JDEP
(Jurnal Dinamika Ekonomi Pembangunan)

ISSN (Online): 2614-2546
Volume 9 Nomor 1, Bulan 2026
DOI: 10.33005/jdep.v9i1.808

Do ICT and Green Energy Policies Reduce Environmental Degradation? A Panel Analysis of Developing Nations

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Diterima: 5 Juni 2025 | Revisi: 25 Desember 2025 | Disetujui: 20 Januari 2026 |

Diterbitkan: 30 Januari 2026

ABTSRAK

Purpose – Environmental degradation remains a critical challenge for developing countries, impeding sustainable development. This study examines the collective impact of energy policies, the green economy, and technological development on environmental degradation. Method – Using static panel data with a Fixed Effect Model (FEM), the study analyzes 119 developing countries (2012–2021) based on World Bank data. Findings – Renewable energy, fossil fuels, and electricity increase carbon emissions, while government expenditure, tax revenue, and industrial activity reduce them. Green economy policies, labor intensity, HDI, and forest cover are linked to higher emissions. Technology also positively correlates with emissions. Implications – Improving energy efficiency and boosting renewable energy investment are vital for reducing emissions and ensuring environmental sustainability in developing nations. Originality – This study advocates for the green growth model as a holistic policy framework to mitigate environmental degradation sustainably, balancing economic growth with ecosystem conservation.

Keyword: Environmental Degradation, Energy Policy, Green Economy, ICT Development

How to Cite:
Basri & Herianti (2026). Do ICT and Green Energy Policies Reduce Environmental Degradation? A Panel Analysis of Developing Nations. *JDEP (Jurnal Dinamika Ekonomi Pembangunan), 9*(1), 1-5.

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INTRODUCTION

The dynamics of global economic development often compel countries and societies to choose between economic progress and environmental protection. Research in economics and the environment is extensive and dynamic, exploring the interplay between economic activities and their environmental impact (UN DESA, 2023). However, environmental degradation can result if effective environmental protection strategies are not implemented. Sustainable environmental development demands strict protection strategies, long-term planning, cost-effectiveness, and policy integration (IPCC, 2022).

Economic development in many countries often prioritizes short-term goals, frequently leading to the overexploitation of natural resources. This approach has caused numerous agrarian challenges for governments and societies, such as environmental degradation, ecosystem destruction, and declining public health quality. Recognizing the critical importance of environmental protection as a foundation for sustainable development, UN Secretary-General António Guterres emphasized in a UN Environment Programme report the urgency of environmental restoration and protection. Such efforts are essential to addressing environmental injustice, bridging gaps, and empowering communities (Lange, 2021).

As hubs of global population growth, developing countries play a pivotal role in shaping the future of the world's environment. With rapid population growth rates, these nations stand at the crossroads of global progress (Dasgupta & Mäler, 1990). Their contributions to social, economic, and technological dynamics present both domestic challenges and global opportunities. These countries are often the battleground where technological growth, urbanization, and sustainability efforts intersect, making them crucial players in achieving a balance between development and environmental conservation (Li et al., 2024).

Concerns about environmental degradation have been increasingly voiced in recent decades, particularly by developing countries that are members of the Organization of Islamic Cooperation (OIC). These nations face the dual challenge of preserving the environment while achieving sustainable economic development. OIC member countries, despite their geographical diversity, human resources, and varying levels of development, share common challenges such as deforestation and widespread environmental damage (SESRIC, 2023).

One prominent form of environmental degradation in developing countries is the rising level of air pollution, which increasingly threatens public health and quality of life. This issue is primarily driven by industrialization and the growing scale of urbanization, both of which place mounting pressure on the environment (Rudra & Chattopadhyay, 2018). This situation demands immediate attention, as developing countries must seek dual solutions to reconcile economic growth with environmental sustainability.

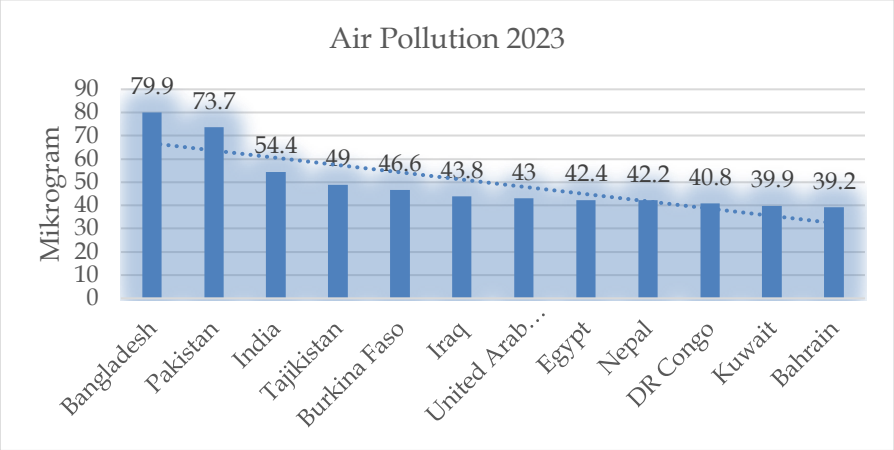

Chart 1. Highest Air Pollution Countries Data
Source: Iqair 2023

Chart 1. Highlights the trend of countries with the highest levels of air pollution globally, with Bangladesh ranked first, recording a pollution concentration of 79.9 µg/m³, followed by Pakistan (73.7 µg/m³) and India (54.4 µg/m³) (Earth, 2024). The majority of countries on this list are developing nations, including members of the D-8 (Developing Eight) such as Bangladesh, Pakistan, and Egypt. These countries face significant challenges in managing air pollution, primarily caused by human activities.

Energy is increasingly recognized as a controversial and critical factor in addressing environmental issues. The supply of energy resources plays a pivotal role in determining the economic development of developing countries, but it is also a major contributor to environmental degradation (Afriyanti et al., 2018). Changes in energy usage patterns begin with resource extraction, and while the use of fossil fuels has improved living standards for much of the global population, dependence on these fuels has substantial negative impacts on society.

Dincer (1999), underscores the seriousness of environmental issues, particularly pollutant emissions and environmental degradation, emphasizing that the energy sector must be managed carefully to ensure a sustainable future. However, the pursuit of environmental sustainability faces challenges, such as industrialization a key driver of economic growth which increases energy demand (Guo et al., 2015). This creates a dilemma for developing countries. Empirical evidence Valadkhani et al. (2019), further suggests that the environmental impact of energy use varies based on energy consumption patterns and the policies implemented by governments.

The concept of green economic development has long been a focus of researchers, beginning with Meadows' work in Rome, which introduced the idea of limits to economic growth. Meadows warned that, if growth patterns and natural resource use persisted as they did in the 1970s, resources would be depleted rapidly (Meadows et al., 1972). This foundation evolved into sustainable economic thinking and the concept of green income (Burton, 1987). A green economy promotes sustainable development by

integrating social dimensions, fostering economic growth, and maintaining environmental quality (Schmitz & Lema, 2015). This approach offers strategic benefits, reframing debates around obstacles into discussions of opportunities for transitioning to a low-carbon and green economy.

In this context, the framework of green economic development should shape discourse and policies globally, especially in developing countries. These nations are pivotal actors striving for environmentally sustainable development and fulfilling international commitments to mitigate the adverse environmental impacts of economic progress (OECD, 2015). This raises a critical question: can the green economy provide a viable solution to address environmental degradation in developing countries? By integrating economic growth, social equity, and environmental sustainability, the green economy offers not just a pathway to low-carbon development but also an opportunity for developing countries to lead global sustainability efforts (Zou et al., 2023).

In the digital age, information and communication technologies (ICT) serve as a double-edged sword for environmental sustainability. On the one hand, ICT promotes energy efficiency, green innovation, and better resource management. On the other hand, its infrastructure's carbon footprint, e-waste, and rising energy consumption pose significant challenges. This raises a critical question: is ICT's net environmental impact positive, or does it exacerbate sustainability challenges? Briglauer et al. (2023), highlight the dual nature of ICT, noting that its environmental impact depends on how it is utilized. The production, use, and disposal of ICT devices contribute to CO2 emissions through increased electricity demand. According to the SMART 2020 report by the Global e-Sustainability Initiative (GeSI, 2019), CO2 emissions from the ICT sector account for approximately 2.8% of total global emissions. However, ICT also has the potential to reduce emissions by up to 15% of the projected global total. Understanding the net impact of ICT on the environment is essential, though empirical evidence remains limited, particularly for developing countries (GeSi, 2019).

The relationship between energy policy, the green economy, and technological development in reducing environmental damage remains an open question. This study seeks to address this gap by exploring the complex interplay among these factors in developing countries. The holistic approach adopted in this research aims to provide valuable insights for policymakers and academics, helping them design development strategies that promote economic growth while safeguarding the environment. This study calls for heightened global awareness of the need for cross-sector collaboration and innovation to harmonize human needs with environmental sustainability.

Amidst complex global challenges, developing countries hold a strategic position—not only as recipients of environmental impacts but also as catalysts for transformative change. Can these nations leverage their unique potential to create development strategies that align with ecosystem preservation while enhancing global competitiveness? This research explores opportunities, identifies challenges, and proposes solutions rooted in the harmony between humanity and the planet.

RESEARCH METHODS

This study aims to develop the Environmental Kuznets Curve (EKC) hypothesis as an analytical framework, with a focus on developing countries (Gill et al., 2018; Kong & Khan, 2019). These nations are undergoing economic transitions often accompanied by rising emissions and environmental degradation. However, with appropriate policy interventions, they hold significant potential to accelerate the transition toward reduced emissions without replicating the pollution-intensive development patterns of developed countries. This approach not only provides contextual solutions for developing nations but also contributes significantly to global sustainable development efforts.

Building upon the intellectual foundation of the Meadows model (Meadows et al., 1972), which provided a seminal system-level warning about the consequences of unchecked growth, this study proposes an applied empirical model tailored for developing countries. While Meadows' 'Limits to Growth' highlighted the why of sustainability, our model focuses on the how in a specific context. We develop a testable green economic growth model that integrates three critical contemporary policy pillars—energy policy, the green economy, and ICT development alongside fiscal and industrial variables. This approach moves from broad systemic warnings to specific, evidence-based policy insights, aiming to identify practical leverage points for reconciling rapid economic growth with environmental preservation in the developing world.

Additionally, while developing countries typically have lower per capita emissions than developed nations, their large populations can significantly impact total annual emission rates. Using multiple linear regression analysis, the equation model utilized in this study is presented as follow:

$$CO2it = \beta 0 + \beta 1REit + \beta 2FFEit + \beta 3EEit + \beta 4GEit + \beta 5TRit + \beta 6INDit + \beta 7LIit + \beta 8HDIit + \beta 9FCit + \beta 10ICTit + \mu i + \varepsilon it \quad (1)$$

$$CO2it = \beta 0 + \beta 1REit + \beta 2FFEit + \beta 3EEit + \beta 4GEit + \beta 5TRit + \beta 6INDit + \beta 7LIit + \beta 8HDIit + \beta 9FCit + \beta 10ICTit + \lambda Controlit + \mu i + \varepsilon it \quad (2)$$

In this study, CO_2 (carbon dioxide) emissions serve as the primary indicator of environmental degradation. This choice is justified both scientifically and pragmatically. Scientifically, CO_2 is the primary anthropogenic greenhouse gas, its accumulation being the primary cause of climate change the most critical and systemic form of global environmental degradation (IPCC, 2022). Pragmatically, CO_2 emissions serve as a robust proxy for aggregate anthropogenic pressures from economic activity and provide highly standardized, comparable cross-country data essential for panel analyses (Global Carbon Project, 2025).

In the equations, CO2 represents carbon emissions. REit denotes renewable energy consumption, FFEit represents fossil fuel energy consumption, EEit refers to

electricity energy demand, TRit indicates tax revenue, GEit stands for government expenditure, and INDit represents industrial value-added. Reflecting the green economy dimensions, LIit measures labor intensity (economic dimension), HDIit represents the Human Development Index (social dimension), and FCit refers to forest cover (environmental dimension). ICTit denotes the level of information and communication technology development.

While the Environmental Kuznets Curve (EKC) provides the overarching theoretical context, our core model focuses on the policy variables above. The relationship for economic growth (EG) is specified linearly. This approach is motivated by the primary aim of isolating the effects of specific policy levers and is supported by literature suggesting that for a broad panel of developing countries—which are predominantly on the ascending limb of the EKC—the income-emission relationship is often effectively linear and positive, showing no evidence of a turning point within their current development stage (Stern, 2004; Al-Mulali et al., 2015). Therefore, EG is included as part of the control variables vector (λControlit), which also encompasses foreign direct investment (FDI) and urbanization (URB). The coefficients β1, β2, ..., β10 and λ are parameters to be estimated. μi captures time-invariant country-specific effects, and Ɛit is the idiosyncratic error term.

The object of this research consists of developing countries selected based on data availability. A total of 119 developing countries were chosen, as they are considered representative of developing nations facing environmental damage and rising emissions, which require effective mitigation strategies. The data used in this study were obtained from the World Bank and Our World in Data, covering the past ten years (2012–2021). Academics studying environmental degradation, particularly carbon emissions, have employed various indicators tailored to their research objectives. In this study, the authors aim to measure the interplay of energy policies, the green economy, and technological development while incorporating several key variables closely linked to factors that influence environmentally sustainable development (Lee et al., 2023; Peng et al., 2023; Appiah-Otoo et al., 2023). Furthermore, we evaluate the role of government budgets and tax revenue.

In addition, we examine the impact of technological development policies on carbon emissions, as proposed by (Tsaurai & Chimbo, 2019). This study also includes control variables economic growth, foreign direct investment, and urbanization—which are strongly associated with carbon emissions in developing countries, as noted by (Jafari et al., 2012) and (Huang et al., 2022). For a detailed overview of the variables used and their measurements, refer to Table 1 below:

Table 1.
Variable of Measurenment

Variables	Symbols	Unit of Measurenment
Environmental Degradation (CO2)	CO2	Emission Co2 (metric tons per capita)
Renewable Energy	RE	% of renewable energy consumption

Fosil Fuel Energy	FFE	% Primary Energy Consumption
Electrity Energy	EE	Electrity Demand Years
Government Expenditure	GE	(% of GDP)
Tax Revenue	TR	(% of GDP)
Industry	IND	Value Added (% of GDP)
Green Economy (Labor Intensity)	LI	Labor Force Total
Green Economy (HDI)	ED	Conposite Index
Green Economy (Forest Cover)	FC	(% of Land Area)
ICT Development	ICT	Mobile Cellular subscription (per 100 people)
Foreign Direct Investment	FDI	GDP (Annual %)
Economic Growth	EG	BOP Current U$$
Urbanization	URB	% of Urban Population

Source: Computed by Authors

RESULT AND DISCUSSION

Descriptive statistics for the main study variables are summarized in Table 2, To simplify the discussion, we focus on the minimum and maximum values observed across countries and years during the study period.

Table 2.
Descriptive Statistics of Main Regression

	CO2	RE	FEE	EE	TR	GE	IND	LI	HDI	FC	ICT
Mean	3.45	36.13	78.25	66.40	15.26	14.46	11.16	8.450.0	0.665	33.37	102.78
Median	2.21	30.20	82.10	2.79	9.15	14.37	14.28	4,377.7	0.693	31.07	104.25
Maximum	18.79	93.40	99.80	1714.7	147.64	84.19	31.53	78,100.0	0.880	91.69	185.55
Minimum	0.08	0.10	15.30	0.05	0.000	0.0000	0.0000	1.5	0.352	0.30	7.43
Std.Dev	4.12	27.43	18.55	190.45	8.85	7.71	6.03	12,345.5	0.122	21.96	33.67
Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Obs.	1034	1034	1034	1034	1034	1034	1034	1034	1034	1034	1034

Source: Data Processed

Descriptive statistics for the main study variables are summarised in Table 2. To simplify the discussion, we focus on the minimum and maximum values observed across countries and years during the study period. The highest carbon emissions per capita were recorded in China in 2021 at 18.79 metric tons, while the lowest, 0.08 metric tons, was observed in Saint Kitts and Nevis in 2012. Renewable energy consumption peaked in Uganda at 93.4% in 2012, whereas Antigua and Barbuda reported the lowest level at 0.1% during the same year. The share of fossil fuels in primary energy consumption was highest in Lesotho at 99.8% in 2012, while Ecuador reported the lowest value of 15.3% in 2015. Electricity demand reached its peak in India in 2021 at 1,714.7 kWh per capita, while Tonga recorded the lowest value of 0.05 kWh per capita in 2013. The most significant labour force was observed in Paraguay, at approximately 78.1 million people (78,100.0 in

thousands), whereas the Marshall Islands reported the smallest labour force at around 1,500 people (1.5 in thousands).

The Human Development Index (HDI) reached its highest score of 0.88 in Poland in 2019 and its lowest score of 0.352 in Nigeria in 2012. The most extensive forest cover was recorded in Gabon in 2012 (91.7% of land area), while Mauritania had the least forest cover in 2021 (0.3%). Finally, Seychelles achieved the highest level of ICT development (185.55 mobile cellular subscriptions per 100 people) in 2019, while Myanmar recorded the lowest level (7.43 subscriptions per 100 people) in 2012.

Table 3.
Panel Data Regression Results Fixed Effect Model

Variable	Non control variables	With control Variables
RE	927214.7	974240.1
	(0.125)	(0.070)
FFE	18035.3	31878.5***
	(0.199)	(0.000)
EE	2243387***	2186360***
	(0.000)	(0.000)
GE	-328809.1	-201520.3
	(0.633)	(0.789)
TR	-172326.4	-42669.8
	(0.633)	(0.895)
IND	-5278704***	-4870042***
	(0.000)	(0.000)
LI	13.42032***	14.3975***
	(0.000)	(0.000)
HDI	1.010.00***	763.000***
	(0.000)	(0.000)
FC	5809050**	5933693***
	(0.013)	(0.005)
ICT	341116.6**	247375.3
	(0.023)	(0.062)
FDI		0.00339***
		(0.000)
EG		49585.3
		(0.889)
URB		6086703***
		(0.000)
C	493.000***	633.000***
	(0.000)	(0.000)
OBS	1.035	

Source: Data Processed

After the estimation, we selected the Fixed Effects Model (FEM) for further analysis. The primary consideration in using FEM is its ability to absorb country-specific, constant, and omitted variables throughout the study period. This prevents bias that

could arise if such heterogeneity is correlated with the independent variables. The selection of FEM was based on the results of the Hausman Specification Test. This test rejects the null hypothesis that the Random Effects Model (REM) estimator is more efficient, thus indicating that FEM is the more appropriate model ($\chi 2 = 47.63$, p-value < 0.01).

Before delving into this study's results, we present the environmental quality score report based on the assessment conducted by the Centre for Research and Training in Statistics, Economics, and Social Affairs for Islamic countries. This report evaluates the environmental quality performance of developing countries, particularly the Member States of the Organisation of Islamic Cooperation (OIC).

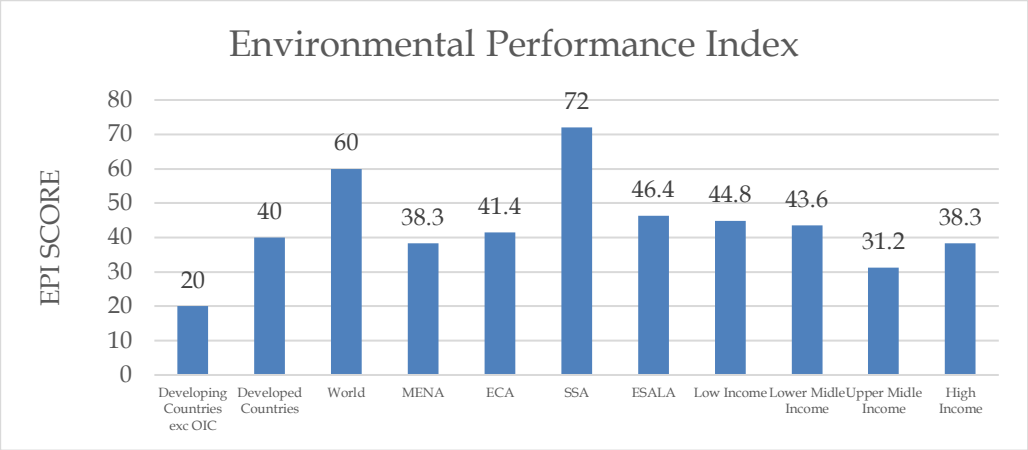

Chart 2. Environmental Performance Indeks
Source: Statistical, Economic and Social Research and Training Centre for Islamic Countries

The chart indicates that OIC countries and other developing nations are stagnating in terms of environmental performance. This stagnation reflects a lack of innovation in addressing environmental degradation. Acemoglu's assertion supports this observation, highlighting that developing countries often prioritize economic growth through extractive industries (Malik, 2020). This approach exacerbates environmental damage and results in declining environmental performance. In contrast, developed countries, with their stronger economic growth capabilities, are able to create sufficient fiscal and monetary space to achieve significant improvements in their environmental performance index.

Furthermore, the discussion of the findings in this study clearly demonstrates that investment in clean energy, particularly in developing countries, remains a significant challenge. This is evidenced by the positive coefficient value of renewable energy, indicating its inability to reduce carbon emissions, which contribute to environmental degradation. This finding aligns with a report by the World Economic Forum, which highlights that the lack of funding places developing countries at a disadvantage compared to developed nations in investing in the renewable energy sector (Tompson, 2023). Several factors contribute to this concern, including fiscal

constraints, socio-economic challenges, and climate risks, all of which complicate capital acquisition and significantly increase the cost of financing clean energy projects in these countries.

On the other hand, the International Energy Agency offers an interesting perspective, noting that the recovery from the pandemic, coupled with responses to the energy crisis, has accelerated global investment in clean energy at a faster rate than investments in fossil fuels (IEA, 2021).

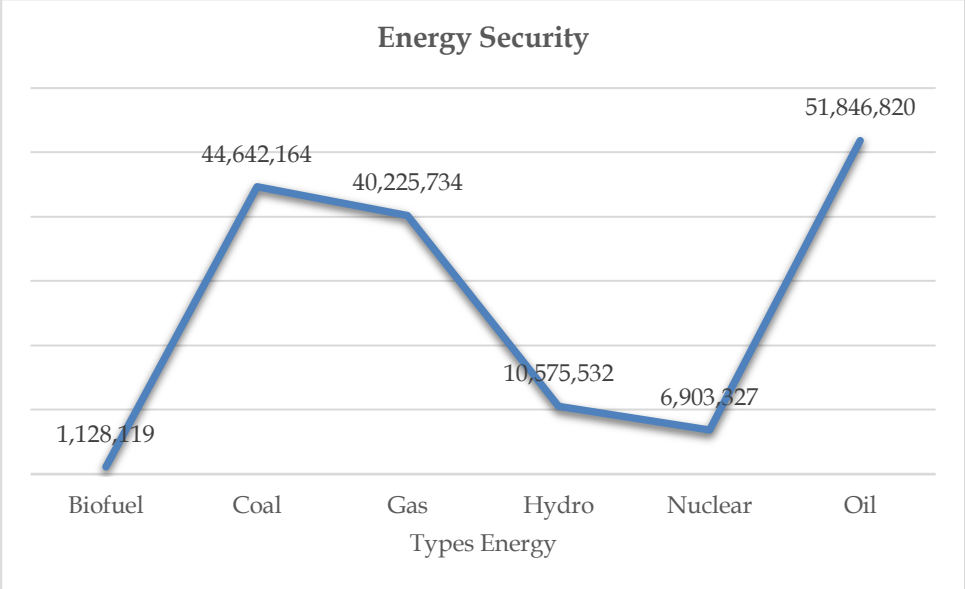

Chart 3. Energy Security Data
Source: International Energy Agency (2021)

However, this chart actually shows an uneven investment gap. Energy security shocks and price spikes caused by the geopolitical risk of the Russian invasion of Ukraine have drained the financial resources of developing countries. As a result, without strong funding, developing countries find it difficult to finance the energy transition or supporting infrastructure. The next challenge for developing countries is the condition of fossil energy.

This result confirms the empirical study by Shahsavari & Akbari (2018), which highlights that increasing carbon emissions in developing countries, primarily from fossil fuels and electricity energy, are central causes of environmental damage. This is linked to global energy demand, where fossil fuels play a significant role in increasing greenhouse gas emissions. This issue is further exacerbated by the rapid population growth in developing countries. In particular, energy plays a crucial role in improving human welfare and contributing to economic growth in these countries. Additionally, the rise in carbon emissions in developing countries is driven by a significant increase in the use of conventional fuels (coal, oil, and natural gas) to meet the rapidly growing energy demand. This is compounded by the production of electricity from conventional

energy sources, which accounts for 40% of global primary energy. Therefore, the impact of fossil fuel and electricity energy use, which produces harmful emissions, cannot be overlooked as it hinders sustainable development. This issue is also supported by the International International Energy Agency (2021), scientific report, which reveals the accumulation of global fossil energy use.

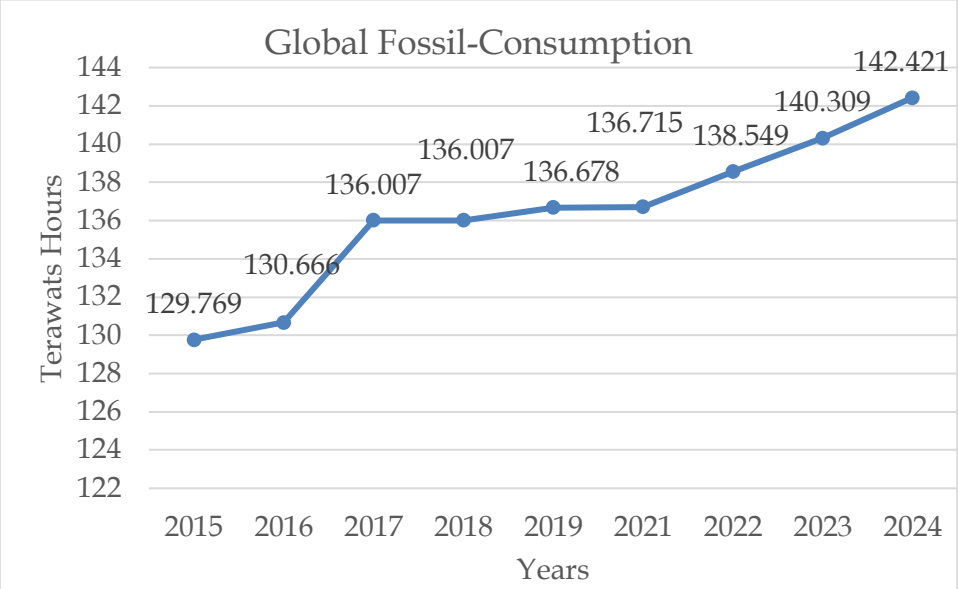

Chart 4. Total World Fossil Energy Use
Source: International Energy Agency 2021

The trend of increasing global fossil energy consumption, as shown above, is a concern that will contribute to global environmental damage, including excessive resource exploitation (Bilgen, 2014).

Further observations attempt to analyze the impact of government spending on environmental damage in developing countries. The study found positive results, as government spending was able to reduce carbon emissions that contribute to environmental damage. Therefore, this finding affirms the research by Halkos & Paizanos (2013), which suggests that government spending in developing countries, including redistributive transfers, can impact increasing income equality and ultimately raise demand for maintaining environmental quality. Additionally, the demand for good environmental quality becomes a luxury public good, and with a proportional budget allocation, it can provide an efficient solution to maintain balance between economic growth and environmental quality. The government, as both the manager and regulator of society, has an obligation to protect the environment. Government spending on environmental protection can promote sustainable development, improve public health, and ensure ecosystem stability (Niu, 2024). In efforts to carbon emissions, it emphasizes the necessity for the government to reduce its negative impacts. The government plays a key role as a policy implementer and regulator in fostering economic development while ensuring environmental preservation (Tang et al., 2024).

This study also correlates tax revenue or fiscal policy with environmental damage. A significant reason for this is how the composition of fiscal expenditure can affect the level of environmental damage. For example, theoretical discussions show that environmental damage results from economic sensitivity. Thus, environmental damage

in developing countries can be technically internalized through fiscal policy to ensure environmental sustainability (Erdogan, 2024). This consideration cannot be separated from the phenomenon in which developing countries often rely on economic growth driven by extractive natural resource patterns. Ultimately, increased pressure on the environment due to greater economic growth, along with industrial activities, can damage the environment. However, this finding supports the empirical study by Özmen et al. (2022), which emphasizes the importance of reallocating fiscal expenditure towards the environment. The role of government spending and fiscal policies focused on environmental quality can help reduce environmental damage. In line with the United Nations Environment Programme (UNEP) perspective, aligning government spending and creating fiscal space for broader green investment can contribute to achieving sustainable development (SDGs) and the Paris Climate Agreement. Therefore, the government can strengthen and collaborate with think tanks, research institutions, and international and intergovernmental organizations to reduce environmental damage (UNEP, 2024).

The next research result concerns the green economy, starting from the economic dimension by considering labor intensity. Our research did not meet the expected outcomes, as the goal of the green economy is to reduce the risk of environmental damage, such as emissions, as promoted by the green economy framework developed by the (Global Green Growth Institute, 2015). However, the analysis in this finding suggests that labor intensity is often generated by labor-intensive sectors, such as manufacturing, traditional agriculture, and industries relying on extractive natural resources and fossil energy. According to a scientific report by the World Economic Forum, this rapid change has reformed the global labor market, creating a demand for new jobs and skills in the future. This drives differences in economic growth paths, both within countries and between developed and developing countries. This condition also calls for an energy transition to reconfigure the sectoral composition of the workforce and stimulate demand for new jobs and skills (Forum, 2023).

Although these sectors can absorb large amounts of labor, in developing countries, the increase in labor is often not accompanied by the application of environmentally friendly technology. This presents a significant challenge for developing countries, which still require economic growth and poverty alleviation, while also dealing with the consequences of rising carbon emissions. It is also important to have a shared understanding that the increase in HDI is often supported by industrialization and urbanization, which in this study showed positive results on carbon emissions (Agency, 2020). These two phenomena also lead to increased energy consumption in every country, continuing to rise (Brodny & Tutak, 2020). Therefore, this study does not argue that an increase in HDI can worsen environmental quality. To ensure quality human development, environmental policy must be a normative concept that must be considered by implementing effective regulations. The environmental policy revolution is a stimulus for technical development, forming superior human resources (Hsu et al., 2021).

On the other hand, the environmental dimension represented by forest cover also has a positive impact. Although land cover has the potential to absorb carbon, the reality in developing countries shows that deforestation and forest destruction are still rampant due to economic pressures for industrial development and agricultural land clearing (Jafari et al., 2012). This situation illustrates that while the green economy aims to balance economic growth, social inclusion, and environmental conservation, its implementation in developing countries still faces various obstacles.

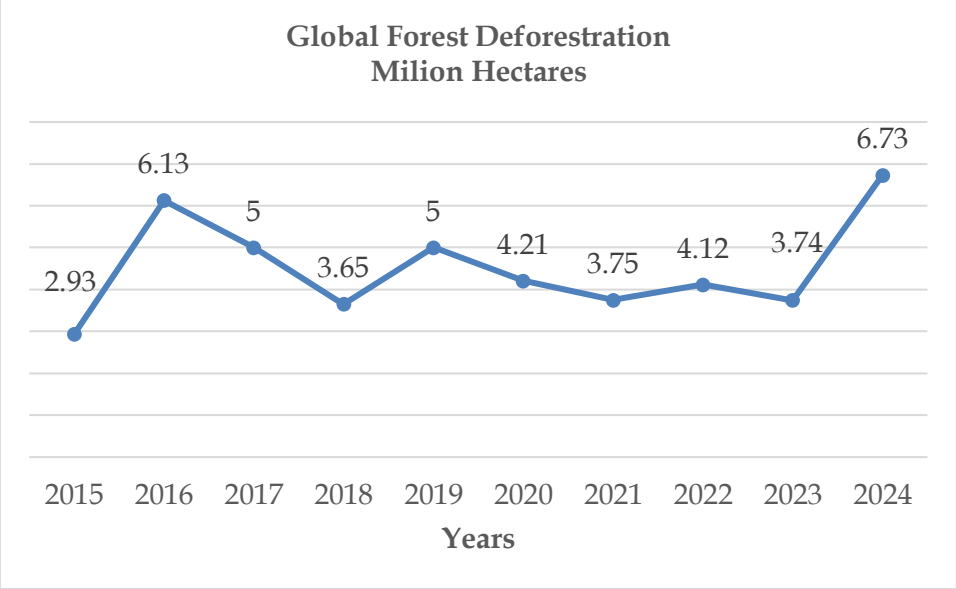

Chart 5. Global Primary Moist Forest Loss
Source: Global Forest Watch (2024)

The chart above shows the development of global primary moist forest loss, which accounts for 16% of the total cover loss during the same period. The total area of primary moist forest globally decreased by 7.4% during this time frame (Global Forest Watch, 2024). This situation is certainly linked to less sustainable forest management and the weak implementation of environmental policies, which have hindered land cover from functioning optimally in absorbing carbon. Therefore, the findings that show a positive impact of the green economy on carbon emissions reflect a transition that has not yet fully succeeded in reducing emissions, amidst the efforts of developing countries to achieve sustainable development.

The study also found surprising evidence that the industrial sector in developing countries can actually reduce carbon emissions. This finding contradicts the common belief, supported by various empirical studies, that industry is often the largest contributor to carbon emissions. However, the transformation of this sector provides a great opportunity to reduce emissions. These results provide concrete evidence of how the green manufacturing industrial model, when applied by the government, can be more efficient in reducing waste and energy consumption (Rusinko, 2007). For example, a scientific report from the World Economic Forum reveals the astonishing fact that industrial sectors, which are often difficult to decarbonize, collectively contribute around 40% of CO2-equivalent emissions. This includes heavy industries such as cement, aluminum, chemicals, and oil and gas, which are known as hard-to-abate sectors due to the nature of production and the technology used. However, empirical studies (Sinha & Chaturvedi, 2019), support our findings that emissions from the industrial sector can be reduced by increasing energy efficiency, capturing CO2 emissions, and finding alternative fuels. This condition has become an attraction for governments

worldwide to encourage the use of technologies such as carbon capture and energy efficiency, which can absorb emissions produced and help achieve net-zero emissions. Therefore, this step is becoming increasingly important for industrial sectors that are transforming sustainably to reduce their carbon footprints (Sinha & Chaturvedi, 2019).

The data analysis in this study shows that technology has not yet served as a catalyst for reducing environmental damage or carbon emissions. This finding confirms the results of an empirical study by Briglauer et al. (2023), which suggests that the increasing use of ICT can be a determining factor for the intensity of carbon emissions. In fact, ICT's contribution to emissions is estimated to have reached 4% of total global emissions in 2020, and it continues to rise each year.

Additionally, the International Telecommunication Union (ITU) revealed that this sector is growing rapidly, so that its greenhouse gas emissions now rival those of the aviation industry. Moreover, its energy needs often put pressure on resources. In the context of developing countries, the impact of ICT shows a high level of heterogeneity, leading to a significant increase in carbon emissions. As a result, policymakers face challenges in making the right decisions to reduce emissions from the ICT sector and manage resources effectively. Based on these findings, the World Bank and the ITU have warned that collaboration between the digital and energy sectors is essential to reducing ICT emissions and promoting the adoption of sustainable energy use (ITU, 2024).

In conclusion, various control variables in this study—such as foreign investment, economic growth, and urbanization—reveal results that should be an important consideration for policymakers in developing countries. The level of economic growth in developing countries, as discussed in the Environmental Kuznets Curve (EKC) theory, is often a primary cause of environmental damage because countries focus too much on economic development to spur productivity. However, the challenge these countries face is achieving sustainable environmental development, which requires a dual solution (Krueger & Grossman, 1995). Additionally, the level of foreign investment in developing countries is often faced with a trade-off, as discussed in the halo pollution hypothesis. This theory suggests that loosening environmental policies to attract foreign investment can, in fact, lead to various environmental problems (Tabash et al., 2023). Therefore, the hope is to encourage the use of environmentally friendly technologies and a large-scale green economic transition as an efficient solution.

CONCLUSSION

Environmental degradation in developing countries underscores the urgent need to initiate transformative strategies that balance economic growth with environmental conservation. However, this study found that the increasing use of fossil fuels and electricity remains the primary source of rising carbon emissions, thereby damaging the environment. Meanwhile, the role of renewable energy, projected as a development model capable of reducing carbon emissions, still faces challenges for developing countries. The lack of human resources and adequate budget allocations makes this

assumption remain largely theoretical. On the other hand, other dependent variables considered in the study—such as Government Expenditure, Tax Revenue, and Industry—yielded interesting results, showing that they can help reduce environmental damage.

The function of the green economy in developing countries still requires further evaluation to effectively serve as a catalyst for reducing carbon emissions. Technology also plays a crucial role in this study, as it is identified as a key contributor to the intensity of carbon emissions. Therefore, further research is needed to understand how technology can be effectively integrated into green economic policies to create synergies that can accelerate the transition to sustainable development. Again, it is clear from our analytical framework that developing countries largely align with the Environmental Kuznets Curve (EKC) theory, which suggests that increased economic growth is often accompanied by environmental damage during certain phases. This phase is evident in various variables tested, which show positive results for carbon emissions. This condition highlights the important task for policymakers to understand the goals of sustainable development by ensuring a pollution-free environment. This represents a turning point in the EKC theory, where economic growth can be achieved while maintaining environmental sustainability.

The main limitation of this study is that, although we attempted to examine the determinants of carbon emissions in developing countries, several countries were excluded due to limited access to research data. These limitations may lead to various interpretations. Therefore, we acknowledge that this study remains controversial, as several factors may have a strong influence on carbon emissions. This area remains an interesting avenue for future research, especially concerning developing countries that were not included in this study and are rarely the focus of academic attention.

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