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The Impact of Environmental Degradation on Sustainable Development

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Abstract:

Environmental degradation, driven by industrialization and population growth, has emerged as a critical global challenge, disproportionately impacting the most vulnerable communities. A significant factor contributing to this issue is the rapid rise in greenhouse gas emissions, particularly Carbon Dioxide (CO_2), which accelerates climate change and its widespread effects. Simultaneously, Fossil Fuel Subsidies (FFS), initially introduced to enhance energy access and stimulate economic growth, have faced growing criticism for distorting markets, slowing the transition to renewable energy, and deepening environmental and social inequalities. Hence, addressing these challenges requires urgent action to reform FFS and reduce CO_2 emissions, which are pivotal to achieving the United Nations Sustainable Development Goals (SDGs), especially affordable and clean energy (SDG 7) and climate action (SDG13). The present study conducts a multiple regression model by using the Estimated Generalized Least Squares (EGLS) method across 37 countries from 2010 to 2022. It aims to analyze the impact of environmental degradation captured by FFS and CO_2 emissions on sustainable development (SD). In addition, it studies the moderating role of CO_2 emissions in affecting the relationship between FFS and SD. The results show that the FFS has a positive and significant impact on SD, while CO_2 emissions has a negative and significant impact on SD. In the meantime, the interaction term of the FFS and CO_2 emissions has a negative and significant impact on SD. This indicates that CO_2 emissions is moderating the relationship between FFS and SD by altering its impact on SD.

Keywords: Environmental Degradation, CO_2 Emissions, Fossil Fuel Subsidies, Sustainable Development.

1-Introduction:

Environmental degradation, driven by unsustainable resource extraction and exacerbated by industrialization, population growth, economic expansion, and urbanization, has become a pressing global concern. Both natural processes and human activities contribute to this phenomenon, leading to the depletion of resources, biodiversity loss, and habitat destruction, with severe impacts on local, regional, and global environments (Thakur et al., 2014). The poorest and most vulnerable communities are disproportionately affected, facing challenges such as water and air pollution, waste mismanagement, deforestation, and soil degradation, all of which threaten their health and livelihoods.

A significant driver of environmental degradation is the sharp increase in greenhouse gas (GHG) emissions, largely resulting from rapid industrialization and the adoption of modern lifestyles. Carbon dioxide (CO_2), in particular, is the leading contributor to global warming, intensifying climate change and its associated impacts, such as rising sea levels and extreme weather events. In 2023, global CO_2 emissions reached a record of 37.4 billion tons, marking a 1.1% increase from the previous year, with China, the United States, and India identified as the largest emitters (IEA, 2023). Recognizing the urgent need for action, the international community has prioritized reducing carbon emissions, with governments, researchers, and businesses focusing on innovative strategies and technologies to achieve sustainability goals (Zhao et al., 2024).

The issue of FFS has gained global attention as a critical component of the environmental and economic sustainability agenda. These subsidies, defined by the World Trade Organization (WTO, 2006) as government programs providing financial benefits to fossil fuel-related activities, often result in lowered energy production costs and increased revenues for energy suppliers (Kojima and Koplow, 2015). While originally designed to promote energy access and economic growth, FFS have been widely criticized for perpetuating market distortions, hindering renewable energy development, and disproportionately benefiting wealthier households, thereby exacerbating social and environmental inequities (UNDP, 2021).

FFS have well-documented economic, social, and environmental drawbacks, especially in developing countries. These subsidies divert substantial financial resources, reducing governments' capacity to invest in critical sectors like education, healthcare, and public infrastructure. This diversion also hampers the growth of renewable energy capabilities and the transition to clean energy. Reducing such subsidies could free up fiscal resources to significantly improve the living conditions of the poorest 60% of the global population (Zhuawu & Garg, 2023).

Recent estimates indicate that the global FFS reached a record of USD 1 trillion in 2022, primarily driven by energy price volatility and geopolitical tensions, particularly the Russian–Ukrainian conflict. Governments implemented measures such as price caps, tax reductions, and fiscal support to mitigate energy costs for consumers. Despite a brief decline in 2020 due to reduced demand during the COVID-19 pandemic, the upward trend in subsidies, especially in emerging markets and developing economies persists (IEA, 2023). Addressing these subsidies is critical for achieving sustainability goals, as they significantly contribute to environmental degradation and climate change.

Reforming FFS has been highlighted as an essential step toward sustainable development. The G20 Summit in 2009 marked a turning point, with world leaders committing to phasing out "inefficient" subsidies, a commitment later integrated into the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 of Responsible Consumption and Production. In 2014, 27 countries had initiated or planned reforms to address these challenges (IEA, 2014). Transitioning away from FFS, coupled with investments in renewable energy and targeted support for vulnerable populations, offers a pathway to achieving economic stability, social equity, and environmental sustainability. Sustainable development policies, such as promoting renewable energy and fostering innovation, hold the potential to balance economic growth with environmental protection and social well-being, paving the way for a more resilient future (Abouzeid, 2024).

The United Nations' SDGs provide a global framework to address pressing challenges like poverty, inequality, climate change, and environmental degradation. The SDGs emphasize the importance of balancing economic growth with environmental protection and social equity. Reducing carbon emissions which is considered as a major driver of climate change is essential to achieving these goals. SDG 13 specifically calls for urgent action to combat climate change through reducing greenhouse gas emissions, enhancing climate resilience, and fostering international cooperation. Furthermore, emission reductions are essential for achieving other SDGs, such as SDG 7, which focuses on affordable, reliable, and sustainable energy access by advancing clean energy technologies and improving energy efficiency (Yang et al., 2023). However, the sophisticated relationship between carbon emissions and the progress of SDGs across regions remains underexplored and requires further research to better understand these dynamics.

International frameworks have significantly influenced global efforts to address climate change. The United Nations Framework Convention on Climate Change (UNFCCC, 1992) set the stage for coordinated climate action. The Kyoto Protocol (1997) established binding emission reduction targets for industrialized nations, while later agreements, including those from Copenhagen and Cancun, emphasized limiting global temperature rise to mitigate climate risks (UNFCCC, 1997). The Millennium Development Goals (MDGs) in 2000 and the SDGs in 2015 expanded this focus by addressing a broader range of sustainability issues, from poverty to environmental conservation (UN, 2024).

The concept of the Environmental Kuznets Curve (EKC), introduced in the 1990s, suggests a potential decoupling of economic growth from environmental degradation. According to the EKC, environmental pressures increase during the early stages of economic growth but stabilize and eventually decline as income levels rise and societies prioritize cleaner technologies and environmental awareness (Grossman and Krueger, 1994; Banuri and Opschoor, 2007). While the EKC provides a theoretical framework, achieving such transitions requires deliberate investments in green technologies and comprehensive policy reforms.

Efforts to reduce carbon emissions and FFS are essential for aligning with SDG targets, especially as these emissions play a central role in exacerbating climate challenges. By focusing on clean energy initiatives, enhancing energy efficiency, and reforming FFS, countries can pave the way toward a more sustainable, equitable, and environmentally resilient future (Abouzeid, 2024; Edwards, 2005).

The main objective of this study is to analyze the impact of environmental degradation captured by FFS and CO_2 emissions on sustainable development in 37 countries during the period 2010-2022. The contribution of the research and the research gap is highlighted in capturing the impact of environmental degradation by including both CO_2 emissions and FFS in addition to examining the impact of CO_2 as a moderator to the relationship between FFS and sustainable development through an interaction term for the two variables to show how FFS impact on SD can be altered with the increase in CO_2 emissions.

2. Literature Review:

The relationship between carbon emissions and economic development is complex and interconnected. In some countries that are endowed with petroleum resources, higher carbon emissions tend to negatively impact economic growth, as increased CO_2 emissions often hinder progress. However, on a global scale, rising carbon emissions can temporarily boost economic growth. This relation can vary according to some factors, such as different countries, economic development levels, different industries, and time periods (Yang et al., 2023).

There is a debate about the relationship between CO_2 emissions and economic growth. Kayani et al. (2023) remarked that effective policies, such as carbon taxes, cap and trade systems, and the adoption of renewable energy, can help reduce emissions even as the economy grows. In addition, investing in energy-efficient technologies and renewable resources can break the link between economic growth and rising emissions. However, in some instances, as introduced in the studies of Saboori et al. (2012) and Fujii and Managi (2013), an inverted U-shaped trend is observed in specific industries such as paper, wood, and construction, where emissions initially increase with economic growth but eventually decline once a certain development stage is reached. While other industries exhibit sustained links. Azzam (2016) found that CO_2-related environmental degradation hampers economic growth. Similarly, Zhang and Da (2015) showed that economic growth in China has been a major driver of rising carbon emissions, illustrating the environmental toll of rapid industrial expansion. These findings confirm that the relationship between carbon emissions and economic growth depends on the region, industry, and stage of development.

The study of Kayani et al. (2023) concluded that economic growth frequently results in higher greenhouse gas emissions as energy demands increase and industries expand. Moreover, during the early phases of economic development, emissions typically grow in parallel with GDP due to greater reliance on fossil fuels and energy-intensive processes. Saboori et al. (2014) revealed a long-term, two-way connection between GDP and CO_2

emissions with the energy use in OECD countries' transport sectors, suggesting a reinforcing cycle between economic growth and energy consumption.

Moreover, Fiscal pressures from FFS drive reforms in many middle- and low-income countries, as these subsidies distort markets and impose heavy burdens on government budgets. Beyond their direct fiscal impact, subsidies reduce the competitiveness of the energy sector by favoring capital-intensive industries, discouraging investment, and facilitating illegal activities like fuel smuggling. While removing these subsidies can lead to higher fuel prices, prompting governments to implement social protection measures and monitor supply chains, it may also negatively affect economic growth and employment, particularly in nations reliant on fossil fuel exports. In this case, businesses might react differently, some may absorb increased costs to soften the impact on consumers, while others may pass costs along, potentially reducing consumption and employment. Thus, while reforms pose challenges, they also offer opportunities to balance short-term economic impacts with long-term sustainability and energy transition goals.(Zhuawu and Garg, 2023).

Environmental degradation also affects social development. Carbon emissions pose significant challenges to global sustainable development by driving climate change and impacting various aspects of society, including population growth, poverty, employment, pricing, health, food security, and energy stability. The transition to a low-carbon economy and the introduction of climate change policies brings opportunities and challenges for employment and poverty reduction. On the positive side, this shift can generate new jobs in industries like clean energy, supporting economic growth and alleviating poverty. However, clean and renewable energy industries often require a highly skilled workforce, which may limit opportunities for workers who are employed in the traditional energy sectors. This shift could lead to social instability and widen inequalities if not carefully managed. (Yang et al., 2023; Wang, 2022)

According to Nabi et al. (2020), there is a positive relationship between poverty and CO_2 emission, thus higher poverty rates are often linked to increased carbon emissions. On the other hand, Farooq (2019) stated that cutting carbon emissions can lead to cleaner air, better public health, and a lighter strain on healthcare systems. Covert et al. (2016) and Manberger (2021) have argued that lowering carbon emissions typically requires reducing reliance on fossil fuels, which can present challenges for economic growth. These challenges might include potential energy shortages and the need for industries to undergo significant restructuring to transition to cleaner, more sustainable energy sources. so Low-carbon development plays a vital role in promoting green economic growth, enhancing social well-being, and ensuring effective environmental protection and management.

Repurposing FFS can create critical fiscal space for governments to fund social protection programs aimed at supporting disadvantaged groups. This is especially important because higher fuel prices resulting from subsidy removal can significantly impact low-income households. Increased fuel costs for essential services like cooking, heating, lighting, and transportation can reduce disposable income and potentially deepen poverty. Moreover, higher fuel costs often translate to increased prices for goods and services, further burdening consumers (Coady et al., 2015).

To mitigate these effects, governments must conduct thorough welfare analyses to assess the impact of subsidy reforms on households. This analysis helps determine the compensation measures needed to offset the increase in costs, which could include targeted cash transfers, social security payments, tax reforms, and employment-boosting programs. Addressing these socio-political sensitivities requires balancing fiscal reform with a commitment to social equity, ensuring that the most vulnerable populations are protected from the adverse consequences of subsidy removal. This approach emphasizes that fossil fuel subsidy reform, while essential for long-term sustainability, must be carefully designed to minimize short-term harm to households, particularly the poor. (UNDP, 2021).

According to the IMF (2022), removing FFS and aligning fuel prices with their true market values could reduce global fossil fuel CO_2 emissions by 36% below baseline levels by 2025, contributing to the Paris Agreement's climate goals of limiting global warming to 1.5-2°C. The primary goal of FFS reforms is to reduce fossil fuel production and consumption, which directly supports climate change mitigation. In developing countries, these reforms generally lead to positive environmental impacts, such as reduced greenhouse gas emissions, improved air quality, and greater promotion of renewable energy sources (Coady et al., 2015; Skovgaard & van Asselt, 2018).

However, reforms need to be accompanied by supportive policies, such as incentives for renewable energy production, and efforts to prevent a shift toward non-renewable fuels. The transition must also ensure energy access for low-income households, as seen in India's LPG subsidy scheme (IISD, 2018), which enabled poor households to transition to cleaner cooking fuels. Hence, careful planning is necessary to avoid adverse effects on energy access, and repurposing subsidies to support upfront energy access costs can help ensure a transition to modern and sustainable energy systems (Greve and Lay, 2023).

The present study contributes to the growing literature by analyzing the impact of environmental degradation, which is captured by the FFS and CO_2 emissions on sustainable development which will be analyzed in the next sections of the paper.

3. Data Collection and Descriptive Statistics:

This section presents the sources of data for the variables that are employed in the multiple regression model and the descriptive statistics for the variables used in the analysis.

3.1. Data Collection

Table (1) presents the variables employed in the empirical analysis and their data sources.

Table (1): Variables and Data Sources

Variable	Indicator	Source
Sustainable Development (SDI)	Sustainable Development Index	Sustainable Development Report
Fossil-Fuel Subsidies (FFS)	Fossil-Fuel Subsidies	The International Energy Agency (IEA)
CO_2 emissions (CO_2)	per capita CO_2 emissions	Our World in Data
Urbanization (URB)	urban population (% of total population)	Our World in Data
Energy Consumption (EC)	primary energy consumption per Capita	The International Energy Agency (IEA)

Source: designed by the authors

3.2. Descriptive Analysis:

Table (2) shows the descriptive statistics of the variables employed in the analysis to give more insights into the data structure and characteristics.

Table (2) Descriptive Statistics

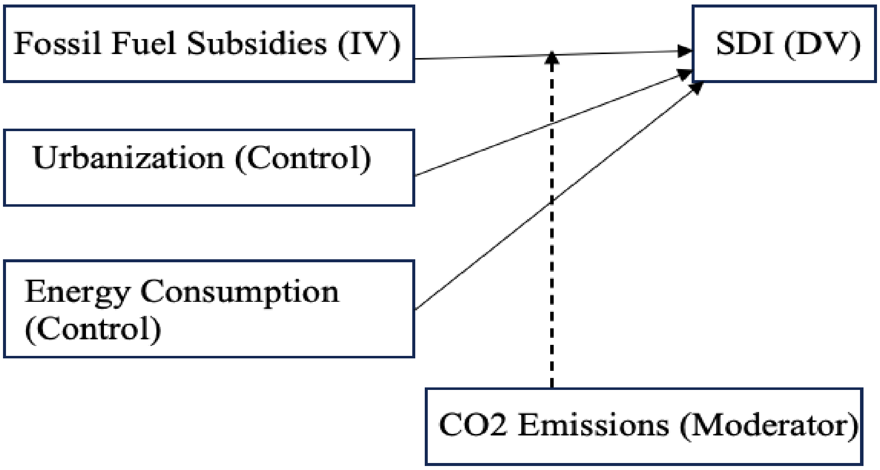
Variables	SDI	FFS	CO_2	URB	EC
Mean	0.620083	0.139336	7.415368	62.57370	1.480170
Median	0.693000	0.067129	3.809140	62.91950	1.254654
Maximum	0.837000	2.077526	48.93290	100.0000	4.803418
Minimum	0.052000	9.82E-06	0.351031	18.19600	0.300864
Std. Dev.	0.211499	0.215362	9.036195	20.36014	0.849458
Skewness	-1.434484	4.176609	2.061453	-0.065398	1.471657
Kurtosis	3.934788	28.63255	7.008758	2.316339	5.440645
Jarque-Bera	150.9881	12052.83	548.3859	8.034630	242.4459
Probability	0.000000	0.000000	0.000000	0.018001	0.000000

Source: Author's calculation by using E-views.

4. Model Specification

The present study examines the impact of environmental degradation on sustainable development. Following the studies of Owede and Ezaal (2022), Abouzeid (2024), and Dong et al. (2024) CO_2 emissions and fossil fuel subsidies are used to capture the effects of environmental degradation on SD. The interaction term of the two variables is used to estimate the impact of CO_2 emissions as a moderator for the relationship between FFS and SD. The control variables used in the model are urbanization and energy consumption as shown in figure (1). The study is conducted by using a panel multiple regression model for 37 countries over the period 2010-2022. The model is conducted by using the panel Estimated Generalized Least Squares (EGLS) method to address the heteroscedasticity problem in order to obtain reliable estimates.

Figure (1): Model Specification



Source: designed by the authors

Equation (1) is designed to represent the multiple regression model using panel EGLS (cross-section weights) method as follows:

$$SDI_{it} = \beta_0 + \beta_1 SDI_{it-1} + \beta_2 FFS_{it} + \beta_3 CO_{2it} + \beta_4 (FFS \times CO_2)_{it} + \beta_5 URB_{it} + \beta_6 EC_{it} + \varepsilon_{it} \quad (1)$$

i = 1,……,37

t = 1,……,13

Where:

SDI_{it} = Sustainable Development Index in country i, year t.

SDI_{it-1}= the lagged Sustainable Development Index (one-period lag) in country i, year t-1.

FFS_{it} = fossil-fuel Subsidies in country i, year t. CO_{2it}= per capita CO_2 emissions in country i, year t.

URB_{it} = urban population (% of total population) in country i, year t.

EC_{it} = primary energy consumption per GDP in country i, year t.

5. Results and Discussion:

This section presents the estimation results of the impact of environmental degradation on SD. Before proceeding to the multiple regression analysis, the study conducts the unit-root test to check the stationarity of the variables. It tests also the correlations between the variables through the correlation-coefficients matrix to determine the direction and the magnitude of the relationships between the variables.

5.1. Unit-Root Test

Table (2) shows the unit-root test results to determine the stationarity of the variables employed in the model and hence their order of integration.

Table (2): Unit-Root Test Results

Variable	Statistic	Prob.	Order of Integration
SDI	-5.60016	0.0000	Level, I(0)
FFS	-6.80185	0.0000	Level, I(1)
CO2	-2.08057	0.0187	Level, I(0)
URB	-10.7499	0.0000	Level, I(0)
EC	-4.11640	0.0000	Level, I(0)

Source: Author’s calculation by using E-views.

5.2. Correlation Coefficients Matrix

Table (3) shows the coefficients of the correlation matrix to assess the strength and direction of relationships among variables. Following the established threshold of 0.8 (Kennedy, 2003; Memon et al., 2021), all pairwise correlations were found to be below this limit, indicating the absence of multicollinearity in the proposed regression model.

Table (3): Correlation Coefficients Matrix

Variables	SDI	FFS	CO2	URB	EC
SDI	1				
FFS	-0.0588	1			
CO2	-0.8634	0.0215	1		
URB	-0.4818	0.0594	0.6532	1	
EC	-0.3439	0.1560	0.4927	0.3707	1

Source: Author's calculation by using E-views.

5.3. The Regression Model Results

According to the regression model results shown in Table (4), the R-squared indicates that the variation in the explanatory variables that are employed in the model explains 99% of the variation in sustainable development measured by SDI. It is important to note that the autocorrelation problem was present in the estimation, thus the lag of the dependent variable (SDI_{t-1}) is included in the model to correct the problem and obtain reliable estimates.

Table (4): The Regression Model Results

Dependent Variable: SDI

Variable	Coefficient	t-Statistic	Prob.
C	0.01413	6.7149	0.0000*
SDI_{t-1}	0.98864	391.50	0.0000*
FFS	0.01077	5.4001	0.0000*
CO_2	-0.00016	-3.0456	0.0000*
$FS \times CO_2$	-0.00151	-7.6699	0.0000*
URB	-0.00004	-2.3099	0.0000*
EC	-0.00156	-1.7282	0.0846***
R-squared	0.9923		

S.E. of regression	0.0181
F-statistic	39598
Prob(F-statistic)	0.0000
Durbin-Watson stat	1.9695

Source: Author's calculation by using Eviews.

*Significance Level at 1%.
***Significance Level at 10%.

The results in Table (4) shows that the FFS has a positive and significant impact on SD. This is explained by the contribution of these subsidies to the economic growth which is an essential component of the SD process. This result is in line with Owede and Ezaal (2022) who found that fossil fuel consumption that is increased by the FFS has a positive impact on economic growth in the short-run. For the CO2 emissions, it has a negative and significant impact on SD. This is because of the negative environmental effects such as the ecological damage that are caused by these emissions. This is consequently adversely impacting environmental sustainability. This result is consistent with the study of Dong et al. (2024) that found a negative impact of CO2 on SD. The interaction term of the FFS and CO2 emissions has a negative and significant impact on SD. This indicates that CO2 emissions is moderating the relationship between FFS and SD. This indicates that subsidies are being used effectively to support energy access, economic growth, or social development, which enhances sustainability. The positive impact of FFS on SD that is converted to a negative and significant impact in the presence of CO_2 emissions through the interaction term, indicates that the negative consequences of CO_2 emissions on SD are surpassing the positive effects of subsidies, which diminishes its impact in promoting SD. This means that FFS is promoting SD through stimulating economic growth, however, due to the negative consequences that are revealed through the negative impacts of CO_2 on environmental sustainability, it affects SD negatively. For urbanization and energy consumption, the results revealed that they have a negative and significant impact on SD at 1% and 10% significance level respectively.

6. Conclusion and Policy Recommendation:

This study analyzes the relationship between FFS and CO_2 emissions as main components of environmental degradation and crucial factors that affect sustainable development. The findings reveal that FFS can positively impact SD by stimulating economic activity, while the ecological degradation and climate challenges caused by increased CO_2 emissions significantly offset these benefits, thus undermining environmental sustainability. The interaction between FFS and CO_2 emissions highlights their dynamic. While subsidies may temporarily contribute to SD through enhanced economic growth or improved energy access, the resulting environmental harm diminishes these gains, leading to a net negative impact on sustainability. This calls for a balanced approach to policy-making that addresses both economic and environmental considerations to ensure a more sustainable future.

To achieve sustainable development, it is essential to phase out inefficient fossil fuel subsidies, redirecting savings to renewable energy, infrastructure, and social welfare to protect vulnerable groups. Promoting clean energy adoption through incentives and investing in research can enhance energy efficiency and reduce reliance on fossil fuels. Carbon pricing, such as taxes or cap and trade systems, should hold industries accountable for emissions, with revenues funding green infrastructure and supporting households. Global cooperation under frameworks like the Paris Agreement can set ambitious climate goals, with developed nations assisting others in adaptation and mitigation efforts. Prioritizing equitable access to energy, particularly for underserved communities, and supporting low-income households through targeted aid ensures inclusivity. Economic policies must balance growth and environmental goals through green strategies and industrial innovation.

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