaysia and Iran have relatively high CO_2 emissions per capita compared to other D-8 members. The high CO_2 emissions per capita in these two countries reflect their high levels of industrialization and dependence on fossil fuel-based energy to support economic activity. Meanwhile, countries such as Bangladesh, Pakistan, and Nigeria have relatively low CO_2 emissions per capita, despite facing environmental pressures from population growth and limited energy infrastructure.

These differences in per capita CO_2 emissions indicate that environmental pressures in D-8 countries are not homogeneous. These variations reflect differences in economic structure, energy mix, technological efficiency, and environmental policies implemented in each country.

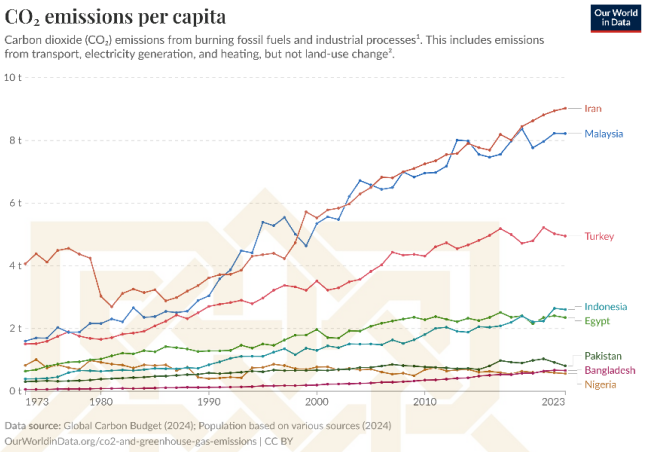

Figure 1.1 CO_2 Emissions Per Capita in The D-8 Countries

Source: worldindata.org, (2025)

Figure 1.1 according to Our World in Data (2024) shows that Malaysia and Iran consistently rank among the countries with the highest CO_2 emissions per capita among D-8 members, while Bangladesh and Nigeria rank lowest. Indonesia, Egypt, Turkey, and Pakistan rank in the middle, with a tendency to increase in line with economic growth and increased energy consumption. This pattern shows that increased economic activity and energy demand in D-8 countries have different implications for environmental quality, depending on the economic structure and energy policies implemented by each country.

Previous studies have examined the relationship between economic activity and CO_2 emissions. Grossman and Krueger (1995), through the Environmental Kuznets Curve (EKC) hypothesis, stated that the relationship between economic growth and environmental degradation is shaped like an inverted U curve. In the early stages of development, an increase in per capita

income tends to increase CO_2 emissions due to industrialization and fossil energy consumption. However, after reaching a certain income level, increased prosperity encourages environmental awareness, the application of clean technology, and stricter environmental policies, thereby potentially reducing CO_2 emissions.

A number of empirical studies support the EKC hypothesis, particularly in developed countries and some developing countries. Choi et al (2021) show that the relationship between per capita income and CO_2 emissions is non-linear, although the EKC turning point differs between countries. However, other studies show mixed results, even rejecting the validity of the EKC hypothesis in certain developing countries. This shows that the relationship between economic growth and CO_2 emissions is greatly influenced by the structural context and policies of each country.

In the context of energy, energy consumption is a major factor contributing to CO_2 emissions. Tsandra et al. (2023) found that fossil energy consumption has a positive and significant effect on increasing CO_2 emissions, while increased use of renewable energy has a negative effect on emissions. These findings emphasize the importance of the energy mix structure in determining environmental quality. Al Arif et al. (2021) also showed that dependence on fossil fuels in developing countries worsens environmental quality due to high carbon intensity.

However, research results are not always consistent. Landapa (2024) found that although economic growth has a significant effect on CO_2 emissions, the effect of energy consumption is not always significant in some countries. These differences in results indicate the role of other factors, such as energy efficiency, technological advances, and environmental policies, which moderate the relationship between energy consumption and carbon emissions.

In addition to economic growth and energy, trade openness is also an important factor in explaining CO_2 emission dynamics. Grossman and Krueger (1991) explain that international trade can affect the environment through three main mechanisms, namely scale effect, composition effect, and technique effect. In developing countries, increased trade often enlarges the scale of production and energy consumption, thereby potentially increasing CO_2 emissions. Research by Tsandra et al. (2023) and Gilberth and Esya (2025) shows that in many developing countries, the impact of trade openness on CO_2 emissions is still dominated by the scale effect.

Theoretically, the relationship between the research variables and carbon dioxide (CO_2) emissions can be explained through several main theoretical foundations. First, the effect of economic growth on CO_2 emissions is explained through the Environmental Kuznets Curve (EKC) Theory, which states that in the early stages of economic development, an increase in per capita income tends to increase environmental degradation due to industrialization and the use of fossil fuels. However, as income levels and environmental awareness

increase, economic growth has the potential to encourage the use of environmentally friendly technologies, thereby reducing CO_2 emissions. (Grossman and Krueger, 1995)

Second, the effect of energy consumption on CO_2 emissions is explained by the Environmental Kuznets Curve (EKC) hypothesis, which suggests that at the early stages of economic development, increasing energy consumption particularly fossil fuel based energy leads to higher CO_2 emissions, while at higher income levels emissions may eventually decline as cleaner technologies and energy efficiency improve. Third, the role of renewable energy in reducing CO_2 emissions is explained by the Theory of Substitution and Energy Efficiency, which emphasizes that substituting fossil fuels with renewable energy and increasing energy efficiency can reduce carbon intensity in energy production and consumption processes. (Grossman and Krueger, 1995; Ernst R. Berndt, 1975)

Fourth, the effect of trade openness on CO_2 emissions is explained by the Scale Effect Theory in International Trade, which states that increased trade and production activities can enlarge the scale of economic activity and energy consumption, thereby potentially increasing CO_2 emissions, especially in developing countries if not balanced with the application of environmentally friendly technologies and adequate environmental policies. Meanwhile, trade openness can increase emissions through an increase in the scale of economic

activity, especially if it is not balanced with the application of environmentally friendly technologies. (Grossman & Krueger, 1991)

Although the literature on CO_2 emissions is quite extensive, studies that specifically discuss the D-8 countries are still relatively limited. Most previous studies have focused on developed countries or large groups of countries such as the G20, so the results may not be entirely relevant to the context of developing countries with economic and environmental characteristics such as the D-8. In addition, differences in previous research results indicate the need for more contextual studies that take into account the specific conditions of developing countries.

Based on global climate change conditions, the natural characteristics of D-8 countries, variations in CO_2 emission levels, as well as previous research findings and existing theoretical frameworks, a study on carbon emissions in D-8 countries is relevant. This study aims to provide an empirical description of the relationship between economic growth, energy consumption, renewable energy, and trade openness on CO_2 emissions in D-8 countries. By focusing on the specific characteristics of developing countries and a relatively recent observation period, this study is expected to enrich the environmental economics literature and provide relevant policy input in efforts to achieve environmentally sustainable economic development.

B. Research Problems

1. How does economic growth (GDP per capita) affect CO_2 emissions in the D-8 countries?
2. How does energy consumption affect CO_2 emissions in the D-8 countries?
3. How does renewable energy affect CO_2 emissions in D-8 countries?
4. How does trade openness affect CO_2 emissions in D-8 countries?

C. Research Objectives

This study aims to explore the possibility of achieving economic development without causing damage to environmental sustainability, particularly in relation to CO_2 emissions in D-8 countries. This study aims to investigate the role of several determining factors such as GDP per capita, energy use, renewable energy, and trade openness in influencing carbon emission levels. By examining the combined effects of these variables, this study seeks to understand how economic progress can go hand in hand with ecological preservation efforts. In addition, these findings are expected to provide valuable input in designing green economic strategies that balance development priorities with environmental and social responsibilities.

D. Research Benefit

1. Theoretical Benefits

It is hoped that this study will contribute to economic development, particularly in the areas of environmental and energy economics. By examining how variables such as economic growth, energy consumption, renewable energy, and trade openness affect carbon dioxide emissions in developing countries, the findings of this study enrich the literature on factors that influence carbon dioxide emissions in developing countries. This study also determines whether the Environmental Kuznets Curve (EKC) applies to D-8 countries. The aim is to improve our understanding of the dynamics of the relationship between economic development and environmental damage in the context of developing and middle-income countries.

2. Practical Benefits

The results of this study are expected to serve as a reference for governments and policymakers in D-8 countries in formulating more sustainable development strategies. The findings on the impact of renewable energy and trade openness on carbon emissions can be used as a basis for formulating more effective energy, trade, and environmental policies. Thus, this research can assist governments in striking a balance between economic growth and efforts to reduce carbon emissions so that sustainable development goals (SDGs) can be achieved.

3. Academic Benefits

This research can be used as a reference for academics, students, and researchers interested in the topics of climate change, sustainable development, and energy policy. The research methods used, namely panel data analysis and econometric model testing, are expected to serve as a reference for future research on similar issues, both in developing and developed countries.

E. Writing Systematics

This final project consists of five chapters. The discussion structure reflects the researcher's train of thought from beginning to end. The details are as follows.

CHAPTER I INTRODUCTION

This chapter discusses the background of the research, which includes several things, namely the phenomenon of the research object, theoretical basis (summary), and supporting data attached. In addition, the first chapter also includes the problems raised by the researcher, as well as the objectives and benefits of this research. Then it ends with a comprehensive discussion to get an overview of the research objectives.

CHAPTER II THEORETICAL FRAMEWORK

In this chapter, the author outlines the current framework of thinking and hypothesis development to facilitate the researcher's understanding by

explaining the definitions and important ideas in the relevant theories used in the second chapter. This chapter also explains the research gap and describes previous studies related to the author's research.

CHAPTER III RESEARCH METHODOLOGY

This chapter presents a comprehensive explanation of the research methodology employed in this study. It outlines the research variables, including dependent, independent, and control variables, along with their operational definitions. In addition, this chapter explains the data sources, data collection techniques, and the period of observation used in the research. Furthermore, it describes the analytical methods, models, and instruments applied to process and analyze the data in order to address the research objectives and test the proposed hypotheses.

CHAPTER IV RESEARCH RESULTS AND DISCUSSION

This chapter elaborates on the research findings obtained from the data analysis. It begins with a descriptive analysis to provide an overview of the characteristics and trends of the research variables. Subsequently, the chapter presents the results of the empirical analysis and discusses their implications in relation to the research questions and hypotheses formulated in the first chapter. The discussion also compares the findings with relevant theories and previous empirical studies to provide a deeper interpretation of the results.

CHAPTER V CONCLUSION

This final chapter summarizes the main conclusions derived from the research findings. It highlights the key insights and contributions of the study in addressing the research objectives. In addition, this chapter provides practical and policy-related recommendations for relevant stakeholders. Lastly, it discusses the limitations of the study and offers suggestions for future research to improve and extend the findings of this research.

CHAPTER V

CONCLUSION

A. Conclusion

Based on the results of panel data analysis using the Fixed Effect Model (FEM) for the seven D-8 countries during the period 2012–2021, with variables of GDP per capita, energy consumption, renewable energy, and trade openness on CO_2 emissions, the following conclusions can be drawn:

1. The effect of economic growth (GDP per capita) on CO_2 emissions

   The results show that GDP per capita does not have a significant effect on CO_2 emissions in D-8 countries. This finding indicates that an increase or decrease in per capita income does not directly determine changes in carbon emissions. In other words, economic growth in D-8 countries has not been fully accompanied by changes in production structures and technologies that have a real impact on the environment. These results also show that the Environmental Kuznets Curve (EKC) pattern has not been empirically observed in the context of the D-8 countries during the study period.

2. The effect of energy consumption on CO_2 emissions

   Energy consumption has been proven to have a positive and significant effect on CO_2 emissions in the D-8 countries. This means that the higher the level of energy consumption, the greater the carbon emissions produced.

This finding reflects the D-8 countries' continued strong dependence on fossil-based energy sources, so that increased economic and energy activity has a direct impact on increased environmental degradation.

3. The effect of renewable energy on CO_2 emissions

   Renewable energy has a negative and significant impact on CO_2 emissions. This shows that increasing the share of renewable energy in the national energy mix can reduce carbon emissions. This finding confirms that the transition to clean energy is an important instrument in emission control efforts and supports the sustainable development agenda in developing countries such as the D-8 members.

4. The effect of trade openness on CO_2 emissions

   The results of the study show that trade openness does not have a significant effect on CO_2 emissions. This indicates that international trade activities in D-8 countries have not directly been a major determining factor in the increase or decrease in carbon emissions. The impact of trade on the environment is likely influenced by other factors, such as the structure of exports and imports, the type of industry, and the level of adoption of environmentally friendly technologies.

5. The simultaneous effect of GDP per capita, energy consumption, renewable energy, and trade openness on CO_2 emissions

   Simultaneously, GDP per capita, energy consumption, renewable energy, and trade openness have a significant effect on CO_2 emissions in D-

8 countries. This shows that carbon emission dynamics cannot be explained by a single factor, but rather are the result of interactions between economic growth, energy consumption patterns, clean energy transition, and involvement in global trade. This research model has a very strong explanatory power, as reflected in the high coefficient of determination value.

B. Limitations

This study has several limitations that need to be considered in interpreting the results and developing further research. First, the variables used in the model are still limited to GDP per capita, energy consumption, renewable energy, and trade openness. Other factors such as the quality of environmental regulations, the level of urbanization, industrial structure, production technology, and the energy policies of each country were not included in the model, even though these factors have the potential to have a significant impact on CO_2 emissions. Second, this study uses annual aggregate panel data, so it is unable to capture short-term dynamics or very short-term fluctuations that may occur in CO_2 emissions and energy consumption.

In addition, the use of a Fixed Effect model with AR(1) correction provides a very high model fit, but the high R-squared value may also indicate the possibility of dominant variables or multicollinearity that has not been completely eliminated. This study is also limited by the availability and

consistency of data across countries in the D-8 group, which may have differences in data quality. Given these limitations, the results of this study should still be interpreted with caution and serve as a basis for further research using more diverse variables, alternative estimation methods, or datasets with better time resolution.

C. Recommendations

Based on the results of this study, there are several recommendations that policymakers, government officials, and future researchers may wish to consider. Given that renewable energy has been proven to play an important role in reducing CO_2 emissions, D-8 countries need to continue increasing their use of clean energy sources such as solar, wind, hydro, and biomass. Governments in each country can accelerate the development of renewable energy through investment incentive policies, the development of green energy infrastructure, and the strengthening of regulations related to the use of environmentally friendly energy.

In addition, dependence on fossil fuels must be gradually reduced, given that fossil fuel-based energy consumption is the main cause of increased carbon emissions. This can be achieved by improving energy efficiency in the industrial, transportation, and household sectors, as well as encouraging the adoption of low-emission technologies. Although economic growth does not directly affect carbon emissions, the D-8 countries can still utilize international

cooperation as a means of transferring environmentally friendly technologies and improving cleaner production standards. Economic growth that does not significantly affect carbon emissions demonstrates the need for a more sustainable development direction, so that increases in community income are not accompanied by greater environmental pressure. The government can consider development policies that emphasize green innovation, low-carbon industries, and the implementation of stricter environmental standards.

As a suggestion for further research, it is recommended to include additional variables such as environmental regulation quality, urbanization level, industrial structure, or technological innovation in the model, so as to provide a more comprehensive understanding of the factors that influence CO_2 emissions. Thus, future research results are expected to enrich the literature and provide a broader picture of carbon emission dynamics in developing countries.

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