Macroeconomic indicators of environmental sustainability: A worldwide perspective

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DEDICATION

I dedicate this work to my parents, siblings, and Dr. Wasim Abbas Shaheen who believed in me and supported me throughout the study period.

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

ES	Environmental Sustainability
FDI	Foreign Direct Investment
REC	Renewable Energy Consumption
UB	Urbanization
TRO	Trade Openness
EF	Ecological Footprint
PG	Population Growth
EG	Economic Growth
LFPR	Labor Force Participation Rate
GMM	Generalized Method of Moments

ABSTRACT

Global warming is the major environmental concern and the main cause of it is the greenhouse effect caused by greenhouse gases. CO_2 is the most potent greenhouse gas. To effectively control global warming, there is a need to identify potential macroeconomic activities that trigger and mitigate these emissions. This study measures the effects of foreign direct investment (FDI), renewable energy consumption (REC), urbanization (UB), trade openness (TRO), and ecological footprint (EF) on environmental sustainability by taking CO_2 emissions as a proxy for it. The study employs panel data of 143 countries from 2001 to 2020. Data show the presence of cross-sectional dependency and slope heterogeneity and suggest the use of second-generation panel unit root tests, which confirm the presence of unit root at either level or the first difference. The Westerlund cointegration test confirms the presence of a long-term connection between the variables. The study uses System GMM to estimate the parameters and finds that REC mitigates CO_2 emissions and restores the environment, while FDI, UP, TRO, and EF trigger these emissions leading to environmental degradation. The study also prescribes policy recommendations for improvement in environmental quality.

Keywords: Environmental Sustainability, Foreign Direct Investment, Renewable Energy Consumption, Trade Openness, CO_2 emissions.

CHAPTER 1: INTRODUCTION

1.1 Background of the study

Global warming has become a major environmental issue for this century. It refers to a long-term increase in the average temperature of the Earth's surface leading to climate change. Now it has been confirmed that the Earth is 1.1 degrees Centigrade warmer than it was before the start of the industrial revolution (Calvin et al., 2023). The cause of global warming is the greenhouse effect, the phenomenon in which greenhouse gases like CO_2, CH_4, O_3, etc., trap the heat emitted by the Earth's surface in the atmosphere, and as a result the temperature of the atmosphere increases. Naturally, there is a limited concentration of these greenhouse gases in the atmosphere which is necessary to trap that much heat sufficient to create the temperature which is suitable for living on this planet. Without this greenhouse effect, the Earth would have been much colder, making it difficult for most forms of life to sustain here (Shahzad, 2017). Figure 1.1 shows the relationship between temperature and CO_2 emissions.

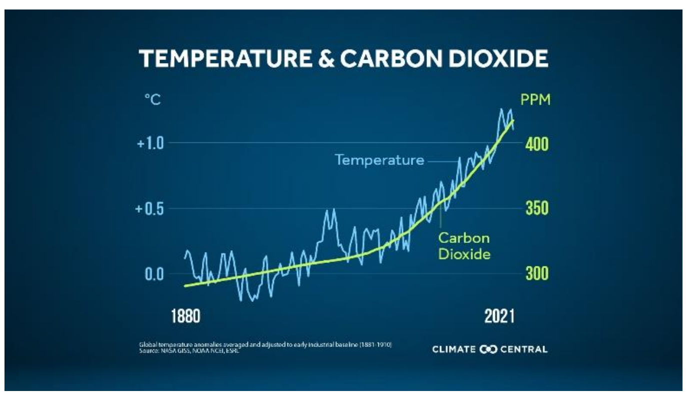

Figure 1.1:Relationship between temperature and Carbon Dioxide emissions.

Since the start of the industrial revolution, the concentration of these greenhouse gases has increased in the atmosphere leading to more greenhouse effect and hence more hikes in temperature. Carbon Dioxide is the most prominent gas among these greenhouse gases. Natural sources of CO_2 include volcanic eruption and decomposition of organic matter. Other sources are human activities like burning fossil fuels. These human activities are the main cause behind such a huge concentration of CO_2 in the atmosphere, which in turn causes more greenhouse effect leading to a rise in the Earth's temperature. In 2019 the concentration of CO_2 in the atmosphere was 410 parts per million which is higher than that of any year during the last 2 million years

(Calvin et al., 2023). Figure 1.2 shows the percentages of different greenhouse gases in the atmosphere.

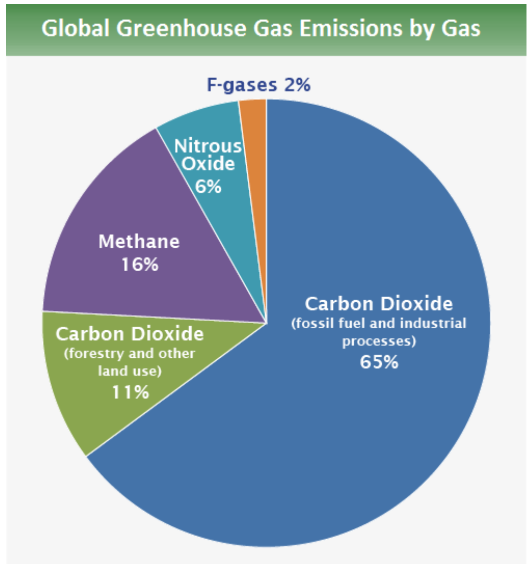

Figure 1.2: Global Greenhouse Gas Emissions by Gas

The destructive effects of global warming include rising temperatures, changing precipitation levels, warming of the oceans, melting of glaciers, rising sea levels, extreme weather events, health risks, and droughts. Some of the historic devastations caused by global warming include:

2010 and 2022 floods in Pakistan. In 2010, Pakistan faced severe flooding leading to the loss of 1985 people, affecting 0.2 billion people, and a loss of $9.7 billion of tangible assets (Waseem & Rana, 2023). In 2022 floods killed 1033 people, displaced 5.4 million people, directly and indirectly affected 33 million persons, and destroyed crops over an area of 2 million acres (Waseem & Rana, 2023). Monsoon rains agitated by climate change-induced weather patterns were the cause of these floods which led rivers to overflow. These floods didn't only cause infrastructure damage and human loss but also put Pakistan under critical issues of food security. Millions of people have lost their homes and livelihoods. Millions died due to the outbreak of diseases after floods. Pakistan, which is already a poor country, where the government doesn't have enough money to run its regular operations, came under a critical economic crisis due to floods and was forced to spread its hands in front of other countries and humanitarian organizations. Wildfires in California are another example of the devastation caused by global warming. California saw the deadliest wildfires in 2017 and 2018, burning more than 1.2 million hectares, causing 150 deaths, and economic losses of more than $40 billion (Goss et al., 2020).

The smoke spread across the state, leading people to breathe degraded air. These fires were the result of statewide warming and a decline in precipitation levels.

Heat waves in Europe represent another serious effect of global warming. Since the start of this century, Europe has faced five extreme Heat waves in the years 2003, 2010, 2015, 2018, and 2022. Alone in 2022, these heat waves have caused over 20,000 deaths due to heat (Khodayar Pardo & Paredes-Fortuny, 2024). These heat waves have numerous adverse effects including mortality, wildfires, disruption of Agriculture system, and public infrastructure.

Following this discussion, we may have an idea of the importance of this issue and the urgency to take steps towards declining this increase in temperature for ourselves and our future generations. The only way we can reduce global warming is by controlling the culprit behind it which is CO_2. To stop the hike in CO_2 concentrations in the atmosphere, there is a need to effectively monitor and control those activities that are the cause of these emissions. From here we come to know the term environmental sustainability. Environmental sustainability has been a subject of wide discussion for the last few years. It involves the use of natural resources like air, water, topography, etc., in such a responsible manner that our future generations don't suffer in their lives and enjoy the same level of prosperity and wellness as we do, if not better than us. It involves not only the limited use of natural resources but also their protection from degradation. In a true sense, environmental sustainability involves the protection of the whole biosphere including oceans, atmosphere, and land. This term is not limited to the responsible use of just an individual resource. It involves the use of renewable energy, recycling of metals, limiting plastic use, sustainable farming, etc. So, the less concentration of CO_2 in the atmosphere, the less hike in temperature and the more sustainable our environment will be.

Organizations and governments of different countries are now putting their efforts into addressing this environmental problem and coming up with solutions that provide growth to the industry while keeping the environment safe from the destructive fallouts of weather modification by abating Carbon discharges. The only possible solution is to monitor the different activities that are causing Carbon discharges into the atmosphere and set them as indicators for environmental sustainability and then make policy to limit that activities to the extent that either they don't harm the environment or do it to the minimum.

Some of the prominent efforts in this regard include:

The United Nations Framework Convention on Climate Change (UNFCCC), formed in 1992 and implemented in 1994. Today the European Union along with 196 other countries is a part of this convention. These countries are called parties to the convention. The first conference of the parties was held in 1995 for the very first time. Berlin Mandate was its first decision in which the parties decided that industrial countries should make the first step in reducing greenhouse gas emissions and the developing countries should follow at later stages (Kuyper et al., 2018). Kyoto Protocol was embraced at the third conference of parties on December 11, 1997, as a lead of UNFCCC, and became effective on February 16, 2005. It commits developed industrialized economies to limit their greenhouse gas emissions according to individually assigned targets by undertaking domestic measures including the European Union (8%), the United States (7%), and Canada and Japan (6%) during a period of five years from 2008 to 2012. Overall, these individual targets sum up to an average of 5% reduction in emissions as compared to emission levels in 1990 (Telesetsky, 1999).

The Paris Agreement is a treaty on climate change and 196 countries are part of it. It was adopted in Paris on December 12, 2015, at the UN climate change conference (COP 21). This agreement binds all countries to undertake efforts to hold the hike in global temperature to well below 2 °C, relative to pre-industrial levels and to put efforts to limit global warming to 1.5 °C (Cabrera et al., 2018). The Glasgow climate pact was adopted in 2021 at the 26th conference of the parties (COP 26). It stressed reducing CO_2 discharges by 45% by 2030 and to net zero around 2050 to restrict global warming to 1.5°C. The Glasgow climate pact also stressed the countries to reduce Methane and other non-CO_2 greenhouse gases by 2030. This pact is quite comprehensive in its approach and set new programs on global warming mitigation, adaptation, and climate finance (Depledge et al., 2022). The 28th conference of parties (COP 28), took place in Dubai in 2023. Over 160 countries participated in this conference. It was discussed that the CO_2 emission reduction efforts are not being made according to the Paris agreement and there is a need to reset those reduction targets (Jiang et al., 2024). Loss and damage fund was the first agenda of COP 28. Nineteen countries made contributions to the fund and raised up to USD 792 million. A historical decision to transition away from fossil fuels was taken. Fossil fuels were mentioned as the major reason behind global warming as 89% of the CO_2 emissions was from energy sector alone (Arora, 2024).

It is such an important issue that the United Nations has included it in the list of sustainable development goals (SDGs) that the world must achieve by 2030. SDG 13 is “Take urgent action to combat climate change and its impacts”. Its aim is to include climate change initiatives into the domestic policies of each country, educating the masses about climate change, its alleviation, early warning, and adaptation, and enhancing adaptive capacity and resilience to climatic hazards in all countries (Purnell, 2022).

Following this discussion about the global efforts being made to reduce emissions and thus global warming, we can get an idea of how pressing this problem is. However, these efforts are meaningless if they are not targeted at specific macroeconomic activities that are the cause of these CO_2 emissions on a large scale. To effectively curb these emissions, it is imperative to find out those macroeconomic activities that can be the potential source of CO_2 emissions and whether renewable energy consumption, which is being heavily stressed, abates CO_2 emissions. After finding out those macroeconomic activities that can be the potential source of CO_2 emissions and the role of renewable energy, a policy can be designed, and more realistic targets can be made to reduce emissions from these activities by regulating them. Previously, many studies have examined the microeconomic activities that cause CO_2 emissions, but these studies fall short when it comes to making effective policies regarding the complex activities that are the drivers of Environmental Sustainability.

This study adds to the existing literature by filling this gap firstly through the identification of macroeconomic activities including Foreign Direct Investment (FDI), Urbanization (UB), Trade Openness (TRO), and Ecological footprint (EF) that can be a potential source of CO_2 emissions. The studies on the microeconomic aspects of environmental sustainability fall short of comprehensively addressing this problem as discussed earlier. So, the objective of this study is to identify macroeconomic activities that can be the potential source of CO_2 emissions and resultantly contribute to global warming. Secondly, the study analyzes the role of renewable energy consumption in abating CO_2 emissions and whether it can be a source to achieve environmental sustainability goals set by global organizations.

1.2 Problem statements

Problem Statement 1:

Identification of macroeconomic activities causing CO_2 emissions. The studies on the microeconomic aspects of environmental sustainability fall short to comprehensively address this problem as discussed earlier. So, the aim of the study is to identify and analyze macroeconomic activities that can be the potential source of significant CO_2 emissions and resultantly contributing to global warming.

Problem Statement 2:

Analyzing the role of renewable energy consumption in restoring environmental sustainability

As discussed previously that stress is being given for the consumption of renewable energy, the study analyzes the role of renewable energy consumption in abating CO_2 emissions and whether it can be a source to achieve environmental sustainability goals set by global organizations.

1.3 Rationale of the study

Global warming is the pressing problem of this century, leading to severe economic, social, and environmental consequences. Given the acuteness of this problem, it is imperative to study the underlying macroeconomic drivers of CO_2. Another reason for carrying out this study is the long-going global debate on the importance of environmental sustainability. As the countries are thinking of ways regarding reduction of emissions and transitioning towards renewable energy to achieve long term environmental sustainability, it is essential whether renewable energy reduces these emissions, and if yes, then to what extent. Overall rationale of the study lies in the urgent need to understand the potential macroeconomic activities driving CO_2 emissions and the role of renewable energy in mitigating these emissions.

1.4 Significance and contribution of the study

The significance and contribution of the study reside in the following aspects.

1.4.1 Informing policy makers

By examining macroeconomic drivers of CO_2 emissions, the study provides numerous valuable insights to policy makers in the field of environment. It helps in the identification of specific activities and sectors that significantly contribute to these emissions, leading to the development of targeted regulation and policies to effectively reduce these emissions.

1.4.2 Promoting sustainable development.

Transition towards sustainable energy use is essential and crucial for achieving long term environmental sustainability. This study provides quantified and positive role of renewable energy use in mitigating CO_2 emissions, highlighting opportunities for investments in clean energy and resource efficient industries, leading to economic development while abating CO_2 emissions.

1.4.3 Supporting global climate treaties.

The study provides future international climate agreements to form targets and policies based on quantified data related to activities triggering CO_2 emissions. It helps in making sure that the future climate agendas and policies are evidence based and updated to the evolving challenges of climate change and global warming.

1.4.4 Awareness and call to action

The study raises awareness among businesses and the public about the potential impacts of macroeconomic activities on the climate. This in turn helps mobilizing action and foster collaboration across different sectors to take collective action for the betterment of the environment.

In sum, the significance of the study lies in informing key policy makers, promoting renewable energy use, supporting global climate agreements, and raising awareness regarding the immediate need of taking action to restore our climate. By addressing these key issues, the study plays a crucial part in international efforts aimed at the mitigation of global warming and helps in building a more sustainable and better future for all of us.

1.5 Objectives of the study

The objectives of the study include:

- To assess the impacts of macroeconomic activities including foreign direct investment, renewable energy consumption, urbanization, trade, and ecological footprint on sustainability of environment by using CO_2 discharges as a representative for it.

- To measure synergies and potential trade-offs between the variables.

1.6 Research Questions

- What are the impacts of foreign direct investment, renewable energy consumption, urbanization, trade, and ecological footprint on CO2 emissions?
- What are the potential trade-offs between the variables?

1.7 Initial Findings

Here are some of the initial findings from the study. The mean value of ES is 204873.72 Kilo tons, it means that on an average the sample countries released 204873.72 Kilo tons of CO_2 in the atmosphere during a period from 2001 to 2020. This initial finding supports the claim that CO_2 emissions have been increasing since the industrial revolution. The average value for trade is 82.252%, which is quite a high value and that's why it can have a significant impact on CO_2 emissions. The maximum value for renewable energy consumption is 98.34% and it would be interesting to know its effects on the mitigation of CO_2 emissions. The mean value of ecological footprint is 3.465 global hectares per person and maximum value of 43.67 global hectares per person, these values can have a driving effect on CO_2 emissions. The initial findings are in favor of the hypotheses that we developed for this study.

CHAPTER 2: LITERATURE REVIEW

This chapter gives a review of the previous studies that are related to the variables of interest.

2.1 Dependent Variable:

2.1.1 Environmental Sustainability:

Environmental Sustainability has been measured in different ways like Akbostancı et al. (2009) used carbon dioxide emissions per capita in Turkey as an indicator of the environment. I. Khan & Hou (2021) measured the effects of environmental and socioeconomic sustainability on carbon emissions for thirty IEA countries and they measured CO_2 emissions in kilotons of oil equivalent from burning of fossil fuels. Chatti (2021) used CO_2 emissions in kilotons from liquid fuel consumption and explored the association between transport, information and communication technology, and CO_2 emissions. Chin et al. (2022) used CO_2 emissions in metric tons per capita to assess the impact of green finance on environmental degradation in BRI region. Saeed Meo & Karim (2022) examined the role of green finance on the environment by measuring CO_2 emissions per capita as an indicator of the environment. Udeagha & Ngepah (2023) used CO_2 emissions to measure environmental sustainability for BRICS economies. Hailemariam & Erdiaw-Kwasie (2023) used per capita carbon emission as an indicator of environmental sustainability and studied its association with the indicators of circular economy. Adebayo et al. (2024) studied environmental sustainability of Thailand by taking three measures including CO_2 emissions in metric tons per capita, ecological footprint and load capacity factor in the units of global hectares per capita and stated that load capacity factor is more accurate indicator of environmental sustainability. Liu et al. (2024) used CO_2 emissions in kilo tons as a proxy for environmental sustainability and explored the nexus between natural resources, fintech, urbanization, and environmental sustainability in China.

2.2 Independent Variables:

2.2.1 Foreign Direct Investment:

Many scholars have used foreign direct investment in their studies like Abdo et al. (2019) measured FDI in terms of Per capita at current prices US$ and studied its influence on the environment for Arab countries. Fagbemi & Osinubi (2020) used FDI as net inflows % of GDP in the country and studied the interaction between human capital development and FDI. Dornean et al. (2022) analyzed the association between sustainable development and FDI in European countries and calculated FDI as % of GDP. H. S. Lee et al. (2021) used FDI as inflows and outflows both in units of (USD/GDP) and explored the relationship between outward FDI, inward FDI, CO_2 emissions, and research and development for BRICS countries. Opoku et al. (2022) investigated the impacts of environmental degradation on Foreign Direct Investment and measured FDI as net inflows (% of GDP). Samour et al. (2022) analyzed the effects of FDI and financial development on renewable energy in UAE and measured FDI as percentage of GDP. Kamal et al. (2023a) used FDI as China's outward foreign direct investment measured as stock of China's outbound FDI to each BRI country (US $ millions) and explored the effects of institutional quality on the environment in relation with China's FDI in BRI countries. Brohi & Suzuki (2023) measured FDI as % of GDP and studied the role of green innovation and FDI in South Asia. L. Wang et al. (2024) assessed the role of FDI and other variables on environmental sustainability in G20 economies and measured FDI as net inflows (% of GDP). Sarpong et al. (2024) measured FDI as FDI inflows (% of GDP) and studied association of FDI and CO_2 emissions in Africa. Guo & Yin (2024) measured FDI as net inflows (BoP, current US$) to investigate the relationship between FDI, CO_2 emissions, fintech, and green energy imports in China.

Most of these studies used FDI in units of (% of GDP) and produced different results, but our study uses FDI in units of net inflows in millions (balance of payment current USD) which had not been used in the previous studies and therefore, it might produce interesting results.

2.2.2 Renewable Energy Consumption:

Renewable energy consumption has been used is many studies like Sadorsky (2009) measured it in billions of kWh as net wind, solar, geothermal, wood and waste electric power and analyzed the link between renewable energy usage and income for emerging economies. Omri & Nguyen (2014) used renewable energy consumption in terms of billions of kilowatt hours as net solar, wind, wood, geothermal and waste electric power consumption and explored its drivers. Shahbaz et al. (2020) measured renewable energy consumption as kg of oil equivalent per capita and examined its effects on economic growth. Q. Wang & Wang (2020) measured renewable energy consumption as million ton of oil equivalent and investigated its relationship with economic growth in OECD countries. Salari et al. (2021) used renewable energy consumption in their study in units of thousands of British thermal units per capita and analyzed the association between economic progress, renewable and non-renewable energy consumption for U.S. states. Ehigiamusoe & Dogan (2022a) measured renewable energy consumption as % of total final energy consumption and analyzed its role and real income in CO_2 emissions in low-income economies. Mukhtarov et al. (2022) measured renewable energy consumption as percentage of total final energy consumption and investigated the aftermath of financial progress on renewable energy consumption in Turkey. Adebayo, Kartal, et al. (2023) measured renewable energy use as % of total final energy consumption and studied its effects on environmental quality. L. Wu et al. (2023) calculated renewable energy consumption in units of exajoules and studied the role of renewable energy consumption and financial progression on the sustainability of environment for Nordic countries. Nuţă et al. (2024) utilized renewable energy consumption in their study as percentage of total energy consumption and explored its relationship with urbanization, environmental degradation, and economic growth. Simionescu (2024) measured renewable energy consumption as percentage of total final energy consumption and assessed its effects on pollution for V4 countries.

While most of the studies used renewable energy consumption inn units of (% of final energy consumption) and our study also uses the same unit, but no study has measured its effects on panel data of 143 countries and our study fills this gap in literature.

2.2.3 Urbanization:

McGee & York (2018) measured urbanization as percentage of individuals of a country living in an urban area and analyzed its association with CO_2 emissions in less developed economies of the world. Cetin et al. (2018) studied the relationship of urbanization and CO_2 emissions and measured urbanization as share of total population. Ahmed et al. (2019) measured urbanization in units of urban population as percentage of the total population and investigated its non-linear relationship with CO_2 emissions. Akorede & Afroz (2020) measured urbanization as percentage of total population and investigated its relationship with energy consumption, CO_2 emissions, and economic growth in Nigeria. Odugbesan & Rjoub (2020) used urban population as a proxy for urbanization and studied relationship between urbanization, CO_2 emissions, energy consumption, and economic growth for MINT countries. W. Z. Wang et al. (2021) used ratio of urban population to total population as a measure of urbanization and studied its impacts on CO_2 emissions for OECD countries. Musah et al. (2021) measured urbanization as percentage of total population and analyzed its link with carbon emissions in West Africa. B. Li & Haneklaus (2022a) used urban population as percentage of total population as a proxy for urbanization and investigated association between urbanization, trade openness, CO_2 emissions, clean energy consumption, and GDP in G7 countries. Nihayah et al. (2022) measured urbanization as percentage of people living in urban areas and analyzed its nexus with CO_2 emissions and economic activity in Indonesia. Tawfeeq (2023) measured urbanization as percentage of urban areas in a state and explored the impacts of urbanization, and energy use on CO_2 emissions for United States. C. C. Lee & Zhao (2023) used ratio of urban population to total population as a proxy for urbanization. Ramzan et al. (2024) measured urbanization in terms of urban population as percentage of total population and studied the influence of urbanization, geothermal energy, nuclear energy, and agriculture development on CO_2 emissions and ecological footprint. Xu et al. (2024a) used urban population in percentage as a proxy for urbanization and investigated its association with CO_2 emissions.

The above-mentioned studies measured the effects of renewable energy consumption on the environment for a specific geographic region, it would be interesting to have a holistic view covering the whole world and see how renewable energy consumption affects the environment. To fill this gap, our study uses 143 countries and provides a worldwide perspective on the effects of renewable energy consumption on the environment.

2.2.4 Trade Openness:

Fan & Hossain (2018) measured trade openness as sum of imports and exports as a percentage of GDP and studied its relationship with CO_2 emissions, technological innovation, and economic growth for China and India. Munir & Ameer (2018a) measured trade openness in units of trade as a percentage of GDP and investigated the effects of trade openness, urbanization, technology, and economic growth on the environment of emerging Asian economies. Mahmood et al. (2019) used sum of imports and exports of goods and services to the GDP of the economy as a proxy for trade openness and explored its association with CO_2 emissions in Tunisia. Afridi et al. (2019) measured trade openness in units of trade as percentage of GDP and analyzed the impact of trade openness, per capita income, and energy consumption on CO_2 emissions in SAARC region.

Rahman et al. (2020) measured trade openness as trade to GDP ratio and studied the impact of trade openness, CO_2 emissions, and population density on the economic growth of South Asian economies. Kwamena Tachie et al. (2020) measured trade openness as the sum of exports and imports ratio GDP od a country and measured its effects on the environmental pollution of EU-18 economies. Dauda et al. (2021) used exports plus imports to the GDP as a proxy for trade openness and explored the link between trade openness, CO_2 emissions, and innovation for nine African countries. A. G. Khan et al. (n.d.) used trade as a percentage of GDP and inspected the linkage of trade openness, energy usage, financial an economic development on carbon emissions for an emerging economy. Afesorgbor & Demena (2022) measured trade openness as sum of exports and imports divided by GDP and studied its association with environmental emissions. Salam & Xu (2022) measured trade openness as (total trade between China and country *x* divided by the total GDP of the country x) * 100 and analyzed its connection with the environment of 88 BRI countries. Wenlong et al. (2023) measured trade openness as sum of imports and exports divided by GDP and investigated the impacts of technological innovation, energy efficiency, trade openness, and institutional quality on greenhouse gas emissions. L. Abid et al. (2023a) measured trade openness as sum of exports and imports divided by GDP and examined the impacts of trade openness, economic growth, corruption, and energy consumption on CO_2 emissions in West Africa. Ghazouani & Maktouf (2024) used the ratio of the sum of imports and exports to GDP for each period as a proxy for trade openness and probed the impacts of trade openness, economic growth, and natural resources on CO_2 emissions for oil exporting economies. Suleman et al. (2024) measured trade openness as Trade/GDP and inspected the drivers of trade openness and their effects on CO_2 emissions for emerging countries.

Trade is increasing day by day and more and more countries from different continents are now involved in it. So, it would be interesting to know how it is affecting our environment. The previous studies considered a specific group of trading countries as a sample for study but our study considers the whole world and thus finds how trade affects the environment on a large scale.

2.2.5 Ecological footprint:

Destek et al. (2018) measured ecological footprint as a sum of forestlands, fishing grounds, grazing land, cropland, and carbon and built-up land footprints and analyzed the environmental

Kuznets curve in Europe union. Katircioglu et al. (2018) measured ecological footprint in units of global hectares of countries and tested the quality of ecological footprint because of tourism development. Solarin (2019) measured ecological footprint in terms of global hectares per capita and studied its convergence with carbon footprint per capita. Sabir & Gorus (2019) used the sum of crop land, fishing, grazing, forest, CO_2 emissions, and built-up crop land to measure ecological footprint and evaluated the effects of globalization on ecological footprint for South Asian economies. M. Ahmad et al. (2020) gauge ecological footprint in units of global hectares per capita and investigated the impacts of technological innovations, economic growth, and natural resources on ecological footprint. Ahmed et al. (2020) used Per capita ecological footprint of Consumption to measure ecological footprint and examined the impacts of human capital and urbanization on ecological footprint. Pata (2021a) quantified ecological footprint as global hectares per capita and examined the impacts of globalization, agriculture, renewable energy generation on carbon dioxide emissions and ecological footprint. Prince Nathaniel (n.d.) measured ecological footprint in units of global hectares per capita and scaled the influence of economic complexity on CO_2 emissions and ecological footprint for ASEAN countries. X. G. Wang et al. (2022) gauged ecological footprint as global hectare of land and investigated its drives in China. Kızılgöl & Öndes (2022) used global hectare of land as a measure of ecological footprint and evaluated the role of foreign direct investment, trade openness, economic growth, urbanization, natural resource rent, and renewable energy consumption on ecological footprint of OECD countries. R. Li et al. (2023a) measured ecological footprint in units of global hectares per capita and investigated whether renewable energy reduces per capita ecological footprint and per capita carbon emissions. Y. Khan et al. (2023) measured ecological footprint in units of global hectares per capita and scrutinized linkages among ecological footprint, energy consumption, and urbanization. Hasan et al. (2024) measured ecological footprint in global hectares per person and assessed the dynamics among ecological footprint, renewable energy, and oil consumption. Saqib et al. (2024a) used global hectares per person to gauge ecological footprint and explored how financial progress, energy use and environmental technologies affect green growth and ecological footprint.

The above-mentioned studies fall short in describing the effects of ecological footprint on environmental sustainability. These studies measured the effects of different variables on ecological footprint. Our study measures changes in CO_2 emissions due to changes in ecological footprint and this makes our study unique.

2.3 Connection of dependent and independent variables:

2.3.1 Environmental sustainability and Foreign direct investment

The main objective of FDI for developing economies is to enhance technological advancements by bridging the capital gaps (Kamal et al., 2023b). From a theoretical lens, there are two contesting views on the linkage of environmental sustainability and FDI for the host economies, i.e. the pollution halo and pollution heaven hypotheses. Walter & Ugelow (1979) gave the pollution heaven hypothesis which says that the advanced industrial economies relocate their high pollution-industries to the developing economies because the strict environmental regulations in the developed countries enhance the cost of production, so it’s feasible for them to transfer their high polluting industries to the developing nations where the environmental regulations are laxed and thus they save their cost of production, but, in turn, damage the environment. This process of transferring emissions from the countries having strict regulations to the countries with lenient regulations is known in the literature as the “carbon leakage effect” (Ertugrul et al., 2016). Contrary to the pollution heaven hypothesis, the pollution halo hypothesis states that FDI transmits more advanced technology and enhanced management practices that help in improving the environment in the FDI-receiving countries (Birdsall & Wheeler, 1993). Various studies have been carried out to investigate the impacts of FDI on the environment. Some of these studies are in the favor of pollution heaven hypothesis (Emre Caglar, 2020; Gorus & Aslan, 2019; Gyamfi et al., 2021; Sarkodie & Strezov, 2019; Terzi & Pata, 2020), while some studies provide support to pollution halo hypothesis (Ahmad & Du, 2017; Huang et al., 2017; Mert & Bölük, 2016; Rafindadi et al., 2018; Zhang & Zhou, 2016). So, there is no unanimous agreement regarding the role of FDI in the environment.

Bokpin (2017) investigated the outcome of FDI inflows on the environment by taking panel data of 24 years ranging from 1990-2013 for African countries and concluded that FDI causes the degradation of the environment. Wawrzyniak & Doryń (2020) showed a positive association between CO_2 emissions and FDI, by investigating panel data from 1995 to 2014 for 93 developing and emerging countries. Sarkodie et al. (2020) studied the effects of FDI on the environment in 47 sub-Saharan African economies by taking panel data from 1990-2017 and they showed that FDI enhances greenhouse gas emissions. Omri & Bel Hadj (2020) carried a study for twenty-three emerging countries by taking panel data ranging from 1996 to 2014 and by applying non-interactive regression, they disclosed that FDI deteriorates the environment. Tang et al. (2021) explored the nexus of FDI and environmental sustainability by applying the dynamic panel GMM technique on panel data of 114 countries and the results of the study show that FDI has a significant positive association with the degradation of the environment. Viglioni et al. (2024) studied the linkage of FDI and the environment for G20 countries through panel data ranging from 2001 to 2017 and they showed that FDI leads to an increase in carbon emissions, thus supporting the pollution heaven hypothesis.

On the contrary, M. Abid (2017) explored the association of FDI and the environment by taking panel data of EU and MEA countries from 1990-2011 and the results support the pollution halo hypothesis that FDI alleviates environmental sustainability. Mensah & Adom (2017) concluded through their study that FDI is negatively associated with CO_2 emissions, thus supporting the pollution halo hypothesis. Zakaria & Bibi (2019) examined the association of FDI and the environment in South Asia for panel data ranging from 1984 to 2015, they declared that FDI has curbing effect on carbon emissions and thus reduces the pollution. While some studies show the presence of both the pollution halo and pollution heaven hypotheses like Kivyiro & Arminen (2014) investigated a causal link between FDI and CO_2 emissions for six Sub-Saharan African countries and found that FDI decreases emissions in some countries while the opposite in others. Guo & Yin (2024) revealed that FDI inflows have opposing results, being beneficial during positive shocks and harmful during negative shocks. Keeping in view the above-mentioned studies, we can say that the relationship of foreign direct investment and environmental sustainability needs to be explored in more depth to reach a unanimous decision regarding the effects of FDI on environmental sustainability.

2.3.2 Renewable energy consumption and Environmental Sustainability

Different researchers have studied renewable energy consumption in different ways like, Bhat (2018) studied the interaction of CO_2 discharges, economic growth, and renewable energy consumption for BRICS nations from 1992 to 2016 and deduced that the consumption of renewable energy, reduces CO_2 emissions. The results depict that enhancing the consumption of renewable energy by 1%, results in a decrease of CO_2 emissions by 0.12%.Yao et al. (2019) built an index of renewable energy consumption rate for two longitudinal data sets ranging from 1990 to 2014 comprising of 17 developed and developing economies. They utilized first-generation techniques like DOLS and FMOLS to estimate parameters and declared that the relationship of renewable energy consumption and CO_2 discharges is significant but negative, a 10% hike in renewable energy consumption leads CO_2 emissions to fall by 1.6%. Jebli et al. (2020) investigated the relationship of CO_2 emissions, economic growth, renewable energy consumption, and value-added from 1990 to 2015 for 102 countries which were classified into 4 different income groups. They used generalized method of moments which indicated that renewable energy consumption decreases emissions for all countries except for the lower middle-income classified economies. Huang et al. (2021) explored the association of renewable energy consumption and CO_2 discharges by considering a sample of countries consuming renewable energy as a major energy source for the period of 2000-2015. They utilized GMM estimation technique and found a significant negative association between the two. A 1% escalation in the consumption of renewable energy declines CO_2 emissions by 0.5%. Ehigiamusoe & Dogan (2022b) explored the aftermath of renewable energy consumption and real income on carbon discharges for low-income economies. The results show that renewable energy abates carbon discharges while real income adds to emissions.

Apergis et al. (2023) studied the interplay of carbon dioxide emissions and consumption of both forms of energy i.e. renewable and non-renewable in Uzbekistan over the period ranging from 1985 to 2020. They used ARDL to estimate the association between the variables. The analysis shows that CO_2 discharges and renewable energy are inversely related. Adebayo et al. (2023) investigated the interplay of CO_2 discharges, renewable energy consumption, technological innovation, and natural resources for BRICS economies from 1990 to 2019. They utilized (CS-ARDL) technique to estimate long and short-run associations. The results depict that CO_2 discharges decrease with an escalation in the consumption of renewable energy. Yesbolova et al. (2024) evaluated the impacts of industrial production and consumption of renewable energy on CO_2 by taking panel data ranging from 2000 to 2020 for Turkic republics. They used panel data regression to analyze the data and came up with the result that renewable energy consumption abates carbon emissions. Mamkhezri & Khezri (2024) assessed the effects of renewable energy utilization and research and development on CO_2 discharges on panel data consisting of 54 countries and the period from 2003 to 2017. By using spatial fixed effects and a two-way time panel analysis, they disclosed that the consumption of renewable energy assists in lowering CO_2 discharges. They also stressed shifting to high-tech clean energy sources for a better and sustainable environment.

The above-mentioned studies show that renewable energy consumption reduces the emission of carbon dioxide and thus mitigates the issue, but all these studies fail to provide a holistic view of the world. Some countries have a greater percentage of renewable energy usage than others and it is intriguing to know the reduction in CO_2 by the combined influence of the countries utilizing renewable energy around the world. After all global warming is a problem not associated with a specific country or a region, it's a problem of the world. Our study fills this gap by analyzing the data of 143 countries.

2.3.3 Urbanization and environmental sustainability

The nexus of Urbanization and environmental sustainability has been investigated in different ways like, Wang et al. (2018) investigated the linkages between energy utilization, urbanization, economic development, and CO_2 discharges. They utilized a balanced panel dataset of 170 nations divided into groups based on the development stages of countries and for years ranging from 1980 to 2011. They tried to establish causality between the variables. They found long-term, two-way causality between CO_2 discharges and urbanization for lower-middle-income countries, unidirectional causality between urbanization and CO_2 for upper-middle-income and lower-income countries, short-run and one-way causation running from urbanization to CO_2 was found in high-income economies, and bidirectional but short-run causality between urbanization and CO_2 in low-income countries. Ali et al. (2019) studied the impacts of urbanization on CO_2 in Pakistan by taking time series data ranging from 1970 to 2014. They utilized Auto Regressive Distributed Lag (ARDL) for analyzing data. They found that urbanization enhances carbon emissions. They also found that there exists unidirectional and short-run causation from urbanization to CO_2 emissions. They advised the government to intervene and help people adopt green technologies and to educate people regarding the health of the environment. Muhammad et al. (2020) researched the impacts of international trade and urbanization on CO_2 emissions in 65 BRI countries from 2000 to 2016. Panel quantile regression was used to measure non-linear relationship and 2 SLS was used to handle the issue of endogeneity. They found an inverted U-shaped relation between CO_2 and urbanization in high-salaried nations.

Mehmood & Mansoor (2021) explored the association of CO_2 and urbanization for Pacific and East Asian countries from 1982 to 2014. For econometric analysis, ARDL was utilized. The results show that urbanization significantly decreases CO_2 emissions in Japan, China, Mongolia, and Hong Kong. On the contrary, urbanization increases CO_2 emissions in Singapore, South Korea, and Macao. Mignamissi & Djeufack (2022) examined the relationship between the intensity of CO_2 and urbanization in 48 African nations over the period of 1980-2016. They used augmented STIRPAT for econometric analysis. They disclosed that in Africa, urbanization enhances the discharges of CO_2. This effect is more significant in countries having lower initial emissions. They grouped countries according to their natural resources and found that urbanization is a cause of CO_2 releases in countries having fewer natural resources. Chen et al. (2023) investigated the effects of new urbanization on CO_2 discharges in China. The data consisted of 31 Chinese provinces with a base year of 2003. They disclosed that the increasing levels of new urbanization promote the emissions of carbon dioxide and spread it to neighboring provinces. Xu et al. (2024b) measured the non-linear impacts of urbanization routed on carbon dioxide discharges in eight most populous nations of the world from 1975-2020. By utilizing (FMOLS) and Dynamic Display Unrelated Regression (DSUR), they concluded that the percentage of small cities and urbanization have a positive relationship with emissions, but their squares have a negative relationship with CO_2 emissions which supports the inverted U-shape of EKC theory.

With the increase in urbanization, some regions show a fall in CO_2 discharges, and some show an increase in these emissions. This may be due to the prevailing policies regarding the expansion of urban areas, strict regulations may lead to low emissions while lenient or no regulations may cause urbanization to enhance CO_2 emissions. Overall, the trend shows that more and more people are now migrating to urban areas for better employment, health, and other services, and it would be of interest to know how this migration to urban areas and their expansion have affected our environment. Our study provides a holistic view of this relationship by analyzing data of 143 economies.

2.3.4 Trade openness and Environmental Sustainability

Munir & Ameer (2018b) investigated the repercussions of trade openness, technology, urbanization, and economic progress on the degradation of the environment for 11 Asian emerging economies over the period 1980-2014. By utilizing the augmented STIRPAT model, they showed that a U-shaped EKC hypothesis exists between SO_2 emissions and trade openness. This inverted shape indicates that the SO_2 emissions increase as trade increases and after some point SO_2 emissions decrease while trade keeps growing. Lv & Xu (2019) examined the heterogenous effects of urbanization and trade openness on CO_2 discharges for 55 middle-income economies from 1992-2012. STIRPAT model was used for analysis, and it shows that due to the greater time horizon, trade openness has conflicting impacts on carbon exhausts i.e. it abates carbon discharges in the short run and triggers these releases in the long run where a 1% hike in trade leads to 0.09% increase in CO_2 emissions. Mutascu & Sokic (2020) used wavelet tool to investigate the relation between trade openness and CO_2 discharges for EU countries. The data consisted of the years 1960-2014 to give a holistic view, considering both the pre- and post-union era. The results illustrate that CO_2 discharges, due to strong energy use, economic growth, and shocks, cause an increase in trade. In the long run, exports reduce pollution and imports enhance emissions in the medium term.

Musah et al. (2021) explored the link of trade openness and CO_2 effusions in D8 economies. The study utilized unbalanced panel data from 1990 to 2016. They used AMG, CCEMG, and DCCEMG estimators and the results depict that trade openness is positively linked with CO_2 emissions. Li & Haneklaus (2022) evaluated the linkages between trade openness, GDP, clean energy usage, urbanization, and CO_2 discharges for G7 economies over the period of 1979-2019. EKC was recognized by using ARDL. The results show that a 1% increment in trade leads to a 0.27% hike in carbon emissions per capita in the long run while in the short run, it leads to an increase of 1.51%. Abid et al. (2023) researched the aftermath of corruption, economic growth, energy consumption, and trade openness on CO_2 for selected countries of West Africa from 1980 to 2018. The outcome of the study depicts that in the long run, trade openness degrades the environment i.e. a 1% increase in trade openness brings a 0.1526% hike in CO_2 emissions, while in the short run it does not influence the quality of the environment. Pham & Nguyen (2024) used the Bayesian averaging technique to determine the ramifications of trade openness on the environment for 64 selected developing economies over the period of 2003–2017. They found no evidence of the positive association between CO_2 emissions and trade openness; however, they found a meager hint of the existence of the pollution heaven theory.

It is almost impossible for any country to exist without trade. Trade has expanded more than ever due to modern logistics and ease of communication. The world has become a market, and it will be quite useful to know how this trade is affecting the environment. Previous studies only considered a specific group of trading countries to study trade and environment, but our study uses a sample of 143 countries to give a broader view.

2.3.5 Ecological footprint and environmental sustainability

Katircioglu et al. (2018) used ecological footprint as a representative of environmental sustainability and studied the effects of tourism on it for top 10 tourist countries. By using panel random effects, they concluded that tourism and ecological footprint exhibit an inverted U relation i.e. environment first degrades with an increase in tourism, and after some point it becomes better with the increase in tourism. So, the study shows that the environment improves with the development in tourism for the top 10 tourist countries. Costa et al. (2019) measured ecological footprint as an indicator of sustainability in energy use for the Portuguese textile industry. It also includes the identification of sustainability measures to enhance the efficient use of energy while abating carbon emissions. The outcome reveals that 4890 global hectares was the total footprint for the year 2019 and more than 50% of it was associated with the energy sector. They concluded that utilizing energy in an efficient manner can lead to a lower ecological footprint and thus can make our environment better and more sustainable. Ansari et al. (2020) interrogated the influence of globalization, consumption of energy, and economic progress on the ecological footprint of the Gulf Cooperation Council in the scenario of the Environmental Kuznets Curve model over the period of 1991 to 2017. They used FMOLS and DOLS for analysis and found that the EKC hypothesis doesn't hold for GCC countries. Pata (2021b) performed causality tests and Fourier cointegration to measure the effects of globalization, generation of renewable energy, and farm activities on CO_2 and ecological footprint for BRIC economies for the period of 1971-2016. The results show that renewable energy restores the environment while globalization degrades the environment by expanding the ecological footprint. Moreover, the study also shows that there exists a unidirectional causality from globalization to ecological footprint.

Rüstemoğlu (2022) used logarithmic mean Divisia index and ecological footprint analysis to investigate the actors behind the degradation of the environment in Australia from 1990 to 2017.

The nexus of ecological footprint, population, and real income was considered for decoupling factor analysis. Decoupling between CO_2 and these determinants was also analyzed, as CO_2 is the main reason of increasing ecological footprint. The results show that the ecological sustainability of Australia decreased due to energy industries and deforestation. They found that population, income, and the severity of carbon are the factors responsible for increasing CO_2 emissions in Australia, while energy intensity abates these emissions. The abating power of energy intensity is not much and as a result, it is not able to have a significant impact on decreasing emissions. Li et al. (2023) explored the part of renewable energy consumption in abating per capita ecological footprint by analyzing three income groups from 130 countries over the period of 1992-2019. They used panel threshold regression for econometric analysis and came up with the results that there exists an inverse relation between ecological footprint and renewable energy consumption and this relationship is stronger in countries having low incomes. So, renewable energy is more effective in reducing environmental pressure in poor countries as compared to rich countries. Saqib et al. (2024b) studied the aftermath of financial growth, energy use, and eco-technologies on the ecological footprint in ten countries exhibiting highest ecological footprint over the period 1990-2019. The results show that green growth, eco-innovations, and renewable energy alleviate the environment, however, financial growth and the use of conventional energy deteriorate it. There exists a two-way causality between ecological footprint, green growth, energy use, and eco-innovations. A one-way causal association was found from financial growth to ecological footprint.

Most of the previous studies have used ecological footprint as a dependent variable to study the effects of various factors on it. It has largely been used as an indicator of environmental sustainability. Our study uses it as an independent variable and examines its effects on carbon emissions. Rise is ecological footprint means that human activities have increased, and this can be a potential source of carbon dioxide emissions.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Data and variables

3.1.1 Dependent variable

Environmental sustainability is the dependent variable of the study. Environmental sustainability is the preservation of ecosystem and natural resources for a better life. Different authors have measured it in different ways like Dam & Sarkodie (2023) measured it through inverted load capacity factor. Lei et al. (2023) measured it through total greenhouse gas emissions. Ibrahim & Alola (2020) measured it through total carbon emissions (Metric Tons per capita). However, in our study it has been measured in terms of Carbon Dioxide emissions (Kilo Tons) and the data have been taken from the World Bank. We measured environmental sustainability in terms of CO_2 emissions because carbon dioxide is the most destructive and most prevalent of the greenhouse gases.

3.1.2 Independent variables

Foreign direct investment, renewable energy consumption, urbanization, trade, and ecological footprint are the independent variables of the study. In simple terms, foreign direct investment can be described as cross-border investment. It has been gauged by numerous scholars like Ofori et al. (2023) measured it as net inflow (% GDP). Wencong et al. (2023) measured it in Million US dollars. Wang et al. (2023) measured it in net inflows (Bop, current USD). However, we have measured it in net inflows (Bop, current USD) by taking data from World Bank. Data then converted to million USD. The reason for measuring foreign direct investment in units of (Bop, current USD) is the easy availability of data from the world bank.

Renewable energy means energy from sources like hydro, wind, solar, and nuclear sources. It has been measured in different units like Wang et al. (2023) measured it as a % of total energy consumption by taking data from the World Bank. Adebayo et al. (2023) measured it as a percentage of total energy consumption. Wei et al. (2023) measured it as a percentage of total energy consumption. We measured it in the same units of percentage of total energy consumption by taking data from the World Bank. We measured renewable energy consumption as percentage of total energy consumption because it is easy to compare it with the use of conventional energy and draw better conclusions.

The process of growing cities is known as urbanization. It has been measured in different ways like Warsame et al. (2023) measured it as the Percent of urban population to the total population. Liang et al. (2019) measured it as population density 10,000 people per square kilometer. Esily et al. (2023) measured it as Percent of urban population to the total population. However, in our study it has been measured in terms of total urban population and then converted to millions. The data have been taken from the World Bank. Using total urban population as a unit for urbanization better explains the increasing or decreasing trend in urbanization and that's why we selected it in these units.

Trade Openness can be explained as imports and exports of various goods and services. It has been measured in different ways like Dai & Du (2023) measured it as International Trade Diversification Index. Dam & Sarkodie (2023) measured it as a percentage of GDP. Wang et al. (2023) measured it as a sum of import and export divided by GDP and in percentage terms. However, we have measured it in terms of sum of export and import as percentage of GDP by taking data from World Bank. The reason for selecting trade as percentage of GDP to measure trade openness is the use of the same unit in most of the previous studies.

In simple terms ecological footprint can be defined as a measure of dependency of humans on natural resources. Different researchers have measured it different was like Bozatli & Akca, (2023) measured it in consumption per capita terms. Jie et al. (2023) also measured it in consumption per capita. Zhang & Chen (2023) measured it in global hectares. However, we measured it in terms of global hectares per person/capita by taking data from global footprint network. We used global hectares per person for measuring ecological footprint because of the easy availability of data.

3.1.3 Control variables

Economic growth, population growth, and labor force participation rate are the control variables of the study. Economic growth refers to an increase in the wealth or income of a nation through the production of goods and services. It has been measured in different ways like Rao & Yan (2020) measured economic growth as GDP per capita. Ascencio et al. (2024) also measured economic growth in terms of GDP per capita. T. Wu et al. (2024) measured economic growth in terms of GDP growth (%). However, we have gauged economic growth in terms of GDP growth (annual %). We did it because it is easy to monitor the change in GDP over time.

Population growth is the increase in the number of persons inhibiting a particular geographic area within a set frame of time. It is commonly measured as a percentage increase in the given population over a year. It has been studied in different ways like Agu (2024) studied it in the units of population growth (annual %). Ajayi (2023) measured population growth in terms of percentage (%). Derouez & Ifa (2024) studied population growth as population growth (annual %). Previous studies have used a common unit of population growth (annual %), and that's why we also used this unit in our study.

The labor force participation rate shows the percentage of the people in a population (usually people 15 years old or above) who are either employed or seeking employment. Different researchers have studied it in different ways like McCann (2024) studied it as total of male and female percentage of persons between the ages of 20 and 64 years. Irawan & Khoirudin (2024) measured labor force participation rate in thousands of people who are in the labor force. Emeka et al. (2024) studied labor force participation rate in terms of percentage of total population between 15 and 64 years of age. However, in this study we have measured labor force participation rate as a % of total population (ages between 15 and 64 years). Table 3.1 provides the explanation of the variables.

Table 3.1: List of variables

Variable names	Acronyms	Units	Source
Environmental Sustainability	ES	CO_2 Emissions (Kilo Tons)	World Bank
Foreign Direct Investment	FDI	Net Inflows (Bop, current USD)	World Bank
Renewable Energy Consumption	REC	% of total energy consumption	World Bank
Urbanization	UB	Total urban population	World Bank
Trade Openness	TRO	Trade as % of GDP	World Bank
Ecological Footprint	EF	Global hectares per person	Global Footprint Network
Economic Growth	EG	GDP growth (annual %)	World Bank
Population Growth	PG	population growth (annual %).	World Bank
Labor Force Participation Rate	LFPR	% of total population (ages 15-64)	World Bank

3.2 Sample Selection, Data Collection and Limitations

Secondary panel data of the variables have been collated from 143 countries across the globe for 20 years, from 2001 to 2020. The data have been collected from the World bank and Global footprint network databases. Limitations include unavailability of data for recent years and limited time to complete the study.

3.3 Theoretical Model of the Study

The following theoretical model has been developed based on the selection of the variables of interest.

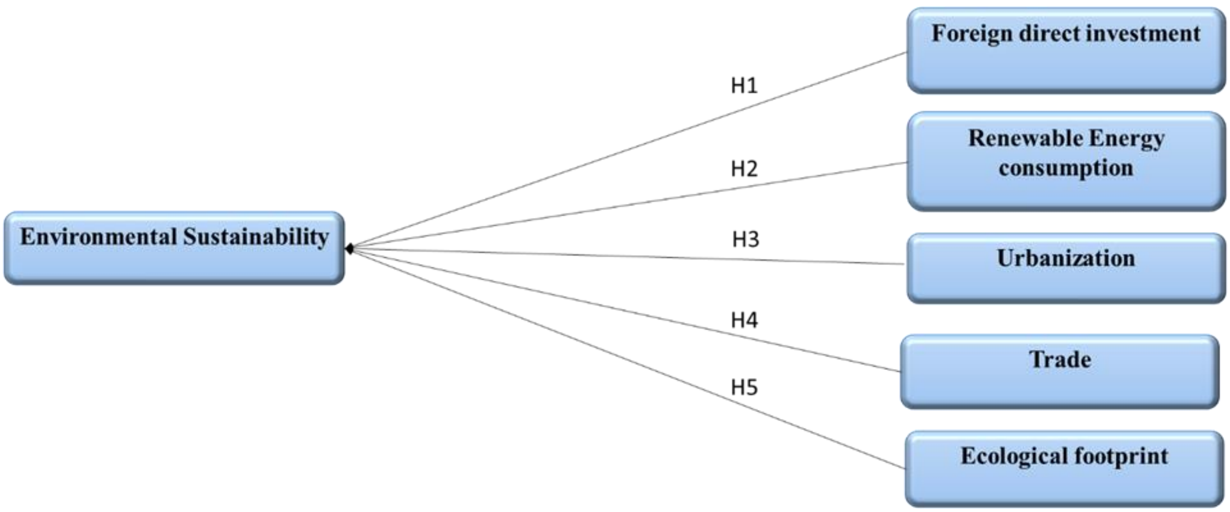

Figure 3.1: Theoretical model

3.4 Research Hypothesis

The study suggests following hypotheses:

1. H1: Foreign Direct Investment
    - Null Hypothesis (H0): Foreign direct investment does not affect environmental sustainability.
    - Alternative Hypothesis (H1): Foreign direct investment affects environmental sustainability.
2. H2: Renewable Energy Consumption
    - Null Hypothesis (H0): Renewable Energy Consumption does not affect environmental sustainability.
    - Alternative Hypothesis (H1): Renewable Energy Consumption affects environmental sustainability.
3. H3: Urbanization
    - Null Hypothesis (H0): Urbanization does not affect environmental sustainability.
    - Alternative Hypothesis (H1): Urbanization affects environmental sustainability.
4. H4: Trade Openness
    - Null Hypothesis (H0): Trade Openness does not affect environmental sustainability.
    - Alternative Hypothesis (H1): Trade Openness affects environmental sustainability.

5. H5: Ecological footprint
    - Null Hypothesis (H0): Ecological footprint does not affect environmental sustainability.
    - Alternative Hypothesis (H1): Ecological footprint affects environmental sustainability.

3.5 Empirical Models of the Study

3.5.1 Base model

$$ES_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 REC_{it} + \beta_3 UB_{it} + \beta_4 TRO_{it} + \beta_5 EF_{it} + \mu_{it} \qquad (1)$$

3.5.2 Extended model

$$ES_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 REC_{it} + \beta_3 UB_{it} + \beta_4 TRO_{it} + \beta_5 EF_{it} + \beta_6 EG_{it} + \beta_7 PG_{it} + \beta_8 LFPR_{it} + \mu_{it} \qquad (2)$$

ES stands for Environmental Sustainability.

FDI stands for Foreign Direct Investment.

REC stands for Renewable Energy Consumption.

UB stands for Urbanization.

TRO stands for Trade openness.

EF stands for Ecological Footprint.

EG stands for Economic Growth.

PG stands for Population Growth.

LFPR stands for Labor Force Participation rate.

3.6 Descriptive Statistics

Table 3.2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ES	2860	204873.72	848185.07	61.6	10944686
FDI	2860	11309.934	41544.394	-330338.47	733826.5
REC	2860	32.479	29.068	0	98.34
UP	2860	23.762	71.142	.02	866.81
TR	2860	82.252	45.363	10.95	437.33
EF	2860	3.465	3.201	.45	43.67
EG	2860	3.272	5.188	-50.34	86.83
PG	2860	1.334	1.336	-5.28	11.79
LFP	2860	66.06	10.298	37.75	89.45

Table 3.2 provides the descriptive statistics of the values of the variables. Each variable in the dataset has 2860 values/observations. Mean gives the average value of all the observations of a variable. The mean value of ES is 204873.72 Kilotons, it means that on an average the sample countries released 204873.72 Kilotons of CO_2 in the atmosphere during a period from 2001 to 2020. The mean value of foreign direct investment (FDI) is 11309.934 million USD, indicating that the sample countries received 11309.934 million USD as net inflows from 2001 to 2020. The average value of renewable energy consumption (REC) is 32.479%, showing that the sample countries met 32.479% of their energy demand from renewable energy sources. The mean value of urbanization is 23.762 million, indicating that the average urban population of the selected countries was 23.762 million during 2001 and 2020. The mean value of trade openness (TRO) is 82.252, means that the average value of trade of the sample countries from 2001 to 2020 is 82.252 as percentage of their GDP. The mean value of ecological footprint (EF) is 3.465 global hectares per person, indicating that on an average a person from the sample countries has ecological footprint of 3.465 global hectares during 2001 and 2020. The mean value of economic growth (EG) is 3.272%, meaning that on average the economy of the sample countries has a growth rate of 3.272% during 2001 and 2020. The mean value of population growth (PG) is 1.334, showing that there is a 1.334% growth in population from 2001 to 20202. The labor force participation rate (LFPR) is 66.06, showing that on average the sample countries have labor force participation rate around 66.06%.

Standard deviation represents the spread or dispersion of individual values of variables around its mean value. A higher standard deviation represents greater spread of the data. The standard deviation of ES is 848185.07 Kilotons, indicating a significant variability in carbon dioxide emissions across the observations. It shows that some countries emit much more or much less carbon dioxide than others. Many factors influence this variability including energy demand, industrial activity, and environmental regulations. The standard deviation of foreign direct investment (FDI) is 41544.394 million USD, showing that considerable dispersion exists in foreign direct investment across the countries. It implies that some countries receive larger or lesser amounts of investments as compared to other countries. Factors influencing the amount of investment include economic policies, political stability, and overall attractiveness of the country's markets. The standard deviation of renewable energy consumption (REC) 29.068, implies some spread in the use of renewable energy relative to total energy consumption across the countries. It indicates that some countries depend more heavily on renewable sources for energy demand than others. Factors behind this spread include government policies, technological advancements, natural resource endowments, and energy infrastructure investments. The standard deviation of urbanization (UB), 71.142 million indicates spread of urban population across the sample countries, suggesting that some countries have larger or smaller urban population than others. Migration pattern, economic opportunities, and infrastructure influence urban population. The standard deviation of trade openness (TRO) indicates the spread of trade intensity across the sample countries, value of 45.363 indicates that some countries have much higher or lower trade than others. Possible reasons include competitive advantage, international trade policies, and market openness. The standard deviation of ecological footprint 3.201 suggests small variability in ecological footprints across the countries. It indicates that some countries have greater or smaller ecological footprints than others. Many factors influence ecological footprint including environmental awareness, resource use efficiency, conservation efforts, and consumption patterns. The standard deviation of economic growth (EG) 5.188, outlines variability in economic growth rates across the sample. It indicates that some countries experience more significant fluctuations in GDP than others. Factors affecting this spread include economic policies, investment and saving levels, external shocks, and technological advancements. The standard deviation of population growth (PG) 1.336, suggests a small spread in population growth rates across the countries. It indicates that some countries exhibit faster or slower population growth than other countries. Factors causing this dispersion include birth and death rates, migration flows, demographic trends, healthcare access. The standard deviation of labor force participation (LFPR) 10.298 shows dispersion in labor force participation rates across the sample countries. It implies that some countries have higher or lower rates of labor force engagement than others. Factors causing this spread may include demographics, government policies, labor market conditions, social norms, and education levels.

Maximum and minimum values indicate the range of the values of a variable. ES haA values ranging from 61.6 Kilotons to 10944686 Kilotons. Foreign direct investment has a minimum value of -330338.47 million USD and a maximum value of 733826.5 million USD, indicating a significant disparity in the size of investments. Renewable energy consumption (REC) ranges from 0% to 98.34%, showing that some countries don’t utilize renewable energy at all, and some countries meet 98.34% of their energy demands from renewable energy. Urbanization (UB) has values between 0.02 million to 866.81 million, indicating that large disparity exists between the countries in terms of the urban population. Trade openness (TRO) has values ranging from 10.95 million USD to 437.33 million USD, indicating that some countries have larger share of trade in their GDP while others have less. Ecological footprint (EF) has minimum value of .45 global hectares per person, indicating that some countries care about their environment, and a maximum value of 43.67 global hectares per person indicating that some countries are ignorant of sustainability. Economic growth (EG) has values ranging from -50.34% to 86.83%, showing that some countries have bad economies than others. Population growth ranges from -5.28% to 11.79%, showing that some countries have mortality rates greater than birth rates. The Labor force participation rate (LFPR) has values between 37.75% to 89.45%, implying that in some countries there is more trend of finding jobs than others.

3.7 Pairwise correlation

Table 3.3: Pairwise correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) ES	1.000								
(2) FDI	0.601	1.000							
(3) REC	-0.159	-0.184	1.000						
(4) UP	0.899	0.492	-0.118	1.000					
(5) TR	0.159	-0.001	-0.305	-0.210	1.000				
(6) EF	0.096	0.181	-0.289	-0.006	0.233	1.000			
(7) EG	0.040	-0.005	0.089	0.057	0.065	-0.069	1.000		
(8) PG	-0.105	-0.117	0.378	-0.088	-0.115	-0.162	0.147	1.000	
(9) LFP	0.106	0.170	0.091	0.054	0.097	0.345	-0.033	-0.136	1.000

Table 3.3 gives the results of pairwise correlation. Pairwise correlations provide the strength of association of variables in a dataset. Each value in the table represents the correlation coefficient of the respective pair of variables. The correlation coefficient of 0.601 represents moderately strong positive association between carbon dioxide emissions and foreign direct investment. This shows that higher levels of foreign direct investments are associated with high levels of carbon dioxide emissions. The correlation coefficient of -0.159 indicates a weak negative association between carbon dioxide emissions and renewable energy consumption. This shows that higher levels of renewable energy consumption are associated with a slight decrease in carbon dioxide emissions. The correlation coefficient of 0.899 shows a very strong positive correlation between

carbon dioxide emissions and urbanization, suggesting that higher levels of urban population are linked with higher levels of carbon dioxide emissions. The correlation coefficient of 0.159 shows a weak positive association between carbon dioxide emissions and trade openness, suggesting that higher levels of trade are associated with somehow decrease in carbon emissions. The correlation coefficient of 0.096 shows a positive but very weak association between ecological footprint and carbon dioxide emissions. It indicates that higher values of ecological footprint are associated with smaller values of carbon dioxide emissions. The correlation coefficient of 0.040 shows a very weak but positive association between carbon dioxide emissions and economic growth, suggesting a slight tendency for higher economic growth to be linked with higher carbon dioxide emissions. The correlation coefficient of -0.105 shows a very weak and negative association between population growth and carbon dioxide emissions, indicating that higher rates of population growth are linked with slightly lower carbon dioxide emissions. The correlation coefficient of 0.106 shows weak but positive association between labor force participation rate and carbon dioxide emissions, suggesting that higher levels of labor force participation rate are linked with slightly high values of carbon dioxide emissions.

3.8 Econometric Methodology

The study uses different econometric techniques to analyze the data. Firstly, it calculates descriptive statistics. Then, it measures the strength of association of the variables using pairwise correlation. After assessing multicollinearity through Variance Inflation Factor (VIF), it checks the presence of cross-sectional dependency by using the Pesaran cross-sectional dependency test. After confirming the presence of slope heterogeneity by using two tests including Pesaran, Yamagata. 2008 and Blomquist, Westerlund. 2013. The presence of slope heterogeneity and cross-sectional dependency suggests the use of second-generation unit root tests including CADF and CIPS. For cointegration, it uses Westerlund cointegration test. Finally, for the estimation of parameters, it uses System GMM as a primary econometric tool. *Figure 3.2* gives the layout of methodology.

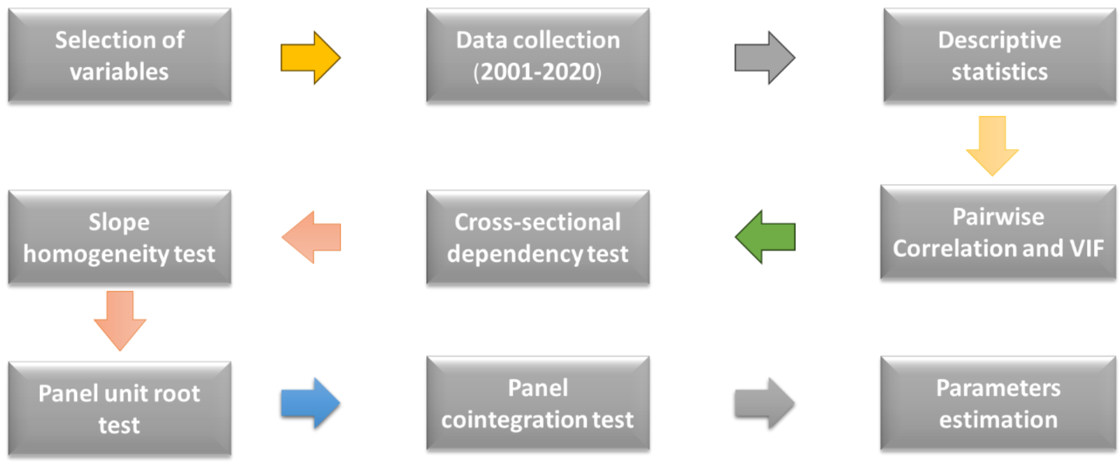

Figure 3.2: Methodology.

3.8.1 Cross-sectional dependency test

To detect cross-sectional dependency in the dataset, the study utilizes cross-sectional test developed by Pesaran (2021). If cross-sectional dependency is not detected, it can lead to biased estimations. The null hypothesis of the test is that there is no cross-sectional dependence in the dataset. Test statistics is as following:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \quad (3)$$

3.8.2 Slope homogeneity test

The slope homogeneity test is commonly used in the analysis of panel data to assure that parameter estimates are reliable. Due to the differences in the structures of different cross sections like their economy, demography, and financial affairs, there is a high probability of detecting slope heterogeneity (Wang et al., 2023) To detect slope heterogeneity in the dataset, the study utilizes slope heterogeneity test developed by (Pesaran & Yamagata, 2008), the equation of which is following:

$$\tilde{\Delta}_{SH} = (N)^{\frac{1}{2}}(2K)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - K\right) \quad (4)$$

$$\tilde{\Delta}_{ASH} = (N)^{\frac{1}{2}}\left(\frac{2K(T-K-1)}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - 2K\right) \quad (5)$$

The null hypothesis of the test states that slope-coefficients are homogenous, which can be expressed in the form of equation as:

$$H0: \beta_i = \beta \; for \; all \; i \qquad (6)$$

$$HA: \beta_i = \beta_i \neq \beta_j \; for \; i \neq j \qquad (7)$$

3.8.3 Panel unit-root test

To detect the presence of unit root in the dataset, the study utilizes second generation unit root tests including cross-sectionally Augmented Dickey-Fuller (CADF) and the cross-sectionally Augmented Im, Pesaran, and Shin (CIPS) developed by (Pesaran, 2007). The equation for CADF test is as follows:

$$\Delta yit = \alpha i + \beta i \, yit - 1 + \gamma i \, yit - 1 + \theta i \, \Delta yt + \varepsilon it \qquad (8)$$

After getting the results of CADF, the study uses these results to find CIPS statistics, the equation of which is following:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \qquad (9)$$

3.8.4 Panel cointegration test

The study utilizes Westerlund panel cointegration test established by (Westerlund, 2007), to determine long term connection among the variables of the study. This second-generation panel cointegration test was selected because it produces reliable and consistent results even in the presence of slope heterogeneity and cross-sectional dependency. To avoid spurious regression, it is essential that long term linkages must exist among the variables (Wang et al., 2023). The expression for Westerlund cointegration is as follows:

$$\Delta Y_t = \delta_i' d_t + \alpha_i \, Y_{it-1} + \sigma_i' \, X_{it-1} + \sum_{j=i}^{\rho_i} \alpha_{ij} \, \Delta Y_{it-1} + \sum_{j=-qt}^{\rho_i} \gamma_{ij} \, \Delta X_{it-1} + \mu_{it} \qquad (10)$$

3.8.5 Parameters Estimation

For the estimation of parameters, it is common to use pooled ordinary least squares (OLS), but it leads to biased parameter estimation due to the endogeneity and unobserved panel fixed effects of the panel dataset. In practice, endogeneity occurs if there is a correlation between the error term and one or more independent variables. The main causes of endogeneity include measurement error and omitted variable bias. To overcome these issues with the analysis of panel data (Arellano & Bond, 1991) established generalized method of moments (GMM) that solves the endogeneity issue by using the lag of dependent variable as an instrument. GMM is considered analogous to maximum likelihood method (ML) for the estimation of coefficients but, instead of establishing assumptions about the entire distribution, it makes assumptions regarding certain moments of random variables, making GMM more robust than ML. These assumptions are known as moment conditions (Ajayi, 2023).

There are certain advantages of using GMM, first being, it considers the endogeneity issues, secondly, it is a dynamic model suitable for a large number of observations, and thirdly, it is designed for panels having the issues of autocorrelation and heteroscedasticity (Blundell & Bond, 2023).

There are two types of GMM, the system GMM (Blundell & Bond, 2023) and difference GMM (Arellano & Bond, 1991). Both control the issue of endogeneity. The difference GMM alters all the independent variables and removes the fixed effects by taking their first difference. The system GMM controls for endogeneity by using more instruments and then alters them by making these instruments uncorrelated with fixed effects (Ajayi, 2023) Given the advantages of system GMM, this study utilizes it as a main model for parameters estimation. The study also utilizes Sargan test to determine the validity of instruments.

CHAPTER 4: RESULTS

Table 4.1 shows the results of the Variance Inflation Factor (VIF), an econometric technique to detect multicollinearity between independent variables of the model. Each row in the above table represents an independent variable of our model, while the columns show the VIF and its reciprocal (1/VIF). The VIF values depict the extent of multicollinearity for each variable, higher values depict stronger multicollinearity. Overall, the table provides crucial insights of the strength of multicollinearity present in the econometric model. The "Mean VIF" of 1.31 shows the absence of multicollinearity among the independent variables (FDI, REC, UP, TRO, EF).

Table 4.1: Variance Inflation Factor

	VIF	1/VIF
REC	1.498	0.667
UB	1.448	0.69
FDI	1.417	0.706
EF	1.326	0.754
LFPR	1.266	0.79
TRO	1.248	0.801
PG	1.227	0.815
EG	1.049	0.953
Mean VIF	1.31	.

Table 4.2:Pesaran Cross-Sectional Dependency Test

Variable	CD-test	p-value
ES	76.431	0.00
FDI	95.67	0.00
REC	3.899	0.00
UB	294.382	0.00
TRO	54.259	0.00
EF	28.025	0.00
EG	172.556	0.00
PG	16.455	0.00
LFPR	21.642	0.00

Table 4.2 shows the result of the Pesaran cross-sectional dependency (CSD) test. This test determines cross-sectional dependency among the values of the dataset. Cross-sectional dependency is the interdependence among different cross-sectional units (countries) in a panel

dataset. The variable column shows the variables of our model for which we conducted the CSD test. The CSD-test column gives the values of the test statistic obtained from the test. It measures the extent of cross-sectional dependency for each variable. The P-value column shows the probability value in relation to the respective test statistic. It gives the probability of observing the test statistic.

The value of the CSD test for the variable "ES" is 76.431, having a p-value of 0. This shows a significant level of cross-sectional dependency among the values of CO_2 emissions. Similarly, for the other variables, the test statistics are quite high, from 3.899 to 294.382, and all have p-values of 0, rejecting the null hypothesis of no cross-sectional dependency. This is evidence of cross-sectional dependency among the different countries that this study includes.

Table 4.3 presents the results of slope homogeneity tests carried out using two different techniques: Blomquist and Westerlund (2013) and Pesaran and Yamagata (2008). The column Delta shows the estimated difference (Delta) in slopes between different countries. The p-value column displays the probability of observing the potential difference in the slopes if the null hypothesis of slope homogeneity is true. p-value of 0 provides evidence against the null hypothesis, showing that the slopes are not homogeneous, thereby rejecting the null hypothesis of homogeneous slopes.

Table 4.4 shows the results of unit root tests carried out using two different methods: CIPS (Cross-Sectionally Augmented Im-Pesaran-Shin) test and CADF (Cross-Sectionally Augmented Dickey-Fuller) test. Both tests are second-generation unit root tests as our data have cross-sectional dependency and slope heterogeneity. 1(0) and 1(1) indicate test values at level and first difference respectively. According to the results, all the variables are stationary at either level or at first difference. So, we reject the null hypothesis of the presence of unit root. It means that the statistical properties remain constant over time, making it easy to analyze the data and get unbiased estimators.

Table 4.3:Slope Homogeneity Tests

	Pesaran, Yamagata. 2008		Blomquist, Westerlund. 2013	
	Delta	p-value	Delta	p-value
	-2.529	0.011	12.373	0.000
adj.	-3.577	0.000	17.498	0.000

Table 4.5 presents the Westerlund panel cointegration test. The negative value of the statistic (-3.5444) provides evidence against the null hypothesis of no cointegration. The small probability value (0.0002) less than 0.005 also indicates strong evidence against the null hypothesis of no cointegration. Therefore, it is concluded that environmental sustainability, foreign direct investment, renewable energy consumption, urbanization, trade openness, and ecological footprint are cointegrated in the long run despite having short-run fluctuations.

Table 4.4:Unit Root Tests

Variables	CIPS		CADF	
	1(0)	1(1)	1(0)	1(1)
ES	-2.003	-3.837*	-1.794*	----------
FDI	-2.58*	----------	-1.884	-3.139*
REC	-1.534	-3.786*	-1.432	-2.488*
UB	-1.345	-2.252*	-1.664	-2.013*
TR	-1.32	-3.398*	-1.442	-2.635*
EF	-2.193*	----------	-1.769	-2.94*
EG	-2.886*	----------	-2.276	----------
PG	-1.645	-2.635*	-1.962	-2.732*
LFPR	-1.145	-3.002*	-1.356	-2.117*

Note: * and ** represent 1% and 5% significance level respectively.

Table 4.5: Panel Cointegration Test

	Statistic	p-value
Variance ratio	-3.5444	0.0002

Table 4.6:Regressions

Variables	(1) ES	(2) ES	(3) ES	(4) ES	(5) ES
FDI	0.253***	0.250***	0.177**	0.250***	0.0594***
	(0.0727)	(0.0727)	(0.0699)	(0.0727)	(0.000183)
REC	241.5	188.1	458.3	188.1	-3,341***
	(406.1)	(416.5)	(446.6)	(416.5)	(15.38)
UB	14,876***	14,904***	15,851***	14,904***	1,640***
	(153.2)	(153.6)	(161.7)	(153.6)	(0.824)
TRO	179.2	121.2	15.31	121.2	453.4***
	(134.7)	(138.6)	(137.1)	(138.6)	(2.510)
EF	19,518***	18,724***	17,418***	18,724***	2,962***
	(2,410)	(2,443)	(2,444)	(2,443)	(87.16)
L.ES					0.864***
					(5.70e-05)
Constant	-241,679***	-261,690***	-304,768***	-261,690***	
	(32,977)	(61,065)	(56,792)	(61,065)	
Sargan					0.999
AR (2)					0.1847

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 4.6 presents the results of various regressions that we have utilized to estimate the coefficients of the variables. This study uses four different regressions to estimate the coefficients, namely multiple linear regression, fixed effects, random effects, and System GMM.

Column (1) presents the results of pooled OLS of dependent and independent variables but excludes control variables. According to this,

FDI and ES are positively associated with each other, meaning that FDI deteriorates the environment. For every 1 million dollars increase in FDI, CO_2 emissions increase by 0.253 kilo tons. The low standard error (0.0727) indicates a high level of accuracy in this estimation. Coefficient for REC is 241.5 having a high standard error of 406.1 and p-value exceeding 10%, showing that REC doesn't have any significant relation with ES. So, we can't interpret the relation of REC and ES confidently. The coefficient for urban population (UP) is 14,876 and the standard error associated with this is 153.2. UB and ES are positively linked to each other, more urban population means more deterioration of the environment. The coefficient is statistically significant at 1% and indicates that for 1 million rise in the urban population, CO2 emissions increases by 14,876 kilo tons. The low standard error indicates a high level of precision in this estimate. The slope coefficient for trade openness (TRO) is 179.2 having a standard error of 134.7 and p-value greater than 10%, indicating that TRO is not significant, and we can't confidently interpret its relationship with environmental sustainability. EF and ES are directly related to each other, and the coefficient of EF is statistically significant at 1%. For every 1 global hectare increase in EF, the CO_2 emissions increase by 19,518 kilo tons, making increase in ecological footprint a threat to environmental sustainability. The low standard error (2,410) demonstrates a high level of precision and accuracy in this estimation.

Column (2) represents the results of pooled OLS of dependent and independent variables including control variables. According to this,

The slope coefficient for foreign direct investment (FDI) is 0.250 and it is statistically significant at the 1% level of significance. This provides strong evidence that FDI has a positive and statistically significant effect on ES. Every 1-million-dollar hike in FDI brings 0.250 kilo tones of CO_2 emissions. The standard error of 0.0727 provides the precision of the estimate. These results for FDI are quite similar to that of the pooled OLS without control variables. The slope coefficient for renewable energy consumption (REC) is 188.1 and has a p-value greater than 10%. This greater p-value shows that REC is not statistically significant and therefore, it is not possible to infer any meaningful connection between RES and ES. The standard error associated with the coefficient of REC is 416.5. The slope coefficient for urbanization (UB) is 14,904 and it is statistically significant at the 1% significance level, giving strong evidence that the UB has a positive and statistically significant effect on ES. A 1 million rise in urban population brings an increase of 14,904 kilo tons of CO_2 emissions, making the environment polluted and unsustainable. The values for slope coefficient and standard error calculated for UB through multiple linear regression with control variables are similar to those of linear regression without control variables. The slope coefficient for Trade openness is 121.2 and p-value greater than 10%, showing that TRO doesn't have a significant relationship with ES and therefore, it is not possible to interpret the results in a meaningful way. Ecological footprint (EF) and Environmental Sustainability (ES) are positively and significantly associated with each other at 1% level of significance. An increase of 1 global hectare per capita rise in ecological footprint leads to 18724 kilo tons hike in CO_2 emissions thus, deteriorating the environment.

The results of pooled OLS with and without control variables are almost similar as REC and TRO are non-significant in both regressions also the values of coefficients and their standard errors don't differ to a greater extent. Pooled OLS with or without control variables does not consider the potential problems associated with the analysis of panel data, problems like cross sectional dependency, slope homogeneity, endogeneity are ignored by multiple linear regression thus making the results biased and faulty.

Further we used two static panel models to analyze the data, column (3) presents the results of fixed effects model and according to this model:

The slope Coefficient for FDI is 0.177 and Standard Error is 0.0699. FDI is positively associated with ES. For a 1 million USD increase in FDI, CO_2 emissions increase by approximately 0.177 kilo tons. The slope coefficient for FDI is significant at 5% level (**), showing that the relationship between FDI and ES is statistically significant. REC doesn't have a significant relationship with ES, as the p-value associated with it is greater than 10% and that's why it is not feasible to interpret its coefficient. The slope Coefficient for UB is 15,851 and has a standard error of 161.7. The relationship of UB and ES is significant at 1% level of significance. For a 1 million rise in urban population, CO_2 emissions increase by 15,851 kilo tons. The slope Coefficient for TRO is 15.31 and has a standard error of 137.1. It is not significant at 1%, 5% or 10% significance level and that's why it is not possible to interpret it in a meaningful way. The slope coefficient of ecological footprint (EF) is 17,418 having a standard error of 2,444. The relationship between EF and ES is significant at 1% level of significance and thus has a strong relationship. EF has a positive connection with ES. For 1 global hectare per person increase in EF, CO_2 increases by 17,418 kilo tons.

After that we analyzed the data using the random effects model and according to this model:

The slope coefficient for FDI is 0.250 and has a low standard error of 0.0727. Its relationship with ES is significant at 1% significance level. It shows that for a 1 million USD increase in FDI, CO_2 emissions increase by 0.250 kilo tons. The relationship between ES and REC is non-significant based on the commonly used levels of significance (such as 1%, 5%, or 10%). And the high standard error of 416.5 as compared to the slope coefficient of 188.1 shows relatively low accuracy and precision in determining the effects of REC on ES. Urbanization (UB) has a slope coefficient of 14,904. UB shows a significant and positive relationship with ES. Their relationship is significant at 1% level of significance, indicating a strong relationship. A 1 million hike in urban population leads to an increase of 14,904 kilo tons of CO_2 emissions. The low value of standard error (153.6) for this coefficient indicates the precision of the estimate. 121.2 is the slope coefficient for Trade Openness (TRO) and it is not significant at 1%, 5%, or 10% levels of significance. So, the relationship of TRO and ES is not significant, and it cannot be interpreted in a meaningful way. Its high standard error of 138.6 also shows that this estimation is not accurate. Ecological footprint (EF) has slope coefficient of 18,724. It has a significant and positive relationship with ES. A rise of 1 global hectare per person in EF is associated with an increase of 18,724 kilo tons of CO_2 emissions. Low standard error of 2,443 for EF also demonstrates that the estimation is precise and accurate.

The results of fixed and random effect models are not accurate as some of the variables are non-significant.

To get reliable estimations, the study uses the Two System GMM for dynamic panel estimation as the main regression analysis to measure the effects of foreign direct investment, urbanization, renewable energy consumption, trade openness, and ecological footprint on environmental sustainability. Column (5) presents the coefficients of the variables that are acquired by using System GMM, according to this:

FDI and ES are positively correlated with each other. The slope coefficient for FDI is 0.0594 and it is significant at 1% significance level (***), indicating a strong relationship with ES. For every 1 million USD increase in FDI, CO_2 emissions rise by 0.0594 kilotons. Renewable Energy Consumption (REC) is negatively associated with ES. It means that with the increase in REC, CO_2 emissions decrease. The slope coefficient for REC is -3,341 and it is significant at 1% significance level. An increase of 1% in REC brings a reduction of about 3,341 kilotons of CO_2 emissions. The slope coefficient for urbanization (UB) is 1,640, indicating a positive relationship with ES. Their relationship is significant at 1%. This indicates that for every 1 million escalation in urbanization, CO_2 emissions increase by 1,640 kilotons. The slope coefficient for Trade Openness (TRO) is 453.4 with a significant level of 1%, showing a positive and significant relationship with ES. This suggests that for every 1% increment in Trade openness, CO_2 emissions surge by 453.4 kilotons. Ecological footprint (EF) is positively and significantly associated with ES. The slope coefficient for EF is 2,962 with a significant level of 1% (***).

This implies that for every 1 global hectare per person expansion in ecological footprint, CO_2 emissions rise by 2,962 kilo tons. Our study uses the Sargan test to ascertain the validity of the instruments the GMM used, the p-value of 0.999>0.05, shows that instruments are valid in this analysis, and we accept the null hypothesis that overidentifying restrictions are valid. After that the study applies an AR test to determine the autocorrelation and value of AR (2) 0.1847 which is greater than 0.05, so we conclude that there is no evidence of autocorrelation.

Keeping in view the above results by system GMM, the null hypotheses of no effect of the variables on environmental sustainability are rejected and alternative hypotheses are accepted.

CHAPTER5: DISCUSSIONS, CONCLUSION AND POLICY RECOMMENDATIONS

5.1 Discussions

This study investigates the effects of foreign direct investment, renewable energy consumption, urbanization, trade openness, and ecological footprint on environmental sustainability. System GMM is used as the main analysis tool to determine the parameters and it produces significant and desired results. According to it, variables like FDI, UB, TRO, and EF show a positive correlation with ES, thus deteriorating the environment through CO_2 discharges. On the other hand, REC mitigates CO_2 discharges and ameliorates the environment. This negative association of REC and ES is also shown by (Adebayo et al., 2023).

All variables show a significant relationship with ES at 1% (***) level, showing that these variables have a strong relationship with ES. FDI has a positive slope which confirms the presence of the pollution heaven hypothesis, and this is consistent with that found by (Gyamfi et al., 2021). Although the slope coefficient for FDI (0.0594) is not very high still FDI degrades the environment, and these smaller emissions must be considered when making policies regarding the environment.

Among the variables that have a positive association with ES and cause CO_2 emissions, ecological footprint stands first i.e. enhancing 2,962 kilo tons of CO_2 with the increase of just 1 global hectare per capita in ecological footprint hence, deteriorating the environment. This is because of the increase in activities that lead to an increase in ecological footprint i.e. transport, land, food, and waste, leading to a cumulative effect of many activities under the umbrella of the term ecological footprint.

5.2 Conclusion

We utilized panel data from 143 countries to find the relationship of Renewable Energy Consumption, Foreign Direct Investment, Urbanization, Trade Openness, and Ecological Footprint with Environmental Sustainability. System GMM analysis shows that all variables except REC deteriorate the Environment through CO_2 emissions and REC reclaims the environment by abating carbon discharges.

5.3 Policy recommendations

By considering the results of the analysis, the following policy recommendations are given for the betterment of the environment. Given the CO_2-abating potential of renewable energy consumption, its use should be encouraged, and the public should be informed regarding its beneficial impacts on the environment. Governments should invest in the production of renewable energy instead of conventional energy. The public should be given a subsidy on the purchase and installation of solar panels. To decrease ecological footprint, promote sustainable land use, including vertical expansion instead of horizontal, recycling of the materials, conserving water, cleaning and reusing it, preferring public transport and electric vehicles. Assess the environmental impacts of major infrastructure projects and other developments to minimize their ecological footprint. To abate CO_2 emissions from trade openness, the Carbon Border Adjustment Mechanism (CBAM) should be Implemented, it imposes a fine based on the percentage of carbon present in imported products. This can lead foreign producers to abate discharges and invest in green technologies. Governments should give subsidies, incentives, and research fundings for the development and adoption of environmentally friendly technologies that abate carbon emissions in manufacturing and transportation. Sustainable supply chain practices should be encouraged, such as sourcing from environmentally responsible suppliers, bridging transportation distances, and reducing packaging waste, to abate the carbon footprint of traded goods.

To achieve environmental sustainability in urban areas, the implementation of urban planning policies that prioritize mixed land use, transit-oriented design, and compact development is critical. This can reduce the need for long-distance commutes and encourage more efficient use of land, leading to lower emissions associated with urban proliferation. Enforce building standards that promote efficient use of energy in residential and commercial areas. This includes measures such as energy-efficient appliances, improved insulation, and the use of green energy sources for cooling and heating. Encourage the application of green building certification programs that help developers construct environmentally sustainable buildings. The amount of green space within cities should be encouraged through the creation of parks, and urban forests. Roof vegetation or kitchen gardening should be adopted as it helps to absorb CO_2 emissions and improve the quality of the air. Urban residents should be educated through awareness campaigns about waste reduction, promote energy conservation, and adoption of public transportation. To control carbon emissions from FDI, the government should implement standards and environmental regulations for national as well as domestic firms operating inside the country. Included in this are emission control measures and emission limits. Technology transfer agreements between foreign investors and local firms should be encouraged to facilitate the adoption of environmentally friendly and cleaner technologies in industries with high CO2 discharges, such as transportation, energy production, and manufacturing. Mechanisms should be developed to channel FDI towards sustainable initiatives like climate bonds and green finance.

5.4 Future Directions

In this study, we took 143 countries and treated these as one sample to analyze the data. This research can be done by sorting these countries into two groups according to their GDP and then comparing the results. This can give valuable insights on the differences of the effects of these variables on Environmental Sustainability for developed and developing economies.

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