UNIVERSITY OF KWAZULU-NATAL

THE IMPACT OF ECONOMIC AND DEMOGRAPHIC FACTORS ON THE ENVIRONMENT IN AFRICA: A CASE FOR NIGERIA, SOUTH AFRICA AND EGYPT

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DECLARATION

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This dissertation is dedicated to my mother and sister, who passed on when I was writing. I am what I am, partly because of you:

"A hundred times every day, I remind myself that my inner and outer life depends on the labours of other men, living and dead, and that I must exert myself in order to give in the same measure as I have received …" Albert Einstein

ABSTRACT

The study of the relationship between environmental degradation and socio-economic factors is almost at its zenith. Contemporary evidence points to economic and population growth as the biggest contributors to ecological decay, worldwide. Much of this evidence is based on empirical studies using CO_2 emissions as the proxy for environmental harm. However, carbon dioxide (CO_2) emissions do not reflect the multi-facetedness of ecological degradation. Moreover, contemporary evidence has not settled the debate on the biggest environmental impact between economic and demographic factors, and what the nature of these impacts is in the long run. This study used the ecological footprint to fill these gaps, since it is a comprehensive barometer of the degradation of the natural environment.

This study investigated the relationship among economic factors (Real Gross Domestic Product (RGDP), energy consumption and trade openness), demographic drivers (population density, urbanization and fertility) and environmental degradation (ecological footprint) in three populous economic giants in Africa (South Africa, Nigeria and Egypt) using panel data from World Development Indicators (WDI) and Global Footprint Network (GFN) for the period 1984 – 2022. The Pooled Mean Group – Autoregressive Distributed Lag (PMG-ARDL) approach was employed to investigate the short- and long-run dynamics.

In the short run, trade openness, fertility rate and FDI were found to worsen environmental degradation, while the remaining variables were found to have insignificant impacts. In the long run, all demographic variables were found to have benign environmental impacts. Specifically, increases in fertility rates bring about environmental improvements, while increases in population density and urbanization have insignificant impacts on the environment. Conversely, all economic factors were found to degrade the environment. Energy consumption is the most significant contributor to environmental damage in the selected countries, followed by economic growth and trade openness. Fossil fuels dominate energy production in the studied countries, and the expanded use of energy to power economic activity is causing the most significant impact on the environment. It is recommended that policymakers in these three countries should consider transitioning to renewable and cleaner energy sources like solar power and natural gas to produce energy. However, the costs and benefits must be carefully considered.

Keywords: Ecological Footprint, Cointegration, Pooled Mean Group, Auto-regressive Distributed Lag, Key Impact Factors

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LIST OF ABBREVIATIONS AND ACRONYMS

ADRL	Auto-Regressive Distributed Lag
AMG	Augmented Mean Group
AIC	Akaike information criterion
ASEAN	Association of Southeast Asian Nations
BIC	Bayesian Information Criterion
BLUE	Best Linear Unbiased Estimator
BRICS	Brazil, Russia, India, China and South Africa
BRICS-T	BRICS plus Turkey
Quad BTU	Quadrillion British Thermal Units
C3S	Copernicus Climate Change Service
CADF	Cross-sectionally Augmented Dickey-Fuller
CCEMG	Common Correlated Effects Mean Group
CCS	Carbon Capture and Storage
CIPS	Cross-sectionally Augmented Im-Pesaran-Shin
CS-ARDL	Cross-sectional Auto-Regressive Distributed Lag
DARDL	Dynamic Autoregressive Distributed Lag
DCCEMG	Dynamic Common Correlated Effects Mean Group
DFE	Dynamic Fixed Effects
DOLS	Dynamic Ordinary Least Squares
DPD	Dynamic Panel Data
ECM	Error Correction Model

EF	Ecological Footprint
EIA	Energy Information Administration
EKC	Environmental Kuznets Curve
EMT	Economic Modernisation Theory
EUE	Ecologically Unequal Exchange
FDI	Foreign Direct Investment
FEOLS	Fixed Effects Ordinary Least Squares
FGLS	Feasible Generalized Least Squares
FMOLS	Fully Modified Ordinary Least Squares
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GFN	Global Footprint Network
GHG	Greenhouse Gas
GMM	General Method of Moments
HI	High-Income
IEA	International Energy Agency
IMF	International Monetary Fund
IPAT	Impact, Population, Affluence and Technology
IPCC	Intergovernmental Panel on Climate Change
IPS	Im-Pesaran-Shin
ISM	Interpretive Structural Modelling
KIF	Key Impact Factors
LI	Lower-Income

LLC	Levin, Lin and Chu
LM	Lagrange multiplier
LMI	Lower-Middle-Income
MENA	Middle East and North Africa
PHEH	Pollution Halo Effect Hypothesis
PHH	Pollution Haven Hypothesis
PLS	Partial Least Squares
PMG	Pooled Mean Group
PMG-ARDL	Pooled Mean Group- Auto-Regressive Distributed Lag
PRDUA	Pearl River Delta Urban Agglomeration
PVAR	Panel Vector Autoregressive
P-VECM	Panel Vector Error Correction Model
RGDP	Real Gross Domestic Product
SEM	Structural Equation Modelling
SESRIC	The Statistical, Economic and Social Research and Training Centre for Islamic Countries
SIMA	Statistical Information Management and Analysis
SNA	Structural Network Analysis
SSA	Sub-Saharan Africa
STIRPAT	Stochastic Impacts by Regression on Population, Affluence and Technology
STIRPUrInAT	STIRPAT model modified to include urbanization (Ur) and industrialization (In)
UMI	Upper-Middle-Income

UNCTAD	United Nations Trade and Development
UNEP	United Nations Environment Program
VECM	Vector Error Correction Model
WDI	World Development Indicators
WITS	World Integrated Trade Solution
WMO	World Meteorological Organization
WST	World-Systems Theory

Chapter 1 : INTRODUCTION

This study seeks to identify the biggest driver of environmental damage in Africa. Humans have pushed the earth's capacity beyond its natural limits due to the growth of their populations and economic activity. This, in turn, has caused environmental problems such as climate change and global warming, threatening our existence. No continent will be more affected by climate change than Africa (Schilling *et al.,* 2020; Hope, 2009; Ayanlade *et al.,* 2023, Intergovernmental Panel on Climate Change (IPCC), 2023). This is because many African livelihoods depend on subsistence farming and pastoralism, which are sensitive to climate. In addition, economic activity is low in Africa, resulting in poverty and poor infrastructure. As a result, it becomes necessary to understand and target the stress factors that contribute the most to environmental degradation in Africa.

1.1 Background of the Study

In both the Sub-Saharan and North African regions, Africa faces serious environmental problems, including land degradation, deforestation, biodiversity loss, water and pollution, and extreme vulnerability to climate change (Charfeddine and Mrabet, 2017). To understand the environmental deletion, there are two critically important considerations which must be explored: how it happens and what causes it.

Starting with how it happens, according to Raworth (2017), environmental problems occur when the earth's capacity to provide ecological services has been exceeded by the demand for these services. As such, environmental pressure must be within the limits of the earth. This is environmental sustainability. One approach that is used to measure environmental sustainability is the ecological footprint (EF) framework (O'Neil *et al.,* 2018). Humans require land and water for agricultural activities, to build infrastructure, for extraction of natural resources, for carbon sequestration and for fishing activities. The ecological footprint is a way of speaking to the latter; EF is defined as a measure of the biologically productive land and water area a population requires for its material, infrastructural and waste absorption requirements, based on its technology and resource management culture (Global Footprint Network (GFN), 2024; Charfeddine and Mrabet, 2017).

On the supply side, biocapacity (BC) is the earth's capacity to regenerate and supply humans with resources and services (GFN, 2024). The unit of measurement for both biocapacity and ecological footprint is the global hectare (gha) which represents a biologically productive hectare with world average productivity (GFN, 2024). The gap between EF and biocapacity gives an ecological overshoot or remainder.

An overshoot is the negative difference between biocapacity and the ecological footprint. It signifies that the environment is being exploited beyond its limits to replenish or regenerate, which results in accelerated environmental degradation and depletion of natural resources. According to GFN (2024), a country with an ecological overshoot must make up for the deficit through trade, over-extraction of resources and emission of gases into the atmosphere. When biocapacity is equal to ecological footprint, the damage to the environment is reversible. When biocapacity is more than the ecological footprint, it is called an ecological remainder or surplus, and this means that the country is on a sustainable path.

In this study, the EF is used as the proxy for environmental damage because of three crucial considerations. The first reason is that the EF framework allows for the measurement of overshoots at a more local geographical area scale. This is important because local environmental drivers are within the control of governments. Examples of such drivers include habitat destruction and invasive species. This is in contrast to drivers like global warming, which cannot be controlled by individual governments. Climate action requires the collaboration of all countries to address it (United Nations, 2015).

Secondly, according to Wang and Dong (2018), most studies use carbon dioxide (CO_2) emissions as the proxy for environmental degradation. However, environmental degradation is not limited to climate change. It also includes other problems like biodiversity loss, soil erosion and deforestation. Because the ecological footprint includes cropland and grazing land, forest, fishing and built-up land in addition to carbon footprints (Charfeddine and Mrabet, 2017; GFN, 2024), it is a better and more comprehensive measure of environmental damage.

The third and final reason is that since the ecological footprint can be calculated per person, region, country, continent and globally, the framework allows for easier international comparisons (Denny and Marquart-Pyatt, 2018).

As of 2019, which is the year with the most recent footprint and biocapacity data, 34 countries out of 54 sovereign countries making up the African continent were biocapacity debtors, which means that they have ecological deficits, and 20 countries are biocapacity creditors, which means they have ecological remainders (GFN, 2024). This means almost two-thirds of African countries are already not on a sustainable path. Based on the remaining sustainable third, some have ecological footprints that are very close to the biocapacity. For ecological debtor countries, two prominent aspects arise. The first is when the overshoot occurred, and the second is how severe the overshoot is in relative terms.

Table 1.1 below shows the ecological position of selected African ecological debtor countries. The figures have been rounded off to one decimal place.

Table 1.1: Sample of African Ecological Debtor Countries

Country	Year of overshoot	EF per capita	BC per capita	Deficit	Percentage EF over BC	Number of earths	Number of countries
Egypt	Before 1960	1.6	0.3	1.3	410%	1.0	5.3
Mauritius	Before 1960	3.2	0.7	2.5	350%	2.0	4.6
Algeria	1975	2.4	0.7	1.7	240%	1.5	3.4
South Africa	Before 1960	3.4	1.2	2.2	180%	2.1	2.8
Djibouti	1991	2.2	0.7	1.5	240%	1.4	3.1
Tunisia	1974	1.8	0.8	1.0	120%	1.1	2.3
Eswatini	1971	3.1	1.4	1.7	120%	2.0	2.2
Uganda	Before 1960	1.1	0.5	0.6	110%	0.7	2.2
Morocco	1975	1.7	0.7	1.0	140%	1.1	2.4
Kenya	Before 1960	0.9	0.5	0.4	100%	0.6	1.8
Zimbabwe	1964	1.1	0.7	0.4	55%	0.7	1.6
Lesotho	1984	1.3	0.7	0.6	79%	0.8	1.9
Nigeria	1971	0.9	0.5	0.4	77%	0.6	1.8
Ghana	1997	1.8	1.0	0.8	88%	1.1	1.8
Tanzania	2001	1.0	0.9	0.1	16%	0.6	1.1
Africa	2007	1.2	1.1	0.1	27%	0.8	1.1

(Source: GFN, 2024).

Starting with the period of 'Year of overshoot', it is clear that a few countries, including Egypt and South Africa, have been on an unsustainable path since before 1960. The significance of 1960 is that it is the starting point of the measurement of EF and BC. Other countries that have been unsustainable for a while include Zimbabwe (1964), Nigeria (1971) and Morocco (1975). Tanzania (2001) is an example of a country that became unsustainable relatively recently. Measured as a single entity, the African continent went into an ecological overshoot in the year 2007. This means that the continent has been on an unsustainable path for eighteen years.

Concerning the severity of the overshoots, rather than looking at the absolute magnitude of the ecological deficit, the EF and BC data can be used to make interesting comparisons

(Earth Overshoot Day, 2022). Firstly, the deficit is divided by the BC to obtain the percentage EF over BC. Based on the table, it is clear that the EF is 402% higher for Egypt than the BC. Mauritius, Algeria, South Africa, Djibouti, Tunisia and Eswatini complete the sample of countries with footprints over 150% of biocapacity. Uganda, Morocco, and Kenya are examples of countries that have footprints that are 100% - 150% over biocapacity. Zimbabwe, Lesotho, and Tanzania are examples of countries with footprints that are 0% - 50% of biocapacity. Africa's EF is 27% above its biocapacity. The implication is that the higher the overshoot percentage, the more severe the environmental degradation would be.

Secondly, the EF per capita is divided by the global biocapacity per capita so that one may have an idea of 'how many earths would be required if every person lived like people from that country' (Earth Overshoot Day, 2022). The 2019 global biocapacity per capita is 1,5844155844 or 1.6 (GFN, 2024). In terms of the table, if every person lived like a South African, we would require 2.1 earths (3.4 /1.6). However, if everyone were to live as a Nigerian, one earth we have will be enough. Thirdly, the EF per capita is divided by the BC per capita to obtain the number of countries required to satisfy the ecological needs of the citizens of that country. For example, 2.3 Tunisians are required to meet the demands of Tunisians regarding nature (2.4/0.7), and it takes five Egypts (1.8/0.4) for all Egyptians' demands on nature to be met. Overall, 1.2 African continents are required if the ecological needs of every African person are to be met. Table 1.2 shows the ecological position of a few ecological creditor countries in Africa.

Table 1.2: Sample of African Ecological Creditor Countries

Country	BC per capita	EF per capita	Surplus	Percentage BC over EF	Number of earths	Number of countries
Côte d'Ivoire	1.2	0.9	0.3	34%	0.6	0.8
Botswana	3.0	2.2	0.8	38%	1.4	0.7
Angola	1.7	1.0	0.7	73%	0.6	0.6
Madagascar	2.1	0.9	1.2	146%	0.6	0.4
Namibia	6.6	2.7	3.9	146%	1.7	0.4
Congo, DR	2.0	0.7	1.3	170%	0.4	0.4
Congo	8.4	1.4	7.3	635%	0.9	0.2
Gabon	18.0	2.0	16.0	811%	1.5	0.1

(Source: GFN, 2023).

Based on the above table, some countries like Namibia, Congo and Gabon have biocapacities that are more than 150% larger than their ecological footprints. Others, like

Madagascar and Angola, have biocapacities that are 100% - 150% larger than their ecological footprints, whereas in Botswana and Côte d'Ivoire, the figures are 0% - 50% more than their ecological footprints. This means that the footprints of these two countries are very close to equalling the biocapacity, signalling that they are close to becoming debtor countries.

The second consideration to understanding environmental damage is what is driving the EF in Africa. In economic theory, environmental damage is driven by, among others, demographic and economic factors. As already alluded to, nature not only provides natural resources that are used in economic activity, it also provides essential life-supporting services needed by humans to survive. Examples of these services include land and water. As such, rising economic activity and the population increase the pressure on the environment. With regard to population, the African population is burgeoning, hence, this increased population impacts negatively on the environment. According to the African Ecological Futures Report (2015), Africa's population is projected to double by 2050, and by 2100, Africans will account for 50% of all people under 18 years on this planet. The Economist (2020) adds that by 2050, Nigeria is predicted to have a population of 400 million, and it will surpass the USA as the third most populous country in the world. The figure below shows the fertility rates of the African and European populations.

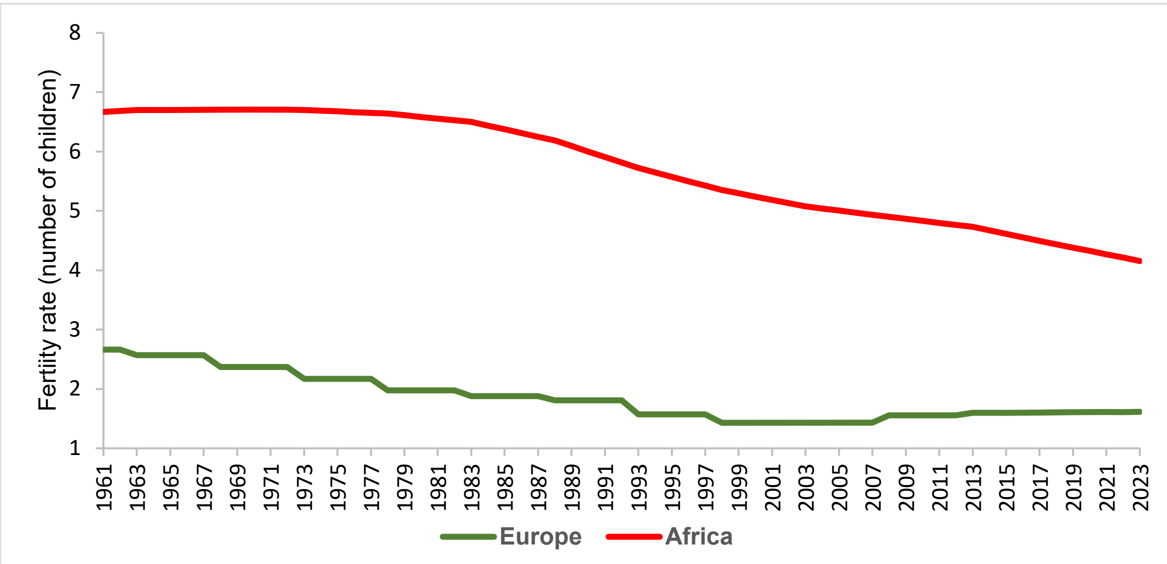

Figure 1.1: Population fertility rates in Africa and Europe (1960 – 2023)

(Source: Macrotrends, 2024)

Figure 1.1 shows that the African fertility rate has consistently exceeded the replacement fertility rate of 2.1 children per woman, which is the fertility level at which a population exactly replaces itself from one generation to the next. One child replaces the mother, and the other child replaces the father. However, the fertility rate is showing a declining trend. In 1961, the fertility rate was 6.7 children per woman, but in 2023, it was 4.2. This is in sharp contrast with Europe, where fertility has consistently been below the replacement rate and falling. In 1961, Europe's fertility rate was 2.7, and by 1998, it was 1.43. In summary, the graph shows that Africa's population is growing, which makes the positive association between population growth and the continent's growing EF easily inferable.

In terms of economic activity, affluence is increasing in Africa. Eight of the twenty fastest-growing economies in the world are from Africa (Tachega *et al.,* 2021; Ecological Futures Report, 2015). As a result of this increase in economic development, many Africans have moved, and many more will move, into the middle class. The higher personal incomes of a bourgeoning middle class are causing an increase in the demand for goods and services, with production increases to meet this rising demand. This increased consumption and production is having a significant impact on the environment. Figure 1.2 below shows the increase in the gross domestic product (GDP) per capita of Sub-Saharan Africa (SSA), which is the poorest region in the world.

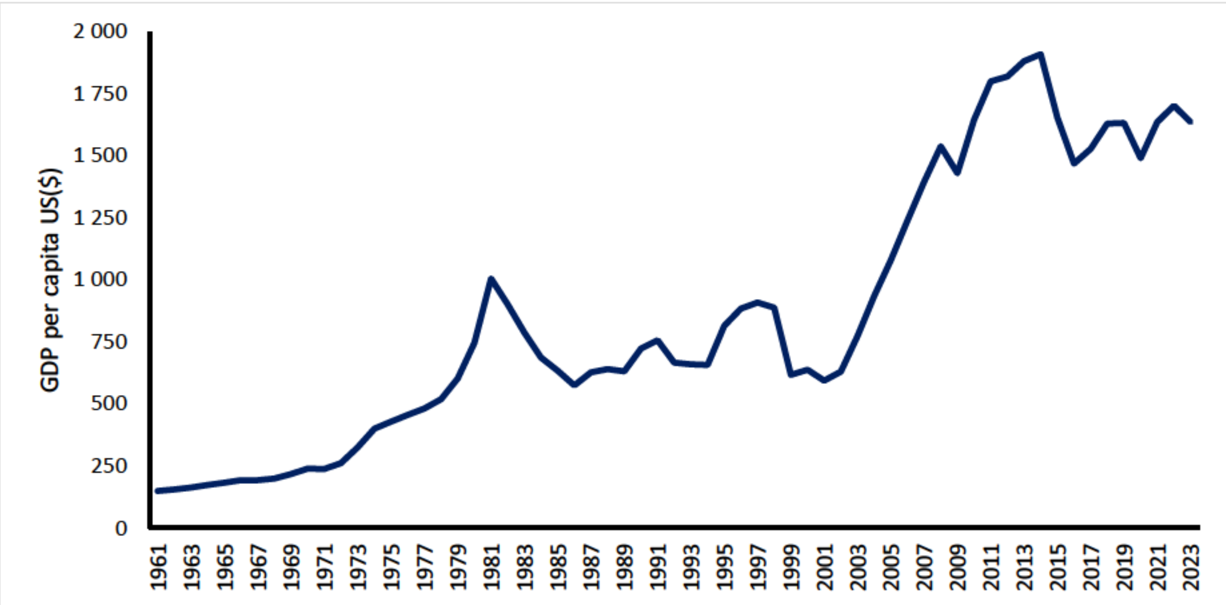

Figure 1.2: Sub-Saharan Africa's GDP per capita (current US$) from 1961 - 2023 (Source: World Bank, 2023)

The graph illustrates a significant economic transformation in SSA, with the region's GDP per capita surging from $149.85 to approximately $1 636.81 between 1961 and 2032. This robust growth is accompanied by a clear, positive correlation between GDP and EF, underscoring the environmental challenges that accompany economic progress.

An important clarification of this relationship between economic growth and ecological deletion is that the issue does not lie in the economy's growth, per se. Rather, it is the nature of economic growth. Growth can be attained by increasing factor inputs, including natural resources. This form of growth is known as extensive economic growth. On the other hand, economic growth can be achieved by enhancing the productivity or efficiency of inputs. This is referred to as intensive economic growth. The distinction between these two types of growth is that extensive growth stems from the accumulation of factor inputs, while intensive growth arises from the enhancement of the quality of factors (Irmen, 2005). Africa is currently experiencing economic growth by utilizing its abundant natural resources, which is leading to environmental degradation (Tachega *et al.,* 2021; Charfeddine and Mrabet, 2017).

In the next two sections, the study looks at the research's problem statement, objective and aims.

1.3 Research Problem

The problem at the heart of this study is of utmost significance: Africa is not on a sustainable trajectory. As Africa's economic activity escalates and its population expands and urbanises, EF is skyrocketing at alarming rates, persistently surpassing biocapacity. The resulting ecological overshoots are inflicting severe environmental damage, posing a threat to future generations' ability to meet their needs. Hence, there is an urgent need to formulate and implement appropriate policies to curb and facilitate the reversal of environmental damage. To this end, the drivers of Africa's environmental damage must be comprehended. These are pivotal inputs in policy design.

1.4 Research Objective and Aims

The overall objective of the research project is to understand the relationship between economic growth and population and environmental harm in Africa. The specific aims of the research are:

- To determine the short- and long-run impacts of demographic factors on the ecological footprint.
- To determine the short- and long-run impacts of economic factors on the ecological footprint.
- To identify the key impact factor(s) on the ecological footprint in the long run.
- To formulate policy solutions for dealing with impact factors, depending on the results.

The results of a study are important as they add to the existing body of knowledge. However, it is important to consider the scope of the study to correctly interpret its results. In the next two sections, we consider the significance and scope of the study. The significance is discussed first, and then the scope will be considered.

1.5 Significance of the Study

Achieving sustainable development is both urgent and critical to Africa's future. This study will contribute to potential policy solutions to quickly reduce the EF for Africa by identifying the key impact factors. Knowing the biggest contributing factors to environmental degradation has important policy implications. Since many factors cause environmental damage, a portfolio of policy instruments is required to address the problem of environmental damage. Naturally, the optimal policy in mitigating environmental degradation targets the biggest causal factor(s). Therefore, knowing the key impact factors allows for identifying the policy instrument with the biggest effect on correction of the problem. As a result, more effort and resources will be dedicated to the formulation and implementation of effective and efficient policies.

Moreover, the study will contribute to the debate on what the primary cause of environmental damage between population and affluence is. This is important because environmental degradation is a 'blame' game. The rich and affluent Western countries see environmental problems as consequences of growing populations in the third world, including Africa, while poor countries blame the affluent countries for environmentally harmful overconsumption (Fletcher *et al.,* 2014; Collins, 2002). Another dimension of the population-affluence debate is that increases in both drivers can bring environmental improvements. Big populations can spur technological innovation, which ameliorates environmental damage (Gleditsh, 2021), while further economic complexity can make people afford and care about environmental quality (York *et al.,* 2003a).

1.6 Scope of the Study

The study will focus on three African countries: Nigeria, Egypt, and South Africa. These countries have two salient features that are critical for this study. Firstly, they are the three biggest economies in Africa. As of 2022, Nigeria was the largest economy with a GDP of $535.34 billion, Egypt is second with a GDP of $ 453.53 billion, and South Africa is the third with a GDP of $ 360.71 billion. All these figures are measured at constant 2015 US$ (World Bank, 2022). Given that SA's GDP for the same year stands at $ 1.97 trillion, Nigeria and South Africa combined contribute $ 0.90 trillion. This means that over 45% of SSA's GDP comes from Nigeria and South Africa. Egypt is the biggest economy in North Africa.

Secondly, these three countries are among Africa's top six most populous countries. The table below shows some demographic statistics for these countries.

Table 1.3: Demographic Information of the Six Most Populous African Countries

Country	Rank	Population	Density (P/km^2)	Fertility rate	Urban pop. (%)
Nigeria	**1**	**223 804 632**	**246**	**5.1**	**54**
Ethiopia	2	126 527 060	127	4.0	22
Egypt	**3**	**112 716 598**	**113**	**2.8**	**41**
DR Congo	4	102 262 808	45	6.1	46
Tanzania	5	67 438 106	76	4.6	38
South Africa	**6**	**60 414 495**	**50**	**2.3**	**69**
Africa		1 460 481 772	49	4.18	54

(Source: Worldometer, 2024)

As of 2023, it is evident that Nigeria is the most populous country on the continent, and it has the highest population density as well. More than half of its population resides in urban areas, which is well over the average African urbanization rate of 43.8%. Nigeria has the second highest fertility rate of 5.1 children per woman, after the Democratic Republic of Congo (DR Congo or DRC), which has the highest fertility rate of 6.1 children, slightly over the continent average. Egypt's population and density of 102.3 million and 113 persons per km^2, respectively, are the third largest after Ethiopia. Forty-one percent of Egyptians dwell in the cities. Egypt's 2.8 children per woman fertility rate is below the African average of

4.18 children per woman. South Africa's population is the sixth largest after DRC. However, based on the countries in Table 1.3, it has the highest proportion of urban dwellers at 69%, but the lowest fertility rate of 2.3 children per woman, which is slightly over the replacement fertility rate of 2.1 children per woman.

Therefore, studying these three countries allows for the assessment of the impacts of environmental drivers to be more comparable. In terms of a country with a very high population and low economic activity, such as Ethiopia or DR Congo, for example, this would most likely skew environmental damage towards population. Similarly, taking a country with high economic activity but a small population, such as Botswana, would generate results biased towards economic variables. As such, countries with simultaneously large populations and high economic activity result in a more balanced assessment of environmental drivers.

Another reason for choosing these countries is data availability. As the biggest economies in Africa, their data is relatively readily available compared to other African countries.

The study covers the period 1984 – 2022, a period of 39 years. This period is long enough to establish underlying relationships between the EF and the various demographic and economic factors. For empirical studies, the population variable is often decomposed into the total population, birth rate, density and urbanization (York *et al.,* 2003a). Denny and Marquart-Pyatt (2018) add that some studies will use one or two of these population dynamics to analyse the impact of population. This study will decompose the population variables into density, urbanization and the fertility rate. Similarly, the economic growth variable is decomposed into GDP per capita, trade openness and energy use.

The study has different chapters, each focusing on specific elements. The next section looks at how it is organised.

1.7 Plan of Thesis

This chapter is divided into six Chapters. In Chapter 1, the study is introduced by discussing its background, stating the research problem, outlining the research objectives and highlighting the study's significance. Chapter 2 reviews the theoretical literature that examines the relationship between environmental quality and various economic and demographic factors. Chapter 3 explores the empirical literature on this topic. In Chapter 4, the empirical framework is detailed, including the data sources, key variables and the regression model utilized in the research. Chapter 5 presents and analyzes the estimation results. Finally, Chapter 6 summarizes the key findings and provides the conclusion of the study.

Chapter 2 : THEORETICAL FRAMEWORK

2.1 Introduction

The increasing frequency and intensity of catastrophic environmental impacts constitute largely irrefutable evidence that the earth is in ecological peril, throwing the sustainability of human societies and other living organisms into serious question (Ewing, 2017; York *et al.,* 2003a). There is an overwhelming consensus that the causes of environmental degradation are anthropogenic. As such, scientists are arguing that we are living in the Anthropocene – an epoch of unprecedented ecological and planetary damage emanating from the existence of humans (Ojeda *et al.,* 2019). Due to population increases, rising economic activity and resource extraction, land use change, energy usage, technology, lifestyle and climate policy (Crutzen, 2000; Intergovernmental Panel on Climate Change (IPCC), 2014), humans have pushed the earth's capacity to provide essential services for life, beyond its limits (Ripple *et al.,* 2017; Raworth, 2017; O'Neill *et al.,* 2018). Based on these many drivers, population and economic growth have the biggest impact on the environment worldwide (IPCC, 2014).

While there is almost universal acceptance that population and economic growth are the pre-eminent catalysts of our ecological crises, consensus on which of these two factors is the biggest contributor, and how, precisely, they are related to environmental damage, is elusive (Ewing, 2017:127; York and Dunlap, 2012:286). This is because the key factors identified to be driving anthropogenic, environmental impacts differ across social theories (York *et al.,* 2003a). Thus, the theoretical debate on the biggest cause(s) of environmental damage and the nature of their relationship to the environment is complex and unresolved. However, the seriousness of the ecological crises and the urgency and importance of abating environmental degradation make understanding the linkage between these socio-economic factors and the environment through different theories non-negotiable. This is the concern of this dissertation.

This chapter analyzes different theories that examine the connection between environmental and socio-economic elements. Various theories within environmental sociology contribute to our comprehension of how the natural environment interacts with population dynamics and economic activities. In this review of theories, those that concentrate on the link between economic factors and the environment, being the most relevant, will be addressed first.

Following that, theories that investigate the relationship between demographic factors and the environment will be covered. To provide a well-rounded evaluation of how economic and demographic elements influence the environment, the forthcoming theories will address both positive and negative perspectives.

2.2 Theories of Economic Growth and the Environment

The approaches dealing with the relationship between economic factors and the environment are not in paucity. However, two approaches will underpin this study, namely, economic modernisation theory (EMT) and world-systems theory (WST). Three crucial considerations influence the choice of theories. Firstly, these theories are the dominant frameworks (Sarkodie, 2018; York *et al.,* 2003a). Since they are widely tested, these theories are supported by vast empirical evidence. Therefore, they provide a robust foundation for this study.

Secondly, these theories address the central questions and hypothesis of the research directly. As mentioned previously, there is debate among environmental sociologists about the size and precise nature of the impact of economic growth on environmental quality. EMT is linked to the modernization or green capitalist perspective, to the effect that economic growth, although initially damaging to the environment, brings about environmental quality and improvement in the long term (York *et al.* 2003a.; Ewing, 2017). Thus, EMT offers an optimistic view of economic growth. WST is associated with the political economy or Neo-Marxian perspective, which asserts that economic growth is eternally bad for the environment (York *et al.* 2003a). Hence, WST presents a negative, deleterious view of economic growth.

Lastly, EMT and WST address the African context. As highlighted in Chapter 1, Africa has been experiencing an expansion of economic activity for some time. EMT predicts that environmental improvements should be realized. In contrast, given the high levels of economic integration between Africa and the economically and politically powerful countries, WST identifies the influence of rich, powerful countries on weak ones as a big determinant of environmental damage in poor countries (Jorgenson and Givens, 2013).

In the process of reviewing these theories of economic growth and the environment, EMT theory will be discussed first, followed by WST.

2.2.1 Economic Modernisation Theory (EMT)

This theory is the response of the Neoclassical economics school to the environmental problems in the Anthropocene, blamed on rising economic activity. It posits that economic modernisation is key to curing ecological damage (York *et al.,* 2003a). Economic modernization can be described as the transition of an economy, from a traditional and agrarian economy to a fully mature, industrialized economy, which is characterized by high mass consumption enabled by the creation of markets (capitalism), economic growth, and technological advancement (Bull and Bøås, 2012; Zimbudzana and Matunhu, 2011; Rostow, 1959; York *et al.,* 2003a).

Of course, this modernization process has environmental ramifications since economic growth degrades the environment. From the supply side, a growing economy degrades the environment through high waste generation. The natural resources that are continually extracted to produce goods and fuel machines generate waste (Jorgenson, 2016). In terms of demand, economic growth is associated with increasing consumption, which incidentally generates waste (Gould *et al.,* 2004).

As already alluded to, proponents of the EMT argue that the environmental impact of economic growth changes from being deleterious to ameliorative along the development continuum as a country modernizes. The implication is that economic growth damages the environment at lower levels and protects the environment at higher levels. This temporal, bad-good relationship between the environment and economic growth is referred to as the Environment Kuznets Curve (EKC) hypothesis. The graphical representation of the hypothesis, the EKC, is an inverted U-shaped curve which indicates that environmental impacts rise at lower levels of development, then level, and begin declining with continued economic growth (Stern, 2004; Gross and Kruger, 1991). Figure 2.1 below depicts the EKC.

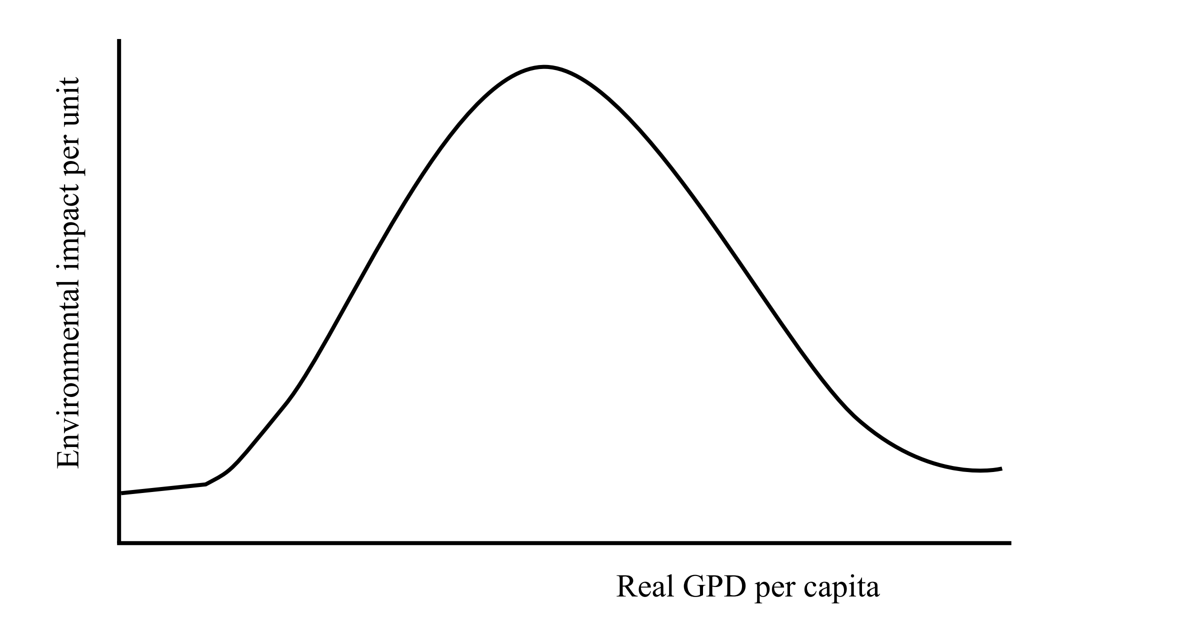

Figure 2.1: Environmental Kuznets Curve

The measure of environmental impact per unit of output is indicated on the vertical axis, and economic growth on the horizontal axis, measured in per capita GDP terms. Starting at lower levels of economic development, increases in income will induce increases in environmental impacts until a threshold level of per capita income is attained. From this aspect, environmental damage in per capita terms will decrease as income continues to increase. To put this economic growth-environmental nexus into perspective, Grossman and Krueger (1991, 1995) and Stern (2004; 2015) discuss three effects which account for the EKC relationship: scale, composition and technique.

The scale effect refers to an expansion of output achieved using the same production techniques (Grossman, 1991). Stern (2004) clarifies that output is expanded at fixed factor-input ratios, output mix and state of technology. As mentioned above, in the initial stages of development, a country will be primitive, having no access to state-of-the-art technologies. Therefore, economic growth is achieved by increasing the quantities of factor inputs, and not by improvements in the quality of inputs. Thus, economic growth at the lower levels of development is extensive, and this kind of growth generates increased environmental impacts. Therefore, the scale effect unambiguously accounts for the rising part of the EKC. It is the scale effect which is the subject of preoccupation by critics of the ameliorating potential of economic growth (Grossman and Krueger, 1991; Stern, 2004, Mol *et al.,* 2009).

The composition effect reflects changes in the output mix and the structure of the economy. As explained by Stern (2004; 2015), as countries develop, they move from agriculture to pollution-intensive heavy industries but then shift to services and light manufacturing, which are not pollution-intensive in the later stages of development. The United States of America (USA) is an example of a country which has moved in the direction of having a growing share of services and a diminishing component of manufacturing in GDP. Therefore, the composition explains the entire shape of the EKC.

The technique effect explains the declining portion by synthesising the impacts of technological improvement and rising affluence. Grossman and Krueger (1991; 1995) explain that the turning point of the EKC is associated with a requisite level of affluence, which makes a society care about, afford and demand environmental quality. This is because environmental quality is conceived of as an expensive luxury good, making it of interest to affluent societies (York *et al.* 2003a). In turn, this demand for environmental protection by the public at this level of affluence puts pressure on both the government and businesses, who now have the resources to have an interest in and invest in environmental protection (Jorgenson, 2016). The big environmental investments made by firms result in technological improvements which enable eco-friendly and efficient inputs to replace those that harm the environment, which is what brings about a reduction in ecological destruction (York *et al.* 2003a; Stern, 2004, 2015). Efficient inputs reduce impacts through productivity gains, and accordingly, lower quantities of raw materials and other polluting inputs are used to make a unit of output. Eco-friendly or cleaner technologies translate to new, cleaner facilities that lower the environmental impact per unit of input (Stern, 2004; 2015).

There are many criticisms of the EKC hypothesis and the EMT theory in general. Stern (2004; 2015) points out that the EKC literature is econometrically weak. He argues that some studies confirm evidence of the EKC, based on the significance and expected signs of regression coefficients, when no or little consideration has been paid to issues like statistical properties of the data (e.g., diagnostic statistics) and model adequacy (e.g., omitted variable bias). In general, these econometric problems are overcome by exploring the descriptive statistics of the data and performing model specifications tests as well as other robustness checks.

Some critics argue that technical efficiency does not necessarily lead to reduced environmental impacts. As explained by York *et al.* (2010), the efficiency of new technology is measured as a reduction in the impact per unit of output and the scale of environmental impacts. This means that technical efficiency can increase production scale to the effect that total resource consumption and pollution emissions increase, although they may have declined in per capita terms. Therefore, by focusing on the falling environmental impact per capita, the EKC may give a misleading impression that the environment is improving by not considering the total or aggregate impacts. The idea that improvement in technology increases resource consumption and does not reduce it is referred to as the Jevons paradox (Jorgenson, 2016).

The EKC has been found to hold for some impacts and not for others. For example, Grossman and Krueger (1991) found EKC evidence for two air pollutants, sulphur dioxide and dark matter (or smoke), but not for suspended particles in the air, which was consistently found to decrease with economic growth. Mills and Waite (2009) and Dietz and Adger (2002) show that biodiversity loss is largely inconsistent with the EKC hypothesis, arguing that because the conservation efforts are far outpaced by anthropogenically driven extinction even in richer countries, biodiversity loss is irreversible and an EKC for it, is a theoretical impossibility.

A big criticism of EKC and EMT, in relation to WST, is their focus on narrowly defined environmental improvements in rich, developed countries like the USA and Japan, without considering how the ecological footprint improvements in these countries are supported by resource extraction, relocation of polluting industries and toxic wastes to poor countries (Foster 2012). Developed countries can shift polluting industries to developing countries through FDI, trade and multinational corporations (Jorgenson and Givens, 2013). Therefore, it is a fallacy to think that economic growth brings, or has brought, environmental improvements to rich countries. The reality is that the burden of ecological destruction is shifted and borne in developing countries, which are used as pollution havens. The underlying mechanisms of the fallacy, namely ecologically unequal exchange (EUE) and pollution haven hypothesis (PHH) will be discussed in detail under WST. A counterargument from EMT on the PHH, referred to as the pollution halo effect hypothesis (PHEH), is that trade and FDI are conduits for the diffusion of advanced, cleaner technologies from developed to developing countries, which allows a reduction of environmental impacts in developing countries (Musah *et al.,* 2022; Jorgenson and Givens, 2013).

EMT is also criticised for being anthropocentric in nature (Carton and Dunlap, 2012; Shrivastava, 1995). Shrivastava (1995) explains that anthropocentrism is the notion that emphasises the separateness, uniqueness, primacy and superiority of the human species. At its core, anthropocentrism views nature as an expendable resource which is to be exploited without any real concern for its integrity by humans as they increase their primary endgame of welfare (Shrivastava, 1995). Neoclassical economists argue that there is no real scarcity of natural resources, as there is almost perfect substitutability between natural and man-made capital, thanks to the imagination and creativity of the human mind (Jolly, 1994). Stubbs and Cocklin (2007) add that because of the espoused resource abundance, neoclassical (or capitalist) organisations focus on short-term financial performance, which involves using high discount rates that favour the exploitation of resources now rather than preserving them for posterity.

As stated in Chapter 1, the two aims of the study are to determine the size of the impact of economic growth on the EF and to formulate policy solutions on how to address the key impact factor. EMT identifies economic growth as the primary driver of environmental change (York *et al.,* 2003a). Hence, this theory predicts that economic growth will have the biggest impact on the environment. Moreover, as noted by York and Dunlap (2012), EMT focuses on environmental improvements and not environmental degradation. This means EMT is a theory that proposes solutions to environmental degradation. As elucidated in the EKC hypothesis, all it takes is further economic development to bring about environmental quality. Stern (2004) points out that the endgame of EMT is sustainable development, which means that proponents of EMT see no fundamental conflict between economic growth and environmental quality. Hence, EMT is relevant to this study because it simultaneously identifies economic growth as the key impact factor of environmental degradation in the short term and a solution to environmental problems in the long term.

Emanating from the preceding discussion, it was pointed out that the two hypotheses of EMT are the EKC and PHEH. This study will test the validity of these hypotheses in Nigeria, Egypt and South Africa. In economic literature, the EKC hypothesis can be assessed in two ways. Firstly, it is tested directly by including the square of Real Gross Domestic Product (RGDP) in the regression as one of the explanatory variables to investigate a non-linear relationship with environmental damage (e.g. Voumik *et al.,* 2022; Erdogan *et al.,* 2020). The coefficient of the square of Gross Domestic Product (GDP) provides evidence of the nature of the U-shaped relationship. When the coefficient of the square of RGDP is negative, it means that there is evidence of the inverted U-shape relationship and thus, the EKC is valid (see Ssali *et al.*, 2019; Ajayi and Ogunrinola, 2020; Udeagha and Ngepah, 2021). At times, the term of RGDP raised to the power of three is employed in the regression, to investigate the nature of the second turning point (Zmami & Ben-Salha, 2020; Sarkodie, 2018).

Secondly, the EKC hypothesis is indirectly assessed with cointegrating approaches, such as augmented mean group (AMG) and auto-regressive distributed lag (ARDL), which estimate the long-run (and short-run) dynamics of economic growth. Cointegration refers to the existence of a long-run equilibrium relationship. If the long-run coefficient of RGDP is negative, it means that economic growth promotes environmental quality in the long run, which in turn indicates the validity of the EKC hypothesis (see Zimon *et al.,* 2023; Afriye *et al.*, 2022).

In terms of the assessment of PHEH, consistent with the EKC framework, the two approaches to testing the EKC hypothesis may be used to assess the PHEH. Firstly, the square of trade openness and/or FDI may be used to assess the PHEH (see Balsalobre-Lorente *et al.*, 2019; Destek and Okumus, 2019). The coefficients of the square of trade and FDI are interpreted in the same way as the EKC hypothesis. A negative coefficient validates the PHEH (see Balsalobre-Lorente *et al.*, 2019; Abbasi *et al.*, 2023).

Secondly, under the cointegration approach, the estimation of both short-run and long-run dynamics for trade and FDI allows for testing the validity of the PHEH in the selected countries. As stated previously, trade and FDI may have short-term environmental impacts, which will eventually be reversed and outweighed by the long-term benefits (Jorgenson and Givens, 2013). In similitude to the assessment of the KEC hypothesis, negative long-run coefficients of trade and FDI suggest that the PHEH is valid.

In this study, we adopt the cointegration approach to test the validity of the EMT hypotheses in Nigeria, Egypt and South Africa. A key factor in this decision is that the econometric software employed does not permit the inclusion of both linear and squares of the relevant variables to the regression equation. The squared variables are dropped because of perfect collinearity with the base variables.

In the next section, the chapter discusses the WST perspective.

2.2.2 World-systems Theory (WST)

The world-systems theory (WST) was propounded by Wallerstein (1974) following his rejection of the use of nation-state as the unit of analysis in socio-economic analyses in favour of a single world system with three economic zones: core, semi-periphery and periphery (Wallerstein, 2004; Wallerstein, 1974). The rationale against using the state as the unit of analysis is that the world is an integrated system of many countries and cultures, with a global division of labour and not a mere collection of many independent countries with occasional and limited interactions (Wallerstein, 2004). Given the dominance of the West in the world order, Wallerstein (2004) adds that this world system is capitalist in nature. The world-system implies that what happens in a country is a function of both internal and external influences. Accordingly, the principal idea in the WST is that a country's internal economic, social and environmental conditions must be interpreted in relation to its position in the global capitalist economy and not just in terms of its internal processes (Jorgenson and Givens, 2013).

York *et al.* (2003a) clarifies that the category into which a country falls in this global capitalist system is decided by its influence in the spheres of global economics, politics and the military. The core nations are the developed countries with capital-intensive production processes and high wage rates (Jorgenson and Givens, 2013). These are the countries that dominate politics and trade relationships with all other countries (York *et al.,* 2003a). The Group of Seven (G7) countries - the United States of America (USA), Canada, France, Germany, Italy, Japan and the United Kingdom (UK) are examples of core nations in WST. On the contrary, peripheral nations have labour-dominant production systems and low wages (Jorgenson and Givens, 2013). These countries, most of which are found in Sub-Saharan Africa, have very low industrialisation indices and political power (York *et al.,* 2003a). For example, a country like Zimbabwe lacks the power to dictate trade relationships. Finally, the semi-peripheral nations occupy an intermediate position in that they have the attributes of core and peripheral countries (Jorgenson and Givens, 2013; York *et al.,* 2003a). South Africa, as an upper-middle-income country, falls into the stratum.

As mentioned already, WST posits that environmental degradation in a country is a function of internal and external processes. With respect to internal influences, as already mentioned, WST belongs to the neo-Marxian political economy perspective, which argues that it is economic growth, the structure of market economies and the institutions of modernity (e.g.

technology) which are responsible for ecological crises (York *et al.,* 2003a). How these factors cause environmental damage is aptly articulated in the treadmill of production (ToP) theory, which was propounded by Schnaiberg in his 1980 book *Environment: From Surplus to Scarcity* (Schnaiberg, 1997; Long *et al.,* 2018).

Schnaiberg (1997) explains that ToP is an economic-political system with three players, namely private corporations, government and workers, who have a common interest in the perpetual expansion of industrial production, economic development and consumption. This is because economic growth allows these three parties to achieve their own individual objectives. The primary objective of capitalist corporations is to maximise profits, whereas the objective of workers is full employment, and that of government is to maximise tax revenue, which it needs to provide social and environmental services. Curran (2017) clarifies that corporations are the principal drivers of economic growth, while governments and workers are trapped in supporting the objectives of corporations. The 'treadmill' in ToP alludes to the pattern in which the relentless profit-seeking action of firms of mechanising production processes with innovative technology not only increases both labour productivity and redundancy (as technically efficient machines mean the labour requirement per unit of production decreases), but also resource consumption and pollution, which leaves a country with environmental and unemployment crises (York and Dunlap; 2018).

As mentioned above, workers and the government are forced to support the environmentally degrading economic expansion. Realising that further economic expansion is the solution to the unemployment crisis, workers seeking to circumvent unemployment are left with no choice but to support the increased production aimed at offsetting increased worker productivity. It is also the expediency of governments that supports increased production because they generate more tax revenue needed for service delivery and environmental protection. Thus, ToP sees capitalism as predicated on continuous economic expansion, which makes it inherently incompatible with the preservation and health of ecosystems in a finite world (Long *et al.,* 2014; Jorgenson, 2016).

With respect to external influences, York *et al.* (2003a) note that WST applies this logic of ToP on a global scale. According to Islam (2016), multinational corporations are at the heart of the global treadmill, which, in pursuit of profit, relocate their operations to developing countries. The latter occurs because in developing countries, governments are already under pressure to develop their nations, and thus are willing to offer concessions and incentives, including cheap labour, to attract international investment. To attract this FDI, developing countries must have lax environmental policies, remove stringent labour laws, offer 'tax haven' conditions and reduce foreign capital regulations aimed at managing the threat of capital flight (Jorgenson and Givens, 2013; Solarin *et al.,* 2017). As a result, these multinationals invest in and introduce cheap, outdated technologies (Jorgenson and Givens, 2013). The result is environmental load displacement, which is defined as the externalisation of environmental harm by high-income nations (Jorgenson, 2012).

Jorgenson and Givens (2013) point out that there are two strands of literature which explain environmental load displacement in WST, namely the pollution haven hypothesis (PHH) or FDI dependency and the environment, and ecologically unequal exchange (EUE). PHH is the thesis that multinational firms outsource dirty industries to poor countries with lenient environmental policies (Nathaniel *et al.,* 2020; Apergis *et al.,* 2023). Here, transnational companies that are headquartered in developed countries create subsidiaries in developing countries (with lax environmental laws) to undertake environmentally damaging production, extraction and disposal activities, and then repatriate the output produced to home markets through exportation. As mentioned above, the reasons for the PHH emanate from the poor quality of the investments by multinational corporations.

EUE refers to the unequal sharing of the burden of environmental destruction among countries through patterns of trade, FDI and differences in political, economic and military power (Jorgenson, 2016; Givens *et al.,* 2019). Developed countries use their political, economic and military clout to coerce developing countries into lopsided agreements. Global institutions such as the World Bank and the International Monetary Fund (IMF), under the control and/ or influence of high-income countries, encourage developing countries to focus on export-oriented production, which they promote as indispensable to economic development and integration into the world economy. However, the terms of trade and the goods that are traded are ecologically in favour of developing countries in three ways:

Firstly, trade allows rich countries to extract material resources from poor countries to use in their capital-intensive production processes and then export toxic wastes from their production to poor countries (Jorgenson and Givens, 2013; Tong *et al.,* 2022). Secondly, it allows developed countries to import clean goods produced by the dirty industries that relocated to developing countries from developed countries. As already stated, FDI and multinational corporations allow high-income countries to shift environmentally damaging production to poor countries. Thus, trade allows developing countries to consume goods of which production could have caused big environmental impacts within their boundaries without bearing the environmental costs of their production. Lastly, the terms of trade favour developing countries in terms of the physical quantities exchanged. Developed countries import disproportionately more goods than they export to developed countries but still end up with a favourable balance of trade (Dorninger *et al.,* 2021).

Thus, the crux of WST is that core countries simultaneously exploit resources from peripherical countries and dump hazardous wastes in these weaker countries (Jorgenson and Givens, 2013). The result is that while it is the rich countries who place more stress on the global environment, it is the developing countries who are disproportionately bearing the brunt of degraded and stressed ecosystems (Jorgenson, 2016). Proponents of WST argue that trade and FDI are channels through which affluent countries transfer environmental impacts to poor countries. This contrasts with the proponents of EMT, who see trade and FDI as channels for the transfer of cleaner and efficient technologies that ameliorate environmental degradation in developing countries. Due to the PHH and EUE, WST rejects the EKC relationship. As core countries have the power to pollute beyond their national boundaries, it is misleading to only analyse local environmental impacts (York *et al.,* 2003a).

Figure 2.2 below depicts the impact of economic growth in the WST and EMT worldviews. The curve with the broken line is the traditional EKC curve, which only looks at internal impacts. It ignores the ecological damage a country's economic activities, multinational corporations, and trade are causing through FDI in other countries. The solid line is the world-systems view curve, which considers both internal and external impacts. Economic growth is shown to have a monotonically damaging impact on the environment. Thus, as noted by York *et al.* (2003a), WST proponents argue that all empirical evidence in support of the EKC hypothesis is spurious. The implication is that in WST, economic growth is not compatible with environmental quality and, thus, sustainable development.

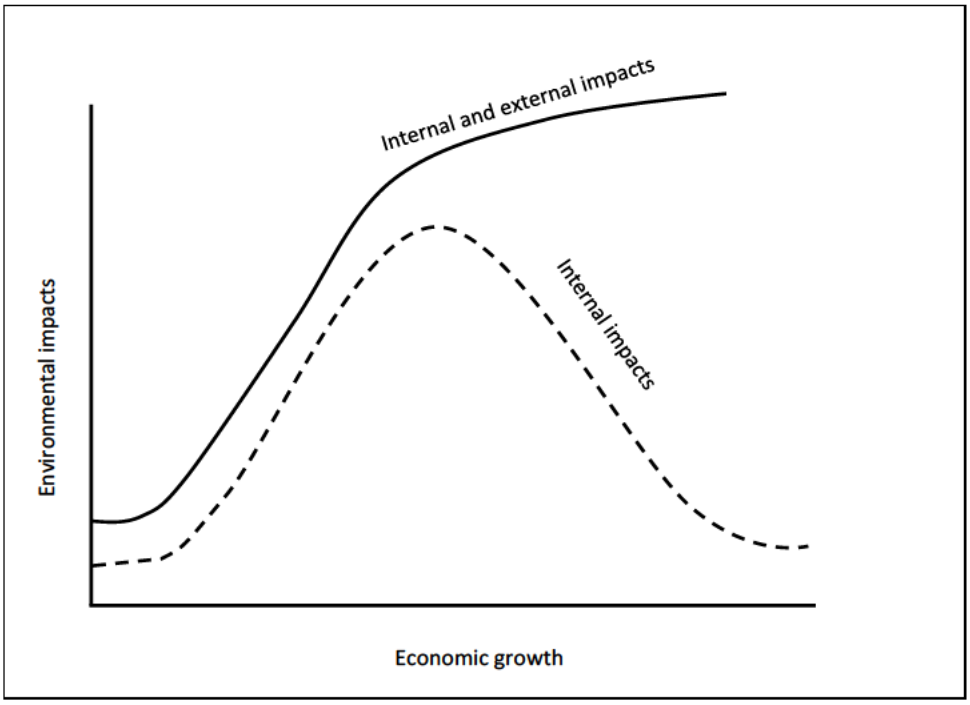

Figure 2.2: EKC in Neoclassical economics and WST frameworks

(Source: York et al., 2003a, 284)

It should be noted, however, that the tension between PHH and PHEH has important implications for the shape of the traditional EKC curve. The EKC hypothesis reconciles these two dichotomous viewpoints using its scale and technique effects (Abbasi *et al.,* 2023). The scale effect explains the PPH by positing that accelerating economic growth using FDI intensifies environmental destruction (PHH). In contrast, the technique effect explains the PHEH by positing that the transfer of environmentally benign technologies via FDI reduces environmental degradation. The domination of the scale effect means that FDI causes environmental degradation, while the domination of the technique effect means that FDI results in environmental improvements. It may be concluded that the rising part of the EKC is due to the dominance of the scale effect and thus reflects the PHH. Conversely, the declining part is due to the dominance of the technique effect and is thus reflective of the PHEH. Therefore, the EKC validates both the PHH and PHEH. This is in line with the EMT assertion that FDI can have temporary negative impacts on the environment in the short run.

The WST has its criticisms. Consistent with the political economy perspective, WST is criticised by modernisation theorists for rejecting the PHEH and EKC hypotheses. According to modernisation theorists, the PHEH and EKC (were) obtained due to the replacement of economic rationality (profit maximisation) by ecological rationality (environmental consciousness) in the daily behaviours of institutions and actors such as business and government at later stages of economic development, when environmental problems are severe (Mol, 1995; Mol *et al.,* 2009).

During periods of environmental crises, ecologically rational industries or businesses invest in and deploy eco-friendly technologies to minimise environmental externalities over and above internalising them voluntarily; regulation by the environmental state would be stringent, making it the most important pre-condition for eco-innovation, and multinational companies would then champion international diffusion of these eco-innovations (Huber, 2008).

The result is that the technologies would reduce environmental damage worldwide. However, as per the Jevons paradox explicated above, political economy advocates concede that technically efficient technologies reduce resource consumption per unit of output but maintain that due to the relentless profit-seeking of corporations, these technologies accelerate the scale of production, and as a result, total resource consumption and emissions increase. The result is that economic growth has a harmful, monotonic or homogenous impact on the environment, which is in contrast to the EKC hypothesis. In addition, WST maintains that all FDI investments by powerful countries in the Global South are ecologically unfriendly since these poor countries have lax environmental laws as they are under intense pressure to generate economic growth.

Somerville (2021) identifies two problems with the EUE theory. Firstly, the main problem is its lack of coherence or explanatory force, in that its description of the patterns of global power inequalities has no underlying explanation. Specifically, the ‘exchanges’ envisaged in EUE appear to be unidirectional, unrequited flows of resources disproportionately from poor to powerful countries, and not real exchanges at all. While it is agreed that these flows disadvantage the Global South and must, therefore, be slowed down, the magnitude of the slowing down needed to benefit poor countries or hurt rich countries is not known.

In addition, Somerville (2021) argues that unequal exchange is traditionally restricted to wage differentials, which are only explored in neo-Ricardian terms – i.e. workers in the Global South are paid much lower wages than those in the Global North. As such, introducing the concept of *ecologically* unequal exchange convolutes the picture by including factors external to the exchange relations (environmental harms) as an inherent part of the exchange.

EUE views the transfer of value primarily through the lens of material or biophysical resources rather than exchange value. It also assumes that these resources can be assessed based on their monetary worth. This leads to confusion, as monetary value and exchange value are not equivalent; exchange value depends on the specific resources traded and the prices paid for them. In this scenario, unequal exchange occurs when the monetary value surpasses the exchange value. As a result, two significant issues arise: the rationale for the imperial appropriation of resources and the exploitation of labour remains poorly defined, and the environmental consequences of producing and distributing these resources are neglected.

In terms of relevancy to the study, WST identifies economic growth as the biggest contributor to environmental degradation (York *et al.* 2003a) and disputes the assertion of EMT that economic growth is a panacea to ecological destruction in the long run. More importantly, by identifying the Global North through their economic activities as the real culprits of environmental degradation worldwide, WST exonerates the growing populations of the Global South who are blamed by the Global North. Thus, WST is useful in settling the debate on who is most responsible for environmental devastation.

It is important to note that of the two strands of literature in WST, namely PHH and EUE, this dissertation will only focus on PHH. Thus, the validity of EUE will not be tested. The first reason for using PHH is that it is a direct antithesis of EMT's PHEH, which will be investigated in this study. The second reason is that testing the validity of the EUE is a complex process. For example, the process involves tracking the inter-regional flow of biophysical resources as well as financial flows (Moran *et al.,* 2013; Dorninger *et al.,* 2021; Hickel *et al.,* 2022); comparing the price of a resource in a developing country to the price of the same resource in a developed country (Moran *et al.,* 2013); and tracking emissions flows between core and peripheral countries (Jorgenson, 2011; Fritzgerald and Auerbach, 2016; Tong *et al.,* 2022). Thus, the impact of both FDI and trade on the environment will be discussed under PHH – PHEH.

Under the discussion of how the study will test EMT propositions, it was highlighted that in the approach of investigating non-linear relationships, the EMT hypotheses (EKC and PHEH) are validated if the coefficients of square of the relevant variables (i.e. GDP, trade and FDI) are negative. Given that the WST is the antithesis of EMT, results contradicting EMT confirm WST. Specifically, the EKC hypothesis is invalid when the square of RGDP coefficient is positive (see Rahman, 2017; Erdogan *et al.,* 2020; Kindo *et al.*, 2023) and the PHEH is invalid when the square of trade and FDI coefficients are positive (see Pradhan *et al.*, 2021; Destek and Okumus, 2019).

As mentioned above, the concern of this dissertation is not on non-linear relationships but on cointegrating relationships that analyze short- and long-term dynamics. In this approach, WST propositions are validated if the long-run coefficients of GDP, trade and FDI are positive. A positive RGDP long-run coefficient indicates the validity of the WST worldview (see Sharif *et al.*, 2023; Chekouri *et al.*, 2020). Similarly, positive long-run coefficients of trade openness and FDI indicate that the PHH is valid (see Duodu *et al.*, 2021; Renyong and Sedik, 2023; Solarin *et al.*, 2017; Sun *et al.*, 2017).

This chapter now turns its attention to the discussion of the theories that examine the demography-environment nexus.

2.3 Theories of Demography and the Environment

Myriad theories explicate the links between demography and the natural environment. According to Jolly (1994), the literature on the demography-environment nexus can be segregated into four main theoretical frameworks: Neoclassical economics, classical economics (and natural science), dependency and political regional ecology perspectives and intermediate variables. Jolly (1994) further explains that in the Neoclassical tradition, high populations are good for the environment, provided that there are no market distortions. The theoretical framework grounded in neoclassical economics is the Cornucopian approach.

In contrast, classical economists argue that big populations are the root cause and biggest contributors to environmental degradation. The approach, based on classical economics, is called Neo-Malthusian Environmentalism, or simply Neo-Malthusianism. In the dependency and political regional ecology perspectives, a highly unequal distribution of income and resources between rich and poor countries at a cross-national level (dependency theory), and between the affluent and poor citizens in a country (political ecology), fuels high fertility among the poor, which then ultimately leads to unsustainable resource use and thus, environmental degradation (Jolly, 1994). As such, it is not the high population that is the root cause, but rather poverty, which is orchestrated by the affluent (Fletcher *et al.,* 2014; Collins, 2002).

Lastly, the intermediate variable theory is a fusion of the first three theories, thereby making it the basis for a single, associated framework (Jolly, 1994). According to this theory, the population is a proximate cause of environmental degradation, which means it is a channel through which the impacts of the ultimate causes of environmental degradation, like poverty, polluting technologies and extraction of resources from poor countries by rich countries, are intensified.

Out of these four approaches, the dominant two are Neo-Malthusianism and Cornucopianism (or Boserupian) (Fan *et al.,* 2006; Ghanem, 2016; Jolly, 1994). Neo-Malthusian environmentalism offers a pessimistic, deleterious view of population growth, while the Cornucopian (or Boserupian) approach offers a positive, optimistic view of population growth. Therefore, these two theories give a balanced view of the impact of population on the environment. In this section of the theoretical review, the Neo-Malthusian approach will be discussed first, followed by the Cornucopian view.

2.3.1. Neo-Malthusianism Environmentalism

Neo-Malthusianism is the idea that a big population causes ecological disasters (Follett, 2020). This is because it exerts pressure, which causes overshoots of the limits of the earth's carrying capacity, resulting in environmental problems with potentially disastrous consequences (Raworth, 2017). This approach is a reincarnation of the works of Thomas Malthus, who, in 1798, prophesied the perils of overpopulation and population growth in his book '*An Essay on the Principle of Population'* (Kopnina and Washington, 2016). Malthus posited that the fixed supply of land and resources implied a finite world, which has natural limits to its capacity to provide food (Ojeda *et al.,* 2019). He further propounded that populations grow at a rate which far outpaces that of the growth in food supply. The natural consequence of this mismatch would be that the per capita share of food would continue to decline, and eventually, the minimum food requirement would become a hard limit for population growth. The core of Malthus's theory is that there is a long-term optimal, sustainable level of the population – the earth's carrying capacity – which, if exceeded, brings starvation, disease and war (Friedrichs, 2019).

Malthus' prediction of starvation, misery and poverty was contradicted by circumstances in the following centuries. In the nineteenth century, the population had grown, but at a much slower pace than what he had predicted (Kulkarni, 2016). The Industrial Revolution brought unprecedented affluence to Europe, which allowed for investments in sanitation, health and education, resulting in reduced child mortality (Follett, 2020). In the twentieth century, the Green Revolution saw people produce (and throw away) more food beyond imagination (Kopnina and Washington, 2016). However, these developments did not kill the Malthusian spirit.

In the 1940s, the concept of the environment as an amalgamation of physical and biological realities emerged after the degradation of the earth's ecosystems in the form of soil erosion and water scarcity, and reduction in the numbers of wildlife and pollution was observed (Locher, 2019). In the 1960s and 1970s, when the world population grew rapidly from 3 billion in 1960 to 4 billion in 1975 (Follett, 2020), environmental damage became a global threat (Locher, 2019). Inevitably, it became necessary to understand the causes of the environmental crises. As a result, scholarly work on understanding the impact of population and economic growth on the looming limits of the earth's carrying capacity peaked (Kulkarni, 2016; Seidl and Tisdell, 2008). Contrary to political economy and modernisation theorists who blamed capitalism and economic growth for the ecological crises, Neo-Malthusian environmentalists unequivocally attributed the crises to overpopulation (Locher, 2019). This is the resurgence of Malthus' view and the birth of Neo-Malthusianism (Follett, 2020). Neo-Malthusians applied Malthus' ideas of the natural limits of the earth to the natural environment, and not to subsistence.

Two publications in 1968 catapulted Neo-Malthusian Environmentalism into a mass or even dominant movement (Merchant, 2022). Firstly, Paul Ehrlich, the protagonist of Neo-Malthusian environmentalism, published The Population Bomb, in which he predicted environmental collapse, global starvation and massive deaths emanating from unbridled population expansion in the following decade (Fletcher *et al.,* 2014; Collins, 2002; Ehrlich, 1968). Secondly, Garrett Hardin (1968) corroborated the link between overpopulation and environmental damage in his essay called The Tragedy of the Commons. Using a pastoral example of grazing lands and cows, he demonstrated that overgrazing would be the result when farmers kept on adding cows to the common resource (Hardin, 1968). The veiled message conveyed by Hardin was that the world's limited resources (grazing lands) were being degraded (overgrazing) by the rapidly increasing number of people (cows), whose adverse impacts were affecting everyone (Locher, 2019; Pham *et al.,* 2020).

In the summer of 1970, a team of international researchers at the Massachusetts Institute of Technology (MIT), the Club of Rome, undertook the most famous Neo-Malthusian modelling exercise to date (Friedrichs, 2019). They explored scenarios with five factors that they deemed to determine and limit economic growth: population growth, agricultural production, natural resources depletion, industrial production and pollution generation (Raworth, 2017, Meadows *et al.* 1972). In their report published in 1972, referred to as the Limits to Growth, the Club of Rome identified resource scarcity as a hard limit to both economic and population growth (Meadows *et al.*, 1972). In this situation of scarcity, burgeoning population, as well as increasing affluence, would result in economic and ecological collapse. As such, the hope of man living indefinitely on earth depended on him limiting population and economic growth (Meadows *et al.* 1972).

As indicated above, Neo-Malthusians link the natural limits of the earth to environmental degradation, and not to food shortages, as espoused by Malthus. There are two complementary frameworks in Neo-Malthusianism that are used to characterise the finitude of the earth and measure environmental sustainability, namely EF and planetary boundaries (O'Neill *et al.,* 2018). The EF framework was discussed in Section 1.1, where it was used to illustrate the unsustainable trajectory of African countries.

In the planetary boundaries framework, the natural limits of the earth, or the ecological ceiling, is a composite of nine planetary boundaries that are related to nine critical processes: climate change, ocean acidification, chemical pollution (novel entities), nitrogen and phosphorous loading (biochemical flows), freshwater withdrawals, land conversion, biodiversity loss, air pollution and ozone layer depletion (Raworth, 2017; O'Neill *et al.,* 2018). Each boundary quantifies the threshold level of anthropogenic disturbances that should not be breached if the Earth is to have stable and hospitable planetary conditions (Richardson *et al.,* 2023). For example, the climate boundary is 350 ppm (parts per million) of carbon dioxide (Raworth, 2017). However, according to the National Oceanic and Atmospheric Administration (NOAA), emissions reached a new record of 424 ppm in May 2023. Thus, climate change is a serious problem because the boundary has long been breached.

As mentioned earlier, the breach of planetary boundaries is a perilous situation, leading to environmental problems with catastrophic consequences (Ojeda *et al.,* 2019). Scientific evidence indicates that six out of nine boundaries (climate change, biodiversity loss, land conversion, biochemical flows, novel entities and freshwater change) have already been crossed (Richardson *et al.,* 2023). This is why global warming, climate change, biodiversity loss, soil erosion and freshwater shortages are all signs of the unprecedented environmental degradation of the Anthropocene. In light of these challenges, Neo-Malthusian environmentalists argue that large and growing populations are driving the ecological overshoots. Therefore, understanding the population-environment nexus from a Neo-Malthusian perspective is crucial.

Ehrlich (1968), quoted in Merchant (2022:547-8), notes that 'Too many cars, too many factories, too much detergent, too much pesticide, multiplying contrails, inadequate sewage treatment plants, too little water and too much carbon dioxide – can all be traced easily to *too many people*.' Birdsall (1992) explains the two mechanisms through which population growth influences greenhouse gas emissions in developing countries. Firstly, large populations translate to a high demand for fossil fuel-generated energy. Secondly, large populations fuel deforestation by destroying forests for firewood or agricultural production, which all increase CO_2 emissions. Therefore, population growth affects the environment and the economic activities of production and consumption (Raworth, 2017; Crutzen, 2002; Satterthwaite, 2009).

The IPAT model, which is ascribed to Ehrlich and Holdren (1971), is the dominant framework for understanding anthropogenic environmental damage. It postulates that the impact on the environment (I) is the multiplicative product of three primary drivers: population (P), affluence or economic activity (A), and technology (T) (Sarkodie, 2018; Pham *et al.,* 2018). Thus, the IPAT model is represented as follows:

$I = PAT$

where I is the environmental impact, P is population size, A is Affluence, and T is technology.

The IPAT model was created from the debate between Neo-Malthusians, Paul Erlich and John Holdren, who posited that population growth was responsible for environmental damage happening in the USA in the 1960s, and Barry Commoner, a degrowth advocate, who argued that technology and increasing consumption per capita were to blame (Chertow, 2001; Merchant 2022). The original specification of the IPAT model by Erlich and Holdren, before Commoner disputed it, was as follows (Pham *et al.,* 2020; Chertow, 2001):

$I = P \times F$

where I represents the impact on the environment, P denotes population size, and F denotes the impact per capita and represents other factors that are influenced by changes in population, such as technology and economic growth. This formulation of the IPAT equation simultaneously confirms Neo-Malthusian conviction of the centrality of population in causing environmental damage and how societal conditions, including technology and economic growth, compound the population's impact. Hence, Neo-Malthusians agree that economic growth and technology degrade the environment, although they play second fiddle to the population.

York *et al.* (2003a) note that Neo-Malthusians, in addition to population size and growth, stress the importance of population structure and density in explaining environmental degradation. The structure of the population relates to urbanization, defined as the percentage of the population living in urban areas (Effiong, 2017; Cobbinah *et al.,* 2015), and the proportion of the economically active, defined as those between the ages of 15 and 64, who are willing and able to work (Fan *et al.,* 2006).

Zhu and Peng (2012) describe three pathways in which urbanization drives the ecological footprint through carbon emissions. Firstly, with constant technology and energy structure, the higher production and residential housing associated with urbanization results in increased energy demand, which in turn causes emissions to increase. In Africa, energy is produced from fossil fuels. Secondly, the higher demand for infrastructure and dwelling housing inherent in urbanizing societies, increases the demand for building materials that are emission intensive. Finally, urbanization is associated with the conversion of grasslands and woodlands, and these land-use changes result in the release of carbon, sequestered in the destroyed biota (animal and plant life in a particular habitat). With respect to the proportion of the economically active, a population with a high labour force has bigger environmental impacts than a population with a big proportion of economically inactive people. Lastly, a densely populated area should see more environmental impacts than a sparsely populated area, as there is a higher demand for the services of nature.

Neo-Malthusianism has been critiqued and as explained by Fletcher *et al.* (2014), the biggest criticism of Neo-Malthusian comes from the political ecology school. Political ecologists argue that Neo-Malthusians attribute environmental degradation to the poor, while failing to acknowledge the role played by hegemonic interests in environmental crises. As discussed in the WST theory above, transnational corporations, international financial institutions (e.g., the IMF) and development assistance organizations (e.g., World Bank), promote the extraction of natural resources from poor countries through exports to developed countries. The resultant environmental problems are then blamed on poor people, who have the smallest ecological footprints and very little access to natural resources. As noted by Ojeda *et al.* (2019), political ecologists do not argue that big populations are not degrading the environment. The issue is that population is not the primary cause of the environmental crises.

The other important critique comes from the Boserupian or Cornucopian perspective. This group of Neoclassical economists rejects the Neo-Malthusian idea of a fixed carrying capacity and natural limits of the earth, based on the assumptions of constant technology, constant consumer tastes and preferences, and a fixed quantity of natural resources (Jolly, 1994). Neo-Malthusians believe that environmental scarcities are hard limits for both economic and population growth (Meadows *et al.,* 1972). As highlighted above, an increase of population beyond its optimal level not only exacerbates ecological scarcities, leading to economic collapse, but causes the pressure on the environment to overshoot planetary boundaries, leading to severe environmental problems characterizing the Anthropocene (Meadows *et al.,* 1972; Raworth, 2017).

In contrast, Cornucopians argue that natural resources can be substituted with manufactured capital or technology, meaning there is no resource scarcity and, thus, no limits to growth (Stern, 2004; Stubbs and Cocklin, 2006). The core of the Cornucopian critique is that Neo-Malthusians stress the fixity of natural resources with “a highly defective way of thinking about resources … as given, autonomous of human productive and creative forces, as if they were independent of human action, and impervious to transformation through technology, choice, and inventiveness” (Simon, 1990 quoted in Aligica, 2009:76). According to Simon, the earth is resourceful, since there is no limit to human ingenuity, which is the ultimate resource (Simon and Khan, 1984; Simon, 1981, 1996). This technology also rectifies environmental problems (Fletcher *et al.,* 2014). Therefore, Neo-Malthusians do not see people as the source of creativity and innovation, which makes big populations contributors to environmental quality (Fletcher *et al.,* 2014). It should be noted, however, that Neo-Malthusians acknowledge the positive impact of technology on the environment, but they do not believe it can overcome ecological crises (Jolly, 1994).

Another criticism of Neo-Malthusianism is that it is not grounded in empirical evidence. Merchant (2022) points out that Ehrlich (1968), in his book The Population Bomb, linked population growth to the many causes of environmental degradation, such as too many cars and factories, without using any historical data. The author notes that the reason could be that Ehrlich, as a professor in butterfly biology, was not an expert on questions of the human population and the environment. Julian Simon (1990) quoted in Aligica (2009), confirms that Neo-Malthusian doomsayers neglect past experience because of their preoccupation with the future. However, scientific inquiry requires that theories be based and founded on empirical data against which they are ultimately tested. The implication is that the present and the future cannot be understood if one is clueless about the terms of reference with the past. For example, the climate crisis is framed in a Neo-Malthusian perspective of doom, that should the threshold of 1.5°C of global warming be breached, there would be catastrophic consequences, but there is no empirical evidence to back these assertions (Gleditsch, 2021).

However, between February 2023 and January 2024, the world's average temperatures exceeded the 1.5^0 C limit (Copernicus Climate Change Service (C_3S), 2024), and during this period, storms, droughts and fires were reported across the planet, including in Turkey and Libya (World Meteorological Organization (WMO), 2024). It can be argued that the Neo-Malthusian prophesies of doom are now being fulfilled.

Neo-Malthusianism is relevant to this study as it identifies the population as the biggest contributor to environmental degradation. Consequently, it predicts that the coefficient of population in the regression model will be the greatest. This fulfils one of the aims of this study, which is to determine the size of the impact of population on the ecological footprint. As a result, the underlying question of what size the impact of population on the EF in Africa is incidentally addressed. In addition, the theory presents one side of the overpopulation debate. Based on the findings of the study, this dissertation will contribute to the discussion by validating or disproving Neo-Malthusianism in the African context.

In the next section, the chapter discusses the Cornucopian perspective.

2.3.2 Cornucopian Perspective

The theory of Cornucopianism is the response of Neoclassical economists to the environmental problems in the Anthropocene, blamed on rising populations. It is a direct contradiction of Neo-Malthusianism. Jolly (1994) notes that the concern of Neoclassical economists is the ability of an economy, supported by a finite natural resources base, to provide a decent level of affluence to a rapidly growing population. The author adds that two factors can bring perfect reconciliation between the finitude of resources and material affluence for the populace into fruition: the substitutability between manufactured and natural capital and technological improvement, which leads to productivity gains in the use of resources in production. The result is that, even in its finitude, the earth is plentiful, and this bountifulness constitutes the meaning of cornucopianism (Jonsson, 2014).

There are two theses of Cornucopianism: one focuses on limits to growth and environmental scarcities, and the other on environmental degradation. The main advocate of the first strand, general cornucopianism, is Julian Simon, regarded as the arch-cornucopian, following his many publications on resources, the environment and population (Aligica, 2009; Jackson, 1995). The protagonist of the second strand is Ester Boserup (1965), an agricultural economist who disputed Malthus's conclusions due to his treatment of technology as an exogenous factor (de Sherbinin *et al.,* 2007). In these two theses, favourable environmental outcomes are due to high populations. In the immediate paragraphs below, this chapter discusses the Simonian cornucopianism first, followed by the Boserupian theory.

As indicated above, Neoclassical economists generally believe that manmade capital can replace natural capital when natural resources are scarce. This position is espoused in the Neo-classical production function, which includes capital as a factor of production, without discriminating between natural and manmade capital (Daly, 1999). It is this substitutability between natural and man-made capital, which makes the exhaustion of natural resources inconsequential (Solow, 1974). In this process of natural and man-made capital substitution, free markets play an important role (Jolly, 1994; York *et al.,* 2003a). As explained by Jackson (1995), the increasing demand for resources by growing populations creates temporary shortages, leading to higher prices of natural resources. In turn, these higher prices spur the prospection for new resources. If this fails, substitutes for these resources will be developed and introduced through technical progress, leading to the long-run elimination of resource shortages, and lower prices to levels below what they initially were.

The result is an improvement in human welfare from this population growth, which initially seemed perilous. Solow (1974) explains that the technology that allows the prospection of new deposits of a resource or its complete replacement with manufactured capital is referred to as backstop technology. Jackson (1995), quoting Simon, adds that developing countries can also benefit from their big populations, as a higher population density is a requirement and stimulant of trade and specialisation, which, together with the introduction of free markets, would generate improvements in infrastructure (technology) and education.

However, ecological economists dismiss this construct of seamless substitutability between the different forms of capital. In this worldview, natural and man-made capital are complements and not substitutes (Daly, 1999). The ecological economics production function is due to Nicholas Georgescu-Roegen, who rewrote the 'Solow-Stiglitz' variant of the Neo-classical production as follows (Daly, 1999):

$$Q = K^a R^b L^c$$

where Q is output, K is the capital (man-made) stock, R is the flow of natural resources, and L is the labour supply. This production function encapsulates the complementarity of man-made and capital, which is epitomized by the fact that man-made capital is manufactured from natural resources (Daly, 1999).

It was indicated above that the key area of conflict between Malthus and Boserup is the exogeneity or endogeneity of technological advancement due to population increases. Maquette (2017) explains that Malthus regards technology (agricultural implements) as exogenous because, in his time, just as in pre-industrial times, agricultural technology was fixed, which meant that the productivity of the environment (land resources) was also fixed. Hence, in Malthus's worldview, technology and the environment (land resources) are autonomous variables that work together to determine population, defined as population growth and size. In contrast, Boserup writes about the aftermath of the industrial and agricultural revolutions and the period during the green revolution, where technology was broader, including tools (tractors), techniques (fallow patterns) and inputs (fertiliser).

As a result, in analysing the relationship between population (size, growth and density), technology and the environment (land resources), Boserup argues that changes in population provoke technological innovation, which in turn influences the production capacity of the environment. According to Jolly (1995), Boserup posits that an increasing population density is associated with decreasing returns to the land per worker hour, and this leads to increased pressure on the land to compensate for the increase in population. As a result, the quest for higher productivity per unit of land forces people to adapt or innovate, which leads to the intensification of land use, starting with the reduction of fallow periods to multiple cropping cycles. Although it is possible for land intensification to lead to land degradation in the form of soil erosion, propagated by the cultivation of hills or reduction, soil fertility, due to shorted fallow periods to the point that it does not allow the land to replace lost nutrients, simple technology like using fertilisers and terracing, can prevent such degradation (Jolly, 1994). As indicated by Oudman (2013), Boserup derived her thesis from tracking the historical agricultural progress from the era of primitive hunter-gatherer societies to multi-cropping systems, with a particular focus on the implementation of new technologies in the development of agricultural systems.

Therefore, the core of the cornucopian theory, through the synthesised lenses of Simon and Boserup, is that big populations reduce environmental problems through incentivising technological innovation. Since humans are the ultimate source of innovation and creativity, a higher population means a bigger supply of creative people, leading to abundant human ingenuity (de Sherbinin *et al.* 2007). This means that population growth is good for the environment (Gleditsh, 2021; Kosamu *et al.,* 2019). Accordingly, Cornucopians assert a negative relationship between environmental degradation and population, thereby making any regression results showing that population is damaging to the environment spurious at best (Fan *et al.,* 2006). The culprits of environmental damage in Cornucopianism are market failures and ecologically faulty technologies (de Sherbinin *et al.,* 2007). Free markets spur technological advancement because they allow innovators to reap profits from their inventions, unlike command economies, where inventions are part of national service (York *et al.,* 2003a).

The Cornucopian theory has its own critics. Ecological economists heavily criticise it on two fronts. Firstly, Neo-classical economists deny limits to growth because they do not accurately depict the relationship between the environment and the economy. As explained by Daly (2019), Neo-classical economists see the natural environment as the extractive sector of the economy. In mathematical terms, the environment is a subset of the economy. Ecological economists posit that the economy is contained by the environment, and thus cannot expand beyond the bounds of the environment (Daly, 1999). It is this belief that the economy can grow indefinitely, which lends Cornucopianism to being anthropocentric.

Secondly, as discussed above, Cornucopians assert that perfect substitution opportunities exist between manmade and natural capital. Indeed, in some cases, manmade capital can replace natural resources in production. For example, the rise in the price of natural resources forces producers to use synthetics and consumers to replace resource-intensive products with other goods (Jolly, 1994). Contemporary evidence to buttress the Neo-Malthusian assertion, is the discovery of fibre optic cables that are now used in electrical wiring and communication lines in place of copper (Nasong'o, 2017).

However, there are instances where these substitution possibilities, espoused by Cornucopians, are not there. As argued by DesRoches (2019) and Reijnders (2021), critical natural capital cannot be substituted with man-made or other, natural capital. Critical natural capital refers to the parts of the environment that contribute to life support systems, biodiversity and other important functions (DesRoches, 2019). Reijnders (2021) qualifies that the substitution of man-made capital for natural capital is currently centred on resource efficiency, which means the use of fewer natural resources per unit of output. He adds that this does not necessarily mean that the pressure on the natural resource has been diminished to the point of substitution. The reason is that although production uses a smaller part of the natural resource, the scale of production may increase to such an extent that, in absolute terms, the consumption of the natural resource increases. This is the classic Jevons paradox alluded to earlier.

Cornucopians are also criticized for seeing every person as a possessor of ingenuity, which can be used to ameliorate environmental problems. Critics of Cornucopianism argue that a big population does not necessarily translate to higher levels of human ingenuity. Based on the Cornucopian thesis, Nigeria, with a population of over 213 million people, should be technically more advanced than Japan, which has about 117 million odd people - a difference of just under 90 million. However, the reality is that Japan is one of the most technologically advanced countries, far ahead of India, which has about 1.4 billion people. This means that intervening and underlying factors, like poverty and lower education outcomes, reduce a population's 'innovator coefficient. '

The Cornucopian theory is relevant to this study, as it counterbalances Neo-Malthusianism by identifying the population as a neutral or even ameliorating factor of the environment. As pointed out earlier, what causes environmental damage are wrong technology and market distortions. The theory, therefore, does not place too much value on the size of the population coefficient but on its significance and sign in the regression results. By determining the impact only, and not the size of the impact, Cornucopian theory partially fulfils the aim of this study of determining the size of the impact of population on the ecological footprint. As a result, the underlying question of the size of the population's impact on the EF in Africa is partially addressed. However, this theory is relevant in accentuating the significance of the study in contributing to the overpopulation – overconsumption debate between the Global South and Global North.

2.4 Conclusion

Except for a few sceptics, there is scientific consensus that the world is in unprecedented ecological crises with climate change and global warming at the pinnacle. Consequently, determining or identifying the root cause(s) of ecological destruction is at the epicentre of natural and social sciences enquiry. Three factors, namely population, affluence and technology, have long been identified as the primary drivers of environmental degradation. However, contemporary evidence is pointing to population and affluence as the biggest causes of the environmental crises. The dominant perspectives or theories of environmental change do not agree on the precise nature of the relationships, the relative sizes of their impacts, and the different pathways in which these primary drivers affect the environment. This debate is far from being settled.

Both EMT and WST explain the economic growth-environment nexus. These two theories are in harmony over the primacy of economic growth in ecological destruction. However, differences emerge when the analysis shifts to impacts at higher levels of economic development. Using the EKC hypothesis, EMT advocates argue that economic growth has a heterogeneous impact on the environment. It damages the environment when a country is poor but brings about environmental improvements once a country is rich enough to demand and afford environmental quality. It is through the development and deployment of efficient technologies that environmental improvements are achieved. Conversely, WST proponents assert that economic growth has a damaging, ever-intensifying impact on the environment. Although they agree that technological improvements reduce environmental impacts per unit of output, WST proponents maintain that technically efficient technologies accelerate production so that the increased scale of production increases overall resource consumption and environmental impacts. They further allege that the EKCs in rich countries occur due to environmental load displacement to poor countries through the mechanisms of trade and

FDI. Thus, the correct way of analysing the relationship between economic growth and the environment is to consider both internal and external impacts.

In the context of developing countries, EMT advocates posit that trade and FDI are mechanisms through which efficient technologies are deployed in poor countries. These technologies allow the economies of poor countries to grow with falling environmental impacts. This is the PHEH effect, which is contradicted by WST advocates, who argue that the technologies transferred by powerful countries into poor countries through trade and FDI are of low quality. This is because poor countries have lax environmental laws and are desperate to pursue economic growth at any cost. The result is that the environments in poor countries are devastated by the ensuing production, while the environments in rich countries improve due to the externalisation of dirty production. This is the PHH.

In the case of African countries (Nigeria, South Africa, and Egypt), both EMT and WST hold sway. Because of the high prevalence of poverty and unemployment in Africa, citizens, on one hand, cannot afford and are thus not interested in environmental quality. On the other hand, corporations do not have the resources to invest and develop efficient technologies; and the government lacks the finance to enforce stringent environmental regulation. Thus, workers and governments must support economic growth, which multinational corporations drive, at all costs. In Africa, multinational corporations are the key drivers of economic growth. Given that internal players in African economies are not yet ecologically rational, it is highly unlikely that multinational companies are bringing clean and efficient technologies to Africa. Overall, this suggests that both FDI and economic growth are damaging the African natural environment. The implications are that the EKCs of African countries are yet to reach their turning points and that the PHEH is not yet valid. Thus, WST seems to have more explanatory power in relation to the impact of economic growth on the environment.

Neo-Malthusian environmentalists and Cornucopians explicate the demography-environment nexus. Neo-Malthusians argue that a big, dense, urbanizing population is the primary driver of environmental damage. Such a population necessitates rising production of goods, which is enabled by technology that may even be ecologically faulty. Given the finitude of the earth in providing environmental services, the result of this dirty economic expansion is ecological destruction. This pessimistic view of population is contradicted by

Cornucopians, who believe that big populations spur the development of technologies that bring about environmental improvements.

In Africa, Neo-Malthusian environmentalism appears to have more credence than Cornucopianism. Cornucopians see each and every person as an embodiment of creativity and innovation. However, this is far from the truth, particularly in Africa, which is on the peripheries of scientific, financial and industrial innovation. Even in developed and technically advanced countries, the proportion of innovative people in the population is small. Given that African people are not highly innovative, the ameliorative technology argument of Cornucopians essentially falls away. As such, this leaves the African people solely as an environmentally destructive species.

In summary, Neo-classical economists, through economic modernization and cornucopianism, have an optimistic view of population and economic growth. Big populations do not damage the environment. Rather, they are the source of technological innovations that eventually negate and reverse the negative environmental impacts of economic growth. WST and Neo-Malthusian environments agree that technological improvements can have a positive effect on the environment, but the ensuing bigger scale of production means that the destructive environmental impacts of economic growth will increase. WST differs from Neo-Malthusians in that the former see economic growth as the biggest driver of environmental damage, while the latter identify population as the greatest cause of ecological devastation. Thus, Neo-classicals agree with WST on the primacy of economic growth in causing environmental degradation, but they disagree on the exact nature of the relationship. In addition, they also disagree on the impact of population on the environment.

This chapter explored the various economic and demographic theories of environmental damage. These theories have divergent views on the impact of economic and demographic factors on the environment. The next chapter will explore the empirical evidence for these theories.

Chapter 3 : EMPIRICAL LITERATURE REVIEW

3.1 Introduction

As demonstrated in Chapter 2, various theories explain the impact of economic and demographic factors on the environment, which has led to considerable debate on how various socio-economic factors impact the environment and how their relative contributions to environmental change compare. This chapter now focuses on the empirical work in this space.

The first section discusses empirical studies on the key impact factors of environmental deletion. This section initially explores the studies that reveal that economic factors have the biggest impact on the environment, after which studies that reveal that demographic factors are the biggest culprits of environmental degradation are discussed. The second section delves into studies that determined that economic activity and population size increases bring about environmental improvements. In this section, the chapter first discusses economic factors, followed by demographic factors. The focus will be based more on studies, using the estimation technique employed in this study, which is discussed below. The third section discusses the reasons why the studies reviewed in the first two sections are different. The fourth section focuses on the relationship between Foreign Direct Investment (FDI) and environmental quality to understand the impact of increased economic integration on the environment. The literature reviewed centres on the Pollution Haven Hypothesis - Pollution Halo Effect Hypothesis (PHH-PHEH) conflict. The fifth section explores the theoretical framework, which explicates how the three primary drivers of environmental damage, as per the Impact, Population, Affluence and Technology (IPAT) model, are further disaggregated into different socio-economic drivers employed in empirical research. In this section, the socio-economic variables employed in the study are selected and justified. The last section is a critical summary highlighting the research gaps.

The devastating effects of increases in economic activity and population size have long been recognized in literature. As a country's economy and population grow, its demand for natural capital services increases. For example, a growing economy can be supported by the accelerated extraction of natural resources, which directly translates to increased environmental degradation. The discussion in Chapter 2 highlighted how population and economic growth can have non-monotonous impacts on the environment. To be concrete, the short-run environmental impacts of increases in socio-economic factors differ from long-run impacts. In addition, the discourse in Chapter 2 also outlined how increases in socio-economic environmental drivers contribute differently to environmental destruction.

Consequently, the study employs the panel auto-regressive distributed lag (P-ARDL) model, to estimate the environmental impacts of various socio-economic drivers. Auto-regressive distributed lag (ARDL) is a widely used econometric model that helps analyze the relationship between variables in both the short and long run (Hussain *et al.,* 2017). An advantage of this model compared to other models is that it may be applied to data that are integrated in different orders (Ssali *et al.,* 2019; Voumik and Ridwan; 2023), making it very flexible for time series and panel analysis. Three different estimators, namely Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effects (DFE), can be used to estimate the P-ARDL model (Noureen *et al.,* 2022). However, the PMG is considered the most efficient of the three estimators (Rafindadi *et al.*, 2018). As a result, the PMG estimator is employed in the study. The model itself is discussed in more detail in Chapter 4. The rest of this chapter highlights the empirical studies that specifically employ the P-ARDL model to investigate the relationship between socio-economic factors and environmental damage, as they are the most relevant to this study's research approach.

The debate between the Global South and Global North, on what the biggest contributor to environmental degradation between economic and population dynamics is, persists. Several studies have considered the respective contribution of economic and demographic factors (e.g., Shuai *et al.,* 2017; Fan *et al.,* 2006; Pham *et al.,* 2018). However, the results of these studies contradict each other at times. Consistent with the World-Systems Theory (WST) perspective, some studies found that economic factors are more damaging to the environment than demographic factors (see Charfeddine and Mrabet, 2017; Sarkodie, 2018, Sorge and Neumann, 2019). In contrast, consistent with the Neo-Malthusian worldview, some studies found that demographic factors destroy the ecological ecosystem more than economic factors (see Wang and Dong, 2018, Sharma *et al.,* 2020).

In this section of the empirical review, key economic drivers of environmental damage are discussed, and then the key demographic environmental drivers will be explored.

3.2.1 Economic Factors

As already alluded to, economic factors are partly responsible for the Anthropocene (the current geological age). The most prevalent economic factors in literature are economic growth (see Fan et al., 2006; Shuai et *al.,* 2017), energy use (e.g., Mujtaba *et al.*., 2022; Wu *et al*., 2021) and trade openness (Duodu *et al.,* 2021). In the review of the empirical studies revealing the primacy of economic drivers of ecological destruction, studies identifying economic growth will be reviewed first, followed by energy consumption, and lastly, trade openness.

3.2.1.1 Economic Growth

In extant literature, economic growth proxied by Real Gross Domestic Product (RGDP) per capita, is an important contributor to environmental decay worldwide. As argued in Chapter 2, a growing economy is associated with adverse environmental impacts like waste generation. Numerous studies have found that economic growth is the biggest driver of environmental degradation. Among the studies, some tested the evidence of the Environmental Kuznets Curve (EKC) hypothesis (e.g., Kindo *et al*., 2023), while others did not test it (e.g., Sharif *et al.,* 2023).

In terms of studies that did not examine the EKC hypothesis, Fan *et al.* (2006) analyzed the factors influencing carbon dioxide (CO2) emissions in China and across the globe between 1975 and 2000. They utilized the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework along with Partial Least Squares (PLS) regression. The countries involved in the study were categorized into four income strata: high-income (HI), upper-middle-income (UMI), lower-middle-income (LMI) and lower-income (LI). The variables assessed included CO_2 emissions, GDP per capita, population size, energy intensity (as an indicator of technology), urbanization and the percentage of the population aged 15 to 64. Data for these variables were obtained from the World Bank's Statistical Information Management and Analysis (SIMA) database. The findings revealed that increases in both economic activity and population size have negative effects on the environment. Notably, economic growth had the most substantial impact, followed by energy intensity, population size, urbanization, and finally, the percentage of the population aged 15 to 64 years. This result, which shows that economic growth exerts a greater influence on environmental degradation than population growth, supports the perspective of WST.

These results in Fan *et al.* (2006) were corroborated by other studies (e.g. Shuai *et al.,* 2017; Sorge and Neumann, 2019). In an attempt to identify the key impact factors (KIF) of global warming, Shuai *et al.* (2017) investigated the impact of population, affluence and technology on carbon emissions using panel and time-series data in 125 countries at different income levels for the period 1990 - 2011. Similar to Fan *et al.* (2006), the countries were divided into four income strata: HI, UMI, LMI and LI. The variables used in the study are CO_2 emissions, urban population (used as an indicator of population growth), GDP per capita and energy intensity. All data, both time series and panel, came from the World Bank Database. Using the STIRPAT framework and cointegration estimation, the results showed that economic and urban population growth degrade the environment. Additionally, the study's results indicated that increases in energy intensity also increase CO_2 emissions. This means that both increases in population and affluence, and technological improvements degrade the environment worldwide. Regarding the relative impacts, results from the panel regression showed that on a global scale, and in UMI and LI panels, the KIF is affluence, followed by technology, and the population is the least. The result showing that economic growth is the primary driver of environmental degradation is consistent with the WST view.

Sorge and Neumann (2019) investigated the environmental impact of population, affluence, technology and urbanization. The authors used data from the World Bank for 76 economies divided into three income tiers: high, middle, and low. African countries included in the study were Algeria, South Africa, Gabon and Benin. The study covered the period 1971 – 2014. The variables used in the study were CO_2 emissions, aggregate population, real per capita GDP, energy intensity (technology) and urbanization, squared and cubed real per capita GDP and urbanization. Using a STIRPAT framework and the dynamic heterogeneous P-ARDL model Statistical Information Management and Analysis (SIMA) estimation, the results showed that in the short term, increases in urbanization do not cause environmental deletion, while increases in affluence and technology degrade the environment. In the long term, increases in population and affluence were found to increase environmental impacts. However, the environmental impact of increases in affluence was the biggest, followed by technology and, lastly, population. This result that increases in population has a lesser impact on emissions than affluence is consistent with the WST theory.

Determined to find the major causes of environmental degradation in Algeria, Africa's second-largest emitter of carbon, Chekouri *et al.* (2020) examined the driving forces of CO_2 emissions using the STIRPAT model from 1971 to 2016. Variables used in the study were

CO_2 emissions, total population, urban population, affluence (RGDP per capita), the square of GDP to assess the EKC hypothesis, and energy intensity. All data came from the World Bank. Applying the PLS regression method, the results revealed that economic growth increases CO_2 emissions, which means it damages the environment in Algeria. All factors were also found to increase carbon emissions, which means that they all contribute to environmental damage. Concerning relative impacts from the regression result, affluence had the biggest coefficient and thus impact, followed by urban population, total population and energy intensity. The result that affluence has a bigger impact on the environment than population dynamics validates the WST perspective.

Sharif *et al.* (2023) studied the role of green technology and energy in sustainable development in five Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) between 1995 and 2020. CO_2 emissions, RGDP, green technology, green energy, environmental taxes and population were the variables employed in the study. Data on RGDP and population was sourced from the World Development Indicators (WDI), data on green technology, environmental taxes and green energy came from the Organization for Economic Co-operation and Development (OECD) website, and British Petroleum provided data on CO_2 emissions. The Cross-sectional ARDL (CS-ARDL) model was employed. The results showed that, both in the short- and long-run, economic growth and population were positively correlated with CO_2 emissions. This means that increases in population and economic activity degrade the environment in Nordic countries. However, the impact of economic growth was shown to be bigger than that of the population in the long run. This result that economic growth damages the environment more than population growth, and is consistent with the WST perspective.

Nathaniel and Khan (2020) studied the environmental impact of various socio-economic factors on the environment in the Association of Southeast Asian Nations (ASEAN) from 1990 to 2016. This region comprises Indonesia, Malaysia, the Philippines, Singapore, Thailand and Vietnam. Variables included in the study were ecological footprint, energy use (non-renewable), urbanization, RGDP and renewable energy use. Data on the Ecological Footprint (EF) came from the Global Footprint Network (GFN) website, and data on the remaining variables came from the WDI. Using the STIRPAT model and Augmented Mean Group (AMG) estimation technique, the results showed that economic growth damages the environment in Association of Southeast Asian Nations (ASEAN) countries. Increases in non-renewable energy use and trade were also shown to degrade the environment. In contrast, increases in urbanization and renewable energy use were shown to have insignificant impacts on the environment. The impact of economic growth was the biggest, followed by non-renewable energy use and trade. The result that economic growth has a bigger impact than urbanization is consistent with the WST theory.

Turning to studies that tested the EKC hypothesis and rejected it, Kindo *et al.* (2023) investigated the impact of FDI on environmental quality in 13 West African countries between 2000 and 2020. Countries studied included Gambia, Mali, Niger and Nigeria. CO_2 emissions (proxy for environment damage), FDI, RGDP per capita, square of RGDP, renewable energy consumption, institutional quality, financial development, human capital, domestic investment (gross fixed capital formation), industrialisation, trade openness and population growth rate were the variables employed in the study. Data came from WDI. The study used the STIRPAT framework and employed quantile regression and Dynamic Ordinary Least Squares (DOLS) for long-run estimation. Results of the DOLS regression showed that economic growth brings environmental improvements in the short run but degrades the environment in the long run. The implication for the EKC hypothesis is that it does not hold for West Africa. Increases in FDI inflows, financial development, human capital, industrialization and the population growth rate were also found to degrade the environment in West Africa. In contrast, increases in renewable energy consumption, institutional quality, domestic investment and trade openness were found to bring environmental improvements to the region. Regarding the magnitude of the degrading impact, economic growth had the largest, followed by population growth rate, FDI, industrialization and human capital. The results that the EKC does not exist and that economic growth degrades the environment confirm the WST theory.

Sarkodie (2018) investigated the drivers of environmental degradation and pollution in Africa for the period 1971 – 2013, focusing on 17 African countries, including South Africa, Nigeria and Egypt. Variables used in the study were EF, agricultural land, birth rate, CO_2 emissions, ecological footprint, energy use, fertility rate, food production index, GDP per capita, permanent cropland and square of GDP. The EF was used as an indicator of environmental damage, while CO_2 emissions were used as an indicator of environmental pollution. All data for the variables came from the WDI, except ecological footprint data from GFN. The study used the Westerlund error-correction model and panel cointegration tests, U-shape test, fixed and random effect estimators, and panel causality test. The fixed effects EF model results indicated that economic activity increases bring short-term environmental improvements but degrade the environment in the long run. This means that supportive evidence of the EKC hypothesis was not found. Concerning the rest of the variables, the results showed that increases in energy consumption, food production, agricultural land, carbon emissions and fertility rate degrade the environment. In contrast, increases in the remaining variables promote environmental quality. In terms of the magnitude of the deleterious impacts, economic growth had the biggest, followed by energy consumption, fertility rate, agricultural land, food production and CO_2 emissions. The result that the EKC hypothesis does not hold and that economic growth is the biggest environmental driver in Africa is consistent with the WST perspective.

Rahman (2017) investigated the impact of various socio-economic variables on environmental quality in the 11 most populous Asian countries: Bangladesh, China, India, Indonesia, Iran, Japan, Korea, Pakistan, the Philippines, Vietnam and Thailand. The study covered the period 1960 - 2014. The variables included in the study were CO_2 emissions, population density, RGDP per capita, the square of RGDP per capita economic growth, energy use and exports. Data was collected from the WDI. The study employed the panel Fully Modified Ordinary Least Squares (FMOLS) estimation for long-run cointegration and DOLS for robustness tests. Economic growth was shown to have a negative relationship with CO_2 emissions but, per the square of RGDP, was found to be positively related to CO_2 emissions. Thus, economic growth damages the environment in the long run. Increases in all the environmental drivers were found to degrade the environment. However, economic growth has the biggest impact, followed by population density, energy use and exports. The finding that invalidates the EKC relationship and shows that economic growth is the biggest driver of environmental deletion in Asia is consistent with the WST perspective.

The next section examines studies identifying energy use as a key driver of ecological destruction.

3.2.1.2 Energy Use (Consumption)

Energy consumption is the second most important environmental stressor in literature (Charfeddine and Mrabet, 2017). This is because energy powers an economy (Nathaniel and Adeleye, 2020). A growing economy is supported by high energy consumption. As such, an economy reliant on dirty energy sources such as coal, such as (in) South Africa, is likely to experience environmental degradation. Consequently, many studies have identified energy use as a key driver of environmental devastation.

Wu *et al.* (2021) investigated the drivers of falling CO_2 emissions in 18 developed countries, including the USA, UK, Sweden, Germany and the Netherlands, from 1990 to 2016. Variables used in the study were CO_2 emissions, total population, GDP per capita, final energy consumption, renewable energy consumption, industrial structure and fossil energy consumption. Data on CO_2 emissions, total population, final energy use and fossil energy use came from the International Energy Agency (IEA), and data on the remaining variables came from the World Bank. Using the STIRPAT and two-way fixed effect models, the study revealed that total population and economic growth had a positive relationship with CO_2 emissions, meaning that both these factors degrade the environment. Renewable energy, energy intensity and final energy consumption were found to be the factors behind the falling CO_2 emissions. In terms of the size of the degrading impacts, fossil energy consumption had the biggest impact, followed by economic growth, total population and industrial structure. The finding that fossil energy consumption has the biggest degrading impact on the environment is consistent with the WST perspective.

Focusing on 16 EU member countries, Alola *et al.* (2019) investigated the environmental impacts of various socioeconomic factors for the period 1997 – 2014. Variables included in the study were ecological footprint, RGDP, non-renewable and renewable energy consumption, trade openness and the fertility rate. Data on the ecological footprint was sourced from the GFN, and the WDI provided data on the socio-economic drivers. Employing the Panel Mean Group- Auto-Regressive Distributed Lag (PMG-ARDL) approach, the study found that, in the short run, both non-renewable and renewable energy consumption had insignificant impacts on the environment, and so did only trade openness and fertility rate. Only RGDP was found to have a significant, degrading impact on the environment. In the long run, the study found that both non-renewable and renewable energy consumption positively correlated with the ecological footprint. This means that increases in these environmental drivers degraded the environment in Europe. The results also showed that increases in RGDP degrade the environment, while increases in trade openness and fertility rate promote environmental quality. Regarding the relative size of the degrading impacts, non-renewable energy consumption had the biggest impact, followed by RGDP, and renewable energy consumption. The result that energy consumption and economic growth have a bigger impact than the fertility rate supports the WST theory.

The findings of Alola *et al.* (2019) are supported by Nathaniel and Adeleye (2020), who studied the challenges of attaining sustainable development in Africa. The study covered the period from 1992 to 2016 and focused on 44 countries, including Ethiopia, South Africa, Nigeria and Egypt. Variables used in the study are ecological footprint and CO_2 emissions as the proxies of environmental degradation, energy use per capita, financial development, RGDP per capita, gross fixed capital formation, urbanization and urban population growth. Data on the various socio-economic variables and CO_2 emissions was sourced from the WDI, and ecological footprint data came from GFN. Two models were estimated, one for CO_2 emissions and the other for EF, with the only difference being that urban population growth was used in the CO_2 emissions model, and urbanization in the EF model. The dynamic panel data (DPD) estimator and General Method of Moments (GMM) estimation techniques were employed.

Results of CO_2 emissions model, under both the DPD and GMM techniques, revealed that energy use is positively correlated with CO_2 emissions. This result implies that increases in energy use, degrade the environment in Africa. In addition, increases in all the other factors were found to degrade the environment, except for the urban population growth rate, which reduces environmental degradation. Regarding the size of the impacts, the results of the DPD estimator showed that energy use has the biggest impact, followed by gross fixed capital formation, financial development, urban population growth and RGDP. The lag of CO_2 emissions was shown to have insignificant impacts. In turn, the results of GMM estimation showed that energy use has the biggest impact, followed by financial development, gross fixed capital formation, RGDP, urban population growth and the lag of CO_2 emissions. The result that energy use has the biggest environmental impact, is consistent with the WST worldview.

Dimnwobi *et al.* (2021) analyzed the effects of population dynamics on environmental quality in Africa's five populous countries (DR Congo, Ethiopia, Nigeria, South Africa, and Tanzania) from 1990 – 2019. Variables used in the study were EF, urbanization, population density, population growth rate, RGDP per capita, age structure, energy consumption and trade openness. Data on EF came from the GFN, while data for all the other variables came from the World Bank database. The Cross-sectionally Augmented autoregressive distributed lag (CS-ARDL) estimation was employed. The short-run results showed that energy consumption has an insignificant environmental impact. The long-run results of the study found that energy use is positively correlated with the EF, which means that increases in energy use, degrade the environment. In addition, all population dynamics and economic variables were also found to degrade the environment. Concerning the magnitude of the impact, energy consumption had the biggest impact, followed by the age structure of the population, population growth rate, RGDP, population density, trade openness and lastly, urbanization. This result shows that energy consumption has the biggest environmental impact in selected African countries, which is consistent with the WST perspective.

Concerned with environmental sustainability in West Africa, Opuala *et al.* (2023) investigated the environmental impacts of various economic and demographic factors between 1980 and 2017. Variables included in the study are EF, financial development, GDP, energy consumption, trade openness, urbanization and natural resource rent. EF data came from the GFN, financial development data came from the International Monetary Fund (IMF), energy consumption data came from the US Energy Information Administration (EIA), and the WDI provided data for the remaining variables. The STIRPAT framework and ARDL model with PMG estimation technique were employed. The results show that increases in energy consumption and all other variables have insignificant short-term impacts. In the long run, increases in energy consumption were shown to increase the EF and, thus, degrade the environment in West Africa. It was revealed that increases in GDP and urbanization degrade the environment, while increases in financial development and trade openness were shown to have insignificant impacts. Energy consumption had the biggest degrading impact, followed by urbanization and economic growth. The result that increases in energy consumption degrades the environment more than increases in urbanization supports the WST perspective.

Musah *et al.* (2021) reinvestigated the PHH in G-20 countries between 1992 and 2018. The countries were analysed as a total sample and three sub-samples: high-, upper-middle- and lower-middle income countries. Variables used in the study were CO_2 emissions, energy consumption, urbanization and FDI. All the data came from the WDI. The Dynamic Common Correlated Effects Mean Group (DCCEMG) panel data estimator was used. The long-run results showed that, in the global sample, increases in energy consumption, FDI inflows and urbanization significantly increase CO_2 emissions, meaning that all the drivers are responsible for environmental harm in developed countries. However, the degrading impact of energy consumption was the biggest, followed by FDI and urbanization. The finding that energy consumption degrades the environment more than urbanization supports the WST perspective.

Xing *et al.* (2023) investigated the impact of economic growth on the environment in 13 developing Asian countries (including China, India, Pakistan, and Indonesia) between 1990 and 2019. CO_2 emissions were used as the proxy for environmental decay. At the same time, RGDP, the square of RGDP, electric power consumption, fossil fuel energy consumption, total population, total trademark applications and the interaction of trademark applications and RGDP are the variables used as environmental stressors. Data on all variables were sourced from the WDI. The STIRPAT and PMG-ARDL models were used. The long-run results showed that an increase in fossil fuel energy consumption degrades the environment in Asian economies. Increases in total population and electric power consumption were also shown to degrade the environment. However, increases in both economic growth and the interaction of trademark applications were found to decrease environmental degradation. In contrast, increases in trademark applications did not significantly impact the environment. Concerning the size of the degrading impact, fossil energy consumption had the biggest impact, followed by total population and electric power consumption. The finding that fossil energy consumption degrades the environment more than the total population. is consistent with the WST perspective.

The next section looks at studies that identify trade openness as a key driver of ecological destruction.

3.2.1.3 Trade Openness

Trade openness is one of the engines of economic growth. As argued by van Tran and Do (2019), trade opens up international markets to a country, which then necessitates and enables domestic production to expand. This industrial expansion leads to higher exploitation of natural resources and high pollution, leading to worsening environmental degradation in terms of quality and quantity. China is a typical example. Its economic growth is supported by a strong manufacturing base, which is sustained by strong exports. However, China is faced with severe environmental problems. Consequently, trade openness has been identified as a key driver of ecological deletion in literature.

Duodu *et al.* (2021) studied the relationship between FDI and environmental quality in 23 SSA countries for the period 2005 to 2019. Four variables were used as proxies of environmental degradation: CO_2 emissions, natural resource depletion, forest reserve depletion and environmental quality index. Variables included as drivers of environmental degradation were policy and institutions for environmental sustainability, FDI, domestic investment, international tourism, trade openness, urbanization, RGDP and the interactive term between political institutions for environmental sustainability and FDI. Data on all the variables came from WDI. The STIRPAT model and system-GMM estimation were employed. The long-run results of the forest reserve depletion model showed that increases in trade openness increase forest reserve depletion. This means that expanded economic integration damages the environment. The results also showed that increases in the interaction of FDI and political institutions, domestic investment and international tourism degrade the environment. Conversely, increases in political institutions, FDI, urbanization and economic growth were shown to reduce environmental degradation. In terms of the size of the degrading impacts, trade openness had the biggest impact, followed by domestic investment, international tourism and the interaction of political institutions. The result that trade openness degrades the environment more than urbanization is consistent with the WST theory and PHH hypothesis.

Renyong and Sedik (2023) analysed the relationship between environmental sustainability and FDI in 18 East African Countries (EAC), including Zimbabwe, Rwanda, Ethiopia and Madagascar. CO_2 emissions, forest reserve depletion and natural resource depletion are the proxies for environmental degradation used in the study. At the same time, FDI, domestic investment (gross fixed capital formation), international tourism, trade openness, urbanization, economic growth, and policy and institution for environmental sustainability (PIES) are the explanatory variables used. All data was provided by the WDI. The study employed the STIRPAT framework and GMM for long-run estimation. Short-run results showed that increases in trade openness have the biggest degrading impact in the CO_2 emissions model, although they did not have significant impacts in the forest reserve and natural resource depletion models. In the long run, increases in trade openness were shown to degrade the environment in all three models. In the forest reserve and natural resource depletion models, the degrading impact of trade openness was found to be the biggest, followed by domestic investment and urbanization. In contrast, economic growth was found to promote environmental quality. The result that trade degrades the environment more than urbanization supports the WST and PHH.

Solarin *et al.* (2021) investigated the relationship between environmental quality and economic growth in Nigeria between 1977 and 2016. The study employed EF as the proxy for environmental deletion and economic growth, urbanization, trade openness and FDI as the socio-economic drivers of ecological decay. EF data came from the GFN website, and data on the rest of the variables were extracted from the WDI. The STIRPAT model and the standard ARDL estimation technique were employed. The short-run results showed that increases in trade increase the EF, which implies that increased trade openness degrades the environment. Increases in all the other variables were shown to degrade the environment, except for urbanization. In the long run, increases in trade openness and FDI were shown to degrade the environment, while increases in urbanization and economic activity were shown to reduce ecological destruction. The impact of trade openness was bigger than that of FDI. The result that trade had the biggest degrading impact on the environment is consistent with the WST and PHH.

Sun *et al.* (2020) analysed the long-run effects of trade openness on carbon emissions in Sub-Saharan African countries between 1990 and 2014. Variables used in the study are CO_2 emissions, RGDP, trade openness, and energy consumption. All data came from the WDI. The study employed the FMOLS and DOLS estimators to examine the long-run effects. The results of both estimators showed that increases in trade openness accelerate CO_2 emissions, which means that trade exacerbates ecological decay. Increases in energy consumption and RGDP were also shown to increase environmental devastation. In both models, trade openness had the biggest impact on the environment in SSA, which is consistent with the WST and PHH.

Shah *et al.* (2022) investigated the determinants of CO_2 emissions in 18 low-income countries, including Haiti, Gambia, Togo and Tanzania, between 2000 and 2020. Population density, trade openness, urbanization, RGDP, FDI and domestic credit to the private sector were employed as the drivers of carbon emissions. All data was sourced from the WDI. The PLS and FE estimation techniques were employed. Results of the PLS estimation showed that increases in trade openness, RGDP and domestic credit to the private sector degrade the environment. Conversely, increases in FDI and urbanisation were found to have a benign impact on the environment. Increases in population density were shown to have an insignificant impact on the environment. The degrading impact of economic growth was the biggest, followed by trade openness and domestic credit. The result that increases in trade openness degrades the environment more than population dynamics is consistent with WST and PHH.

The next section focuses on empirical studies that reveal that increasing population is the primary driver of ecological harm.

3.2.2 Demographic Factors

In direct contradiction to the studies above, other studies have found that increases in population dynamics have a bigger impact on the environment than economic factors (e.g. Poumanyvong and Kaneko, 2010; Li *et al.,* 2023; Wang and Dong, 2018). The key impact demographic drivers identified in the literature, are population size (e.g. Poumanyvong and Kaneko, 2010; Li *et al.,* 2023; Lin *et al.,* 2009); urbanization (e.g. Wang and Dong, 2018; Nathaniel *et al.,* 2019) and population density (e.g. Sharma *et al.,* 2020).

In the review of the empirical studies revealing the primacy of demographic drivers of ecological destruction, studies identifying population size will be reviewed first, followed by urbanization and lastly, population density.

3.2.2.1 Population Size

Poumanyvong and Kaneko (2010) studied the impact of urbanization on energy use and CO_2 emissions in 99 countries between 1975 and 2005. Variables used in the study were the two proxies of environmental damage, total energy use and total CO_2 emissions, population size, per capita GDP, share of industry sector, share of service sector, urbanization and energy intensity. Population, urbanization, GDP and the share of industry and service sectors data were obtained from the World Bank, while emissions and energy data were extracted from the International Energy Agency (IEA). For the two measures of environmental harm and different income clusters, the STIRPAT model was used, together with four different estimation methods, namely pooled OLS, fixed effects (FE), Prais-Winsten (PW), and first differenced (FD). For CO_2 emissions in the global sample (all countries), results from the FD estimation showed that population size and GDP positively correlated with CO_2 emissions. This means that increases in population size and economic growth damage the environment worldwide. In terms of the size of the impact, population size had the biggest impact, followed by economic growth, energy intensity and urbanization. This result that increases in population have a greater, degrading impact on the environment than economic growth is consistent with the Neo-Malthusian perspective.

Li *et al.* (2023) analysed the driving forces of the EF in the Pearl River Delta urban agglomeration (PRDUA), an economically vibrant region in the Guangdong Province of China, between 1990 and 2019. Cities in PRDUA include Zhaoqing, Guangzhou, Huizhou, and Jiangmen. Variables used in the study are EF, total population, affluence, the square of affluence to verify the EKC hypothesis, expenditure on research and development (R&D),

patents certified, urban green area, average temperature and the total amount of water resources. All data was sourced from the EPS data platform and statistical yearbooks of PRDUA cities. Using the STIRPAT model and ridge regression method, the results showed that population size and affluence are positively correlated with EF, implying that these factors degrade the environment. In terms of the size of the impacts in absolute terms, population had the biggest impact of EF, followed by expenditure on R&D, affluence, patent certified and lastly, urban green area. This result of population having the greatest impact on the environment supports the Neo-Malthusian theory.

Lin *et al.* (2009) analysed environmental impacts in China from 1978 to 2006. The variables used were energy consumption, the proxy of environmental damage, total population, urbanization, GDP per capita, industrialization level and energy intensity. All data came from the China County Statistical Yearbook, 1979 – 2007. The study used a variant of the STIRPAT model, namely STIRPUrInAT, modified to include urbanization (Ur) and industrialization (In) variables, and ridge regression to overcome the problem of multicollinearity. The results showed that increases in population, as well as all the remaining variables, have a positive influence on energy consumption, which means they degrade the environment. In terms of the size of the impact, the population had the biggest influence on the environment, followed by urbanization, industrial level, economic growth, and lastly, energy intensity. This result of population increases having the biggest environmental impact is consistent with the Neo-Malthusian perspective.

Knight *et al.* (2013) studied the impact of working fewer hours on the environment in 29 high-income OECD countries between 1970 and 2007. The study employs three dependent variables: EF, carbon EF and total CO_2 emissions. Data on the first two variables came from GFN, and the last variable was from the World Resources Institute. Eight independent variables were used in total. Three came from the decomposition of GDP per capita: annual hours of work per employee, labour productivity and employment to ratio. Data regarding these variables came from The Conference Board. The remaining variables are GDP per capita, total population size, urbanization, manufacturing as a percentage of GDP and services as a percentage of GDP. Data on these variables came from the World Bank. The STIRPAT model and first-difference panel regression were employed. The results of the total CO_2 emissions model showed that increases in population increase carbon emissions, meaning population expansions degrade the environment in selected countries. The results also showed that increases in RGDP and urbanization damage the environment, while increases in work hours and the manufacturing and service shares of GDP bring about environmental improvements. The impact of the population was the biggest, followed by urbanization and economic growth. The result is that population increases have a bigger, degrading impact than economic growth on the environment and is supportive of the Neo-Malthusian perspective.

Hassan *et al.* (2024) studied the impact of nuclear energy generation on CO_2 emissions in the USA between 1973 and 2021. Variables included in the study are CO_2 emissions (the dependent variable) and RGDP, square of RGDP, total population and nuclear energy generation (the independent variables). Data on carbon emissions and nuclear energy generation was sourced from the US EIA, and data on population and GDP came from the WDI. The STIRPAT and EKC frameworks and the dynamic autoregressive distributed lag (DARDL) estimation model were used. The short- and long-run results showed that increases in population increase CO_2 emissions. This means population expansion degrades the environment of the USA. In contrast, increases in economic growth and nuclear generation were found to bring environmental improvements in both the short and long run. The result that population growth is the key driver of environmental degradation in the USA, is consistent with the Neo-Malthusian perspective.

Mujtaba *et al.* (2022) investigated the impact of economic growth, energy consumption, and total population on environmental quality in five regions (South Asia, East Asia, Latin America & Caribbean, North America and Middle East and North Africa (MENA)) between 1971 and 2014. CO_2 emissions were employed as the dependent variable. Data on the four variables came from the WDI. The non-linear ARDL (NARDL) estimation model was used. The short-run results showed that increases in total population increase CO_2 emissions and thus damage the environment in East Asia, MENA and South Asian regions. In contrast, increases in total population were found to have benign impacts on the environment in the Americas. In the long run, population increases were found to degrade the environment in all five regions. In contrast, economic growth was found to promote environmental quality in all regions except MENA. Increases in energy consumption were found to degrade the environment in all regions except MENA. The deleterious impact of the total population on the environment was the biggest in MENA, North America, and South Asia. Energy consumption had the biggest impact in the other two regions. The finding that the increasing population has a bigger degrading impact than economic growth worldwide and more than energy consumption in many parts of the world supports the Neo-Malthusian perspective.

3.2.2.2 Urbanization

Urbanization is an important driver of environmental degradation. As argued in Chapter 1, increasing urbanization damages the environment by increasing the demand for emission-intensive building materials, and releasing carbon sequestrated in biota, destroyed during land conversion. Consequently, some studies found that urbanization is the population dynamic with the greatest impact.

Wang and Dong (2018) investigated the drivers of environmental degradation in 14 Sub-Saharan African countries. Countries included in the study are Angola, Benin, Botswana, Cameroon, Cote d'Ivoire, Ghana, Kenya, Mauritius, Mozambique, Nigeria, Senegal, South Africa, Tanzania and Togo. The period of the study is 1990 – 2014. EF, GDP, non-renewable and renewable energy consumption and urban population were the variables used in the study. EF data was sourced from the Global Footprint Network (GFN), while data for the other variables came from the WDI. Using FMOLS and Augmented Mean Group (AMG) estimators, the study showed urbanization positively correlates with EF. This means that the increasing urbanization levels in SSA are degrading the environment. The study also showed that economic growth and non-renewable energy consumption are positively related to the EF, which means that economic growth and increasing use of non-renewable energy damage the environment in Sub-Saharan Africa (SSA). Renewable energy consumption was found to be negatively related to the EF, which means that increasing the use of renewable energy is good for the environment. In terms of the relative impacts, the study showed that the urban population has the biggest impact on the environment, followed by GDP, renewable and lastly, non-renewable energy. This result shows that urbanization damages the environment even more than economic growth, which is consistent with the Neo-Malthusian theory.

Pham *et al.* (2020) studied the consequences of population, affluence and technological progress on environmental damage in 28 European countries. The authors used data from the World Bank from 1990 to 2014. The variables used were carbon emissions, FDI, energy intensity, renewable energy consumption, trade openness, GDP per capita, population size and urbanization. The study employed a STIRPAT regression model and Panel Vector Autoregressive (PVAR) with General Method of Moments (GMM) style instruments for short-run estimations and FMOLS for long-run cointegration. The long-run results found that urbanization was positively correlated with carbon emissions, which means that increases in urbanization damage the environment in Europe. The results also showed increases in energy intensity, trade openness, and total population harm the environment, while economic growth and renewable energy consumption reduce environmental degradation. The degrading impact of urbanization was the biggest, followed by trade openness, energy intensity and population size. The result that urbanization is the biggest driver of environmental decay in Europe is consistent with the Neo-Malthusian perspective.

Applying the STIRPAT framework and ARDL estimation to time series data, Anser (2019) investigated the impact of energy consumption and human activity on Pakistan's carbon emissions between 1972 and 2014. Data on CO_2 emissions, population growth rate, urbanization, poverty, fossil fuel energy use, renewable energy consumption and hydroelectricity consumption came from WDI. Long-run results showed that increases in urbanization degraded the environment in Pakistan. Increases in population growth rate, RGDP, poverty and fossil fuel consumption were also shown to degrade the environment, while increases in renewable energy and hydroelectricity consumption were shown to promote environmental quality. Concerning the magnitude of the degrading impacts, urbanization had the largest impact, followed by fossil fuel energy use, population growth rate, RGDP and poverty. The result that urbanization is the biggest driver of environmental decay in Pakistan is consistent with the Neo-Malthusian worldview.

Zhang *et al.* (2022) applied three cointegrating regression methodologies (FMOLS, DOLS, and FEOLS to estimate the long-run moderating role of technology innovation and urbanization in Brazil, Russia, India, China and South Africa (BRICS) countries. The study employed panel data between 1980 and 2017 for ecological footprint per capita, financial globalization index, technological innovation, urbanization, RGDP per capita, renewable energy and the interactive terms of technological innovation and urbanization. Data on the EF was sourced from GFN, financial globalization data was collected from KOF Swiss Economic Institute, and data on the rest of the variables came from WDI. The results of the FMOLS and DOLS revealed that increases in urbanization degrade the environment in BRICS nations. Similarly, an increase in GDP and financial globalization were also found to degrade the environment. In contrast, increases in renewable energy consumption, technological innovation and the interactive term were shown to promote environmental quality. The degrading impact of urbanization was the biggest, followed by economic growth and financial globalization. The result that urbanization degrades the environment more than economic growth supports the Neo-Malthusian perspective.

Rahman and Alam (2021) analyzed the relationship between environmental pollution and various socioeconomic drivers in Bangladesh between 1793 and 2014. Variables employed in the study are CO_2 emissions, clean energy, population density, urbanization, RGDP and trade openness. All data was sourced from the WDI. Using the ARDL estimation, the long-run results show that increases in urbanization increase CO_2 emissions and, thus, degrade the environment in Bangladesh. The results also showed that increases in population density and economic growth degrade the environment, increases in clean energy use reduce environmental degradation, and increases in trade openness have insignificant impacts on the environment. The degrading impact of urbanization was shown to be the biggest, followed by population density and economic growth. The result that population dynamics degrade the environment more than economic growth is consistent the Neo-Malthusian worldview.

3.2.2.3 Population Density

Population density was also identified in some studies to be a key demographic driver of environmental harm. Sharma *et al.* (2020) examined the impact of economic and demographic factors in South and Southeast Asian countries between 1990 and 2015. The countries included in the study were Bangladesh, India, Sri Lanka, Malaysia, Nepal, Pakistan, Thailand, and the Philippines. EF, RGDP per capita, non-renewable energy, renewable energy, urbanization, fertility rate and population density are the variables that were used in the study. EF data was collected from the GFN, and data on the other variables came from the WDI. The PMG estimation approach was used. The long-run results showed that population density was positively correlated with the EF, meaning that high population density degrades the environment. Except for energy use, all the remaining variables exhibited a positive correlation with the EF. However, the impact of urbanization was found to be insignificant. This means that renewable energy promotes environmental quality, and urbanization does not worsen environmental degradation in these sampled Asian countries. In terms of the size of impact, population density had the biggest impact, followed by energy use, fertility rate, economic growth and lastly, non-renewable resources. This result that population density has the biggest, degrading impact on the environment, is consistent with the Neo-Malthusian approach.

The results of Sharma *et al.* (2020) were corroborated by Ohlan (2015), who investigated the relationship between CO_2 emissions and four variables: population density, energy consumption, economic growth (represented by RGDP per capita) and trade openness in India for the period 1970 – 2013. Data on all five variables came from the WDI. The ARDL method was used to estimate long-run relationships, while the error correction model (ECM) was used to estimate short-run relationships. In the long run, the research found that population density positively correlated with CO_2 emissions, which means population density damages the environment. This relationship was also found to exist for energy consumption and RGDP per capita. Trade openness was found to have an insignificant impact on CO_2 emissions. Regarding the impact size, population density was found to have the biggest impact, followed by energy consumption and economic growth. The short-run results were similar to the long-run results, with the only difference being that long-run coefficients were bigger. Population density was found to have the greatest impact on the environment. This result is consistent with Neo-Malthusianism.

Focusing on 15 MENA countries for the period 1990 to 2018, Haouas *et al.* (2023) examined the impact of demographic factors on the environment of these countries. Variables included in the study were CO_2 emissions, population density, population size, urban population, RGDP per capita, industry value added, energy intensity and energy use. Data on all the variables was collected from the WDI. Three samples were studied: all countries, developed countries and developing countries. The study used GMM, FMOLS and robust least squares (RLS) estimation methods. The results of the three estimation methods in all three samples showed that population density has a positive relationship with CO_2 emissions, which means that increases in population density degrade the environment. Results of the GMM estimation revealed that, in both the developed and developing countries and samples of the MENA region, the population density was shown to have the biggest degrading impact, followed by urbanization. This result supports the Neo-Malthusian theory.

Li *et al.* (2022) studied the impact of demographic factors and low-carbon innovation on carbon emissions in 285 Chinese cities between 2003 and 2018. Carbon emissions, population size, population density, population quality, low-carbon innovation, RGDP, FDI, industrial development and financial development are the variables used in the study. Data came from the National Bureau of Statistics, the Statistical Yearbook (2003 – 2019), and each city's environmental bulletin (2004 – 2019). The STIRPAT framework and ARDL model with PMG estimation were employed. Three separate models for each population dynamic were estimated. The short-run results of the population density model showed that increases in all factors degrade the environment. In the long run, increases in population density, GDP, FDI and industrial development were shown to degrade the environment. In contrast, increases in low-carbon innovations and financial development were shown to promote environmental quality. The degrading impact of population density was found to be the biggest, followed by industrial development, GDP and lastly, FDI. The result that population density has the biggest degrading impact, is consistent with the Neo-Malthusian perspective.

Focusing on India, Mishra *et al.* (2020) investigated the relationship between greenhouse gas emissions and anthropogenic activities by applying the ARDL bound test to time-series data for the period 1971 to 2014. Total emissions were used as the indicator of environmental damage, and data was collected from the WDI. Fertility rate, population density, RGDP, number of motor vehicles, energy consumption and forest area were employed as the explanatory variables. Data on the number of motor vehicles came from the Ministry of Statistics and Programme Implementation, data on forest area came from the Directorate of Economics and Statistics and data on the remaining variables was sourced from the WDI. Both short- and long-run results showed that increases in population density, fertility, RGDP and energy consumption increase total emissions, implying increases in these factors damage the environment. In contrast, increases in motor vehicles and land area were found to have insignificant short- and long-run environmental impacts. In the long run, increases in population density had the biggest impact, followed by fertility rate, energy consumption and RGDP. The result that demographic factors have bigger impacts than economic factors supports the Neo-Malthusian perspective.

The study moves on to discuss the thesis that increases in demographics and economic activity have benign environmental impacts.

3.3 Further Economic and Population Growth and the Environment

As already shown in Section 3.2 above, numerous studies revealed that economic factors are the biggest contributors to environmental degradation, while other studies showed that increases in population are the biggest contributors to environmental degradation. Hence, empirical literature studies confirm the assertions of WST and Neo-Malthusianism. However, EMT and Boserupians argue that environmental improvements are induced, respectively, by increases in economic and demographic factors. This section aims to explore this debate between EMT advocates and Boserupians. Studies showing benign environmental impacts of increased economic complexity are discussed first, followed by studies showing benign environmental impacts of ballooning populations.

3.3.1 Further Economic Modernisation and the Environment

Although the damaging impact of economic growth on the environment is not under any dispute, what is contentious is the exact nature of the economic growth-environment nexus. As discussed in the previous chapter, EMT proponents argue that economic growth ultimately results in environmental improvements, which is the famous EKC hypothesis. In contrast, advocates of WST argue that economic growth has a monotonically damaging environmental impact. Rich countries attain environmental improvements by exporting pollution to poor countries through trade and FDI. This is the PHH.

This section discusses the empirical studies on the EKC and PHEH hypotheses. The focus will be on the three economic factors. Studies focusing on economic growth will be discussed first, followed by studies focusing on energy use, and studies focusing on trade openness will then be discussed.

3.3.1.1 Economic Growth

The ameliorative impact of further economic growth on the environment is well recognized in the EMT literature. Just as in sub-section 3.2.1.1, we consider studies that test and do not test the EKC hypothesis.

Starting with studies that do not assess the EKC hypothesis, Zimon *et al.* (2023) employed the STIRPAT model and ARDL estimation to investigate the impact of socioeconomic factors on South Korea's environment using time series data provided by the WDI. The study covered the period 1978 to 2021. Variables included in the study are CO_2 emissions, RGDP, total population, nuclear power, renewable energy and fossil energy consumption. The short-run results showed that economic growth degrades the environment. However, the long-run results showed that economic growth has an insignificant environmental impact, supporting the EMPT perspective.

Focusing on SSA, Afriyie *et al.* (2023) examined the relationship between CO_2 emissions and urbanization and industrialization in 37 countries from 1965 to 2017. RGDP and energy consumption were included as control variables. Data on urbanization, industrialization and

RGDP came from the WDI, while the US EIA provided data on energy consumption. The PMG-ARDL approach was employed, and the results showed that economic growth has a neutral impact on the environment in the short run but significantly reduces environmental impacts in the long run. The finding that economic growth is associated with environmental improvements is consistent with the EMT perspective.

In terms of studies that investigated the EKC hypothesis, Chen and Taylor (2020) looked at the relationship between economic development and pollution emissions in Singapore for the period 1900 to 2017. Variables used in the study are chromium emissions, RGDP, FDI inflows, trade openness and existence of environmental regulations. A dummy variable for structural breaks was also included. Data on environmental regulation came from the Anti-Pollution Unit, trade data came from Trading Economics, and data on the other variables came from the Singapore Department of Statistics. The study employed the Vector Error Correction Model (VECM), and the results revealed that there is evidence for an EKC for Singapore, which supports the EMT theory.

Udeagha and Ngepah (2021) examined the relationship between trade openness and environmental degradation in South Africa. Their study covered the period 1960 to 2020. CO_2 emissions were used as the proxy for environmental damage. The explanatory variables were economic growth (RGDP) proxied by scale effect and the square of RGDP to capture the technique effect, trade openness, energy consumption, FDI, technological innovation and industrial value added to GDP. The dynamic ARDL simulation model was used. The results showed evidence of an EKC, which means that the result is consistent with the EMT.

Opoku and Boachie (2019) studied the impact of industrialization and FDI on the environment of 36 African countries, including South Africa, Nigeria, Zimbabwe and Zambia, from 1980 to 2014. Variables included in the study as proxies of environmental degradation are CO_2 emissions, greenhouse gas (GHG) emissions, nitrous oxide emissions and methane emissions. Variables included in the study, as the drivers of environmental damage, are industrialization, FDI, RGDP per capita, the square of RGDP per capita to assess the EKC hypothesis, population growth and trade openness. Data on these variables came from the WDI. The study employed the STIRPAT model and PMG estimation for long-run coefficients. In the CO_2 emissions model, the results found supportive evidence of the EKC hypothesis, implying that economic growth initially damages the environment in

Africa but brings environmental improvements in the long run. This result is consistent with EMT.

Ssali *et al.* (2019) analysed the relationship among environmental pollution, economic growth, energy use and FDI in six SSA countries (Ghana, Kenya, Botswana, Mauritius, Togo, and Benin) between 1980 and 2014. The variables used in the study are per capita CO_2 emissions – the proxy of environmental pollution, per capita RGDP, the square of per capita RGDP to assess the EKC hypothesis, per capita energy consumption and FDI. All data came from the WDI. The study employed the Pooled Mean Group (PMG) estimator in an Autoregressive Distributed Lag (ARDL) model. The study found supportive evidence of the EKC hypothesis, which supports the EMT perspective.

3.3.1.2 Energy Use

As explained before, the EMT proponents posit that a growing economy is associated with technological improvements and demand for clean environments. The switch from dirty to clean and renewable sources of energy is one mechanism through which economic modernization brings about environmental quality. Sarkodie (2018) notes that it is this switch to clean sources of energy that makes energy use crucial to establishing the EKC hypothesis. As such, many studies have shown that renewable energy has a benign impact on the environment.

Using bootstrap ARDL and NARDL approaches, Mumtaz *et al.* (2022) tested the effects of renewable energy, gold and oil prices on South Africa's CO_2 emissions between 1990 and 2019. The study used time series data obtained from the WD. Variables included in the study are CO_2 emissions, RGDP, the spot price of Brent crude oil, the international trading price of gold, renewable energy consumption, and non-renewable energy consumption. Results of the ADRL model showed that in both the short and long run, increases in renewable energy consumption promote environmental quality in South Africa by reducing CO_2 emissions. In contrast, increases in non-renewable energy consumption were found to increase environmental degradation in both the short and long run. The result that switching to renewable energy sources protects the environment is consistent with the EMT theory.

In examining the conditional nexus between renewable energy and environmental quality, Asongu *et al.* (2019) applied fixed effects and quantile fixed effects regression to panel data of 40 SSA countries from 2002 to 2017. CO_2 emissions, RGDP, renewable energy consumption, financial development, trade openness, government effectiveness and regulatory quality are the variables employed in the study. All data were sourced from the WDI. The fixed effects model results showed that increases in renewable energy consumption ameliorate environmental damage in SSA. This result supports the EMT worldview.

Focusing on 10 Asian countries (China, India, Pakistan, Japan, Indonesia, Turkey, South Korea, Thailand, Iran, and Saudi Arabia), Kuo *et al.* (2022) employed the PMG estimator in the CS-ARDL model to investigate the influence of natural resources on environmental quality between 1995 and 2019. Panel data on CO_2 emissions, economic growth, non-renewable energy usage, renewable energy usage and natural resources rent were collected from the WDI. The results showed that increases in renewable and non-renewable energy usage have insignificant impacts on the environment in the short run. In the long run, however, increases in renewable energy usage were found to promote environmental quality, while increases in non-renewable energy usage were found to damage the environment. The finding that expanded transition to renewable energy sources ameliorates environmental decay is consistent with the EMPT perspective.

Using the STIRPAT model and the Feasible Generalized Least Squares (FGLS) estimation, Amer *et al.* (2024) studied the environmental impacts of renewable and disaggregated energy consumption in five GCC countries between 1995 and 2017. Data on CO_2 emissions, renewable energy consumption, energy consumption, economic growth and total population came from WDI, while BP Statistical Review provided data on coal, oil and natural gas consumption. The results showed that increases in renewable energy consumption reduce CO_2 emissions, while increases in all the other energy sources increase CO_2 emissions. The result that increased renewable energy usage promotes environmental quality supports the EMT perspective.

Usman *et al.* (2021) investigated factors abating the ecological footprint in BRICS-T (BRICS plus Turkey) countries between 1980 and 2018. Agricultural value-added, forest area, non-renewable energy utilization, renewable energy utilization and financial development were employed as the variables influencing the consumption ecological footprint per capita. EF data was sourced from the GFN website, financial development data came from the IMF, and WDI provided data for the remaining variables. The study employed MG, AMG and CCEMG estimators for long-run coefficients. The results of all three estimators showed that increases in renewable energy utilization abate the ecological footprint. In contrast, increased usage of non-renewable energy was shown to increase the EF. Thus, the result that switching to cleaner energy sources brings environmental quality is consistent with the EMT perspective.

Zeraibi *et al.* (2021) used the STIRPAT framework and CS-ARDL estimator to study the drivers of the ecological footprint in ASEAN-5 countries (Indonesia, Malaysia, the Philippines, Thailand, and Vietnam) between 1985 and 2016. The study used the EF as the dependent variable and employed economic growth, renewable electricity generation capacity, technological innovation, financial development and population growth as the independent variables. The GFN provided data on the EF, the US EIA provided data on renewable electricity generation capacity, and the WDI provided data on the rest of the variables. The results showed that increases in renewable electricity generation capacity reduce the EF in the short and long run. The finding that expanding renewable electricity generation promotes environmental quality is consistent with the EMT perspective.

In the next section, the study explores trade openness and PHEH.

3.3.1.3 Trade Openness

As indicated above, trade openness has a theoretically ambiguous impact on the environment. Some studies found that increases in trade openness are good for the environment, thus validating the PHEH (e.g. Tachie *et al.,* 2020; Ahmed *et al.,* 2020).

Tachie *et al.* (2020) investigated the influence of trade openness on environmental pollution in EU-18 countries for the period 1990 to 2015. Variables included in the study were CO_2 emissions, trade openness, GDP per capita, energy consumption, and urbanization, and all the data for the variables came from the WDI. The mean group (MG) and augmented mean group (AMG) estimation methods were used. Results showed that trade openness has a negative effect on CO_2 emissions, which means that increases in trade promote environmental quality. This result validates the PHEH and is consistent with EMT.

Ahmed *et al.* (2020) assessed the impact of economic growth, financial development and trade openness on environmental degradation in Egypt for the period 1965 to 2014. CO_2 emissions were used as the proxy for environmental damage. All data came from the WDI. Using the VECM technique for long-run and short-run estimations, the study results showed that trade openness reduces CO_2 emissions in the long run. Economic growth and financial development also have a negative impact on CO_2 emissions. In the short run, trade openness, as well as financial development and economic growth, do not have a significant impact on CO_2 emissions.

Kamal *et al.* (2021) studied the role of fiscal policy, financial development, and FDI in reducing global environmental pollution from 1990 to 2016. A total of 105 countries were included in the study. Fiscal policy, globalization index, FDI, trade openness, urbanization, labour force, domestic investment and CO_2 emissions are the variables employed in the study. Data on all the variables were sourced from the WDI except for the globalization index, which was obtained from the KOF Swiss Economic Institute, and government spending, which came from the International Monetary Fund (IMF). The FMOLS, DOLS, and ARDL – PMG estimation methods were used. Trade openness was shown to have a negative relationship with CO_2 emissions in the long run across the three estimations. The result indicates that increases in trade ameliorate environmental degradation, thus validating the PHEH and EMT perspectives.

The next section of the study delves into the ameliorative impact of a growing population on the environment.

3.3.2 Rising Populations and the Environment

According to Neo-Malthusians, as indicated in Chapter 2, increases in the number of people poses an existential threat as they are precursors of ecological catastrophes. In sharp contrast, Cornucopians see growing populations as good for the environment, as each person is an innovator and/or inventor of environmentally benign technologies. These diametrically opposite viewpoints have been empirically investigated, and both have been validated. Several studies have shown that increments in diverse population dynamics are good for the environment (e.g., Kongbuamai *et al.,* 2020; Marquart-Pyatt, 2015; Charfeddine and Mrabet, 2017; Nathaniel *et al.,* 2020). This section will focus on the demographic factors identified as key impact factors in Section 3.2, namely population density, urbanization and total population. In this section of the dissertation, studies focusing on population size are discussed first, followed by studies focusing on urbanization, and then studies focusing on population density are discussed.

3.3.2.1 Population Size

Voumik *et al.* (2023) investigated the impacts of population growth and economic expansion on environmental sustainability in five South Asian countries (Nepal, Bangladesh, India, Pakistan, and Sri Lanka) from 1972 to 2021. The study used the variables CO_2 emissions, total population, RGDP, urbanization, industrialization, natural resource rents and electrical power consumption. All data was sourced from the WDI, and the CS-ARDL technique was employed. The long-run results showed that increases in total population reduce CO_2 emissions, meaning that an expanding population promotes environmental quality in South Asia. This result is consistent with the Boserupian perspective.

Focusing on economically advanced countries (including the USA, France, Japan and the UK), Usman *et al.* (2022) investigated the relationship between nuclear energy and the ecological footprint for the period between 1980 and 2015. Ecological footprint, RGDP, energy consumption, total population, human capital and nuclear energy are the variables included in the study. EF data came from GFN, nuclear energy data came from the US Energy Information Administration (EIA), data on human capital was provided by Penn World Table (PWT), while data on the remaining variables came from the WDI. Long-run results from the CS-ARDL estimation showed that increases in total population, together with increases in human capital and nuclear energy, bring environmental improvements in rich countries. The result that population growth promotes environmental quality is consistent with the Boserupian worldview.

Voumik and Sultana (2022) investigated the impacts of urbanization, industrialization and renewable energy on the environment in BRICS countries between 1972 and 2021. CO_2 emissions were employed as the proxy for environmental degradation, and total population, RGDP, renewable energy, urbanization, electricity and industrialization were used as the explanatory variables. Data on all variables came from the WDI. Using the CS-ARDL estimation technique, the study found that increases in total population have insignificant impacts on the environment. This result supports the assertions of Boserupians.

Focusing on Italy, Pattak *et al.* (2023) investigated the driving factors of the country's CO_2 emissions between 1972 and 2021. Variables used in the study are CO_2 emissions, RGDP, total population, renewable energy, fossil fuel, and nuclear energy consumption. All data was provided by the WDI. Using the STIRPAT and ARDL models, the study found that all factors do not significantly impact the environment in the short run. In the long run, increases in total population were found to have insignificant impacts on Italy's natural environment.

Increases in renewable energy consumption were also shown to have insignificant impacts, while increases in nuclear energy consumption were shown to reduce environmental degradation in Italy. In contrast, economic expansion and increases in fossil energy consumption degrade Italy's natural environment. The result that population expansion has benign impacts on the environment is consistent with the Boserupian perspective.

Nguyen-Thanh *et al.* (2022) studied the FDI-environment nexus to understand the existence of the PHH in the 'better' world, using a global sample of 96 countries between 2004 and 2014. The sampled countries were further stratified into developing and developed countries. Variables included in the study are CO_2 emissions (the proxy of environmental impact), total population, RGDP, FDI, urbanization, industry, value added and services, value added. All the data came from the WDI. Using the STIRPAT framework and GMM estimation, the study found that, in the long run, increases in total population bring environmental improvements in the global and developing countries model. This result supports the Boserupian perspective.

3.3.2.2 Urbanization

Turning to urbanization, Charfeddine and Mrabet (2017) investigated the effects of economic development and various socio-political factors on the EF in 15 Middle East and North African (MENA) countries. The study covered the period 1975 to 2007. EF, real gross domestic product per capita (RGDP), the square of RGDP to assess the EKC hypothesis, energy use, urbanization, political-institutional index, fertility rate and life expectancy at birth were the variables used. The EF data was sourced from the United Nations Environment Program (UNEP) database. RGDP and energy use data came from the World Development Indicators (WDI) database. Data on the political-institutional index came from the Freedom House website, while data for the remaining variables came from The Statistical, Economic and Social Research and Training Centre for Islamic Countries (SESRIC). The countries were grouped into oil and non-oil exporting countries. The FMOLS and DOLS (dynamic ordinary least squares) estimation methods were used for long-run estimation. The results found that urbanization was negatively related to EF, which means that urbanization reduces environmental degradation. This result that urbanization reduces environmental damage is consistent with the Boserupian or cornucopian view. The study also showed a negative relationship between EF and the other population dynamics (fertility rates and life expectancy at birth), further supporting the Boserupian view.

Ulucak *et al.* (2021) investigated the factors shaping a sustainable environment in the Mediterranean region from 1995 to 2016. Variables included in the study are CO_2 emissions, per capita RGDP, urbanization, renewable energy consumption and non-renewable energy consumption. Using the STIRPAT model and FMOLS estimation, the results revealed that urbanization has a negative relationship with CO_2 emissions, which means urbanization ameliorates environmental degradation in Mediterranean countries. This result that urbanization reduces environmental damage is consistent with the Boserupian perspective.

Nathaniel *et al.* (2020) examined the association between renewable energy, urbanization and ecological footprint in 13 MENA countries for the period 1990 to 2016. Variables used in the study were the ecological footprint, renewable energy, non-renewable energy, urbanization, GDP per capita and financial development. Ecological footprint data came from GFN, and the WDI provided data on the remaining variables. The Augmented Mean Group estimation method was used. The results show that increases in urbanization have an insignificant impact on the EF, which means increases in urbanization do not harm the environment. The result that urbanization has a neutral environmental impact is consistent with the Boserupian theory.

Focusing on six Gulf Cooperation Council (GCC) countries (United Arab Emirates, Oman, Qatar, Kuwait, Bahrain and Saudi Arabia), Zmami and Ben-Salha (2020) studied the determinants of CO_2 emissions for the period 1980 to 2017. Variables included in the study are CO_2 emissions, RGDP per capita, the square of RGDP per capita, energy consumption, urbanization, trade openness and FDI. Data on all these variables were extracted from the WDI. Using the STIRPAT model and PMG – ARDL estimation, the study found that increases in urbanization reduce CO_2 emissions and, thus, promote environmental quality in GCC countries. This result validates the Boserupian approach.

Nathaniel *et al.* (2019) analyzed the relationship between EF, urbanization and energy consumption in South Africa. The variables used in the study were EF, urbanization, energy use, financial development and RGDP per capita. Data on the EF was sourced from the GFN, and the data on other variables was sourced from the WDI. The study covered the period 1965 – 2014. Using the ARDL estimation technique, the study found that urbanization is positively related to the EF in the short run but negatively related to the EF in the long run. This means that urbanization damages the environment in the short term, but further urbanization has a benign environmental impact. These results validate the Boserupian perspective.

Using the STIRPAT framework and dynamic panel ARDL model with PMG, MG, and DFE estimations, Abdelfattah *et al.* (2018) studied the relationship between population dynamics and CO_2 emissions between 1990 and 2014. The study covered the Arab region, and countries that are part of the study include Kuwait, Egypt, Morocco, Qatar and Saudi Arabia. Variables used in the study are CO_2 emissions, RGDP, total population, energy intensity, industrialization (value added of industry as a percentage of GDP), urbanization and institution (rule of law index). Data on institutions was sourced from World Governance Indicators, and data on the rest of the variables came from WDI. Long-run results of the PMG and DFE estimations showed that increases in urbanization bring environmental improvements. In contrast, the MG estimation showed that increases in urbanization have an insignificant impact on the environment in the Arabic world. The result that increases in urbanization have benign impacts on the environment supports the Boserupian perspective.

3.3.2.3 Population Density

Kongbuamai *et al.* (2020) examined the determinants of the ecological footprint in Thailand from 1974 to 2016. Variables used in the study were EF, tourism, trade openness, population density, RGDP per capita and energy use. The EF data was extracted from the GFN, and data on the remaining variables came from the WDI. The study used the ARDL bounding test approach to estimate the short-run and long-run effects and the VECM Granger causality to assess the direction of the effects. The long-run results revealed a negative relationship between population density and EF, which means population density reduces environmental degradation in Thailand. The result that increases in population density reduce environmental degradation is consistent with the Boserupian perspective.

The results in Kongbuamai *et al.* (2020) are corroborated by Marquart-Pyatt (2015), Shah *et al.* (2022) and Sahoo and Sethi (2021). Focusing on West Africa for the period 1961 to 2005, Marquart-Pyatt (2015) analyzed the factors affecting environmental sustainability. Countries included in the study were Burkina Faso, Ghana, Mali, Niger and Nigeria. Variables included in the study are EF, RGDP per capita, total population, urbanization, age dependency ratio, rural population density, arable land and land area. All data came from the World Bank. Using the Prais-Winsten (PW) regression model with panel-corrected standard errors, the study found that rural population density was negatively correlated with the EF, meaning that increases in density promote environmental quality. This result is consistent with the Boserupian theory.

Focusing on low-income countries, Shah *et al.* (2022) investigated the determinants of CO_2 emissions from 2000 to 2020. A total of 21 countries, including Tanzania, Tajikistan, Nepal, and Rwanda, were studied. CO_2 emissions were used as the dependent variable, while population density, trade openness, RGDP, FDI, urbanization and domestic credit to the private sector were the independent variables used. All data came from WDI. The PLS and fixed effects (FE) estimation techniques were used. Results of the PLS model revealed that increases in population density have a neutral impact on the environment in studied countries, while results of the FE model showed that increases in population density promote environmental quality. The result that increases in population density are benign to the environment supports the Boserupian perspective.

Sahoo and Sethi (2021) investigated the impact of renewable energy on the EF in developing countries for the period 1990 to 2016. Variables used in the study were EF, renewable energy, natural resources, non-renewable energy, RGDP per capita, trade, globalisation index, urbanization, population density and human capital. Data on EF was sourced from GFN; data on renewable and non-renewable energy came from IEA; data on human capital came from the Penn World Tables; data on the globalisation index came from the KOF Swiss Economic Institute, Dreher, and data on the remaining variables came from the World Bank. The AMG, MG and DCCE estimation methods were used. The results of all three estimations showed that population density had an insignificant impact on EF. This result, which shows that increases in population density have a neutral impact on the environment, is consistent with Boserupian theory.

Jiang *et al.* (2022) assessed the effect of various socioeconomic factors on consumption-based CO_2 emissions in BRICS countries from 1985 to 2018. Variables employed in the study are consumption-based CO_2 emissions, and data came from the Global Carbon Atlas database; RGDP and population density, where data was sourced from the WDI; coal consumption, which was sourced from the BP Statistical Review of World Energy; and environment-related technologies, where data came from the OECD website. The STIRPAT framework and the Driscoll and Kraay's standard error estimation approach were employed. The long-run results showed that increases in population density reduce consumption-based

CO_2 emissions in BRICS countries. The result that increases in population density reduce environmental degradation is consistent with the Boserupian perspective.

Using time series data between 1971 and 2016, Ahmet *et al.* (2021) analysed the relationship between economic globalization, economic growth, financial development and the ecological footprint in Japan. Variables employed in the study are ecological footprint, whose data was obtained from the Global Footprint Network; RGDP per capita, financial development, and population density with data collected from the WDI; energy consumption, with data sourced from BP Statistics; and economic globalization, where data came from the KOF index. The symmetric and asymmetric ARDL were employed. Results of the symmetric ARDL showed that increases in population density have an insignificant effect on the ecological footprint in the long run. However, in the short run, increases in population density were found to increase the EF. The result that increases in population density do not worsen environmental degradation is consistent with the Boserupian worldview.

In the next section, the study discusses the causes of differences in the results of the empirical studies reviewed.

3.4 Economic Growth and Demographic Drivers Discussion

The empirical literature reviewed above shows conflicting results on the contribution of economic growth and demographic drivers. Some studies indicated that greater environmental degradation is attributable to increased economic complexity (e.g., Fan *et al.,* 2006; Wu *et al.,* 2017; and Duodu *et al.,* 2021). In contrast, burgeoning populations were identified as the primary causes of environmental ills typifying the Anthropocene (see Poumanyvong and Kaneko, 2010; Ohlan, 2015; Wang and Dong, 2018).

In the same vein, empirical evidence is not conclusive regarding the exact economic or demographic dynamic causing the greatest environmental harm. Concerning economic variables, for example, Shuai *et al.* (2017) and Sorge and Neumann (2019) found that economic growth causes the greatest environmental harm; Wu *et al.* (2019) and Wu *et al.* (2021) found high energy consumption to be the biggest catalyst of environmental degradation, while Duodu *et al* (2021) identified increased trade openness as the biggest threat to sustainable development. With respect to demographic variables, some studies attributed the biggest cause of environmental degradation to be population size (see Hassan *et al*., 2024; Mujtaba *et al.*, 2022). Conversely, some studies found urbanization to be the biggest contributor to environmental degradation (e.g., Pham *et al*., 2020; Zhang *et al.,* 2022), while other studies revealed the unparalleled potency of population density in causing ecological destruction (see Sharma *et al.,* 2020; Ohlan, 2015).

Buttressing the inconclusiveness of empirical studies to explicate environmental degradation is a debate on the monotonicity of impacts. While some studies revealed that both population and economic expansion are causing environmental degradation, as noted above, other studies have shown that increases in the various socioeconomic drivers of environmental degradation, are bringing about environmental quality (see Afriye *et al.*, 2022; Mumtaz *et al.*, 2022; Voumik *et al.*, 2023).

A myriad of factors can explain the divergence in results. The first factor is the use of different proxies for environmental degradation. Some studies used the ecological footprint as the indicator of ecological damage (e.g. Li *et al.,* 2023; Wang and Dong, 2018; Nathaniel *et al.,* 2019; Sharma *et al.,* 2020); some attribute energy consumption as the proxy of environmental damage (e.g. Lin *et al.,* 2009), and some studies blamed CO_2 emissions (e.g. Poumanyvong and Kaneko, 2010; Ohlan (2015). As mentioned in Chapter 1, this study will use the EF as the proxy for environmental degradation as it is a more comprehensive measure of environmental degradation. The carbon footprint is a component of the EF.

The second factor relates to the application of different econometric techniques. For instance, Fan *et al.* (2006) use partial least squares regression; Li *et al.* (2023) and Lin *et al.* (2009) use ridge regression; Sorge and Neumann (2019), Nathaniel *et al.* (2019) and Sharma *et al.* (2020) use ARDL estimation; Shuai *et al.* (2017) use cointegration estimation; and Poumanyvong and Kaneko (2010) use pooled OLS, Shah *et al.* (2021) used the Interactive Fixed Effect (IFE) and Dynamic Common Correlated Effect (D-CCE) estimations, and Wang and Dong (2018) applied the FMOLS and Augmented Mean Group (AMG) estimators. This study will employ the P-ARDL estimation under the IPAT-STIRPAT.

As highlighted above, the P-ARDL framework offers distinct advantages over other cointegration approaches, including the capacity to analyze both long-term and short-term dynamics (Hussain *et al.,* 2017) and handle the assignment of different lag lengths to more than six variables (Ogunlesi and Bokana, 2018). Other researchers have used this approach (e.g. Sharma *et al.,* 2020; Nathaniel *et al.,* 2019; Zmami and Ben-Salha, 2020).

According to Shuai *et al.* (2017), the IPAT approach is one of the four frameworks that can identify key environmental damage impact factors. The other three approaches are Interpretive Structural Modelling (ISM), Structural Network Analysis (SNA) and Structural Equation Modelling (SEM). Unlike the IPAT framework, which uses historical statistical data, the other three methods apply questionnaire survey data and not actual statistical data, and they rely on expert opinion, which introduces subjectivity (Shuai *et al.*, 2017). This leaves IPAT as the only objective method of identifying key impact factors, which makes it the dominant framework. For econometric testing, however, the IPAT model has serious weaknesses, which are overcome by converting it into its stochastic form, STIRPAT (York *et al.,* 2003b, York *et al.,* 2003a). Consequently, consistent with other studies, the STIRPAT model is employed (see Dimnwobi *et al.,* 2021; Opuala *et al.,* 2023). The STIRPAT model is discussed in more detail in Section 3.5.

The third factor pertains to the countries considered. Some studies assess the impact of demographic and economic factors across developmental or income levels, using a global sample of countries. In other words, the countries are not from a specific region but the whole world. Such studies classify the countries into HI, UMI, LMI and LI strata, as previously discussed in this chapter (e.g., Fan *et al.,* 2016; Shuai *et al.,* 2017; Sorge and Sorge and Neumann, 2019; Poumanyvong and Kaneko, 2010). Conversely, some studies focus on a specific income group. For example, Wu *et al.* (2021) focus on developed countries. In turn, other studies focus on countries from specific regions. For example, Wang and Dong (2018) focus on Sub-Saharan countries whereas Sharma *et al.* (2020) focus on South and South East Asia and Shah *et al.* (2021) focus on Western Asia and North Africa. Some studies focus on single countries. For example, Chekouri *et al.*(2020) focused on Algeria, and Nathaniel *et al.* (2019) studied South Africa. Lastly, other studies look at a region or province within a country. For instance, Li *et al.* (2023) studied the Pearl River Delta urban agglomeration (PRDUA) region in the Guangdong Province of China. As indicated, this study will focus on Africa's three most important economies: Nigeria, Egypt, and South Africa. These countries have the largest economies and also large populations.

The fourth factor relates to the different individual, environmental drivers employed in the regression equations. This is particularly true for demographic factors. Some studies use only one demographic factor. For example, Wu *et al.* (2021) and Wang and Dong (2018) use urbanization only; Fan *et al.* (2006), Sorge and Neumann (2019) and Li *et al.* (2023) apply population size (total population); and Ohlan (2015) employs population density. In contrast, some studies use multiple demographic drivers. For example, Chekouri *et al.* (2020) include urbanization and population size; Sharma *et al.* (2020) include urbanization, density and fertility rate; Lohwasser *et al.* (2020) include urbanization, population size and percentage share of the working population. As already indicated, this study will include multiple demographic drivers in the regression equation to adequately capture the magnitude of the various pathways in which population damages the environment. With respect to economic factors, virtually all studies include RGDP. The other economic variables are not applied consistently. For example, in addition to real GPP, Mujtaba *et al.* (2022) employ energy consumption, and Sun *et al.* (2020) employ energy consumption and trade openness. Just like demographic factors, multiple economic drivers will be employed to plumb the multiple pathways through which economic activity impacts the environment. Section 3.6. below will discuss the variables employed in the study and the justification.

The last factor is that the studies reviewed investigate different periods. For example, Fan *et al.* (2006) considered the period 1975 – 2000; Shuai *et al.* (2017) considered the period 1990 – 2011; Nathaniel *et al.* (2019) covered the period 1965 – 2014; Sharma *et al.* (2020) studied the period 1990 – 2015. As discussed in Chapter 2, the impact of an environmental driver can change in nature and magnitude over time. This study will consider a relatively long period, namely 1984 to 2022.

Given the inconclusiveness of the key impact factor's identity, more research must be conducted to provide more evidence. This is the key objective of this research project. The next section of the literature review explores the EMT thesis that further economic integration is good for the environment.

3.5 FDI and the Environment

Although none of the empirical studies reviewed above found FDI to have the greatest impact on the environment, it remains an important driver of environmental damage. As discussed in Chapter 2, FDI is a channel used by developed countries to transfer technologies to poor countries. In Africa, the evidence is the presence of big multinational corporations. For example, multinationals dominate South Africa’s energy (petroleum) and car industries. However, the quality of the FDI significantly impacts the environment and is a cause of debate among the proponents of EMT and WST schools of thought. This FDI-environment nexus is analysed through the PHH and PHEH.

Some studies on the relationship between FDI and the environment validated the PHH. In this space, starting with studies that focused on linear relationships, Solarin *et al.* (2017) investigated the PHH in Ghana for the period 1980 to 2012, using annual time series data. The variables used in the study were total CO_2 emissions, CO_2 emissions from petroleum consumption, GDP, GDP square, energy consumption, renewable energy consumption, fossil fuel energy consumption, FDI, institutional quality, urbanization, financial development and trade openness. Total CO_2 emissions from energy consumption and CO_2 emissions from petroleum consumption data came from the Energy Information Administration database, and data for all the other variables were accessed from the WDI database. Using the ARDL approach with structural breaks, the results showed that FDI is positively related to emissions, which supports the PHH. This means that developing countries damage the environment in Ghana through FDI. This result is consistent with WST.

This result of ecologically damaging FDI in a developing country is confirmed by Sun *et al.* (2017), who studied the validity of the PHH in China, using essentially the same methodology, study period and variables as Solarin *et al.* (2017). The study by Sun *et al.* (2017) used total CO_2 emissions, CO_2 emissions from solid fuels, GDP, GDP square, inward foreign direct investment, energy use, fossil fuel energy consumption, alternative and nuclear energy consumption and four other control variables which were included as a vector: economic freedom, urbanization, net domestic credit (a proxy for financial development) and trade openness. Economic freedom data was sourced from the Fraser Institute website, while data on the rest of the variables came from the World Bank. The study employed the ARDL approach with breakpoint unit root tests and structural breaks. Results showed that FDI incremental flows positively impact both types of emissions, which supports the validity of the PHH, and thus validates the WST perspective.

Opoku and Boachie (2019) studied the impact of industrialization and FDI on the environment of 36 African countries, including South Africa, Nigeria, Zimbabwe, and Zambia, between 1980 to 2014. Variables included in the study as proxies of environmental degradation, were CO_2 emissions, greenhouse gas (GHG) emissions, nitrous oxide emissions and methane emissions. Variables included in the study as the drivers of environmental damage were industrialization, FDI, RGDP per capita, the square of RGDP per capita to assess the EKC hypothesis, population growth and trade openness. Data on these variables came from the WDI. The study employed the STIRPAT model and PMG estimation for long-run coefficients. The results in the CO2 emissions model revealed a positive correlation between FDI and CO_2 emissions, which means increases in FDI damage the environment. This result validates the PHH and WST perspective.

Results in Opoku and Boachie (2019) were corroborated by Nguyen *et al.* (2019), who analysed the relationship between economic integration and CO_2 emissions in 33 emerging economies, between 1996 and 2014. Variables included in the study are total CO_2 emissions, CO_2 emissions from manufacturing and construction industries, CO_2 emissions from other sectors, excluding residential buildings, CO_2 emissions from residential buildings, CO_2 emissions from transport, energy intensity, RGDP per capita, square of RGDP per capita, industrialization, urbanization, trade openness, and FDI. Using the STIRPAT model and the Dynamic Fixed Effects (DFE) ARDL estimation, the study found that FDI inflows increase CO_2 emissions in both the short and long run, which supports the PHH and WST perspective.

As already alluded to, EMT proponents posit that FDI can transition from being environmentally damaging to being environmentally friendly. Some studies have investigated the inverted-U shape relationship and found no supportive evidence. Destek and Okumus (2019) searched for evidence of the PHH in ten newly industrialized countries (Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, South Africa, Thailand, and Turkey) between 1982 and 2013. Variables used in the study were EF, RGDP per capita, FDI per capita, square of FDI per capita and energy consumption. The data on EF came from GFN, and the data on the remaining variables emanated from the WDI. The study employed the common correlated effect (CCE) estimation. The results showed that FDI has a negative correlation with EF, while the square of FDI has a positive correlation with EF. This supports the existence of a U-shaped relationship. The result shows that FDI promotes environmental quality in the initial stages but degrades the environment later. This result is inconsistent with the EMT perspective.

Results in Destek and Okumus were supported by Pradhan *et al.* (2021), who studied the impact of FDI on the environment in BRICS nations from 1992 to 2014. The study included variables such as CO_2 emissions, energy use, RGDP, square of RGDP, FDI and the square of FDI. Data on all these variables was sourced from the World Bank database. The study employed DOLS and FMOLS estimation and found evidence of a U-shape relationship between FDI and CO_2 emissions. This result invalidates the PHEH.

In contrast, some studies found supportive evidence for the PHEH instead, thus validating the EMT perspective. Focusing on Indonesia from 1976 to 2018, Yilanci *et al.* (2023) investigated the impact of FDI on the fishing footprint. Variables employed in the study are fishing footprint (FF), FDI, fishery trade openness, RGDP and square of RGDP. Data on the FF came from GFN, data on RGDP and FDI came from WDI, and data for fishery trade openness was computed manually from exports and imports data. Employing the ARDL Bounds testing technique, the study found that increased FDI reduces environmental degradation, which validates the PHEH and EMT.

Saqib *et al.* (2023) investigated the validity of the PHH or PHEH in 16 European countries between 1990 and 2020. Variables included in the study are EF, RGDP, the square of RGDP, FDI, energy structure, renewable energy and human capital. Data on EF came from GFN, data on human capital was sourced from Penn World Tables (PWT) and data on the remaining variables were extracted from WDI. Using the CS-ADRL, AMG, and Dumitrescu and Hurlin (DH) panel causality tests, the study found that FDI increases and reduces the EF, implying that incremental FDI inflows improve environmental quality in Europe. This result validates the PHEH and EMT.

Rafindadi *et al.* (2018) investigated the effects of FDI and energy consumption on the environment in six Gulf Cooperation Council (GCC) countries from 1990 to 2014. Variables used in the study were CO_2 emissions, RGDP, the square of RGDP, GCC relative per capita income, FDI, gross domestic fixed capital formation, energy consumption, energy use (intensity), the interactive terms between GCC relative per capita income and FDI; gross domestic fixed capital formation and energy use; and FDI and energy use. Data on CO_2 emissions, FDI, real GPPP, energy consumption and energy intensity were sourced from the WDI. The source of data for the remaining variables was not revealed. The study employed the ARDL model and MG, PMG and DFE estimation techniques. Results of the PMG estimation indicated that increases in FDI inflows have an insignificant impact on CO_2 emissions in the short run and reduce CO_2 emissions in the long run. This means that FDI inflows have a benign impact on the natural environment of GCC countries. This result supports the PHEH and EMT.

Mert and Bölük (2016) analysed the impact of FDI and renewable energy consumption on CO_2 emissions in 21 Kyoto Annex countries for the period 2002 to 2010. The countries studied include Australia, Austria, Canada and the USA. Variables included in the study were CO_2 emissions, FDI, RGDP, the square of RGDP, renewable energy consumption, fossil energy consumption and FDI. Data for all variables was extracted from the World Bank Database. The PMG estimation technique was employed. The study's results revealed that increases in FDI reduce CO_2 emissions, which means FDI inflows promote environmental quality. This result validates the PHEH.

Furthermore, evidence of the inverted U-shape was found in some studies, like Balsalobre-Lorente *et al.* (2019) and Abbasi *et al.* (2023). Focusing on MINT (Malaysia, Indonesia, Nigeria, and Turkey) countries, Balsalobre-Lorente *et al.* (2019) tested the PHH and PHEH concurrently for the period 1990 to 2013 by investigating the existence of an inverted-U relationship. Variables used in the study were EF, FDI, the square of FDI to test for a non-linear relationship, RGDP per capita, the square of GDP per capita to test for the EKC hypothesis, renewable energy consumption and urbanization. All data came from the WDI. The FMOLS and DOLS estimation techniques were employed. The results of both models revealed an inverted U relationship between FDI and EF. This suggests that increases in FDI increase the EF and thus degrade the environment in the early phases. However, a threshold level has been achieved, and further FDI inflows reduce the EF and thus promote environmental quality. The study's results validate the EMT perspective.

Abbasi *et al.* (2023) assessed the validity of both the PHH and PHEH. This study focused on Asian countries, including China, Japan, India and Pakistan, between 1985 and 2020 by investigating an inverted-U relationship. Variables used in the study were CO_2 emissions, FDI, the square of FDI, tourism, urbanization, tourism, energy consumption, GDP per capita and square of GDP. All data was sourced from the WDI. The study used the ARDL framework and PMG estimation and showed that FDI is positively related to CO_2 emissions in the long run, but its square is negatively related to CO_2 emissions. inverted-U relationship between FDI and CO_2 emissions, which supports EMT

The studies reviewed in this section reveal an ambiguous impact of increases in economic integration on the environment. Some studies show that economic integration is beneficial to the environment in support of the PHEH. In contrast, other studies found evidence supportive of the PHH. The causes of the differences in results are the same factors that have already been highlighted – i.e. differences in environmental degradation proxies, econometric techniques, period of study, variables used in the regression equation and countries studied. Consequently, the divergent and inconclusive empirical results justify further research.

The next section discusses the framework used to choose the variables used in the study for empirical analysis.

3.6 The STIRPAT Model as a Framework

This section presents the general framework of the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model. The reason for doing so here is that the STIRPAT model "has become a widely employed methodological approach within social science research, largely used to understand the complex relationships between human social systems and the non-human environment. The general assumption of the model is that anthropogenic environmental impacts are a multiplicative function of population, affluence and technology" (McGee, Clement and Besek, 2014: 81). This model, therefore, allows for a consideration of the core theories relevant to the issue of economic growth, population, and the environment. Following this discussion, the previous empirical literature is used to demonstrate how different measures of input have been used in practice, building on the data and methodology presented in the following chapter.

This STIRPAT model can be traced back to the IPAT model which, as highlighted in Chapter 2, is the IPAT model is the dominant framework for understanding anthropogenic environmental damage. According to this model, environmental degradation is determined by three primary drivers: population (P), affluence or economic activity (A), and technology (T) (Sarkodie, 2018; Pham *et al.,* 2018).

The IPAT model, however, has some limitations that prevent a more nuanced econometric and theoretical analysis of the impacts of environmental drivers. Firstly, IPAT gives the proportional impact of environmental change for one factor while holding the other factors constant (Fan *et al.,* 2006). This means that it does not allow for non-monotonic or non-proportional effects from driving forces (York *et al.,* 2003b). Stated differently, the model does not permit the environmental impacts attributable to each primary driver to be isolated and analyzed concurrently. Secondly, the IPAT model does not have an error term; thus, it disallows hypothesis testing (York *et al.,* 2003a).

Thirdly, the IPAT model does not allow the disaggregation of the primary drivers of environmental damage or the addition of other environmental stressors (Zmami and Ben-Salha, 2020; Sarkodie, 2018). As mentioned above, climate policy and lifestyle are some factors identified as among the causes of environmental damage, but these are excluded from the IPAT model. Furthermore, affluence and population have underlying dynamics that differ from country to country. For example, as mentioned previously, economic growth can be intensive or extensive. Extensive growth damages the environment because it is associated with high resource extraction and, therefore, energy use. Thus, energy use becomes an important dynamic necessary to fully understand the different pathways of economic growth that damage the environment. Similarly, the magnitude of the environmental impacts of a growing, rapidly urbanizing population will differ from a population that is growing rapidly in rural areas. As such, urbanization becomes a critical demographic factor to include to plumb the impact of growing populations fully.

To overcome these challenges, the IPAT model is converted to a stochastic form, which constitutes stochastic impacts by regression on population, affluence and technology or STIRPAT (Pham *et al.,* 2020; York, *et al.,* 2003a). The basic STIRPAT model may then disaggregate P, A, and T further, which results in the extended STIRPAT. By considering how the IPAT, STIRPAT and extended STIRPAT models have been discussed in previous studies, it is possible to see how these questions are considered in practice. This has been seen in the discussions above, where similar studies have employed different variables to consider similar problems.

As the empirical literature reviewed above shows, researchers use different variables to investigate the environmental impact of growing populations, expanded economic activity and technology. These different variables speak to the disaggregation of the primary drivers in the IPAT model. With respect to impact (I), different proxies of environmental damage have been employed in empirical studies. This include CO_2 emissions (e.g. Voumik *et al.*, 2023; Amer *et al.*, 2024; Kuo *et al.*, 2022); ecological footprint (e.g. Dimnwobi *et al.,* 2021; Charfeddine and Mrabet, 2017; Usman *et al.,* 2021); energy consumption (see Lin *et al.*, 2009) and forest reserve and natural resource depletion (see Renyong and Sedik, 2023; Duodu *et al.*, 2021).

With respect to affluence (A), the economic factors that have been used in practice include RGDP per capita (e.g. Fan *et al.*, 2006; Sorge and Neumann, 2019; Sharif *et al.*, 2023);

energy consumption (e.g. Wu *et al.*, 2021; Alola *et al.,* 2019; Nathaniel and Adeleye, 2020); industrialization (e.g. Afriye *et al.*, 2022; Lin *et al.*, 2009; Lin *et al.*, 2009; Udeagha and Ngepah, 2021); trade openness (e.g. Tachie *et al.,* 2020; Ahmed *et al.*, 2020) and FDI (see Pham *et al.,* 2020; Kamal *et al.*, 2021; Solarin *et al.*, 2021; Renyong and Sedik, 2023).

Turning to population (P), the demographic dynamics into which population has been contemporarily disaggregated include population size (see Poumanyvong and Kaneko, 2010; Knight *et al.*, 2013; Voumik *et al.*, 2023); urbanization (e.g. Charfeddine and Mrabet, 2017; Ulucak *et al.*, 2021; Pham *et al.,* 2020); population density (e.g. Sharma *et al.*, 2020; Haouas *et al.*, 2023); population growth rate (e.g. Kindo *et al.*, 2023; Dimnwobi *et al.*, 2021); fertility rate (e.g. Sharma *et al.*, 2020; Sarkodie, 2018) and age structure (e.g. Dimnwobi *et al.,* 2021; Charfeddine and Mrabet, 2017).

Lastly, technology (T) can also be disintegrated into various factors such as energy intensity (e.g. Fan *et al.*, 2006; Shuai *et al.,* 2020; Sorge and Neumann, 2020; Nguyen-Thanh *et al.*., 2022); green technology (see Sharif *et al.*, 2023); energy efficiency, residential energy consumption and share of industrial activity (Shuai *et al.,* 2020; Pham *et al.*, 2020; Anser, 2019). Urbanisation (Anser, 2019) and trade (Nathaniel and Khan, 2020) have also been used to represent technology and the latter and above case studies indicate that technology can be represented by variables, which may be demographic or economic. As noted by Anser (2019), the disaggregation of technology depends on the researcher's focus.

This study uses the EF as the proxy of environmental degradation (I). Two main factors influence the choice. Firstly, as highlighted in Chapter 1, the EF is a more appropriate indicator as it captures the multi-dimensional nature of environmental damage, in contrast to CO_2 emissions, the most prevalent indicator of environmental damage in literature, which is limited to climate change. In Chapter 1, it was mentioned that the EF adds four more footprints to the carbon footprint: cropland, and grazing land, forest, fishing and built-up land. Therefore, the EF is a more comprehensive measure of environmental damage.

Secondly, as noted, CO_2 emissions are the most common indicator of environmental damage in literature. Charfeddine and Mrabet (2017) confirm that empirical studies using EF as a proxy for environmental damage are in paucity. Therefore, the impacts of the various socio-economic factors on the environment are not adequately understood. As a result, by using the EF as the dependent variable, the study addresses the gap and contributes to empirical knowledge.

Turning to affluence, we disintegrate A into RGDP per capita, energy use and trade openness. Starting with RGDP, the variable is employed because it is the most common economic factor used in empirical research. A scan through the empirical literature reviewed above shows that RGDP is used as an explanatory variable in every study. This confirms that RGDP is the most important variable in environmental sociology (Charfeddine and Mrabet, 2017; Lohwasser *et al.,* 2020).

Concerning energy use, the study employs the variable because it is commonly used due to its position as the second most crucial variable in environmental sociology (Charfeddine and Mrabet, 2017). Its inclusion makes sense in the African context. The expansion of African economies is supported by increased energy consumption, of which fossil fuels are Africa's biggest energy source (Nathaniel and Adeleye, 2020; Tachega *et al.,* 2021). As mentioned, Africa is experiencing extensive economic growth – i.e., growth achieved by employing more natural resources.

Lastly, as shown in the empirical literature review above, trade openness is one of the most important determinants of environmental degradation. Although trade openness is a commonly used driver of environmental degradation in literature, the study employs it mainly due to its relevance to the research focus. Trade is a venerated engine of economic development in Africa and worldwide (Sakyi and Egyir, 2017). As such, the economic growth Africa is experiencing is inextricably linked to its aggressive pursuit of economic integration through various policies (Osei-Assibey and Dikgang, 2020). Much of the trade in Africa is between Africa and the rest of the world and not among African countries (Tadesse, 2024). This exposes the continent to EUE.

Turning to demography, P is disintegrated into population density, urbanisation and fertility rate. As Lohwasser *et al.* (2020) note, population size is the most important demographic driver of environmental damage in literature. The empirical literature review above corroborates this. However, in this study, it is not employed. The reason is data constraints in terms of non-stationarity. Consequently, the fertility rate instead of population size is employed. The reason is that changes in the fertility rate mirror changes in the total population (Charfeddine and Mrabet, 2017). This means that the impact of the changes in fertility on the environment mirrors the environmental impacts of total population growth. Fertility rate is not commonly employed in empirical research, so its implications on environmental degradation are not fully understood, therefore, the study contributes to knowledge in this respect. The inclusion of the fertility rate is relevant in the African context because, as already stated, it is a determinant of population size, which is causing significant environmental impacts.

As shown in the empirical studies reviewed above, urbanization is one of the most commonly used demographic variables in empirical studies. It can be argued that it is the second most important demographic variable after the total population. Africa is one of the fastest-urbanizing regions (Gambe *et al.,* 2023). Therefore, part of the environmental damage in Africa is attributable to urbanization. Lastly, population density is included in the study because it is a commonly used variable in empirical literature.

Concerning the last primary driver, technology (T), FDI is employed in the study to represent technology for two reasons. The first is data constraints. Energy intensity is the most commonly used proxy of technology in literature; however, data is missing for some years in the study period. The second is relevance to the research. FDI is a bigger channel for technological advancement than local innovation (Mustapha and Mendi, 2024).

The next section concludes this chapter.

3.7 Conclusion

This chapter reviewed the empirical studies on the impact of socio-economic factors on the environment. The vast extant literature reviewed points to the enormous need and effort of scholars from diverse environmental sociology approaches to understand the most significant contributing factors to the intensification of environmental crises of the Anthropocene and the precise nature of the environment-driver relationships. The results of the empirical literature reviewed above confirm the contemporary evidence that increases in both economic activity and population are having big deleterious impacts on the natural environment in Africa and the rest of the world.

However, there is inconclusive evidence on whether expanding economic activity or a burgeoning population is the primary cause of environmental harm in Africa. Some studies reveal that economic factors are the most potent drivers of ecological devastation, and some ascribe demographic factors.

Furthermore, there is also conflicting evidence on the long-run impacts of increased economic modernity and population growth. Some studies indicated that increased economic development degrades the environment, thus refuting the EKC and PHEH hypotheses. In contrast, some studies have shown that increased economic growth brings environmental improvements, thereby supporting the EKC and PHEH hypotheses. In terms of demography, there is evidence that increases in population density, urbanization, and fertility rate are having destructive impacts on the environment, confirming the assertions of Neo-Malthusians. However, there is also compelling, competing evidence that increases in the various demographic factors are benign to the environment, thereby validating the propositions of Boserupians.

Much empirical evidence on the environmental impacts of various socio-economic drivers is based on carbon emissions as the proxy of environmental degradation since it is the dominant indicator of environmental damage in literature. However, as highlighted above, carbon emissions are a narrow measure of environmental degradation compared to EF, which captures the multi-facetedness of environmental damage but is not as commonly used. The implication is that the true impact of socio-economic drivers on the environment is not fully understood. The study employs the EF as the proxy for environmental damage.

Furthermore, Africa is a continent whose Great Acceleration – rising economic activity and burgeoning populations – is in its infancy. Africa's three biggest economies, South Africa, Nigeria and Egypt, which are incidentally among the most populous countries on the continent, provide a glimpse of what the environmental impacts of big populations and high economic activity are, and thus will be, for the rest of the continent. To the best of our knowledge, no study has focused solely on these countries in a common framework. The study considers the impact of socio-economic factors on the EF in Egypt, South Africa and Nigeria to address the gaps mentioned above.

The next chapter will focus on data and research methods to achieve the research objectives.

Chapter 4 DATA AND METHODS

In Chapter 3, it was shown that the empirical evidence on the biggest contributor to environmental degradation in Africa was inconclusive. This chapter deals with the practical ways of solving the research problem – i.e., the research method, techniques and tools employed to establish the key impact factor. Furthermore, the chapter elaborates on the data and econometric model used in the study. In this section of the dissertation, data sources are discussed first, followed by data description and measurement, initial tests, estimation techniques, and lastly, diagnostic and robustness checks are discussed.

4.1 Data Sources

The research focuses on three African countries, namely South Africa, Nigeria and Egypt, for a period spanning three decades from 1984 to 2022. The biggest influence on the choice of the period of study is that it is sufficiently long to understand the impacts of the various environmental drivers. Another consideration for including the most recent years, specifically 2021 and 2022, even though data for some variables is unavailable, is that it makes the study as current as possible. All data is available as an annual frequency, and this is consistent with other studies (see Voumik *et al.*, 2023; Afriye *et al.,* 2022; Opoku and Boachie, 2019). The data set consists of both time-series and cross-sectional elements, resulting in a panel data set with three cross-country units (N = 3) collected over thirty-nine years (T = 39). This means that there are 39 observations for each variable in the three countries. Consequently, for the whole sample, there will be 117 observations for each variable (39 yearly observations for each country multiplied by three countries – i.e., 39 x 3 = 117).

The variables used in the study are the ecological footprint (EF), which is the proxy for environmental degradation or the dependent variable: population density, urbanization, fertility rate, GDP per capita, energy consumption, trade openness and FDI. Population density, urbanization and fertility rate are the demographic variables; RGDP per capita, energy consumption and trade are economic factors, and FDI is the technology variable. EF data was extracted from the Global Footprint Network (GFN) website, while the World Bank's WDI database provided data on all explanatory variables. As noted by Pham *et al.* (2020), using data from one source means that the data is well-matched, which contributes to the consistency and robustness of the results. However, where data from WDI is incomplete, data is extracted from other reliable sources. More detailed descriptions of the variables are provided in the next section.

In addition, consistent with many empirical studies (e.g. Dimnwobi *et al.,* 2021; Wang and Li, 2021, Charfeddine and Mrabet, 2017; Nathaniel and Khan, 2020), all the variables are transformed to their natural logarithms. As explained below, this is done after the descriptive statistics have been explored, as they are one of the reasons that necessitate log transformations.

The next section describes the measurement of the variables employed in the study. It starts with the ecological footprint, followed by the economic factors (real GDP per capita, energy use and trade openness), demographic variables (population density, urbanization and fertility rate), and lastly, the technology variable (FDI).

4.2 Data Description and Measurement

4.2.1 The Ecological Footprint

Following Wang *et al.* (2022) and Shah *et al.* (2021), the EF indicator is the proxy for environmental degradation and, therefore, the dependent variable in this study. It measures the amount of biologically productive land and water required by an individual, population or activity to meet its natural services requirement in the form of resources for consumption and sinks for waste assimilation at the prevailing state of technology and resource management practices (GFN, 2024). Hence, the determination of the EF involves approximating the amount of natural capital a population requires to meet resource and waste absorption demands, and the quantity of natural capital is measured in global hectares. Following Charfeddine and Mrabet (2017), the EF indicator employed in this study is the sum of five footprints: cropland and grazing land, forest, fishing, CO_2 emissions and built-up land or infrastructure.

The data is extracted from the Global Footprint Network (GFN) website and comes in annual frequency. The variable has a total of 117 observations: 39 for South Africa, 39 for Nigeria and 39 for Egypt. The EF was last measured in 2019, meaning that each country's first 36 observations (1980 – 2019) have been observed. Data for the years 2020 – 2022 comprise of estimates. However, these estimates are provided by the GFN.

EF is measured in global hectares (gha). This is consistent with various studies (see Charfeddine and Mrabet, 2017; Mujtaba *et al.,* 2022).

As elucidated previously, CO_2 emissions is the most prevalent measure of environmental decay in literature. The few studies that employ the EF as the proxy for environmental degradation, are inconsistent in the precise metric of the EF used. Some use the EF per capita (see Dimnwobi *et al.,* 2021; Wang *et al.,* 2022), while others use the total EF (see Charfeddine and Mrabet, 2017; Mujtaba *et al.,* 2022). In this study, we follow Charfeddine and Mrabet (2017) and Mujtaba *et al.* (2022), and employ the total EF to represent environmental degradation.

The reason for this is that the EF per capita can fall, which can give the illusion that environmental destruction is slowing down. The declining trend of EF per capita may be attributed to a rapidly increasing population rather than declining aggregate impacts. Thus, the EF per capita can decrease, while the total EF increases. This is particularly true in Africa, where the population is growing at relatively higher rates. Therefore, using the aggregate EF makes the most sense. In addition, CO_2 emissions, the more popular proxy of environmental degradation, are often employed in their actual levels (metric tonnes) and not per capita terms (see Shahbaz *et al.,* 2019; Shah *et al.,* 2021).

4.2.2 Real GDP per Capita (RGDP)

Gross domestic product (GDP) is the most prevalent measure of economic activity in a country, and its growth in real terms (increase in actual output at constant prices) is referred to as economic growth. It is the sum of the gross value added by producers residing in the economy, which is adjusted for product taxes and subsidies that are excluded from the value of the products (World Bank glossary). GDP per capita is the GDP divided by the mid-year population, whereas RGDP per capita is GDP per capita measured at constant prices.

In the study, the RGDP variable is measured in 2015 constant US$. This is consistent with other studies (e.g. Voumik and Sultana, 2022; Voumik *et al.,* 2022; Wang *et al.,* 2022). The data is extracted from the World Bank's WDI database and comes in annual frequency. A total of 117 observations are used in the study, with each country contributing 39 variables.

RGDP is included in the study as the proxy of economic growth, which makes it an economic factor of primary interest. In extant literature, economic growth is the most important determinant of environmental quality (Sarkodie, 2018; Nathaniel and Khan, 2020). However, the relationship between the environment and RGDP is complicated. While there is theoretical consensus that economic growth degrades the environment in the short run, theorists disagree on the nature of the long-run relationship. On one hand, proponents of the EKC hypothesis argue that increasing economic complexity enables technological advancements and demand for environmental quality, which bring about environmental improvements once a threshold level of affluence has been achieved. On the other hand, opponents of the EKC hypothesis argue that technological improvements accelerate the scale of production, which overpowers any efficiency gains. This makes the destructive impact of economic growth on the environment monotonic and ever-intensifying.

It was stressed in previous chapters that the study would estimate short- and long-run impacts of economic growth on the EF. The short-run coefficient of RGDP is expected to be positive to show the destructive impact of economic growth on the environment in the short run. However, there is no expected value of the long-run coefficient. If the coefficient is negative, then economic growth has benign long-run impacts on the environment, and if the coefficient is positive, affluence has a long-run destructive impact on the environment in the selected African countries.

4.2.3 Energy Use (Consumption)

As Charfeddine and Mrabet (2017) point out, energy use is identified in the literature as the second most significant driver of ecological devastation. It is included in the study as the second economic factor. Total energy use relates to the use of primary energy from combustible biomass (solid, liquid, and gas), animal products and industrial waste before conversion to end-use fuels, such as electricity and refined petroleum products. The variable is measured in per capita kg of oil equivalent, and data is sourced from the WDI and the EIA databases in annual frequency.

Data extracted from the WDI is based on the period 1984 to 2014, as 2014 is the year the WDI last reported energy consumption data. By implication, data from 2015 to 2022 is extracted from the EIA database (https://www.eia.gov/international/data/world). However, the data from the EIA is measured in quadrillion British thermal units (quad Btu). To convert Btu to kg of oil equilavent (koe), conversion units supplied by BP's Statistical Review of World Energy (2021) and EIA are used. In the last step of the conversion process, we divide the total koe for each year by total population to obtain the per capita koe.

Energy use is what powers the economy. The relationship between the environment is also not straightforward, as it depends on whether the energy source is renewable or non-renewable (fossil-based). Increases in renewable energy use promote environmental quality, while increases in fossil or non-renewable energy use worsen ecological devastation (see Ulucak *et al.,* 2021; Wang and Dong, 2018; Sharma *et al.,* 2020).

In this study, we do not analyze the impacts of renewable and non-renewable energy use separately. We use total energy consumption (see Dimnwobi *et al.,* 2021; Nathaniel and Khan, 2020; Usman *et al.,* 2022). The reason is that in Africa, energy use is predominantly fossil-based. As Nathaniel and Adeleye (2020) confirmed, fossil fuels, coal and natural gas, are the major energy sources in Africa, and these are non-renewable. Therefore, high energy use causes serious environmental degradation. As such, the coefficient of energy use is *a priori* expected to be positive to indicate that increases in energy use accentuate environmental degradation in Africa.

4.2.4 Trade Openness

Trade openness is one measure of the degree of economic integration between a country and the rest of the world. It is the third and final economic variable used in the study. Trade openness is measured as the sum of exports and imports divided by GPD and is expressed as a percentage of GDP. Consequently, trade openness is measured as % of GDP, which is consistent with various studies (e.g. Tachie *et al.,* 2020; Ahmed *et al.*, 2020; Kamal *et al.*, 2021).

South Africa's and Egypt's trade data were sourced from the WDI database, while Nigeria's trade data was sourced from the World Bank's World Integrated Trade Solution (WITS) (https://wits.worldbank.org) and United Nations Trade and Development (UNCTAD) Statistics (https://unctadstat.unctad.org) databases and the Index Mundi website (https://www.indexmundi.com). All data is in annual frequency.

The relationship between trade openness and environmental degradation is complicated. By opening up external markets to a country, trade expands production, and consequently, this causes a higher exploitation of natural resources and, thus, degradation of the environment (van Tran and Do, 2019). As per EUE theory, trade results in developing countries specialising in producing environmentally damaging goods, in which they have a comparative advantage (van Tran and Do, 2019). In addition, the PHH argues that trade is one avenue through which rich countries export ecologically unfriendly technologies. This means trade openness is positively related to environmental decay (e.g. Sun *et al.,* 2020; Udeagha and Ngepah, 2021). In contrast, the PHEH says that trade allows efficient technologies to be transferred from rich to poor countries, which then results in environmental improvements in the poor countries. This means trade openness is negatively related to environmental degradation (e.g. Tachie *et al.,* 2020; Kamal *et al.,* 2021).

We expect the long-run coefficient of trade openness to be positive. Although the selected countries have the biggest economies in Africa, they have not reached the development level that allows them to dictate the terms of trade with developed countries, which are their major trading partners. In addition, the high unemployment rates may cause the countries to have lax environmental policies; this means trade is not a conduit for the transfer of clean technologies from developed countries to Africa.

4.2.5 Population Density

Population density is one of the important demographic drivers of anthropogenic environmental degradation in the literature (see Mishra *et al.,* 2020; Haouas *et al.*, 2023). It refers to the number of people per square kilometre of land area, so population density is measured in numbers. The study does not adjust the measurement of this variable and annual data are sourced from the WDI database.

The relationship between population density and environmental degradation is not straightforward. On one hand, an increasing population density means higher demand for the services of nature, such as agricultural land and fishing. This means that population density is positively related to environmental deletion (e.g. Sharma *et al.,* 2020; Ohlan, 2015; Rahman, 2017; Ahmed *et al.,* 2014; Haouas *et al.,* 2023). On the other hand, increases in population density are believed to be associated with environmental improvements, as more humans mean more inventions and thus, a higher supply of environmentally friendly technologies (de Sherbinin *et al.,* 2007; Gleditsh, 2021). Therefore, increases in population density are negatively related to ecological destruction (e.g. Kongbuamai *et al.,* 2020; Marquart-Pyatt, 2015). A positive long-run coefficient of population size means that increases in the population density of the countries under study, increase the ecological footprint. In contrast, a negative long-run coefficient of population size means that increases in population size, decrease the ecological footprint in the countries studied.

In this study, we expect the long-run coefficient of population density to be positive. As indicated in Chapter 2, Africa is not a hub of technological innovation. Therefore, the Boserupian thesis that each person is a custodian of environmentally benign technologies, has less applicability to African countries.

4.2.6 Urbanization

Urbanization is an important determinant of environmental degradation in the existing literature (Wang and Dong, 2018; Poumanyvong and Kaneko, 2010). Urbanization refers to the proportion of a country's population living in urban areas, measured as a percentage. Urbanization data is in annual frequency and was sourced from the WDI database.

Consistent with population density, the relationship between urbanization and environmental quality is complicated. Urbanization is sometimes associated with environmental devastation, due to its positive influence on greenhouse gas emissions (see Pham *et al.*, 2020; Zhang *et al.*, 2022). On the other hand, urbanization is seen as a structure of modernity that promotes the development of ecologically rational institutions and technologies, that help ameliorate environmental decay. Thus, increases in urbanization can reduce environmental destruction (e.g. Ulucak *et al.,* 2021; Zmami and Ben-Salha, 2020) or, at the very least, do not significantly impact environmental decay (Nathaniel *et al.,* 2020).

We expect the long-run coefficient of urbanization to be positive. According to Charfeddine and Mrabet (2017), a major influence of urbanization on the environment is whether or not urban expansion is planned. Using South Africa as an example, the country may have the highest urbanization rate in Africa; however, much of it can be attributed to the proliferation of settlements that do not have the requisite infrastructure, such as sanitary and drainage facilities. In addition, the inhabitants of these settlements are poor and, therefore, cannot afford clean technologies in the form of consumer durables.

4.2.7 Fertility Rate

The last demographic variable in the study is fertility rate, which refers to the number of children a woman would give birth to if she survived to the end of her childbearing years. Thus, the variable is measured as a number, and no modification is made. Data, which is in annual frequency, was taken from the WDI database.

The impact of increases in the fertility rate on the environment is not unequivocal. Since the fertility rate is a factor of population change, the impact of the changes in the fertility rate on the environment is mirrored by the impact of total population growth on the environment. Consequently, an increase in fertility rate increases the ecological foot by increasing land-use change, accentuating land degradation, biodiversity loss and climate change (Charfeddine & Mrabet, 2017). This means that increases in the fertility rate aggravate environmental damage (see Sharma *et al.,* 2020; Sarkodie, 2018). However, increases in fertility rates can improve environmental quality since more people are associated with the development of environmentally-friendly technologies, that reduce the ecological footprint (see Alola *et al.,* 2021).

Consistent with the other demographic variables, we expect the fertility rate to have a positive relationship with the environment. As already argued, African populations are not renowned innovators, and therefore, increasing fertility rates means higher dependence on natural resources, which degrade the environment.

4.2.8 Foreign Direct Investment (FDI)

Foreign direct investment (FDI) is another important determinant of environmental degradation in the literature (see Sun *et al.,* 2017; Solarin *et al.*, 2017). In this study, it is included as a proxy for investment. FDI is the sum of equity capital, reinvested profits and other long- and short-term capital, as per the balance of payments. It is the investment required to acquire a lasting management stake in a company operating in another country.

FDI data is sourced from the WDI database and presents as an annual frequency. The data is measured as a percentage of net inflows to GDP. Net inflows are the difference between FDI inflows from the rest of the world and FDI outflows to the rest of the world. These FDI flows are measured in current US dollars.

The relationship between FDI and the environment is ambiguous. On one hand, the PHH argues that FDI degrades the environment in poor countries because it is a channel used by rich countries to move dirty industries to these countries. In this case, FDI causes environmental damage (e.g. Solarin *et al.,* 2017; Opoku and Boachie, 2019). On the other hand, the PHEH sees FDI as a conduit for the transfer of clean technologies from rich to poor countries, and here, FDI inflows bring environmental quality to poor countries (e.g. Renyong and Sedik, 2023; Saqib *et al.,* 2023).

The long-run coefficient of FDI is *a priori* expected to be positive. Due to the prevalence of unemployment and poverty, African governments are making concerted efforts to attract FDI and inspire economic growth and therefore, they must create accommodating conditions, including lax environmental policies.

The definition and measurement of these variables and the expected long-run signs are presented in the table below. After that, the next section delves into the initial tests, starting with descriptive statistics, followed by the correlation test, cross-sectional dependence test, unit root test, optimal lag selection and finally, cointegration test.

Table 4.1: Data Description and Expected Long-run Signs of Variables

Variable	Code	Definition	Measurement	Expected sign	Economic explanation
Ecological footprint	EF	The sum of cropland, grazing land, forest, fishing, built-up land, and carbon footprints.	Gha (millions)	N/A	This is the dependent variable
Population density	Den	The total number of people in a square kilometre	Numbers	+	Higher density results in a higher demand for nature's services, not the invention of environmentally friendly technologies.
Urbanization	Urb	The proportion of total people staying in urban areas	%	+	Increased unplanned urbanization due to rural-urban migration is not associated with the use of efficient technologies.
Fertility rate	FR	The number of children per woman	Number	+	A synonym of population growth which results in a higher demand for the services of nature.
Real GDP per capita	RGDP	Gross domestic product divided by midyear population	(constant 2015 US $)	+/-	Increased economic activity means a higher rate of resource extraction and waste generation, but it can also induce a demand for environmental quality and the development of clean technologies.
Energy use	EU	The use of primary energy before transformation to other end-use fuels (such as electricity and refined petroleum products).	Per capita kg of oil equivalent)	+	Increased energy use accentuates environmental deletion.
Trade openness	Trd	The sum of exports and imports divided by GDP	% of GDP	+	African countries are still economically weak to dictate terms of trade and afford clean technologies
Foreign direct investment	FDI	Foreign direct investment, net inflows (% of GDP)	Net inflows (% of GDP)	+	Because of lax environmental policies, rich countries have the leeway to bring ecologically destructive technologies.

Source: Author's own compilation

4.3 Initial Tests

4.3.1 Descriptive Statistics

Following Sakodie (2018), the descriptive statistics of the data are first examined to understand the underlying characteristics of the variables before econometric modeling and estimation. Descriptive statistics are measures that summarise the key characteristics of a dataset. In this study, the characteristics we are interested in relate to the data's central tendency, dispersion and shape of frequency distribution.

Central tendency points to the proneness of observations in the dataset to converge around a particular value. As such, a measure of central tendency or summary statistic is a single value that describes a set of data, by identifying the central position of the data (Laerd Statistics, n.d.).The mean, mode and median are the most common measures of central tendency. The mean is the arithmetic average of the dataset. It is calculated by dividing the sum or total of the values in the dataset, by the number of observations in the dataset. The mode is the observation in the dataset that occurs most frequently. Lastly, the median is the value at the center of the data set, when the data is arranged in ascending or descending order – i.e., it divides the observations of the dataset into two equal parts.

Thus, based on measures of central tendency, the interest is in identifying single value(s) to summarise the data. The mean is the most commonly used summary statistic in literature, despite its unique challenge of being influenced by outliers, which are unusually small or big observations relative to others in a data set. In this study, consistent with extant literature, we use only the mean for central tendency (see Zmami and Ben-Salha, 2020; Dimnwobi *et al.,* 2021). The mean sufficiently communicates the differences in the level of variables across the panel country units.

Turning to dispersion, the concern is with the variation or spread of the data. According to Dimnwobi *et al.* (2021), the spread of the data is an important factor in the validity and reliability of estimation results. Data that is widely spread must be transformed into their natural logarithms to reduce dispersion and skewness, thereby bringing the data to a normal distribution (Mujtaba *et al.,* 2022). As discussed below, normally distributed data is a requirement in linear regression for efficient and unbiased estimates. In the study, we used the standard deviation and minimum and maximum statistics to assess the dispersion of the panel data.

The standard deviation, which measures the proximity of the observed values to the mean and the range are the two commonly used statistics for describing dispersion. In contrast, the range is the difference between a data series' maximum and minimum values. Intuitively, the maximum is the greatest value, while the minimum is the lowest. Bigger measures of dispersion signal high variability and vice-versa.

Lastly, measures of shape describe the distribution of the data. The interest is in determining whether the data is normally distributed and homoscedastic. Normality of data and homoscedasticity are two requirements of general linear models that ensure that regression results are efficient and reliable (Charfeddine and Mrabet, 2017; Mujtaba *et al.,* 2022). General linear models are the most widely applied data analytic procedures in behavioural sciences, including psychology and economics (Rosopa and Schaffer, 2013). As already mentioned, data that is not normally distributed must be transformed into its logarithmic form.

Homoscedasticity refers to constant variance or variance homogeneity of the error term, and this assumption contributes to the ordinary least squares (OLS) estimator employed in general linear models being the best linear unbiased estimator (BLUE). Under homoscedasticity, estimates are efficient and unbiased. If the assumption of homoscedasticity is violated (i.e., heteroscedasticity - non-constant variance of the error), the OLS estimator is inefficient, affecting the reliability of conclusions and inferences. Hence, detecting and addressing heteroscedasticity is important.

Determining the shape of a distribution involves checking the symmetry or departure (skewness) and the height and sharpness of the central peak (kurtosis). Skewness relates to the position of a distribution's mean relative to the median and mode values (Dermir, 2022). A distribution is symmetrical when the mean is in the middle of the distribution and asymmetric or skewed when the mean is not in the middle (Dermir, 2022). A distribution is negatively skewed when the mean is less than or to the left of the median and mode (Hatem *et al.,* 2022). Conversely, distribution is positively skewed when the mean is greater than or to the left of the mode and median.

A skewness value of zero is noted for a normal (or symmetric) distribution, a skewness value of less than zero (negative) means that the distribution is negatively skewed, and a skewness value of more than zero means that the distribution is positively skewed (Dermir, 2022). In general, if the skewness falls between -0.5 and 0.5, the data is regarded as reasonably symmetrical; if the skewness is between -1 and -0.5 or between 0.5 and 1, the data is considered moderately skewed; and if the skewness is below -1 or above 1, the data is deemed highly skewed (Hatem *et al.,* 2022).

As indicated above, kurtosis is concerned with the peakedness of a distribution. A kurtosis value of three means that the distribution is normally distributed (mesokurtic), a value less than three means that the distribution is flat (platykurtic), whereas a value above three means that the distribution is peaked (leptokurtic) (Taylor, 2019). Thus, a variable is considered to be normally distributed if it has a kurtosis value of 3, and a skewness of 0.

Skewness indicates the presence of heteroscedasticity because they have common causes. They are both caused by outliers and inherent heterogeneity in data, resulting from varying levels of dispersion in different subgroups (Faster Capital, n.d.). Data heterogeneity is common in panel data, where data from each panel unit exhibits differing levels of dispersion. A log transformation addresses heteroscedasticity. As skewness addresses both heteroscedasticity and the shape of the distribution, this study interprets skewness in terms of the shape of the distribution, which is consistent with the literature.

Exploring descriptive statistics and employing log transformations are standard in extant literature. As noted above, log transformation is important as it addresses high dispersion, normality and heteroscedasticity (variance) problems, thereby improving the efficiency and validity of results (Charfeddine and Mrabet, 2017; Mujtaba *et al.,* 2022; Ogunsola, 2021). For example, Muindi (2021) explored descriptive statistics and found that the data was not normally distributed, necessitating log transformation. However, researchers are not consistent regarding the stage of the transformation.

Some researchers transform the variables from the onset and perform all econometric analyses, including descriptive statistics, using the transformed variable (e.g. Zmami and Ben-Salha, 2020; Mujtaba *et al.,* 2022). Other researchers transform variables after performing descriptive statistics, which provide evidence (in terms of variance and normality) that justifies the transformation of the data for further econometric analysis (e.g. Dimnwobi *et al.,* 2021; Wang and Li, 2021). Lastly, some studies perform descriptive statistics and other preliminary tests, such as unit root tests using raw data, and only use natural logarithms during the econometric estimation of the model (e.g., Nathaniel and Khan, 2020; Rafindadi *et al.,* 2018). One reason for taking natural logs during estimation is that the methodology adopted by the researcher requires it. For example, in the STIRPAT methodology, all variables are expressed in natural logarithms to interpret coefficients as ecological elasticities (Ssali, 2019; Zmami and Ben-Salha, 2020).

In this study, we follow the methodology of Dimnwobi *et al.* (2021), Sarkodie (2018), Assamoi *et al.* (2019), and Wang and Li (2021). Raw data is used for descriptive statistics, and then log transformations are done based on the normality and heteroscedasticity, indications as revealed by descriptive characteristics and the attractiveness of associated superior regression results. Using raw data paints has advantages, as employing actual variables paints the correct picture regarding the level or value of the variables and their distributions (Nathaniel and Adeleye, 2020).

The analysis was undertaken in STATA 18, and the results are presented in Chapter 5.

4.3.2 Correlation Test

Following Pham *et al.* (2020) and Duodu *et al.* (2021), a correlation coefficient matrix is used to examine the strength of the relationship between the variables. Correlation is the degree and strength of association between two variables. A correlation coefficient (r) reveals the direction and magnitude of a linear correlation among variables. Regarding direction, the correlation coefficient can be negative (-) or positive (+). A negative coefficient signifies a negative relationship between paired variables (two variables linked together to study their relationship), whereas a positive value signifies a positive relationship between paired variables. In terms of magnitude, the values of the correlation coefficient range between -1 and +1, with -1 signifying a perfect negative relationship, +1 signifying a perfect positive relation, and 0 signifying no relationship between the paired variables.

The correlation test is important because it is an indicator of multicollinearity (Duodu *et al.,* 2021), which is a phenomenon in econometrics where there are strong correlations among explanatory or independent variables, making it difficult to separate the effects attributable to an individual variable (Bhandari, 2024). The canonical rule of thumb is a correlation coefficient of 0.8 (Pham *et al.,* 2020), and a correlation coefficient above 0.8 indicates the presence of multicollinearity; a solution is to drop one of the variables.

4.3.3 Cross-sectional Dependence (CD) Test

After the correction test, the study tests the presence of cross-sectional dependence, as ignoring it causes estimation problems (Wang and Dong, 2018), such as loss of efficiency and consistency (Zmami and Ben-Salha, 2020; Rafindadi *et al.,* 2018). Cross-sectional dependence is attributable to factors that cause experiences in one country to be transmitted to other countries, such as high economic and financial integration and geographic proximity (Zmami and Ben-Salha, 2020; Dimnwobi *et al.,* 2021). Following Dimnwobi *et al.* (2021), the study employed the Breusch-Pagan Lagrange multiplier (LM), given that the time dimension is greater than the cross-section dimension. The null hypothesis is that there is no cross-sectional dependence (Duodu *et al.,* 2021), and it is rejected if the p-value is less than 5% (Dimnwobi *et al.,* 2021). The LM CD test is specified as follows (de Hoyos and Sarafidis, 2006; Wang and Dong, 2018):

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\, \hat{\rho}_{ij}^{2} \rightarrow \chi^{2}\, \frac{N(N-1)}{2} \qquad (1)$$

where $\hat{\rho}_{ij}$ is the sample estimate of the pairwise correlation of the residuals, T is the time interval, and N represents the number of cross-sections. LM is asymptotically distributed as $\chi 2$ with N(N − 1)/2 degrees of freedom (de Hoyos and Sarafidis, 2006).

Cross-sectional dependence is important because it informs the type of unit root tests to be conducted. If cross-sectional dependency is not found, first-generation unit root tests such as the Levin, Lin and Chu (LLC) and Im-Pesaran-Shin (IPS) tests are used to evaluate data (see Shuai *et al.,* 2017; Sarkodie, 2018; Pham *et al.,* 2017). As noted by Wang and Dong (2018), if cross-dependency is found, then the second-generation panel unit root tests, such as the Pesaran Cross-sectionally Augmented Dickey-Fuller (CADF) and the Pesaran cross-sectionally Augmented Im-Pesaran-Shin (CIPS) panel unit root tests are employed.

In addition, cross-sectional dependence is necessary for determining the appropriate cointegration tests; cointegration points to the existence of long-run relationships between the dependent variable and the various independent variables (Duodu *et al.,* 2021). When cross-sectional dependence exists, then first-generation cointegration tests such as the Kao and Pedroni must be employed (see Shaari *et al.,* 2021). Conversely, second-generational cointegration tests such as Westerlund must be employed, if cross-sectional dependence exists (Wang and Dong, 2018; Sakordie, 2018).

4.3.4. Unit Root Tests

Apart from data normality and homoscedasticity, the data series' stationarity, a situation where a series' mean, variance and autocorrelation remain constant over time, is another requirement for robust estimation results. Performing a regression with non-stationary variables would yield spurious results (Pham *et al.,* 2020; Mujtaba and Ashfaq, 2021). In addition, there is no trend (upward or downward movement in the data) or seasonality (periodic fluctuations) with stationary data (Tate, 2023).

A non-stationary series is said to have a unit root. Therefore, to determine the stationary of the data, we conducted first-generation unit root tests, given that no evidence of cross-sectional dependence was found. Specifically, we employed the Augmented Dicky Fuller (ADF) and Levin, Lin, and Chu (LLC) tests (see Shuai *et al.,* 2017; Sarkodie, 2018; Pham *et al.,* 2017; Rafindadi *et al.,* 2018). The reason for using these tests was that they are commonly applied tests for panel data (Shuai *et al.,* 2017). The null hypothesis is that the panel has a unit root, and it is rejected if the p-value is less than 5%.

These unit root tests are based on the ADF equation, which is specified as follows (Charfeddine and Mrabet, 2017; Nathaniel and Khan, 2020):

$$\Delta y_{it} = \lambda_i + \mu_i y_{it-1} + \beta_i t + \sum_{j=1}^{p} \phi_{ij} \, \Delta y_{it-j} + \varepsilon_{it} \tag{2}$$

where y_{it} is the variable of interest, μ_i are the persistence parameters, Δ is the first difference operator, λ is the drift – an intercept constant, βt is the time trend coefficient, p is the optimal lag length, ϕ_{ij} are coefficients of Δy_{it-j} and ε_{it} is an independent residual term.

The stationarity test results reveal the order of integration or the level at which the data series is stationary. A data series can be stationary at level or after differencing. When a data series is stationary at level, it means the raw data is stationary, and it is said to be integrated of order zero, which makes it an I(0) process. When a data series is integrated of order one, I(1), it is stationary at first difference. Similarly, an I(2) process is a variable integrated of order two, which means it is stationary at second difference. It must be noted that higher orders of integration are possible. In general, however, most variables are stationary after a second differencing. It is also possible for some variables not to be stationary.

Unit root results are an important determinant of the estimation technique that should be employed (Shrestha and Bhatta, 2017). When all the variables are stationary at level or I(0), the appropriate estimation technique is the ordinary least squares (OLS) or vector autoregressive (VAR) model (Shrestha and Bhatta, 2017). If all variables are stationary after the first difference, or are integrated of order I(1), then a cointegration test must be performed (see Charfeddine and Mrabet, 2017; Wang and Dong, 2018). Cointegration means the existence of long-run equilibrium relationships among variables. The Panel

Vector Autoregressive (PVAR) model is used if variables are not cointegrated, and the Panel Vector Error Correction Model (P-VECM) is used if variables are cointegrated. Lastly, when the variables are stationary at different levels – i.e., they are a mix of I(0) and I(1) and are cointegrated, the Panel Autoregressive Distributed Lag (P-ARDL) model is used (see Rafindadi *et al.,* 2018; Dimnwobi *et al.,* 2021; Usman *et al.,* 2022).

4.3.5 Optimal Lag Selection

As discussed below, it is important to determine the cointegration of variables. Before evaluating the cointegration of the variables, it is essential to establish the correct number of lags to incorporate into the model (Mdluli, 2021). The optimal lag length aids in minimizing serial correlation in the residuals (Muindi, 2021).

In this study, we employ the Bayesian information criterion (BIC) to determine the optimal lag lengths of the variables and the model. BIC is the default lag selection criterion in Stata. The Akaike information criterion (AIC) was also employed for robustness checks. Following Opoku and Boachie (2019), the optimal lag lengths were determined by conducting an individual ARDL analysis for the time series of each country, utilizing a maximum lag of one, and documenting the selected lags. The most common lag across all variables among the countries was chosen for the entire panel.

4.3.6 Cointegration Test

The study moves to cointegration tests after the unit root tests. As indicated above, the cointegration test examines the long-run equilibrium relationship among variables, meaning that any disturbance will be corrected and equilibrium will be restored (Wang and Hwang, 2007). In addition, cointegration implies Granger causality, which means that the long-run relationships are causal (Wang and Hwang, 2007). These relationships Given the absence of cross-sectional dependence, we employ first-generation cointegration tests (Wang & Dong, 2018; Sakordie, 2018). According to Äorsal (2007), cointegration tests are mainly residual-based or maximum-likelihood-based. Kao and Pedroni's tests are examples of residual-based tests, and the LR-bar test is an example of a maximum-likelihood-based test.

Following various studies (e.g. Teng *et al.,* 2020; Dimnwobi *et al.,* 2021; Mujtaba and Ashfaq, 2021; Wang and Li, 2021), the study adopts the residuals approach and employs the Kao (1999) and Pedroni (1999, 2004) cointegration tests. The null hypothesis is that no cointegration exists in the panel data series (Dimnwobi *et al.,* 2021). This hypothesis is rejected at the 5% level of significance (Mujtaba and Ashfaq, 2021).

The next section explores the PMG-ARDL model and cointegration in greater detail.

4.4 Estimation Technique

After confirming the stationarity of the variables at different levels, the study adopts the panel autoregressive distributed lag (P-ARDL) model framework to investigate the impact of socio-economic dynamics on environmental quality in the three African countries under study. The ARDL model has two components: autoregressive (AR) and distributed lag (DL). The autoregressive (AR) component reflects the notion that the lagged values of a variable are an important determinant of its prevailing value, while the distributed lag (DL) component reflects the notion that lagged values of the explanatory variables impact the dependent variable (Jmaii and Gargouri, 2024).

The ARDL approach is attractive because it establishes short- and long-run relationships between the ecological footprint and its socio-economic drivers (Dimnwobi *et al.,* 2021; Nathaniel and Khan, 2020). It uses an error correction mechanism (ECM) that measures the speed at which a system returns to its long-run equilibrium after a short-run shock (Kripfanz and Schneider, 2023). In the short run, variables might adjust due to temporary changes or shocks, while in the long run, they may settle into a stable equilibrium relationship.

The P-ARDL methodology was selected for its distinct merits over conventional cointegration techniques such as the VECM, which include the following (Pesaran *et al.,* 1999; Ssali *et al.,* 2019; Voumik and Ridwan, 2023):

(i) It allows the combined use of variables with different levels of integration, specifically I(0) and I(1) but not I(2).
(ii) It allows the determination of both short- and long-run dynamic parameters.
(iii) It permits different variable lags.
(iv) Its long-run model's unbiased estimates address serial correlation issues, omitted variables and endogeneity concerns.

The general specification of an ARDL(p, q, q, …., q) model is as follows (Pesaran *et al.,* 1999):

$$y_{i,t} = \sum_{J=1}^{p} \varphi_{ij}\, y_{i,t-j} + \sum_{J=0}^{q} \delta'_{i,j}\, x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

where Y_{it} is the dependent variable, X_{it} is a (k x 1) vector of explanatory variables.

Equation (3) says that a dependent variable is determined by its own lags and that of explanatory variables.

Following Sorge and Neumann (2019) and Zmami and Ben-Salha (2020), an error correction model must be estimated if variables are cointegrated. This error correction model is written as follows (Ssali *et al.,* 2019):

$$\Delta y_{i,t} = \omega_i\left(y_{i,t-j} - \theta_i' x_{i,t}\right) + \sum_{J=1}^{p-1} \varphi_{ij}^* \, \Delta y_{i,t-j} + \sum_{J=0}^{q-1} \delta^{*\prime}{}_{ij} \, \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (4)$$

where:

where $\omega_i = -1(1 - \sum_{j=1}^{p} \varphi_{ij})$; $\theta_i = \sum_{j=0}^{p} \delta_{ij} / (1 - \sum_k \delta_{ik}$;

$$\varphi_{ij}^* = -\sum_{m=j+1}^{p} \varphi_{im} \; (j = 1,2, \ldots., p-1);$$

$$\delta_{ij}^* = -\sum_{m=j+1}^{q} \delta_{im} \; (j = 1,2, \ldots., q-1)$$

In equation (4), $\left(y_{i,t-j} - \theta_i' x_{i,t}\right)$ is the error correction term that represents the long-run relationship between the explained and explanatory variables; θ_i represents the long-run impacts of the various determinants of the dependent variable; δ^* represents the short-run effects of the dependent variables on the dependent variable; Δ is the first difference; ω_i is an error correction term that measures the speed of the adjustment of the explained variables to its long-run equilibrium as the independent variables change. A value of zero for ω_i means that there is no cointegration relationship between the dependent and independent variables (John, 2022). Rafindadi *et al.* (2018) clarify that the error correction coefficient must be negative ($\omega_i < 0$) to indicate long-run relationships. In addition, it must be significant and not less than -2 to prove the stability of the model (Sorge and Neumann, 2019; Rafindadi *et al.,* 2018).

It was mentioned earlier that, in this study, EF is a function of economic growth, energy use, trade openness, population density, urbanization, fertility rate and FDI. The extended STIRPAT model employed in this study is specified in the multiplicative form as follows:

$$EF_{it} = \alpha RGDP_{it}^{\beta_1} EU_{it}^{\beta_2} TO_{it}^{\beta_3} DEN_{it}^{\beta_4} URB_{it}^{\beta_5} FR_{it}^{\beta_6} FDI_{it}^{\beta_7} \varepsilon_{it} \quad (5)$$

where EF is the ecological footprint, RGDP is the RGDP per capita, EU is energy use, TO is trade openness, DEN is population density, URB is urbanisation, FR is the fertility rate and FDI is foreign direct investment, ε is the error term, β_1 - β_6 are parameter estimates, and subscripts i and t represent the panel cross-section and time dimensions, respectively. Equation (4) says that the impact on the environment, represented by EF, is the multiplicative product of the various socio-economic factors, as defined above.

Following Sarkodie (2018) and York *et al.* (2003a), equation (5) is converted to a linear form via log transformation so that the estimated coefficients are estimated as ecological elasticities, which represent the relative contribution of each driver to environmental harm, as follows:

$$lnEF_{it} = \alpha + \beta_1 lnRGDP_{it} + \beta_2 lnEU_{it} + \beta_3 lnTO_{it} + \beta_4 lnDEN_{it} + \beta_5 lnURB + \beta_6 lnFR_{it} + \beta_7 lnFDI_{it} + \varepsilon_{it} \quad (6)$$

Where β_1 - β_6 are ecological elasticities, all the variables and subscripts remain as defined in equation (5).

Following Sorge and Neumann (2019) and Anser (2019), equation (6) can be written in the form of equation (3) as an extended dynamic heterogenous ARDL (p, q_1, …q_7) model as follows:

$$EF_{i,t} = \mu_i + \sum_{J=1}^{p} \varphi_{ij} EF_{i,t-j} + \sum_{J=0}^{q1} \delta_{1i,j} RGDP_{i,t-j} + \sum_{J=0}^{q2} \delta_{2i,j} EU_{i,t-j} + \sum_{J=0}^{q3} \delta_{3i,j} TO_{i,t-j} + \sum_{J=0}^{q4} \delta_{4i,j} DEN_{i,t-j} + \sum_{J=0}^{q5} \delta_{5i,j} URB_{i,t-j} + \sum_{J=0}^{q6} \delta_{6i,j} FR_{i,t-j} + \sum_{J=0}^{q7} \delta_{7i,j} FDI_{i,t-j} + \varepsilon_{it} \quad (7)$$

Where δ_{ij}, φ_{ij} μ_i, i, t, p, q, and j are defined the same as in equation (3). An important point is that all the variables are expressed in their natural logarithms. As indicated above, the transformation of the variables is justified by the findings from the exploration of descriptive statistics and the use of the STIRPAT framework.

Equation (7) can be written in error correction model (ECM) form, like equation (4), as follows:

$$\Delta EF_{i,t} = \mu_i + \omega_i\left(EF_{i,t-j} - \theta_i' x_{i,t}\right) + \sum_{J=1}^{p-1} \varphi_{ij}^{*} \Delta EF_{i,t-j} + \sum_{J=0}^{q-1} \delta_{ij}^{*\prime} \Delta x_{i,t-j} + \varepsilon_{it} \quad (8)$$

where Xit = RGDPit, EUit, TOit, DENit, URBit, FRit, FDIit is the vector of environmental drivers with information regarding countries and time periods; and j is the number of lags determined by standard model selection criteria. Equation (8) is the model that we estimate.

The mean group (MG) and pooled mean group (PMG), due to Pesaran and Smith (1995) and Pesaran *et al.* (1999) are the two common estimation techniques to estimate the short- and long-run dynamics of equations (4) and (8) (Sorge and Neumann, 2019; Li and Ingham, 2020; Noureen *et al.,* 2022). The dynamic-fixed effects (DFE) technique is the third estimation approach that is also often used for the P-ARDL model (Rafindadi *et al.,* 2018; Nguyen *et al.,* 2019). The MG estimator permits all coefficients and error variances across countries to differ. Thus, with the MG estimator, no homogeneity restrictions are imposed on cross-sectional parameters, which means that the possibility of identical parameters across countries is ignored. According to Pesaran and Smith (1995), different time series regressions are run for each country separately, and the coefficients are computed as unweighted averages of the estimated coefficients. A shortcoming of the MG estimator is that it is likely to be inefficient in panels with a small country dimension (N), although it may be consistent (Li and Ingham, 2020).

Rafindadi *et al.* (2018) add that the MG estimator will be inconsistent and thus will produce misleading results in situations where slope homogeneity is present in the slope parameters across the group. The DFE estimator permits heterogenous cross-country intercepts but imposes homogeneity on slope coefficients and error variances (Rafindadi *et al.,* 2018). Pesaran and Smith (1995) warn that the DFE estimator is susceptible to serious heterogeneity bias under conditions of slope heterogeneity and small sample size.

Lastly, the PMG estimator assumes that the long-run coefficients are homogenous but allows short-run coefficients, as well as the intercepts and error variances, to change across groups (Ssali *et al.,* 2019; Ahmad *et al.,* 2022). In addition, the PMG is an intermediate estimator between the MG and DFE estimators, as it combines pooling and averaging estimation methods (Munir, 2022) and employs a maximum likelihood method. According to Li and Ingham (2020), PMG estimations start with the employment of a concentrated maximum likelihood procedure to jointly estimate the long-run slope coefficients across countries and ends with the employment of maximum-likelihood to estimate country-by-country intercepts, short-run coefficients, the speed of adjustment and error variances. The

PMG estimator is a more efficient estimator than both the MG and DFE estimators (Ahmad *et al.,* 2022; Pesaran *et al.,* 1999; Rafindadi *et al.,* 2018).

Consequently, following Mujtaba and Ashfaq (2021), Noureen *et al.* (2022), and Teng *et al.* (2020), the study employs the PMG estimator, culminating in the use of the PMG-ARDL approach.

The next section examines the diagnostic and robustness checks to assess the model's fitness.

4.5 Diagnostic Tests and Robustness Checks

After the model is estimated, the study conducts some diagnostic tests and robustness checks to verify the validity of the regression model and results. In this section, diagnostic tests are discussed first, and then robustness checks will be discussed.

4.5.1 Diagnostic Tests

Diagnostic tests concern validation of the assumptions of OLS regression and multicollinearity issues. As highlighted in Subsection 4.2, the assumptions of OLS include normality of residuals, homogeneity of variance (homoscedasticity) and correct model specification (inclusion of relevant variables and exclusion of irrelevant variables). This study tests these assumptions, starting with normality and homoscedasticity, and followed by model specification. The last diagnostic test is the multicollinearity test.

The normality of the residuals is tested using the kernel density estimate combined with a normal density, which is overlaid over the kernel density in the combined plot. In the normality test, the null hypothesis is that the residuals are normally distributed, and the alternative hypothesis is that the residuals are not normally distributed (Mdluli, 2021).

Regarding homoscedasticity, the Breusch-Pagan heteroscedasticity test was conducted to determine if residuals exhibit a constant variance. The null hypothesis is based on the premise that the variance of the residuals is homogenous, and it is not rejected when the probability value of the chi-square statistic is greater than 5%. To confirm the robustness of the results of the Breush-Pagan heteroschedasticity test, a residual-versus-fitted (Rvf) plot was drawn. The Rvf plot is a graph which plots residuals against fitted variables. It shows the pattern of residual plots (data points) in relation to a horizontal line (yline(0)). If the data points show a random scatter around the line, this is indicative of homoscedasticity. In contrast, if the scatter exhibits a pattern (e.g. a trend, curved or cone shape), this is indicative of heteroschedasticity (UCLA, n.d.).

Turning to model specification, a model specification error arises when crucial variables are excluded from the model or when extraneous variables are included. When important variables are omitted, the shared variance with the included variables may be inaccurately assigned to those variables, leading to an increased error term. Conversely, incorporating unnecessary variables can cause their shared variance with the included variables to be mistakenly attributed to them. These model specification errors can profoundly impact the estimation of regression coefficients (UCLA, n.d.).

The linktest is employed in the study and is based on the idea that one will only find an additional independent variable by chance, if a regression is properly specified. This test creates two new variables: `_hat` for predicted values and `_hatsq` for squared predictions. After refitting the model with these variables, `_hat` should be significant, as it indicates the predicted value, while `_hatsq` is not expected to be significant if the model is correctly specified. The p-value for `_hatsq` is evaluated to check its significance.

Concerning multicollinearity, the correlation matrix in Section 4.2 above showed that urbanization is highly correlated with RGDP, with a pairwise correlation of 0.851, which is indicative of potential multicollinearity problems as it is above the canonical 0.8. Multicollinearity makes estimated coefficients unstable and unreliable, which makes it very difficult to make meaningful inferences from the results of a regression model (Bhandari, 2024). Since the correlation matrix indicates but does not confirm multicollinearity, we formally conducted a multicollinearity test. Following Pham *et al.* (2020) and Nathaniel and Adeleye (2021), the variance inflation factors (VIFs) test was performed to examine potential multicollinearity to gain further insight and robustness. A VIF above 10 confirms multicollinearity issues (Nathaniel and Adeleye, 2021).

4.5.2 Robustness Checks

Robustness checks assess the reliability and consistency of the regression results under different conditions or assumptions. The study checks the robustness of the long-run results. In this space, following Assamoi *et al.* (2019), we employ the dynamic ordinary least square (DOLS) method. According to Charfeddine and Mrabet (2017), DOLS outperforms FMOLS, the other cointegration estimation method, in small samples. This is because it deals with simultaneity bias and includes lags and leads within the regressors (Assamoi *et al.,* 2020). The equation estimated to generate the DOLS estimates is specified as follows (Assamoi *et al.,* 2020):

$$lnEF_{2t} = B'X_t + \sum_{j=-m}^{m} \theta_j \, \Delta lnRGDP_{t-j} + \sum_{j=-n}^{n} \emptyset_j \, \Delta lnEU_{t-j} + \sum_{j=-0}^{0} \gamma_j \, \Delta lnTO_{t-j} + \sum_{j=-p}^{p} \varphi_j \, \Delta lnDEN_{t-j} + \sum_{j=-q}^{q} \vartheta_j \, \Delta lnURB_{t-j} + \sum_{j=-r}^{r} \omega_j \, \Delta lnFR_{t-j} + \sum_{j=-s}^{s} ℷ_j \, \Delta lnFDI_{t-j} + v_i \qquad (9)$$

Where X=[1, lnRGDP, lnEU, lnTO, lnDEN, lnEURB, lnFR, lnFDI]; $B = \alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_{08}$ and *m, n, o, p, q, r, s,* t are the lengths of leads and lags of regressors and $\theta, \emptyset, \gamma, \varphi, \vartheta, \omega,$ ℷ are the estimated coefficients of lagged and led regressors, and *v* is the constant component of the error term.

4.6 Conclusion

This chapter provided a nuanced discussion of the methods employed in the study to plumb the environmental impact of socio-economic drivers in Africa. It began by elucidating the data regarding sources, measurement and expected signs of variables. Then, it proceeded to detail the numerous initial tests that will be performed to investigate stationarity, correlation, and cross-sectional dependence. The Augmented Dicky Fuller (ADF) and Levin, Lin, and Chu (LLC) tests are the specific unit root tests to investigate stationarity, while the Breusch-Pagan Lagrange multiplier (LM) test will be employed to investigate cross-sectional dependence. More importantly, the chapter described the estimation technique that will be used to fulfill the study's objectives in understanding the impacts of economic and demographic factors on the environment, namely the PMG-ARDL approach. An advantage of this approach is that it permits the simultaneous estimation of both short and long-run dynamics. Lastly, the chapter explored diagnostic tests and robustness checks. Diagnostic checks include the kernel density estimate for the normality of residuals, the Breusch-Pagan heteroscedasticity test and variances inflation factors for multicollinearity. The DOLS estimation technique is employed for verifying the validity of the long-run results.

Chapter 5 RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents and discusses the findings from the empirical analysis conducted to explore the relationship between economic and demographic factors and environmental degradation in Nigeria, South Africa, and Egypt over the period 1984 to 2022. The primary objective of this chapter is to interpret the results obtained from the Pooled Mean Group – Autoregressive Distributed Lag (PMG-ARDL) model, which examines the short- and long-run dynamics between the ecological footprint and its economic and demographic determinants.

Before estimating the model, a series of time-series pre-estimation tests were performed, including unit root and cointegration tests. The first section explores descriptive statistics focusing on the mean, maximum, minimum, standard deviation, skewness and kurtosis values. The subsequent section presents the correlation test. CD test results are presented in the third section, with unit root test outcomes examined in the fourth section. The PMG-ARDL regression results are analysed in the following section, starting with long-run results and ending with short-run results. Diagnostic tests and robustness check results are examined in the sixth section. The last section of the chapter is a conclusion.

5.2 Descriptive Statistics

Descriptive statistics of the variables were explored to understand the characteristics of the data and assess the spread, heteroscedasticity, and normality of the distributions of the relevant variables. These descriptive statistics are presented in Table 5.1. See Appendix A1 for country-by-country statistics.

Table 5.1:Descriptive Statistics for All Countries

Variable	Mean	Std. dev.	Min.	Max.	Skewness	Kurtosis	Obs.
EF	153.61	34.44	83.76	203.49	-0.2238	1.8056	117
RGDP	2 665.07	2 109.14	270.03	8 737.04	1.0715	3.2842	117
EU	1 330.37	851.93	486.92	2 904.28	0.7123	1.6267	117
TO	42.83	12.21	9.14	71.68	-0.4289	3.3445	117
DEN	90.14	55.21	27.01	263.58	1.0193	3.1396	117
URB	46.70	10.50	24.87	68.34	0.1775	2.5082	117
FR	4.20	1.48	2.26	6.70	0.2767	1.5489	117
FDI	1.69	1.79	-0.70	9.70	2.3548	9.8877	117

Source: Author's own computation

5.2.1 Ecological Footprint (EF)

The minimum and maximum values give a wide range, which indicates high volatility (dispersion), as does the standard deviation. The kurtosis of 1.81 means that the EF is flat or platykurtic, indicating that the EF is not normally distributed. Various studies support these results (see Nathaniel *et al.,* 2019; Nathaniel and Adeleye, 2021; Alola *et al.,* 2019).

5.2.2 Real GDP per Capita (RGDP)

The reported minimum, maximum, and standard deviation values show that the RGDP is highly dispersed. The reported skewness of 1.07 indicates that economic growth data does not follow a normal distribution, as does the kurtosis value of 3.28, which indicates that the distribution is peaked (leptokurtic). These RGDP results are consistent with various studies (e.g. Sharif *et al.,* 2023; Haoaus *et al.,* 2023; Shah *et al.,* 2021; Afriyie *et al.,* 2022; Assamoi *et al.,* 2019).

5.2.3 Energy Consumption

Energy consumption does not follow a normal distribution. The standard deviation is 851.93 koe, which indicates high dispersion. In addition, the distribution is moderately skewed and flat (platykurtic), as evidenced by the skewness and kurtosis values. This result is consistent with Assamoi *et al.* (2019), Nathaniel and Adeleye (2021), Ahmed *et al.* (2020) and Alola *et al.* (2019).

5.2.4 Trade Openness

The standard deviation shows that the data series has a big spread, and so do the minimum and maximum values. The kurtosis value of 3.34 means that the distribution is leptokurtic (peaked). These results indicate that the series does not follow a normal distribution. The finding is consistent with many studies (see Dimnwobi *et al*., 2021; Shah *et al.,* 2022; Alola *et al.,* 2019; Pham *et al.,* 2020).

5.2.5 Population Density

The population density series does not follow a normal distribution. The skewness value of 1.02 indicates that the distribution is highly skewed, and the standard deviation is high, which is indicative of high dispersion. The results that population density data is not normally distributed are corroborated by multiple studies (see Dimnwobi *et al.,* 2021; Wang and Li, 2021, Haouas *et al.,* 2023).

5.2.6 Urbanization

The standard deviation indicates that the data is very dispersed and, thus, is not normally distributed. This is supported by the kurtosis of 2.51, which reveals that the data is flat (platykurtic). The findings are consistent with Wang and Dong (2018), Ahmed *et al.* (2020), Afriyie *et al.* (2022), Haouas *et al.* (2023) and Nathaniel *et al.* (2019).

5.2.7 Fertility Rate

The kurtosis of 1.55 implies that the distribution is not normally distributed, and so do the minimum and maximum values that give a range of 4.4 children, which alludes to wide dispersion. The result that the fertility rate data is not normally distributed is corroborated by other studies (e.g., Charfeddine and Mrabet, 2017; Alola *et al.,* 2019).

5.2.8 Foreign Direct Investment

The standard deviation is 1.79%, which indicates small variations in FDI inflows across these countries. The skewness value is 2.35, meaning the series does not follow a normal distribution. This is supported by the kurtosis value of nearly 10, which indicates the series is highly leptokurtic. The result that FDI is not normally distributed is consistent with other studies (see Alola *et al.*, 2019; Assamoi *et al.,* 2019).

Because some observations of the variable are negative, these observations will be lost if log transformation is done on the original data series, as the logarithm of negative is not defined as a real number (Karakaplan *et al.*, 2020; Bos and Koetter, 2011). The authors point out two common approaches in econometrics in dealing with negative observations during transformation. In the first approach, the negative observations are dropped, which has the drawback of losing valuable data points. The second approach, the most prevalent in literature, is to rescale the series by adding an arbitrary constant to each observation (see Zmami and Ben-Salha, 2020; Bos and Koetter, 2011; Vander Vennet, 2002). For example, Zmami and Ben-Salha (2020) add 100 to the FDI series. The third approach, proposed by Karakaplan *et al.* (2020), involves treating the negative observations as positive. In this study, following Zmami and Ben-Salha (2020), we adopt the second approach and select 100 as the arbitrary constant. Thus, the FDI function used in further econometric analyses is given by the formula:

lnFDI = Log (FDI + 100)

In summary, the standard deviation results show that the data of all variables are volatile, relative to their relative mean values and widely dispersed, except for FDI. The kurtosis and skewness show that all variables do not follow a normal distribution. As a result, all the variables are transformed to their natural logarithms to obtain more reliable results from the econometric analyses.

5.3 Correlation Test

The relationships among the variables were investigated as the first step in detecting multicollinearity. Pairwise correlations above 0.8 indicate potential multicollinearity. This section presents and explores the correlation matrices for the whole sample and individual countries.

5.3.1 Correlation Test Results for All Countries

Table 5.2 below shows the correlation matrix for the whole sample.

Table 5.2: Correlation Matrix for All Countries

	lnEF	lnRGDP	lnEU	lnTO	lnDEN	lnURB	lnFR	lnFDI
lnEF	1.000							
lnRGDP	0.723	1.000						
lnEU	0.279	0.773	1.000					
lnTRD	0.441	0.283	0.325	1.000				
lnDEN	0.102	-0.386	-0.714	-0.418	1.000			
lnURB	0.627	**0.851**	0.737	0.527	-0.517	1.000		
lnFR	-0.603	-0.762	-0.681	-0.534	0.641	-0.767	1.000	
lnFDI	0.195	-0.122	-0.162	0.268	0.102	-0.089	-0.081	1.000

Source: Author's computation using data from the WDI and GFN

The table shows the pairwise correlations between the dependent and explanatory variables, and the correlations among the explanatory variables. Starting with the correlations between EF and economic factors, RGDP per capita is strongly and positively correlated with the ecological footprint, as shown by the pairwise correlation coefficient of 0.723. This result of a strong positive correlation is consistent with the findings of Kongbuamai *et al.* (2021), Borsha *et al.* (2024) and Zeraibi *et al.* (2021). In addition, Solarin *et al.* (2021) also found evidence of a positive correlation between RGDP per capita and EF. Energy use is also positively correlated with EF, as indicated by the pairwise correlation coefficient of 0.279. The result of a positive association between EU and EF is supported by the findings of Islam *et al.* (2021), Nathaniel *et al.* (2020), and Kongbuamai *et al.* (2021). Lastly, trade openness and EF have a positive correlation, as shown by the pairwise correlation coefficient of 0.441. This result is corroborated by the findings of Nathaniel *et al.* (2021) and Dimnwobi *et al.* (2021).

Regarding demographic factors, population density has a positive but weak correlation with the ecological footprint, as evidenced by the pairwise correlation coefficient of 0.102. Dimnwobi *et al.* (2021), Haouas *et al.* (2023), and Sahoo and Sethi (2021) support this result. The results also show that urbanization has a strong correlation with EF, with a pairwise correlation coefficient of 0.627. This result of a positive correlation is supported by the findings of various studies (see Özcan, 2024; Wang and Dong, 2018; Islam, 2021; Raggad *et al.,* 2023). Lastly, the fertility rate is shown to be negatively correlated with EF, as per the pairwise correlation coefficient of -0.6016.

The technology variable, FDI, is positively correlated with the EF, as indicated by the pairwise correlation coefficient of 0.1948. This result is confirmed by Solarin *et al.* (2021) and Özcan (2024).

In terms of correlations among the independent variables, the table shows that RGDP is strongly and positively correlated with energy use and urbanization, with pairwise correlations of 0.773 and 0.851, respectively. In addition, a weak positive correlation of 0.2824 is reported between RGDP and trade openness. In contrast, economic growth shares negative relationships with population density, fertility rate, and FDI. The strongest negative correlations are reported between RGDP and fertility rate, with a pairwise correlation of -0.7608.

Energy use is strongly and positively correlated with urbanization, with a correlation coefficient of 0.737, and is weakly and positively correlated with trade openness, with a correlation coefficient of 0.325. Conversely, energy use has a strong negative correlation with population density, with a coefficient of -0.714, a moderate negative correlation with fertility rate (-0.681), and a weak correlation with FDI (-0.162).

Trade openness has positive relationships with urbanization and FDI, with correlation coefficients of 0.527 and 0.268, respectively. Conversely, the coefficients of -0.418 and -0.534 speak to the negative correlations trade openness shares with population density and fertility rate, respectively.

Interestingly, population density is negatively correlated with urbanization with a pairwise coefficient of -0.517. However, it is positively correlated with fertility rate and FDI with pairwise correlation coefficients of 0.641 and 0.102, respectively.

Urbanization is negatively correlated with the fertility rate and FDI, as shown by the respective pairwise correlation coefficients of -0.767 and -0.089. Lastly, the pairwise coefficient of -0.081 shows that the fertility rate negatively correlates with FDI.

In conclusion, there are negative and positive correlations among the variables. Although there are no perfect correlations among regressors, urbanization is highly correlated with RGDP, with a pairwise correlation of 0.851. This correlation coefficient is above the canonical 0.80, which is indicative of potential multicollinearity problems. In theory, a solution is to drop one of the variables.

However, in this study, the two variables (RGDP and urbanization) are retained for two reasons. First, multicollinearity causes significant and concerning impacts when a variable's VIF is above 10. The results of the VIF test employed in the study to assess multicollinearity showed that the VIF for RGDP and urbanization are below 10. The VIF test results are discussed in more detail in Section 5.91. Secondly, excluding an important (relevant) variable from a regression because of its high correlations with other variables can lead to biased coefficient estimates and false significance (Kalnins and Praitis Hill, 2025; Lindner, *et al.,* 2020). As shown in Chapter 3, RGDP and urbanization are important drivers of environmental drivers, making them critical to satisfying the research objectives. Muindi (2021) and Nyirenda (2019) adopt the same approach of not dropping highly correlated variables due to their importance to their studies.

5.3.2 Correlation Test Results for Individual Countries

Table 5.3 below shows the correlation matrices of the studied countries. Starting with correlations among the EF and explanatory variables, the table shows that in South Africa, RGDP, trade openness, population density and urbanization have very strong positive correlations with the EF, with pairwise correlation coefficients of 0.922, 0.815, 0.921 and 0.944, respectively. RGDP and population density also have strong positive correlations with the EF in Nigeria and Egypt. The pairwise correlation coefficient of population density and EF is 0.940 in both Nigeria and Egypt. In contrast to South Africa, trade openness and EF have weak correlations in Nigeria (0.415) and Egypt (-0.167). Urbanization has a very strong positive correlation with the EF in Nigeria, just like in South Africa, with a pairwise correlation coefficient of 0.94. However, it has a moderate negative relationship with EF in Egypt, and indicates a pairwise correlation coefficient of -0.634.

Across the three countries, the fertility rate has a very strong negative relationship with the EF, with pairwise coefficients of -0.856, 0.809, and -0.874 in South Africa, Nigeria, and Egypt, respectively. FDI has weak positive relationships with the EF in the three countries, with pairwise correlation coefficients of 0.431, 0.111, and 0.244 in South Africa, Nigeria, and Egypt, respectively. Lastly, energy consumption positively correlates with the EF in the three countries. The relationship is very strong in Egypt (0.951) but weak in South Africa (0.444) and Nigeria (0.389).

Table 5.3: Correlation Matrix for Individual Countries

South Africa

	lnEF	lnRGDP	lnEU	lnTO	lnDEN	lnURB	lnFR	lnFDI
lnEF	1.000							
lnRGDP	0.922	1.000						
lnEU	0.444	0.392	1.000					
lnTRD	0.815	0.646	0.569	1.000				
lnDEN	0.921	**0.871**	-0.095	0.659	1.000			
lnURB	0.944	**0.891**	0.196	0.747	**0.984**	1.000		
lnFR	-0.856	-0.744	-0.092	-0.534	**-0.924**	**-0.878**	1.000	
lnFDI	0.431	0.356	-0.024	0.411	0.464	0.467	-0.436	1.000

Nigeria

	lnEF	lnRGDP	lnEU	lnTO	lnDEN	lnURB	lnFR	lnFDI
lnEF	1.000							
lnRGDP	0.831	1.000						
lnEU	0.389	0.304	1.000					
lnTRD	0.415	-0.002	0.462	1.000				
lnDEN	0.940	**0.831**	0.137	0.268	1.000			
lnURB	0.941	**0.823**	0.157	0.297	**0.999**	1.000		
lnFR	-0.809	-0.722	0.125	-0.148	**-0.953**	**-0.947**	1.000	
lnFDI	0.111	0.349	0.269	0.287	-0.239	-0.214	0.352	1.000

Egypt

	lnEF	lnRGDP	lnEU	lnTO	lnDEN	lnURB	lnFR	lnFDI
lnEF	1.000							
lnRGDP	0.888	1.000						
lnEU	0.951	**0.908**	1.000					
lnTRD	-0.167	-0.512	-0.217	1.000				
lnDEN	0.940	**0.944**	**0.949**	-0.356	1.000			
lnURB	-0.634	-0.599	-0.562	0.228	-0.725	1.000		
lnFR	-0.874	-0.794	**-0.835**	0.160	**-0.912**	0.793	1.000	
lnFDI	0.244	0.017	0.279	0.467	0.083	0.173	-0.144	1.000

Source: Author's computation using data from the WDI and GFN

Turning to correlations among explanatory variables and focusing on correlations indicative of multicollinearity, the table shows that RGDP is highly correlated with population density and urbanization in the three countries, with pairwise correlations above 0.81, except that the RGDP and urbanization is -0.599 in Egypt, where RGDP is highly correlated with energy consumption with a pairwise correlation of 0.908. Energy consumption is highly correlated with population density and the fertility rate in Egypt. Intuitively, population density is highly correlated with urbanization and fertility rate in the three countries. However, the pairwise correlation coefficient of population density and urbanization in Egypt is below the threshold of potential multicollinearity. Urbanization and fertility rates are highly correlated in the three countries, and in Egypt, the correlation coefficient is 0.793, which is slightly below 0.81.

In conclusion, many pairwise correlations among the explanatory in the individual countries are very high, suggesting multicollinearity issues. This is particularly true for the correlation between population density and urbanization. In Nigeria, the pairwise correlation is 0.999. These correlations suggest that some variables be dropped. However, none is dropped. The reason is that the study employs panel data techniques and not cross-sectional or time series analyses. According to Baltagi (2005), one benefit of panel data over the other data types is less multicolinearity. Panel data effectively address the correlations often found in time series data by offering increased variation across individuals or groups. This additional variability mitigates the impact of time-related confounding factors, enhancing the precision of the estimated relationships among variables. The 'panel' aspect fundamentally allows for the consideration of characteristics that remain constant over time, which might otherwise result in heightened correlations within a singular time series (Hsiao, 2007). As shown in the panel correlation matrix above, the one pairwise correlation coefficient indicative of possible multicollinearity concerns RGDP and urbanization.

5.4 Cross-sectional Dependence Test

The study used the Breusch-Pagan LM test to investigate cross-sectional dependence. In addition, Pesaran's test was conducted to measure the robustness of the results. The results of the cross-sectional dependence tests are presented in Table 5.4 below.

Table 5.4: Cross-sectional Dependence Tests

	Breusch-Pagan LM test	Pesaran's test
T-statistic	1.322	0.030
p-value	0.724	0.976

Source: Author's computation

The table shows that the probability of the LM test statistic is more than 5%. This means that the null hypothesis of no cross-sectional dependence among the variables is accepted.

Pesaran's test corroborates this result of no cross-sectional dependence and consequently, both unit root and cointegration tests are done using appropriate first-generation tests. Studies that found similar results of no cross-sectional dependence include Balsalobre-Lorente *et al.* (2019). In contrast, studies that did not find evidence of cross-sectional dependence include Zmami and Ben-Salha (2020) and Usman *et al.* (2022).

5.5 Unit Root Tests

In light of accepting the null hypothesis of no cross-sectional dependence, the study employed first-generation unit root tests (LLC, ADF) to determine that no variable is I(2), as required by the ARDL model. The null hypothesis is that the series has a unit root, and the null hypothesis is that the series is stationary. It should be noted that the null hypothesis is rejected if the p-value is less than 5%. Table 5.5 shows the results of the unit root tests.

Table 5.5: Unit Root Tests

Variable	ADF		LLC	
	Critical Value	Order of Integration	Critical Value	Order of Integration
lnEF	46.695*** (0.0000)	I(1)	-4.337*** (0.0000)	I(1)
lnRGDP	29.353*** (0.000)	I(1)	-1.453* (0.073)	I(0)
lnEU	54.082*** (0.000)	I(1)	-3.586*** (0.000)	I(1)
lnTRD	11.2220* (0.082)	I(0)	-2.5029*** (0.006)	I(0)
lnDEN	11.4103* (0.077)	I(0)	15.475** (0.017)	I(0)
lnURB	16.5585** (0.011)	I(0)	-3.023*** (0.001)	I(0)
lnFR	14.376** (0.026)	I(1)	-1.922** (0.027)	I(1)
lnFDI	19.660*** (0.003)	I(0)	-2.787*** (0.003)	I(0)

(Source: Author's own computation)
***, **, and * represent the rejection of the unit root null hypothesis at the 1%, 5%, and 10% significance levels, respectively.

The table shows that the two tests produce similar results regarding the order of integration of the variables for RGDP per capita. The ecological footprint, energy use and fertility rate are stationary at the first difference – i.e. they are I(1) processes. Trade openness, population density, urbanization and FDI are stationary at level – i.e., they are I(0) processes. Lastly, RGDP is reported to be an I(1) process under the ADF test and an I(0) process under the

LLC test. More importantly, no variable is stationary at second difference or I(2). Studies that found mixed orders of integration include Rafindadi *et al.* (2018) and Dimnwobi *et al.* (2021).

In summary, the two tests produce similar results regarding the stationarity of the variables. The variables are a mix of I(0) and I(1), which satisfies a necessary condition for using the PMG-ARDL model.

5.6 Optimal Lag Selection

The BIC was employed to determine the optimal lags of the variables and model to ensure the minimization of serial correlation in the residuals. The AIC was employed for robustness checks. Table 5.6 presents the lag selection by each criterion.

Table 5.6: Optimal Lag Selection

	AIC			BIC		
Variable	**South Africa**	**Nigeria**	**Egypt**	**South Africa**	**Nigeria**	**Egypt**
EF	1	1	1	1	1	1
RGDP	0	1	0	0	0	0
EU	0	0	0	0	0	0
TO	0	1	1	0	0	1
DEN	0	1	1	0	0	1
URB	0	0	1	0	0	0
FR	1	0	1	0	0	0
FDI	0	1	0	0	0	0

(Source: Author's own computation)

The table shows the optimal lag of each variable for each country under the two information criteria. The optimal lag for each variable is the number that appears the most in the three countries. Under the BIC, the optimal lag is 1 for EF and 0 for all explanatory variables. This gives the resultant model: ARDL (1, 0, 0, 0, 0, 0, 0, 0). Under the AIC, the optimal lag is 1 for EF, 0 for RGDP and EU, 1 for TO and DEN, 0 for urbanization, 1 for fertility rate, and 0 for FDI. This gives the resultant model: ARDL (1, 0, 0, 1, 1, 0, 1, 0).

In this study, the BIC model is estimated. No other versions of the model with different lags were estimated. The reason is that in the ARDL framework, the optimal lag order is selected automatically from hundreds of thousands of possible lag order combinations (Kripfganz and Schneider, 2023). This means that the model estimated is the optimal model. See Appendix A3 for output from regression software.

5.7 Cointegration Tests

With respect to cointegration, the study employed the Kao (1999) and Pedroni (1999, 2004) panel cointegration tests to confirm the presence of long-run relationships between the dependent and the various regressors. The results of the panel cointegration tests are presented in Table 5.7 below.

Table 5.7: Panel Cointegration Test

Test	Statistic	t-statistic	P-value
Kao	Modified Dickey–Fuller	-5.670***	0.000
	Dickey–Fuller	-3.157 ***	0.001
	Augmented Dickey–Fuller	-2.679**	0.004
	Unadjusted modified Dickey–Fuller	- 6.583***	0.000
	Unadjusted Dickey–Fuller	-3.298***	0.001
Pedroni	Modified Phillips-Perron	1.063	0.144
	Phillips-Perron	-1.786**	0.037
	Augmented Dickey–Fuller	- 1.6784*	0.047

Source: Author's own computation

*** and ** represent a rejection of the null hypothesis of no cointegration at the 1% and 5% significance levels.

The table shows that for the Kao test, the probability value of all t-statistics is lower than 5%. The null hypothesis of no cointegration is rejected at the 1% significance level for all statistics, except for the Augmented Dickey-Fuller (ADF), which is rejected at the 5%. Thus, the Kao test unequivocally establishes cointegration. Regarding the Pedroni test, two statistics, Phillips-Perron and ADF, have probability values below 5%. These statistics confirm the presence of cointegrating relationships. However, one statistic, the Modified Phillips-Perron, has a probability value above 5%, refuting the long-run relationship between variables. Given that more statistics confirm the existence of long-run relationships between variables than otherwise, the Pedroni test confirms cointegration overall. Thus, the Kao and Pedroni tests reject the null hypothesis of no cointegration.

This result confirming cointegration means that all the explanatory variables have a causal, long-run equilibrium relationship with the EF. As mentioned in the previous chapter, any deviations caused by short-run shocks are corrected at a speed given by the error correction term.

5.8 Panel Autoregressive Distributed Lag Results

The study used the PMG-ARDL model to investigate both long-run and short-run dynamics. In this section, long-run results will be discussed first and short-run results will then be discussed.

5.8.1 Long-run PMG-ARDL Results

The estimated long-run results are presented in Table 5.8 below. The PMG estimator imposes homogeneity on long-run coefficients, implying that the impacts of the various environmental drivers are equal across all countries in the long run. Therefore, the results imply that the long-run contribution of each driver to environmental damage is the same in South Africa, Nigeria, and Egypt. This differs from the MG estimator, which allows long- and short-run coefficients to vary across countries.

Table 5.8: Estimated Long-run Coefficients of Panel PMG-ARDL Model

Dependent variable: lnEF

Variable	Coefficient	Probability
lnRGDP	0.188***	0.000
lnEU	0.212*	0.091
lnTO	0.117*	0.084
lnDEN	-0.084	0.607
lnURB	-0.033	0.924
lnFR	-0.824***	0.000
lnFDI	0.609	0.140

Source: Author's own computation

*** and * denotes the statistical significance at the 1% and 10%, respectively

Table 5.6 shows that RGDP (economic growth) has a significant positive relationship with the ecological footprint at the 1% level of significance. This means that increases in economic activity contribute significantly to environmental degradation in South Africa, Egypt and Nigeria. Specifically, a 1% increase in RGDP causes the ecological footprint to increase by 0.19%. This result supports the WST perspective that economic growth damages the environment in the long run. Incidentally, the finding also invalidates the EKC hypothesis in the selected countries.

This result is not surprising. A growing economy is associated with increased extraction of natural resources, which accelerates their depletion and deforestation. Moreover, it is supported by higher energy consumption, and it leads to increased urbanization and deforestation. Lastly, economic growth is associated with higher incomes for citizens, which leads to increased consumption and waste generation. All these dynamics are associated with higher pollution and emissions. Tachega *et al.* (2021) and Charfeddine and Mrabet (2017) concur that the expanded use of natural resources to generate economic growth is causing environmental degradation in Africa.

This result that economic growth damages the environment in the long run is consistent with studies such as Duodu *et al.* (2021) for 23 SSA countries; Wang and Dong (2018) for 14 SSA countries, Nathaniel *et al.* (2019) for South Africa; Sharma *et al.* (2020) for South and Southeast Asia, and Dimnwobi *et al.* (2021) for five populous African countries (Nigeria, DR Congo, Ethiopia, South Africa and Tanzania). Conflicting results were found by different studies, such as Ssali *et al.* (2019) for six SSA countries, Opoku and Boachie (2019) for 36 African countries, and Zimon *et al.* (2023) for South Korea.

The divergence in results can be attributed to differences in proxies of environmental degradation, econometric techniques employed in the study and geographical scope. For example, Wang and Dong (2018) and Dimnwobi *et al.* (2021) use EF as the proxy of environmental damage. In contrast, Ssali *et al.* (2019) and Zimon *et al.* (2023) use CO_2 emissions to represent environmental degradation. Similarly, Duodu *et al.* (2021) employs GMM estimation, while Ssali *et al.* (2019) uses PMG-ARDL estimation. Lastly, Sharma *et al.* (2020) focuses on South and Southeast Asian countries while Opoku and Boachie (2019) studies 36 African countries. Because this study uses the EF as the proxy of environmental degradations, its findings are consistent with the findings of Dimnwobi *et al.* (2021) and Wang and Dong (2018) but contradict the findings of Ssali *et al.* (2019) and Zimon *et al.* (2023).

It can also be seen from the table under discussion that energy consumption has a significant positive impact on the ecological footprint at the 10% significance level. A 1% increase in energy consumption raises the ecological footprint by 0.21%. Therefore, increases in energy consumption damage the natural environment in the countries under study. As noted by Dimnwobi *et al.* (2021) and Nathaniel and Adeleye (2021), due to the prevalence of energy poverty in Africa, there is a heavy reliance on and inefficient utilization of fossil fuels across the continent, which is coming at a high cost of environmental degradation.

This finding is corroborated in many studies like Sarkodie (2018) for 17 African countries, Wu *et al.* (2021) for 18 developed countries, Alola *et al.* (2019) for 16 EU countries, Nathaniel and Adeleye (2020) for 44 African countries and Rafindadi *et al.* (2018) for 6 Gulf Co-operation Countries (GCC) (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE), and Nathaniel and Khan (2020) for ASEAN countries. On the other hand, the finding is contradicted by many studies, such as Zeraibi *et al.* (2021) for the Association of Southeast Asian Nations (ASEAN-5) countries, Usman *et al.* (2021) for BRICS-T (BRICS plus Turkey) countries, and Amer *et al.* (2024) for five GCC countries.

The main reason for the contradicting results relates to the type of energy source. Studies confirming the damaging impact of increased energy consumption on the environment use fossil fuels. On the contrary, studies revealing the benign environmental impact of increased energy consumption are based on cleaner fuels. As such, they provide supportive evidence that transitioning to cleaner sources of energy reduces environmental degradation. Therefore, this study's results contradict the finding that increased energy consumption brings environmental improvements because the energy consumption variable is constituted by fossil and clean energy consumption. As Nathaniel and Adeleye (2020) state, Africa's energy mix is dominated by fossil fuels.

The study finds that increasing trade openness degrades the environment at the 10% significance level. A 1% trade increase induces a 0.12% increase in the EF, and this result lends support to the PHH and WST perspectives. Studies that corroborate the deleterious impact of increased trade openness of the environment include Shah *et al.* (2022) for 18 low-income countries, Sun *et al.* (2020) for SSA countries, Solarin *et al.* (2021) for Nigeria and Renyong and Sedik (2023) for 18 East African countries. Contradictory findings of benign environmental impacts of increased economic integration are reported by Tachie *et al.*

(2020) for 18 EU countries, Ahmed *et al.* (2020) for Egypt, Ohlan (2015) for India, and Kamal *et al.* (2021) for 105 countries.

The different results of the above studies are explained by differences in proxies of environmental degradation, study period, econometric techniques employed, and countries studied. For example, Solarin *et al.* (2021) use the EF as the indicator of environmental degradation from 1977 to 2016, and Ahmed *et al*. (2020) use CO_2 emissions as the proxy of environmental damage between 1965 and 2014. However, it is intuitive that the differences in countries included in the study hold much sway. All the studies that show that increased trade openness degrades the environment focus exclusively on African countries, which are poor and underdeveloped. On the other hand, EU countries are predominantly rich and developed. Although India is a developing country, its GDP figure is bigger than all European countries except Germany, which indicates it can influence trade terms. Therefore, due to its exclusive focus on African countries, the study's results contradict the results of studies focusing exclusively on non-African countries (e,g. Tachie *et al.*,2020; Ohlan, 2015) and those with the influence of non-African countries (e.g. Kamal *et al.*, 2021).

The long-run degrading impact of trade openness in the selected African countries is unsurprising. African countries are still poor and face high unemployment rates, which, in line with the arguments of political economists, set the tone for the environmentally destructive impact of trade. Firstly, African countries engage in trade as a mechanism to expand the scale of domestic production (Odhiambo, 2022). Export-led economic growth is a growth policy adopted by many countries worldwide, and has had great success in the case of the Asian Tigers and China. Secondly, because of the need to grow their economies and lack of resources, African governments are forced to formulate lax environmental trade restrictions to enable the importation of affordable but environmentally dirty capital goods (Dimnwobi *et al.,* 2021). As a result, African countries are primed to be pollution havens (Jorgenson and Givens, 2013).

Lastly, South Africa, Nigeria, and Egypt are plausibly victims of Ecologically Unequal Exchange (EUE) as they cannot dictate the terms of trade with their large trading partners, developed countries, and China. Various studies have validated EUE theory as a structural feature of global trade. For example, Hao (2019) studied EUE for 89 countries, classified as high-income countries (HICs) and middle- and low-income countries (MLICs), using CO_2 emissions between 1990 and 2015, and found that HICs are net exporters of carbon dioxide

(CO_2) emissions. Jorgenson (2011a) tested EUE using CO_2 emissions between HICs and Central and Eastern European (CEE) countries for the period 1992 to 2005. He found that the impact of vertical flows of exports to HICS on emissions ultimately became ecologically unequal and damaging to the environment in CEE countries over time. Other studies that have validated EUE include Dorninger *et al.* (2021), Hickel *et al.* (2022), Infante-Amate and Krausmann (2019) and Hickel *et al.* (2022).

Turning to demographic factors, the study's results show that increases in population density have an insignificant impact on the environment. This result supports the Boserupian perspective. However, the result is contradictory to *a priori* expectations, and there are two possible explanations why increasing population density is not associated with environmental damage. Firstly, as noted by Charfeddine and Mrabet (2017), it is because a greater proportion of the African population engages in agricultural activities, with lower environmental impacts than industrial ones. Secondly, perhaps due to the influence of the South African situation, the higher levels of unequal income distribution and economic marginalization of the greater population mean that many people have a negligible impact on environmental degradation.

The study's findings are corroborated by Kongbuamai *et al.* (2020) for Thailand, Marquart-Pyatt (2015) for West Africa, Shah *et al.* (2022) for 21 low-income countries and Sahoo and Sethi (2021) for developing countries. Contradictory results are found in other studies, such as Haouas *et al.* (2023) for the MENA countries, Mishra *et al.* (2020) for India, and Sharma *et al.* (2020) for SSEA countries.

Different estimation techniques, study periods, proxies of environmental degradation and type of data (number of countries) are some of the factors explaining the inconsistencies in study results. For example, the results of the study corroborate the findings of Sahoo and Sethi (2021) and contrast the findings of Haouas *et al.* (2023) due to the use of EF as the indicator of environmental degradation. Although Sharma *et al.* (2020) employ the EF as the dependent variable and PMG-ARDL estimation just like the study, the results differ on account of the time horizon and countries included. Sharma *et al.* (2020) focus on SSEA countries, while the study focuses on three African countries. This focus on three African countries results in panel data, which explains the contradictions with the results of Mishra *et al.* (2020), who use time series data by focusing only on India.

Concerning urbanization, the study found that increasing urbanization has insignificant impacts on the environment. Since this result is consistent with population density, it further provides supportive evidence for the Boserupian perspective that the rising African population does not exert deleterious impacts on the environment. Studies that confirm this result that increases in urbanization do not harm the environment, include Charfeddine and Mrabet (2017) for Middle East and North Africa (MENA) countries, Ulucak *et al.* (2021) for the Mediterranean region, Nathaniel *et al.* (2020) for MENA countries and Zmami and Ben-Salha (2020) for Gulf Cooperation Council (GCC) countries. Studies that contradict this result, include Wang and Dong (2018) for SSA countries, Pham *et al.* (2020) for 28 European countries and Zhang *et al.* (2022) for BRICS countries.

The major factor explaining of the differences in the results of these empirical studies is the differences in the countries included in the study. All studies that found that increased urbanization brings environmental improvements to focus predominantly on Arabic countries. The Mediterranean region, MENA, and GCC are at their core groupings of Middle Eastern countries. In contrast, countries that found contrasting results focus on other regions. Similarly, the differences in the study's findings from other studies are partly explained by the dependent variable and estimation technique. The use of EF in the study as the proxy of environmental harm contributes to consistency with the findings of Charfeddine and Mrabet (2017) and contradictions with the findings of Pham *et al.* (2020). Similarly, the employment of the PMG-ARDL estimation technique in the study contributes to differences in results with Wang and Dong (2018).

The benign effect of increasing urbanization on the environment is not as initially expected and this result can be explained by various reasons, which boil down to the quality of the quality of urbanization happening. On the one hand, unplanned urbanization is happening, and this type of urbanization contradicts the three pathways identified by Zhu and Peng (2012) through which increased urbanization degrades the environment. Firstly, unplanned urbanization is not associated with a significantly higher demand for energy since access to energy is limited (Dimnwobi *et al.*, 2021). This is because such urbanization is predominantly driven by informal settlements (Gambe *et al.,* 2023). Secondly, unplanned urbanization is not associated with the demand for emission-intensive building materials, as mushrooming informal settlements are not characterized by large-scale industrial and residential infrastructure development. Thirdly, unplanned urbanization is not associated with significant destruction of grasslands and woodlands. As such, insignificant amounts of carbon sequestered in these destroyed biota are released. This is because peri-urban areas are not dense forests.

On the other hand, planned urbanization in Africa is also happening, and this kind of urbanization is associated with reductions in the EF. As noted by Charfeddine and Mrabet (2017), planned urbanization reduces the EF due to the easier development, maintenance, and operation of environmentally friendly infrastructure and public services, such as piped water, sanitation, and waste management. In addition, urbanization spurs the development of environmentally friendly equipment and machines necessary for the green economy.

In relation to the fertility rate, the results showed that increases in fertility rate reduce the EF and, hence, bring environmental improvements at the 1% significance level. Specifically, a 1% increase in the fertility rate reduces the EF by 0.82%. This result validates the Boserupian perspective, and studies supporting this result include Charfeddine and Mrabet (2017) for MENA countries and Alola *et al.* (2019) for 16 EU countries. Conversely, studies that contradict this study are Sarkodie (2018) for 17 African countries and Sharma *et al.* (2020) for SSEA countries.

Divergencies in the findings of this study and other studies are explained in part by differences in environmental degradation proxy and econometric techniques employed, period of study and countries included. For example, the use of EF and PMG-ARDL estimation explains the similarity of the results of this study with those of Alola *et al.* (2019) but also the differences with the results of Sarkodie *et al.* (2020). Given that Sharma *et al.* (2020) also employ the EF and EF and PMG-ARDL, the divergencies of results from this study's findings can be attributed to differences in the study period and countries studied.

Consistent with other demographic factors, the benign environmental impact of fertility rate increases is contrary to initial expectations. As highlighted in the discussion of the population density results, the majority of people in Africa engage in agricultural activities and are marginalized from mainstream economic participation. Therefore, an increase in the fertility rate in the lower echelons of the population does not significantly impact the environment (Charfeddine and Mrabet, 2017).

Lastly, focusing on FDI, the study's results reveal that increases in FDI inflows do not have significant environmental impacts. This result supports the EMT and PHEH worldviews. Studies that corroborate the findings of the study include Yilanci *et al.* (2023) for Indonesia, Saqib *et al.* (2023) for16 European countries, Rafindadi *et al.* (2018) for six Gulf

Cooperation Council (GCC) countries, and Mert and Bölük (2016) for 21 Kyoto Annex countries. In contrast, studies that refute the study's finding include Solarin *et al.* (2017) for Ghana, Sun *et al.* (2017) for China, Opoku and Boachie (2019) for 36 African countries and Nguyen *et al.* (2019) for 33 emerging economies. Differences in these results are attributable to, among other things, data type and proxy of environmental damage used. Rafindadi *et al.* (2018), Mert and Bölük (2016), Solarin *et al.* (2017), and Sun *et al*. (2017) all use CO_2 emissions as the dependent variable but produce different results because the first two studies use panel data while the last two use time series data. The use of the EF as the dependent variable in this study accounts for similar results with Saqib *et al.* (2023) and different results with Opoku and Boachie (2019).

The result that increased FDI inflows do not harm the environment in the long run was not as expected. One explanation for this result is that, in the long run, multinational corporations would have reaped financial profits from their initial investments, allowing them to invest in more expensive, environmentally friendly technologies. Businesses and institutions first pursue profit maximization before ensuing severe environmental problems force them to be ecologically rational (Mol, 1995; Mol *et al.,* 2009).

In summary, increases in all economic variables degrade the environment in South Africa, Nigeria and Egypt. Conversely, increases in all demographic drivers do not degrade the environments of the studied countries in the long run. In terms of the relative contribution of drivers to environmental destruction, energy consumption has the most significant impact, followed by economic growth and, lastly, trade openness. These results fulfil the objectives of the study, which are to understand the relationship between environmental harm and socio-economic factors and identify the KIF of environmental degradation.

5.8.2 Short-run PMG-ARDL Results

The estimated short-run results are presented in Table 5.9 below.

Table 5.9: Estimated Short-run Coefficients of Panel PMG-ARDL Model

Dependent variable: d.lnEF

Variable	Coefficient	Probability
Error correction term	-0. 462*	0.094
d.lnRGDP	-0.007	0.580
d.lnEU	0.349	0.130
d.lnTO	0.098***	0.003
d.lnDEN	9.365	0.250
d.lnURB	-3.050	0.199
d.lnFR	0.759*	0.055
d.FDI	0.112***	0.001

Source: Author's own computation

*** and * denote the statistical significance at 1% and 10% level of significance, respectively.

The table shows that the error correction term is negative, less than - 2, and significant at the 10% level of significance. As clarified by Rafindadi *et al.* (2018), these are the elements that prove cointegration. This result confirms the results of the Kao and Pedroni cointegration tests that found evidence of cointegration. The effect of this result is that the long-run results discussed above are valid. The magnitude of the error parameter (-0.46) implies that approximately 46% of the short-run shocks that typically disturb the equilibrium are corrected in each period, suggesting that the restoration to long-run equilibrium takes slightly longer than two periods. Thus, whether the shocks are positive or negative, expected or not, they are temporary, as environmental quality will return to its long-run equilibrium.

In terms of the discussion of the impacts of the various drivers, the study found that economic growth does not significantly impact the environment. This result is unsurprising because Africa's economic activity historically has been low, meaning economic growth could not significantly impact environmental quality.

Studies that corroborate this finding include Hossain *et al.* (2024) and Voumik and Sultana (2022). In contrast, studies that refute this finding are Zimon *et al.* (2023) and Usman *et al.* (2022). The differences in results are mainly explained by differences in the economic status of the countries studied. Studies that found that economic growth has insignificant impacts focused on developing countries: Bangladesh (Hossain *et al*., 2024) and BRICS (Voumik and Sultana, 2022). On the other hand, studies revealing contrasting results focused on developed countries: South Korea (Zimon *et al.,* 2023) and 12 developing countries, including the USA, South Korea, Germany, and Japan (Usman *et al.,* 2022). The study contradicts the results of Zimon *et al.* (2023) and Usman *et al.* (2022) because it focuses on South Africa, Nigeria and Egypt, which are all developing countries.

With respect to energy use, the study found that increases in energy consumption have an insignificant environmental impact. This result is intuitive, given that increases in RGDP have insignificant short-run results. Energy consumption is inextricably linked to economic activity. A small, poor economy is characterized by low energy consumption, which means low emissions. Studies that corroborate this finding include Dimnwobi *et al.* (2021), Usman *et al.* (2022), *Kuo et al.* (2022) and Mumtaz *et al.* (2022). In contrast, studies that contradict this finding include Nathaniel *et al.* (2019) and Ohlan (2015).

Differences in the type of data used mainly explain differences in the results. Panel data was used in the three studies that reveal increases in energy consumption have an insignificant environmental impact. For example, Dimnwobi *et al.* (2021) studied 5 populous African countries, and Kuo *et al*. (2022) focused on 10 Asian countries. In contrast, studies with contradictory results used time series data. Nathaniel *et al.* (2019) and Ohlan (2015) studied South Africa and India, respectively. Consequently, it is the use of panel data in the study explains the contradiction between its findings and those of Nathaniel *et al.* (2019) and Ohlan (2015).

Contrary to the results of the other two economic drivers, the study found that increases in trade openness damage the environment in the short run, at the 1% percent significance level. A 1% increase in trade increases the EF by 0.1%. The result is as expected. The biggest exports of African countries are extracted primary goods. For example, Nigeria and Egypt's biggest exports are petroleum products, while South Africa exports precious minerals. Producing these products involves significant environmental degradation and studies that corroborate this finding include Dimnwobi *et al.* (2021), Renyong and Sedik (2023) and

Solarin *et al.* (2021). The result that increases in trade openness damage the environment in the short run is refuted by many studies (see Ahmed *et al.,* 2020 and Kamal *et al.,* 2021). Differences in results can be attributed to the level of economic development of countries included in the study sample. Consistent with this study, studies that show that increased trade openness degrades the environment in the short run focus exclusively on African countries. Renyong and Sedik (2023) focused on East Africa, and Solarin *et al.* (2021) focused on Nigeria. Conversely, Ahmed *et al.* (2020) studied G7 countries, and Kamal *et al*. (2021) focused on 105 countries, including the world's developed and developing countries.

Turning to demographic dynamics, population density was found to have insignificant short-run impacts on the environment. This result, consistent with the long-run results, could be explained by the reality that most Africans engage in agricultural activities with smaller footprints than industrial activities (Charfeddine and Mrabet, 2017). Studies that corroborate this finding include Rahman and Alam (2021) for Bangladesh and Kongbuamai *et al.* (2020) for Thailand. In contrast, studies that refute this finding include Dimnwobi *et al.* (2021) for 5 African countries and Li *et al.* (2022) for 285 Chinese cities. Differences in the results of these empirical studies can be attributed to the data type employed. Rahman and Alam (2021) and Kongbuamai *et al.* (2020) use time series data, while Dimnwobi *et al.* (2021) and Li *et al.* (2022) use panel data. The study's results conflict with those of Dimnwobi *et al.* (2021) because the PMG-ARDL is used in the former, while CS-ARDL is used in the latter. The EF is employed in the study, while CO_2 emissions are employed in Li *et al.* (2022), which contributes to the different results in the two studies.

Consistent with long-run results, the short-run results showed that increases in urbanization do not significantly impact the environment. Two possible reasons can explain this result. Firstly, given that economic growth is a major determinant of urbanization, its insignificant short-run impacts suggest that there is not much urbanization happening, which means less energy consumption and infrastructure development. Secondly, consistent with the long-run results explanation, the urbanization happening in the selected countries is unplanned and, therefore, lacks significant infrastructural development, which degrades the environment. This unplanned urbanization has insignificant environmental impacts. Studies that support this finding include Zmami and Ben-Salha (2020) for GCC countries, Abdelfattah *et al.* (2018) for the Arab region, and Afriyie *et al.* (2023) for BRICST. Contradictory findings were reported in other studies, including those of Anser (2019) for Pakistan and Nathaniel *et al.* (2019) for South Africa. The results of these empirical studies are different due to the use of different data types. All studies corroborating the findings of this study use panel data while studies contradicting the study's finding use time series data.

The results regarding fertility rate showed that increases in fertility rate damage the environment in the short run. This result contradicts initial expectations, the long-run impacts of the variable, and the short-run impacts of the other demographic variables. The result of ecologically detrimental fertility rate increases is corroborated by Mishra *et al.* (2020) for India but is contradicted by Alola *et al.* (2019) for Europe and Sharma *et al.* (2020) for SSEA countries. The difference in the results of the empirical studies relate to the type of data employed. Mishra *et al*. (2020) use time series data, while Alola *et al.* (2019) and Sharma *et al.* (2020) use panel data. The study's results differ from those of Alola *et al.* (2019) and Sharma *et al.* (2020) due to differences in the regions studied. The study focuses on three underdeveloped African countries compared to European and SSEA countries.

Lastly, the study showed that increases in FDI inflows degrade the environment in the short run. The result is consistent with initial expectations. African countries are burdened with socio-economic problems that undermine the implementation of stringent environmental policies as governments race to attract FDI.

This result is supported by Voumik *et al.* (2023) and Assamoi *et al.* (2020). In contrast, the result conflicts with the findings of Ssali *et al.* (2019) and Zmami and Ben-Salha (2020). The differences in the results of these studies are explained partly by differences in estimation techniques and data type used. Voumik *et al.* (2023) use CS-ARDL estimation, while Ssali *et al*. (2019) and Zmami and Ben-Salha (2020) use PMG-ARDL estimation. On the other hand, Assamoi *et al.* (2020) use time series data (Cote D'Ivoire), while Ssali *et al*. (2019) and Zmami and Ben-Salha (2020) use panel data. This study's results conflict with those of Ssali *et al*. (2019) and Zmami and Ben-Salha (2020) because it employs the EF as the proxy of environmental degradation, while the other two studies use CO_2 emissions.

In summary, the short-run results show that increases in most socio-economic variables have insignificant environmental impacts in the three studied countries. Only increases in trade openness, fertility rate, and FDI inflows degrade the environment in South Africa, Nigeria and Egypt. The result that increases in economic integration degrades the environment underscores the position of African countries in influencing trade and FDI terms.

5.8.3 Cross-country Analysis

It was highlighted before that cointegration in the PMG-ARDL model implies homogeneous long-run results in the panel units. In other words, the long-run results discussed above apply equally to the studied countries, meaning that environmental drivers have identical long-run impacts in all countries. However, the PMG-ARDL model does not impose homogeneity in the short run. Thus, each country in the panel will have its own short-run dynamics. In this section, we explore the cointegration (speed of adjustment) and short-run dynamics of the three countries.

The table below shows the short-run results for each of the studied countries.

Table 5.10: Estimated Short-run Coefficients for Individual Countries

Dependent variable: d.lnEF

Variable	South Africa	Nigeria	Egypt
Error correction term	-0.427*** (0.005)	-0.003 (0.957)	-0.957*** (0.000)
d.lnRGDP	0.031 (0.598)	-0.004 (0.911)	-0.007 (0.938)
d.lnEU	0.380** (0.011)	0.732** (0.010)	0.065 (0.532)
d.lnTO	0.108 (0.221)	0.036* (0.063)	0.149** (0.020)
d.lnDen	5.039** (0.011)	-2.077 (0.356)	25.135*** (0.001)
d.lnURB	-7.522 (0.348)	-2.186* (0.080)	0.559 (0.910)
d.lnFR	0.319 (0.163)	1.548 (0.107)	0.411* (0.096)
d.FDI	0.081 (0.763)	0.179 (0.691)	0.076 (0.851)
constant	-0.063 (0.936)	0.129 (0.143)	0.022 (0.990)

Source: Author's own computation

***, ** and * denote the statistical significance at 1%, 5% and 10% levels of significance. The p-values are in the numbers in parentheses.

The results show that the error correction term is significant in South Africa and Egypt but insignificant in Nigeria. This means that the long-run results discussed apply to South Africa and Egypt. The magnitude of the error parameter (-0.427) in South Africa and (-0.957) in Egypt implies that approximately 43% and 96% of the short-run shocks that typically disturb the equilibrium are corrected in each period, suggesting that the restoration to long-run equilibrium takes slightly longer than two periods. Thus, in these two countries (South

Africa and Egypt), whether the shocks are positive or negative, expected or not, they are temporary, as environmental quality will return to its long-run equilibrium. In contrast, the insignificance of the error correction term in Nigeria implies that shocks are permanent and the environmental quality will not return to its long-run equilibrium.

In terms of the short-run environmental impacts of the various drivers, increases in RGDP have insignificant impacts on the environment in all three countries. Given that the long-run results show that economic growth damages the environment, it means that as these three countries experience economic growth, they do so at the expense of environmental quality.

Similarly, increased FDI inflows were shown to have insignificant short-run impacts in South Africa, Nigeria, and Egypt, just like in the long run. This means that as FDI inflows increase over time, they do not contribute to environmental degradation in the individual countries.

Each of the remaining variables significantly affects the environment at least in one country. Firstly, an increase in energy consumption degrades the environment in South Africa and Nigeria. The impact is higher in Nigeria, with a coefficient of 0.732, suggesting that a 1% increase in energy consumption increases the EF by 0.7%. In contrast, increases in energy consumption have insignificant impacts on the environment in Egypt. Energy consumption is the KIF of environmental degradation in the long run. This means that the increased energy consumption to fuel economic growth degrades the environment from the onset in South Africa and Nigeria but only starts to degrade the environment after it has reached a certain level in the long run in Egypt.

Secondly, increases in trade openness have insignificant impacts on the environment in South Africa. In contrast, increases in trade openness significantly degrade the environment in Nigeria and Egypt. The coefficient is higher in Egypt (0.149), suggesting that the impact is bigger in that country. The long-run results showed that increases in trade openness contribute significantly to environmental damage in the three countries. Thus, the lax environmental trade restrictions result in the importation of ecologically unfriendly capital goods in sufficient quantities to cause damage to the natural environment in Nigeria and Egypt from the outset. This situation is different in South Africa, where it takes time for increased trade to harm the environment. Thus, South Africa appears to have more robust trade regulations than Nigeria and Egypt.

Thirdly, increases in population density worsen the environment in South Africa and Egypt, with coefficients of 5.039 and 25.135, respectively. Thus, a 1% increase in population density increases the EF by approximately 5% and 25% in South Africa and Egypt, respectively. Conversely, increases in population density do not significantly impact the environment in Nigeria. As already highlighted, increases in population density have insignificant long-run environmental impacts. For South Africa and Egypt, this means that the environmental impact of their citizens decreases with growing numbers.

Fourthly, increases in urban population bring environmental improvements in Nigeria. However, they have insignificant impacts on the environment in South Africa and Egypt. Relative to the long-run result (insignificant impact), these short-run results mean that increased urbanization in Nigeria is associated with increasing detrimental environmental impacts (i.e. the impact changes from benign in the short run to significant in the long run. For South Africa and Egypt, the environmental impact remains unchanged.

Lastly, increases in the fertility rate worsen environmental damage in Egypt, but just like in the long run, they have insignificant impacts in South Africa and Nigeria. This means that the environmental impact of increasing fertility rate decreases over time in Egypt.

See Appendix A4 for the Stata output of the regression results. The next section explores the results of various diagnostic tests and robustness checks.

5.9 Diagnostic Tests and Robustness Checks

5.9.1 Diagnostic Tests

The first diagnostic test conducted is the Kernel density estimate for the normality of residuals. The plot is presented below.

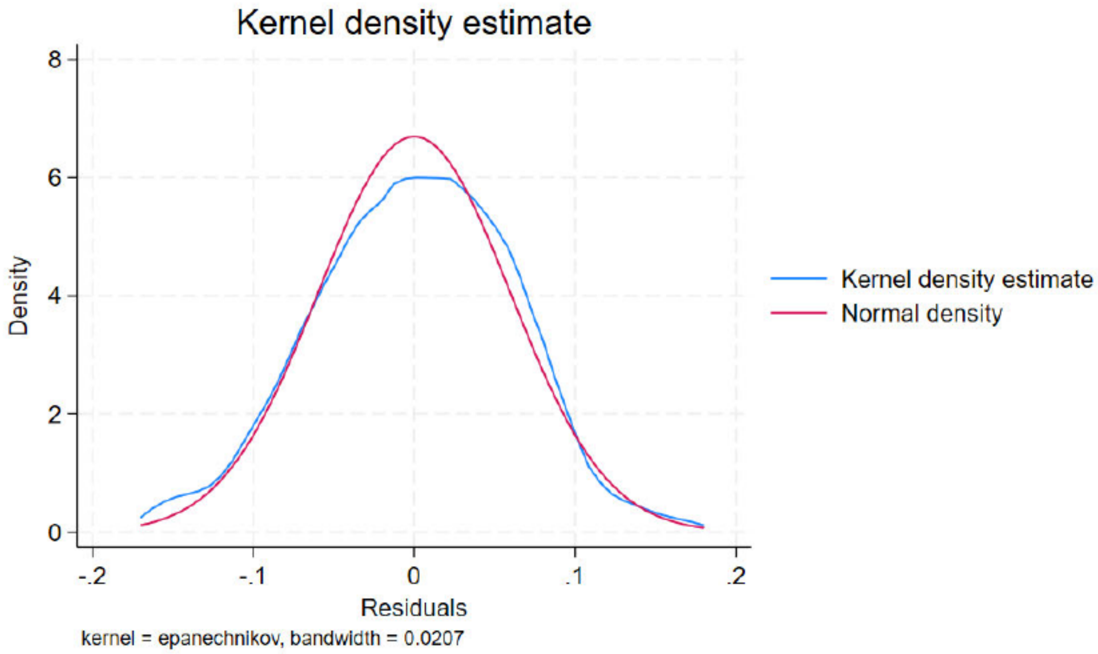

Figure 5.1: Kernel Density Function

(Source: Stata)

The figure above shows that the Kernel density traces the normal density very closely. This confirms that the residuals are normally distributed.

The Breusch-Pagan test for heteroscedasticity was conducted to verify whether the variance of the error terms is constant (homoscedastic). The null hypothesis is that the variance is homogenous and is rejected if the probability is less than 5%. The results of the Breusch-Pagan test are presented in the table below.

Table 5.11: Breusch-Pagan Heteroscedasticity Test Results

Chi-square	Probability
0.29	0.5913

(Source: Author's own computation)

Given that the probability is higher than 5%, we do not reject the null hypothesis. Therefore, the Breusch-Pagan test shows strong evidence of homoscedasticity. To check if the results of the Breusch-Pagan test are robust, a residuals-versus fitted (Rvf) plot was graphed, as shown below.

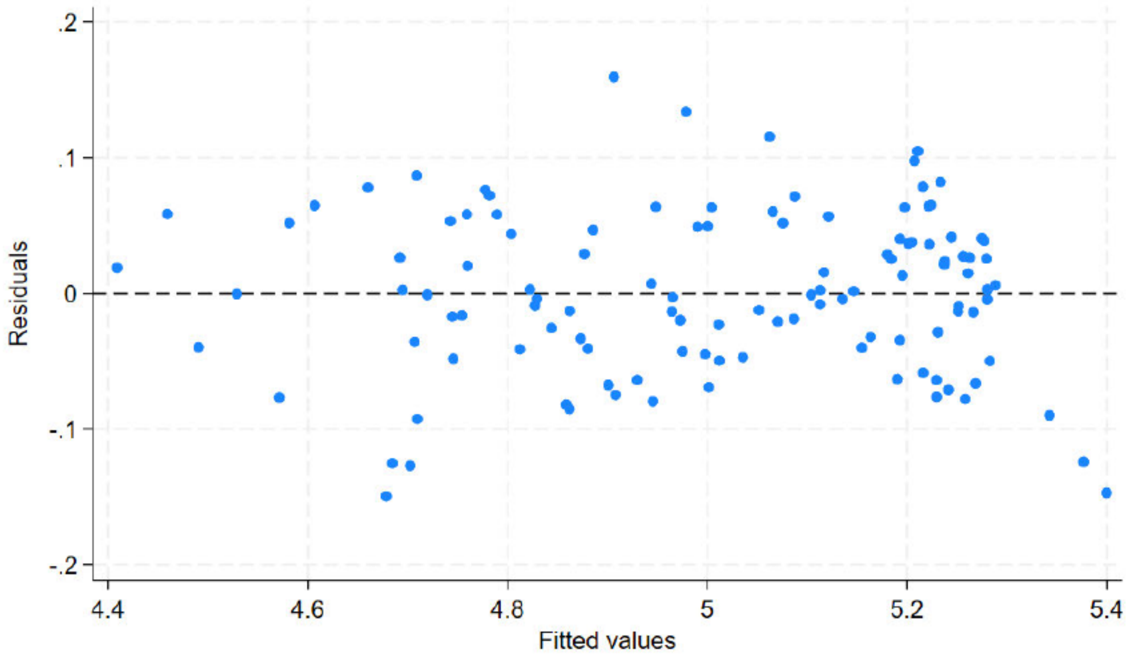

Figure 5.2: Rvf Plot
(Source: Stata)

The above figure shows that the pattern of the data points (residuals) is a random scatter around the dashed line (yline(0)), providing evidence of homoscedasticity. Therefore, the Rvf plot corroborates the Breusch-Pagan result of homoscedasticity. Given that the residuals follow a normal distribution, this means that the regression results are efficient and reliable.

The linktest was employed to test model specification. A model is correctly specified when the _hat variable is significant at the 5% level and the _hatsq variable is insignificant. The results are presented in the table below.

Table 5.12: Results of the Linktest

lnEF	Coefficient	Standard error	Probability
-hat	2.134633	1.013489	0.037
-hatsq	-0.1145711	0.1023098	0.265
-cons	-2.802697	2.505635	0.266

Source: Author's own computation

The table shows that _hat is significant at the 5% level while _hatsq is insignificant. The model is correctly specified, meaning the study neither excluded important variables nor included unimportant variables. Therefore, there are no misspecification errors in the regression results.

See Appendix A5 for the Stata output of the Linktest.

Lastly, variance inflation factors (VIFs) were computed to test for multicollinearity, which makes regression results unstable and unreliable. The rule of thumb is that a variance inflation factor (VIF) of more than 10, indicates multicollinearity and warrants further investigation. The degree of collinearity is assessed using tolerance, defined as 1/VIF. A tolerance value of 0.1, equivalent to a VIF of 10, indicates that the variable is a linear combination of other independent variables. The results of the multicollinearity test are presented in the table below.

Table 5.13: Variance Inflation Factors

Variable	VIF	1/VIF
d.lnRGDP	9.24	0.108172
d.lnEU	5.85	0.170908
d.lnTO	5.62	0.177997
d.lnDEN	5.11	0.195535
d.lnURB	4.11	0.243550
d.lnFR	2.11	0.474875
d.FDI	1.29	0.773203
Mean VIF	**4.76**	

Source: Author's own computation

The table shows that all VIFs are less than 10, and all tolerances are more than 0.1. This means that multicollinearity is not an issue. Therefore, the estimation coefficients are stable and reliable.

Overall, the diagnostic tests show that the model satisfies the basic assumptions of OLS regression. Therefore, the coefficient estimates are BLUE.

5.9.2 Robustness Checks

To test the robustness of the long-run results, the study conducted a DOLS estimation. The results are presented in the table below.

Table 5.14: Long-run DOLS Results

Variable	Coefficient (Beta)	t-statistic
lnRGDP	0.10*	10.39
lnEU	-0.23*	-5.64
lnTO	0.35*	10.61
lnDEN	0.76	1.92
d.lnURB	1.53*	2.35
lnFR	2.53*	14.26
FDI	-1.11*	-3.69

Source: Author's own computation

* represents significance at the 10% level

The table shows that, concerning economic variables, DOLS results confirm the sign and significance of RGDP and trade openness. Increases in these two economic drivers contribute to environmental degradation. In contrast, the results confirm the significance of energy use but contradict its sign. The DOLS result shows that increased energy use promotes environmental quality in the selected African countries. Considering the environmental problems typifying the Anthropocene, switching from fossil to renewable energy sources is one of the approaches proposed to bring about environmental improvements. Therefore, the efforts of the studied countries in transitioning and expanding the use of renewable sources are bringing environmental improvements. This is supported by various studies (see Zeraibi *et al.,* 2021; Usman *et al.,* 2021; Amer *et al.,* 2024)

For demographic variables, the DOLS estimation produced results that are predominantly dichotomous to PMG-ARDL results concerning the sign and significance. DOLS results show that increases in urbanization and fertility rates contribute significantly to environmental degradation in South Africa, Nigeria and Egypt. However, they affirm that increases in population density have an insignificant impact on the environment, despite the positive sign ascribed to population density.

Regarding FDI, DOLS results contradict PMG-ARDL results. They show that increased FDI inflows contribute significantly to environmental quality in Africa's biggest economies. In contrast, PMG-ARDL results show that increased FDI inflows have insignificant impacts. Overall, the results of the two models communicate the same message that increased FDI inflows do not cause environmental damage in South Africa, Nigeria and Egypt.

The hallmark of the differences between PMG-ARDL and DOLS results reflect the identity of the primary degrading driver. In DOLS, the fertility rate has the biggest degrading impact, followed by urbanization, trade openness, and economic growth. Hence, the DOLS largely supports the Neo-Mathusian perspective. However, the results of the PMG-ARDL model should be given more attention. The model was selected due to the data characteristics, specifically unit root and cointegration tests. PMG-ARDL estimation is suited for data with variables showing a mix of I(0) and I(1) processes, and the DOLS is suitable when all the variables are I(1) processes. The DOLS estimation is merely used as a robust check, implicitly implying that all study variables were assumed to be I(1) processes.

5.10 Conclusion

The overarching purpose of this chapter was to undertake an empirical analysis of the environmental impacts of economic and demographic factors in Africa. It began with the exploration of descriptive statistics and correlations. The descriptive statistics indicated that the data is not normally distributed, which prompted a log transformation of the data. The correlation test results showed positive associations between the ecological footprint and the various socioeconomic drivers, except for the fertility rate, which showed a negative association with the EF. Regarding the interrelations among the environmental drivers, RGDP and urbanization reflected a pairwise correlation above the threshold, to exclude potential multicollinearity. However, the multicollinearity test conducted as part of the diagnostic tests ruled out multicollinearity as an issue. The ADF and LLC tests for stationarity were conducted, and the results showed that the variables are stationary at level or after first differencing. This mix of I(0) and I(1) processes leads to the selection of the P-ARDL model for econometric estimation.

Using the PMG estimation technique, the estimated results showed that increases in all economic factors degrade the environment in the long run. A growing economy powered by increased trade and high consumption of fossil fuels damages the environment. In the short run, increases in the economic factors showed mixed impacts, with RGDP and energy consumption having insignificant impacts and trade openness degrading the environment.

In the short run, economic growth and energy consumption are low and thus do not have significant environmental impacts. In contrast, lax environmental trade practices permit the importation of ecologically unfriendly machines, contributing to environmental damage. Examples of these environmentally damaging machines include coal-fired power plants, inefficient or second-hand high-emission industrial equipment, incinerators, and gasoline- or diesel-powered machines and vehicles (Merchant, 2022).

Concerning demographic factors, the long-run results showed that increases in population density and urbanization have insignificant impacts on the environment, while increases in the fertility rate bring environmental improvements. In common with the whole of Africa, the bigger proportion of the populace in the studied countries engages in agricultural activities that are not as damaging to the environment as industrial activities. This explains why increased population density and fertility rate do not have damaging environmental impacts. Similarly, the increased urbanization happening in the studied countries is predominantly unplanned. This kind of urbanization is not associated with big infrastructure projects and high energy consumption, which makes its impact on the environment insignificant. The short-run results of population density and urbanization were consistent with long-run results. Therefore, the explanations for the long-run results hold in the short run. In contrast, short-run results that increases in the fertility rate degrade the environment are inconsistent with long-run results. In respect of the technology variable, FDI, the long-run results showed that FDI inflows have insignificant impacts on the environment, while they degrade the environment in the short run. Corporations prioritize economic rationality (profit maximization) over environmental protection in the short run when environmental problems are less. However, as environmental problems become severe in the long run, firms will prioritize ecological rationality, meaning they will invest in protecting the environment rather than making a profit. These results are valid as the diagnostic tests conducted validate the various OLS assumptions.

The study aimed to understand the impacts of economic and demographic factors on the environment and identify the key impact factor of environmental degradation in South Africa, Nigeria, and Egypt. The overall conclusion from the study's results is that economic factors are responsible for the long-run environmental degradation in the selected African countries. All demographic variables have insignificant long-run environmental impacts. Energy consumption is the biggest environmental driver, followed by economic growth, and, lastly, trade openness.

Chapter 6 CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

The study aimed to assess the relationship between economic and demographic factors and environmental degradation in Africa, focusing on Nigeria, South Africa and Egypt from 1984 to 2022. This was done by analyzing the selected countries collectively, using a P-ARDL model with a PMG estimator. The key objective of the study was to identify the primary driver of environmental degradation in Africa and recommend policies that governments should incorporate to promote environmental quality. This chapter consolidates the different elements of the study and discusses the study's key findings. In addition, it outlines the study's significance and limitations and makes policy recommendations grounded on the findings obtained.

6.2 Summary and Conclusion

The first chapter unpacked the background, research problem, and the study's objectives, significance, scope and organization. The study was triggered by the rapid pace of environmental degradation in Africa and the necessity to identify the driver with the biggest contribution to the ecological problems.

The second chapter delved into the theoretical literature review, focusing on the theoretical constructs that explicate the relationship between environmental degradation and its economic and demographic drivers. EMT and WST worldviews analyzed the economy-environment nexus, while the Neo-Malthusian and Bosepurian theories explored the demography-environment relationship. EMT postulates that economic expansion has short-term deleterious and long-term ameliorative impacts on the environment, and in contrast, WST stipulates that economic growth has monotonic and ever-increasing destructive environmental impacts. Neo-Malthusians maintain that increasing populations degrade the environment, while the Boserupians argue that large numbers of people bring environmental quality.

The third chapter reviewed the empirical literature, and all the theories were empirically validated. Consistent with the WST perspective, economic factors with big, long-run degrading impacts on the environment include economic growth (see Sharif *et al.*, 2023; Nathaniel and Khan, 2020); energy consumption (see Wu *et al.*, 2021; Nathaniel and

Adeleye, 2020) and trade openness (see Duodu *et al.,*2021). In contrast, these same factors were found to bring about environmental improvements in the long run, consistent with the EMT worldview (see Afriye *et al.*, 2022; Mumtaz *et al.*, 2022; Tachie *et al.*, 2020). Regarding demography, consistent with Neo-Malthusianism, total population, urbanisation and population density are the environmental drivers with big degrading impacts (Poumanyvong and Kaneko, 2010 Knight *et al.*, 2013; Knight *et al.,* 2013; Wang and Dong, 2018). Conversely, consistent with the Boserupian worldview, these demographic factors were found to promote environmental quality in the long run (see Voumik *et al.*, 2023; Charfeddine and Mrabet, 2017; Kongbuamai *et al.*, 2020).

Chapter 4 presented the research methodology to be used in the study, and it aimed to define the data and empirical techniques that are used to analyze the impact of socio-economic drivers of environmental deletion. Contrary to many empirical studies which use CO_2 emissions as the proxy of environmental decay, this study used the EF. The reason is that the EF is a more comprehensive measure of environmental degradation. It sums the cropland and grazing land, forest, fishing, built-up land in addition and carbon footprints. The PMG-ARDL model was employed to perform the empirical analysis. The ADF and LLC unit root tests were used to ensure the data was stationary and, in addition, the Breusch-Pagan LM test was employed to investigate the presence of cross-sectional dependence. Lastly, after estimation, various diagnostic tests, including normality, heteroscedasticity and multicollinearity, were employed.

The fifth chapter presented and analyzed the study's results. The study's primary purpose was to determine the environmental impacts of economic and demographic factors in South Africa, Nigeria and Egypt for the period 1984 to 2022. It was the first to focus exclusively on these three countries. Panel data was analyzed using Stata version 18 software.

An environmental degradation model was estimated with the EF as the dependent variable, while RGDP, energy consumption, trade openness, population density, urbanization, fertility rate and FDI were the explanatory variables. RGDP, energy consumption and trade openness were employed as economic factors; population density, urbanization and fertility rate were included as demographic drivers, and FDI was included as the technology variable.

There is a seemingly never-ending debate among environmental sociology theorists on the impacts and the exact nature of the relationships between the environment and socio-economic drivers. Some theorists believe that socioeconomic factors have monotonic impacts on the environment, while others argue to the contrary. In the same vein, some theorists argue that economic factors have bigger impacts on the environment than demographic factors, assertions that other theorists dismiss. This study aimed to plumb the long- and short-run impacts of socio-economic drivers and incidentally identify the key driver of long-run environmental degradation in South Africa, Nigeria, and Egypt (a sample of previously studied countries). The study produced results that address these aims.

Starting with the temporal nature of the relationships, the long-run results showed that increases in all economic factors (i.e., RGDP, energy consumption, and trade openness) significantly increase the EF. The increasing economic modernity in Africa is happening at the cost of environmental sustainability. The findings support the WST perspective and are corroborated by Fan *et al.* (2006), Kindo *et al.* (2023), Dimnwobi *et al.* (2021), Xing *et al.* (2023), and Duodu *et al.* (2021).

In contrast, increases in all the demographic drivers were shown not to damage the environment in the long run. Specifically, the results showed that increases in population density and urbanization have insignificant long-run impacts on the environment, while increases in the fertility rate promote environmental quality in the long run. Therefore, the rising African population is not contributing to environmental degradation. These results validate the Boserupian perspective and are consistent with the findings of Charfeddine and Mrabet (2017), Usman *et al.* (2022), Kongbuamai *et al.* (2020), Pattak *et al.* (2023), Ulucak *et al.* (2021) and Jiang *et al.* (2022). Lastly, the long-run results showed that increases in FDI have insignificant long-run environmental impacts. This result validates the PHEH and is consistent with the findings of Yilanci *et al.* (2023), Saqib *et al.* (2023), and Rafindadi *et al.* (2018). Overall, long-run environmental degradation in South Africa, Nigeria, and Egypt can be attributed solely to economic factors.

Turning to the short run, the results showed that increases in trade openness, fertility rate and FDI significantly increase the EF, while all the remaining socio-economic variables have insignificant impacts on the EF. This means that increased economic integration and fertility rates damage the environment in the short run.

With respect to the aim of identifying the key impact factor of environmental degradation, energy consumption has the biggest impact, followed by economic growth and trade openness. Hence, energy consumption is the environmental driver responsible for much of the ecological deletion in the selected countries. This result is not surprising. In common with the rest of Africa, the three countries studied rely heavily on fossil fuels to generate the power that is fuelling the growth of their economies (see Dimnwobi *et al.,* 2021; Nathaniel and Adeleye, 2021).

In conclusion, the results provide support for the WST and Boserupian worldviews. Increases in all economic factors were found to degrade the environment in the long run. This is consistent with the WST perspective. In contrast, increases in all demographic factors were found not to harm the environment in the long run, which is consistent with the Boserupian view. Therefore, by demonstrating that economic factors, particularly energy consumption and trade openness, drive long-term environmental degradation more than demographic factors, the study challenges prevailing Neo-Malthusian assertions that population growth is the primary stressor on ecological sustainability.

The study explores the policy recommendations in the next section.

6.3 Policy Recommendations

The PMG-ARDL analysis showed that, in the long run, energy consumption, economic growth and trade openness are responsible for the environmental problems in the studied countries. In contrast, population density, urbanization, fertility rate and FDI have insignificant environmental impacts.

Energy consumption was identified as the most significant contributor to environmental degradation in the long run. In the three countries, the carbon footprint is a big component of the ecological footprint (GFN, 2024). In South Africa, the carbon footprint is the largest, accounting for about 70% of the total ecological footprint; in Nigeria, the carbon footprint is the second largest footprint after the cropland footprint; and in Egypt, the carbon footprint and the cropland are more or less the same, but they are much bigger than the other components of the ecological footprint (GFN, 2024). Energy generation (and consumption) is the biggest contributor to the carbon footprint in Africa (IEA, n.d.). For example, in South Africa, energy supply contributes roughly 80% to total emissions (New Development Bank, 2023), Thus, energy consumption is a big threat to sustainability in the three countries.

South Africa, Nigeria and Egypt are signatories to the Paris Climate Agreement, meaning they all have a National Determined Contribution (NDC), which is a national climate action plan detailing how the country will reduce greenhouse gases to help achieve the goal of preventing the global average temperature from exceeding that of pre-industrial times by more than 1.5^0C (Peterson *et al.,* 2023). South Africa and Nigeria have unconditional commitments and net zero (carbon neutrality) plans, while Egypt does not. Unconditional commitment means the contribution to reducing CO_2 emissions without external finance or technical assistance (Peterson *et al.,* 2023). South Africa's unconditional commitment is to reduce CO_2 emissions to 350 – 450 metric tons of CO_2 equivalent by 2030 and it plans to achieve a net zero target by 2030 (IMF, 2023). Nigeria's unconditional commitment set in its Climate Change Act is to reduce CO_2 emissions by 20% compared to the business-as-usual (BAU) projection by 2030 (Noah, 2024).

In terms of the current abatement policies, South Africa is working under the Just Energy Transition (JET) framework, which it launched in 2021 to transition energy production from fossil fuels to renewable energies on a large scale (Bohlmann *et al.,* 2023). This involves decommissioning Eskom's 15 coal plants and repurposing them with renewable energy. JET also includes the development of green hydrogen and electric cars (Just Energy Transition, 2025). The challenge is that JET is a R1.5 trillion investment, and some of the funds were pledged by countries that helped launch it (the European Union (EU), France, Germany, UK and USA). The USA has recently pulled out of the JET program, resulting in the program being threatened (Just Energy Transition, 2025). South Africa implemented a carbon tax in 2019 covering emissions from fossil fuel combustion (Qu, 2023). The tax has been effective in reducing emissions, but this is happening at the cost of economic growth (Abel *et al.,* 2023).

It is recommended that South Africa, instead of starting with transitioning to renewable sources, which is an expensive undertaking it cannot afford, the country must start by transitioning to cleaner non-renewable sources of energy such as natural gas and nuclear. South has significant uranium deposits. However, there are some issues that the government must consider. Nuclear energy comes with issues regarding the disposal of radioactive waste. Building and maintaining a nuclear plant is also expensive. Unlike Nigeria and Egypt, which have significant natural gas reserves, South Africa does not have and must therefore import it, which is costly. The government can increase the carbon tax to make it more effective and use the revenue to implement JET or transition to cleaner sources. The challenge with this policy that the authorities must consider is that the tax is reducing investment and economic growth.

Like South Africa, Nigeria has an Energy Transition Plan (ETP) that concerns the transition from diesel and petrol generators to renewables-backed generators to decarbonise the economy (Heinemann *et al.,* 2022) The problem is that Nigeria has an energy crisis, with only 40% of the population connected to the national grid and have no access to power for more than half the time, which is negatively affecting economic activity (Obafemi *et al.,* 2018; Somoye, 2023). In response, the government is currently expanding its fossil gas and crude oil production to establish a baseload capacity as it considers this decade to be for gas. The transition to renewable energy sources is expected to start only beyond 2030 (Somoye, 2023). Given that Nigeria does not generate enough power which is impacting economic growth negatively, the policy of using its abundant oil and natural gas to generate power in the short term is understandable.

It is recommended that Nigeria build the institutional capacity to attain the baseload capacity in 2030 as planned so that the transition to renewable energies starts. Instead of building the baseload capacity using non-renewables exclusively, policymakers should consider incorporating renewable energies now to allow for a smooth and phased transition. However, transitioning to renewables requires funds, which the country does not have (Somoye, 2023). Therefore, Nigerian authorities should look for international partners to help fund its energy transition, just like South Africa.

As mentioned above, Egypt does not have an unconditional commitment and carbon neutrality goal in its 2050 National Climate Change Strategy published in 2022 (Abdelaty *et al.,* 2023). As a signatory to the Paris Agreement, the country committed in 2023 to reducing emissions in the oil and gas industries from 2.575 $GgCO_2$ equivalent to 0.89 $GgCO_2$ equivalent by 2030 (IEA, 2025). As such, Egypt is making investments in renewable energy (Raihan *et al.,* 2024). However, the priority of the government is to make Egypt a regional energy hub through new investments in oil and gas production and exploration, further consolidating its status as a big fossil gas producer (Esily *et al.,* 2022; Climate Action Tracker, n.d.).

The recommendation is that Egypt must develop a sustained political will to abate CO_2 emissions. Thus, the massive investments the country is making in oil production should be redirected to renewable energies such that it becomes carbon neutral soon.

Another option for the three governments is to enforce energy efficiency standards. Energy-efficient household appliances and industrial equipment, and energy-saving bulbs greatly reduce energy consumption, and thus help protect the government. The governments could subsidize the production of energy-efficient appliances. However, subsidizing industries can trigger trade wars among countries, which often have big economic costs.

Economic growth was identified as the second most important contributor to long-term environmental degradation. To deal with this reality, authorities in the three countries must first consider and balance the trade-offs between economic growth, social development and environmental growth. This balance brings about sustainable development (Raworth, 2017).

Social development is premised on the idea that every person on earth has a right to live a life in which they are not in deprivation of essentials such as food, clean water, gender equality, social equity, a minimum income and decent work, and access to quality education and medical care (Raworth, 2017; O'Neill *et al.,* 2018). However, in Africa, this right is far from being satisfied. Africa is the poorest and most underdeveloped continent on this planet with many challenges including unemployment, low educational attainment, poor health outcomes, violent conflict, income inequality and poverty (O'Neill *et al*., 2018). Even in South Africa, Africa's most developed economy, these problems exist. For example, in 2015, 30.4 million South Africans live in poverty, with more than 10% living in extreme poverty, consuming less than $1.25 per day (Cole, 2015), and in January 2021, 39% of households lacked money to buy food, while 17% of households suffered weekly hunger (Sibeko, 2021). The country is faced with high unemployment, especially youth unemployment, which stood at 45.5% in the third quarter of 2024 (Stats SA, 2024)

To raise the requisite higher standards of living and achieve social development, it is critical that there should be economic development (Raworth, 2017). In other words, social progress is a function of affluence. However, rising affluence increases the demand for nature's services. Nature not only provides natural resources which are used in economic activity, but it also provides essential life supporting services needed by humans to survive – i.e. the ecological footprint (Charfeddine and Mrabet, 2017). The challenge is that the capacity of the earth to provide essential services is limited. It is critical that ecological thresholds are not exceeded because overshoot bring about environmental problems with catastrophic consequences (O'Neill *et al.,* 2018). Therefore, economic growth must be within ecological limits.

Given its importance to Africa in its efforts to eradicate poverty and unemployment, a no-growth policy is not a solution. To ensure sustainable economic growth, authorities and policymakers in South Africa, Nigeria, and Egypt should consider promoting economic sectors that have little ecological impact. In Nigeria and Egypt, the cropland footprint is a very large part of their ecological footprint. Therefore, agricultural activities are driving environmental damage in these countries. Therefore, it is recommended that Nigeria and Egypt adopt sustainable agriculture. A potential challenge is that this new sector may be a low-growth option that creates fewer employment opportunities than environmentally damaging industries. Therefore, promoting environmentally friendly sectors and destroying dirty industries may simultaneously improve the quality of the environment and cause unemployment crises that may lead to social unrest. Policymakers need to balance these issues.

Trade openness was identified as the third most important determinant of environmental damage in the long run and a significant environmental driver in the short run. Trade is vital for Africa as it is a mechanism for expanding domestic production and acquiring advanced technologies and capital goods from developed countries. In this regard, Africa cannot afford to close its economies. Consequently, it is recommended that trade openness be regulated. To this end, governments should consider introducing environmental tariffs to inhibit trade practices detrimental to environmental protection and negotiate trade pacts that champion environmental sustainability. However, governments in the three countries should consider the economic impacts of these policies first before implementing them. As highlighted above, the imposition of trade barriers often triggers retaliation, leading to trade wars that stunt economic growth.

An alternative solution to environmental tariffs is for South Africa, Nigeria and Egypt to trade with countries that have stringent environmental requirements for exports and imports or adopt similar policies. For example, the European Union (EU) does not permit the importation of goods that contain ozone-depleting substances unless there are no viable substitutes (Eur-lex, 2024). It has rules on ecodesign requirements where physical goods, including electronics and machinery, are to be produced with enhanced durability, reusability, upgradability, reparability, energy efficiency and recyclability to protect the environment (European Commission, n.d.). In addition, the EU has emission standards for cars since transport accounts for a quarter of carbon emissions in cities (European Environmental Agency, 2024). As a result of these policies, the EU has managed to reduce emissions (and other environmental impacts) in all sectors of the economy except for the transport sector due to increased demand for transport (European Environmental Agency, 2024). It is recommended that the three African countries increase trade with the EU and/or adopt the EU's environmental policy framework.

However, there are considerations that policymakers in Nigeria, South Africa and Egypt must take. Firstly, the EU is a rich and developed group of countries with the institutional capacity to implement policy regulations. It is better equipped in terms of institutions and funds to enforce environmental regulations than the three African countries. To build institutional capacity, the governments in Nigeria, South Africa and Egypt may have to redirect funds from productive uses or borrow externally which may cause macroeconomic problems of debt, low growth and employment. Secondly, imposing stringent environmental regulations on imports and exports increases their costs. This may discourage investment in the home country and potential balance of payments (BOP) problems may arise. Thirdly, importing environmentally transport machinery from the EU or developing them internally may not be enough to reduce transport emissions. As mentioned above, transport emissions in the EU have increased despite efficiencies due to rising demand for transport. As the populations and economies of the three studied countries are growing, so is the demand for transport. Hence, authorities in these African countries should consider ways to reduce the demand for transport including reducing private transport by providing reliable public transport. However, this strategy has competing problems. For example, in South Africa, although transport emissions contribute to 11% of total emissions, with 90% coming from road transport (Ntuli *et al.,* 2024), the transport sector contributes 6% to total employment (Department of Transport, 2023). Therefore, authorities should consider the potential unemployment and associated socio-political problems that may arise in an environment with high unemployment already.

Governments in South Africa, Nigeria, and Egypt should also consider adopting geoengineering, which allows countries to achieve high economic growth using the current dirty technologies (fossil fuels) without degrading the environment. Geoengineering refers to the intentional large-scale interference with planetary processes. Some geoengineering techniques include carbon capture and storage (CSS), which involves capturing carbon emissions from industrial installations and storing them in geological formations, and direct air capture (DAC), which involves capturing CO_2 from the air and storing it underground. Apart from the costs involved in acquiring the technology, the three governments should also consider technical and physical feasibility, the risks of leakage of sequestered carbon and the resultant contamination of underground water.

Although all demographic variables had insignificant impacts in the long and short run, except fertility, which had negative short-run environmental impacts, it cannot be taken for granted that the benign impacts of increasing population are permanently monotonic. Authorities in the three countries, therefore, should consider promoting family planning programs and female education to attain and maintain sustainable fertility rates. However, a problem with this policy is that it may be considered ‘masculine’ in that it interferes with women’s rights to decide for themselves how many children to have. In addition, once people have bought into having fewer children, it may be difficult to encourage them to have more children. As a result, the country will face labour shortages in the long run. This is the experience of many first-world countries. As such, policymakers need to consider the issues.

The results of a study must be contextualised by its weaknesses or limitations. In the next section, the limitations of the study are explored.

6.4 Limitations of the Study

Energy consumption data from the WDI ended in 2014 and was measured in kg of oil equivalent (koe). Data for 2015 to 2022 was sourced from the EIA and measured in quadrillion British thermal units (quad btu). Although conversion units from the EIA were used to convert quad btu to koe, the conversion is imperfect. Therefore, the slight data measurement inconsistencies may have influenced the results.

The study spans a considerable period (1984 to 2022). However, recent developments in the socioeconomic environment, environmental policies or technological advancements that influence environmental impact may not be fully captured. The Covid pandemic of 2020 disrupted significantly economic activity as businesses were closed during the hard lockdown, which had knock-on effects on carbon emissions and other facets of the ecological footprint (Loh *et al.,* 2021). Thus, the Covid pandemic caused huge changes in data trends in 2020 and subsequent years (Aboy *et al.,* 2024). Because the study did not account for a potential structural break in the data due to the pandemic, the results should be interpreted with care. In addition, although the study period gives 39 observations, nine more than the 30 observations required for the ADRL model to provide meaningful inferences and model fit, an ARDL model performs better when the number of observations is very high. Therefore, the study's results must be interpreted with care, given the relatively lower number of observations.

The PMG-ARDL model assumes that long-run relationships are homogeneous across countries. However, as the Nigerian result revealed, this homogeneity fails to apply due to differences in policy approaches and socio-economic realities in South Africa, Nigeria and Egypt. Therefore, the results of the study are inconclusive on how the various socio-economic factors affect the ecological footprint in each country individually. This speaks to the use of panel data instead of time series data, which allows the dynamics of a country to be explored separately. As discussed in previous chapters, the type of data employed in a study (panel, time series or cross-sectional) is one of the important explanations as to why results differ.

The next section is the last of the report, highlighting how weaknesses of the study can be addressed in future research.

6.5 Suggestions for Future Research

The study's geographic scope is limited. It focused on the three countries selected on the basis of two salient features: the size of the economy and population, and data availability. Therefore, the study's results do not provide insights into how the various socioeconomic factors drive environmental degradation in countries with smaller economies and populations. Therefore, it is imperative to include the smaller countries for comparative purposes. In the same vein, it is prudent to understand Africa's environmental degradation within the context of other regions like Asia and Latin America. Adding countries from these other regions will allow for the identification of global patterns or peculiar regional challenges.

The use of the PMG estimator homogenizes long-run coefficients. In order to fully understand the dynamics in each country, the MG estimator, which allows long-run coefficients to be different, must be used. Alternatively, a separate ARDL model using time series data can be run for each country and then the long-run coefficients may be compared.

The variables employed in the study are highly interrelated. For example, a growing population is associated with economic growth as it is a source of labour. In turn, economic growth increases energy consumption, trade openness, urbanization and the fertility rate as people can afford to have more babies. Therefore, there are endogeneity concerns in the data used in the study. While the long-run ARDL model is robust to endogeneity issues, it does on provided appropriate lags are employed (Jailani and Masir, 2015). Since the ADRL method does not directly tackle endogeneity, employing instrumental variable (IV) regression approaches that address endogeneity directly, such as two-stage least squares (2SLS), Dynamic Panel GMM and Structural Equation Modelling (SEM) will provide more insights on the robustness of the results.

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APPENDICES

A1: Descriptive Statistics for Individual Countries

A1.1 Descriptive Statistics for South Africa

Variable	Mean	Std. dev.	Min.	Max.	Skewness	Kurtosis	Obs.
EF	161.03	32.42	109.65	203.49	-0.1244	1.4124	39
RGDP	4 889.07	1 968.70	1 909.74	8 737.04	0.2258	1.6614	39
EU	2 483.85	176.39	2 121.28	2 904.28	0.2591	2.4926	39
TO	48.76	7.96	34.32	65.97	0.0970	2.4170	39
DEN	39.42	6.19	27.01	49.13	-0.2529	2.1914	39
URB	58.60	5.84	49.09	68.34	0.0273	1.7844	39
FR	2.91	0.73	2.26	4.57	1.1640	2.8919	39
FDI	1.182	1.79	-0.70	9.70	3.1344	14.6755	39

A1.2 Descriptive Statistics for Nigeria

Variable	Mean	Std. dev.	Min.	Max.	Skewness	Kurtosis	Obs.
EF	138.77	34.34	83.76	183.00	-0.2803	1.4174	39
RGDP	1 340.84	900.85	270.03	200.95	0.4414	1.7124	39
EU	707.64	35.77	623.36	785.26	-0.0221	2.6905	39
TO	33.02	11.63	9.14	53.28	-0.3767	2.4975	39
DEN	153.12	45.29	89.31	236.58	0.3359	1.8708	39
URB	38.44	8.58	24.87	53.52	0.1974	1.8046	39
FR	6.04	0.40	5.1	6.70	-0.5582	2.5534	39
FDI	1.53	1.25	-0.04	5.79	1.6923	5.9580	39

A1.3 Descriptive Statistics for Egypt

Variable	Mean	Std. dev.	Min.	Max.	Skewness	Kurtosis	Obs.
EF	161.03	32.42	109.65	203.49	-0.1244	1.4124	39
RGDP	1 765.30	1088.68	637.90	4295.41	0.74085	2.1767	39
EU	709.60	164.13	486.92	970.42	0.2219	1.4435	39
TO	46.73	10.29	29.86	71.68	0.4460	2.4832	39
DEN	77.89	18.71	48.90	110.83	0.1988	1.8571	39
URB	43.06	0.38	42.66	43.95	1.2666	3.4223	39
FR	3.65	0.71	2.4	5.24	0.8859	2.7804	39
FDI	2.38	2.06	-0.20	9.35	1.9660	6.9267	39

A2: Correlation Matrices for Individual Countries

A2.1 Correlation Matrix for South Africa

	lnEF	lnRGDP	lnEU	lnTO	lnDEN	lnURB	lnFR	lnFDI
lnEF	1.000							
lnRGDP	0.922	1.000						
lnEU	0.444	0.392	1.000					
lnTRD	0.815	0.646	0.569	1.000				
lnDEN	0.921	**0.871**	-0.095	0.659	1.000			
lnURB	0.944	**0.891**	0.196	0.747	**0.984**	1.000		
lnFR	-0.856	-0.744	-0.092	-0.534	**-0.924**	**-0.878**	1.000	
lnFDI	0.431	0.356	-0.024	0.411	0.464	0.467	-0.436	1.000

Source: Author's computation using data from the WDI and GFN

AP2.2 Correlation Matrix for Nigeria

	lnEF	lnRGDP	lnEU	lnTO	lnDEN	lnURB	lnFR	lnFDI
lnEF	1.000							
lnRGDP	0.831	1.000						
lnEU	0.389	0.304	1.000					
lnTRD	0.415	-0.002	0.462	1.000				
lnDEN	0.940	**0.831**	0.137	0.268	1.000			
lnURB	0.941	**0.823**	0.157	0.297	**0.999**	1.000		
lnFR	-0.809	-0.722	0.125	-0.148	**-0.953**	**-0.947**	1.000	
lnFDI	0.111	0.349	0.269	0.287	-0.239	-0.214	0.352	1.000

Source: Author's computation using data from the WDI and GFN

AP2.3: Correlation Matrix for Egypt

	lnEF	lnRGDP	lnEU	lnTO	lnDEN	lnURB	lnFR	lnFDI
lnEF	1.000							
lnRGDP	0.888	1.000						
lnEU	0.951	**0.908**	1.000					
lnTRD	-0.167	-0.512	-0.217	1.000				
lnDEN	0.940	**0.944**	**0.949**	-0.356	1.000			
lnURB	-0.634	-0.599	-0.562	0.228	-0.725	1.000		
lnFR	-0.874	-0.794	**-0.835**	0.160	**-0.912**	0.793	1.000	
lnFDI	0.244	0.017	0.279	0.467	0.083	0.173	-0.144	1.000

Source: Author's computation using data from the WDI and GFN

A3: OPTIMAL LAG SELECTION

AP3.1 BIC – South Africa

```
ARDL(1,0,0,0,0,0,0,0) regression

Sample: 1985 thru 2022                                 Number of obs =     38
                                                       F(8, 29)      = 220.42
                                                       Prob > F      = 0.0000
                                                       R-squared     = 0.9838
                                                       Adj R-squared = 0.9794
Log likelihood = 85.659905                             Root MSE      = 0.0291

------------------------------------------------------------------------------
        lnEF | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        lnEF |
         L1. |   .1462268   .1209657     1.21   0.236    -.1011758    .3936295
             |
      lnRGDP |    .108928   .0391665     2.78   0.009     .0288234    .1890325
        lnEU |   .5190625   .1677363     3.09   0.004     .1760033    .8621216
       lnTrd |   .1947559   .0782897     2.49   0.019     .0346355    .3548764
       lnDen |    .457373   .4501622     1.02   0.318    -.4633121    1.378058
       lnUrb |  -.1022883   .6156226    -0.17   0.869    -1.361378    1.156801
        lnFR |   -.132282   .0835615    -1.58   0.124    -.3031844    .0386203
      lnFDi2 |   .2772051   .3289645     0.84   0.406    -.3956028    .9500131
       _cons |  -3.803731   2.262078    -1.68   0.103      -8.4302    .8227379
------------------------------------------------------------------------------

e(lags)[1,8]
      lnEF  lnRGDP    lnEU   lnTrd   lnDen   lnUrb    lnFR  lnFDi2
r1       1       0       0       0       0       0       0       0
```

AP3.2 BIC – Nigeria

```
ARDL(1,0,0,0,0,0,0,0) regression

Sample: 1985 thru 2022                                 Number of obs =     38
                                                       F(8, 29)      = 282.28
                                                       Prob > F      = 0.0000
                                                       R-squared     = 0.9873
                                                       Adj R-squared = 0.9838
Log likelihood = 80.612048                             Root MSE      = 0.0332

------------------------------------------------------------------------------
        lnEF | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        lnEF |
         L1. |   .6642147   .1463614     4.54   0.000     .3648719    .9635574
             |
      lnRGDP |  -.0177174   .0243277    -0.73   0.472    -.0674731    .0320383
        lnEU |     .11623   .2318078     0.50   0.620    -.3578703    .5903302
       lnTrd |   .0561366   .0224693     2.50   0.018     .0101818    .1020914
       lnDen |   1.329264   .7417676     1.79   0.084    -.1878209    2.846349
       lnUrb |  -1.101986   .8524085    -1.29   0.206    -2.845357    .6413848
        lnFR |   .9703505   .6848178     1.42   0.167    -.4302592     2.37096
      lnFDi2 |  -.1914363    .692888    -0.28   0.784    -1.608551    1.225679
       _cons |  -2.669513   3.485567    -0.77   0.450    -9.798298    4.459273
------------------------------------------------------------------------------

e(lags)[1,8]
      lnEF  lnRGDP    lnEU   lnTrd   lnDen   lnUrb    lnFR  lnFDi2
r1       1       0       0       0       0       0       0       0
```

AP3.3 BIC – Egypt

```
ARDL(1,0,0,1,1,0,0,0) regression

Sample: 1985 thru 2022                                Number of obs =     38
                                                      F(10, 27)     = 161.70
                                                      Prob > F      = 0.0000
                                                      R-squared     = 0.9836
                                                      Adj R-squared = 0.9775
Log likelihood = 85.37587                             Root MSE      = 0.0304

------------------------------------------------------------------------------
        lnEF | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        lnEF |
         L1. |  -.0425415   .1682977    -0.25   0.802    -.3878598    .3027768
             |
      lnRGDP |   .1705685   .0446218     3.82   0.001     .0790121    .2621249
        lnEU |   .0444385   .1260027     0.35   0.727    -.2140977    .3029747
             |
       lnTrd |
         --. |   .2377697   .0601148     3.96   0.000     .1144244     .361115
         L1. |  -.1019484   .0429376    -2.37   0.025    -.1900491   -.0138477
             |
       lnDen |
         --. |   40.81272    7.22638     5.65   0.000     25.98541    55.64003
         L1. |  -40.65134   7.183794    -5.66   0.000    -55.39127   -25.91141
             |
       lnUrb |   1.887688   1.303914     1.45   0.159    -.7877234    4.563099
        lnFR |  -1.121927   .2062893    -5.44   0.000    -1.545198   -.6986563
      lnFDi2 |    .727515   .3820042     1.90   0.068    -.0562929    1.511323
       _cons |  -7.391477   4.704633    -1.57   0.128    -17.04459    2.261631
------------------------------------------------------------------------------

e(lags)[1,8]
      lnEF  lnRGDP    lnEU   lnTrd   lnDen   lnUrb    lnFR  lnFDi2
r1       1       0       0       1       1       0       0       0
```

AP3.4 AIC – South Africa

```
ARDL(1,0,0,0,0,0,1,0) regression

Sample: 1985 thru 2022                                Number of obs =     38
                                                      F(9, 28)      = 200.54
                                                      Prob > F      = 0.0000
                                                      R-squared     = 0.9847
                                                      Adj R-squared = 0.9798
Log likelihood = 86.751154                            Root MSE      = 0.0287

------------------------------------------------------------------------------
        lnEF | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        lnEF |
         L1. |   .1850876   .1233764     1.50   0.145    -.0676376    .4378128
             |
      lnRGDP |   .0999469   .0393555     2.54   0.017     .0193309     .180563
        lnEU |     .48591   .1678624     2.89   0.007     .1420594    .8297607
       lnTrd |    .189472   .0775288     2.44   0.021     .0306614    .3482827
       lnDen |   .5471161   .4505932     1.21   0.235    -.3758822    1.470114
       lnUrb |   -.274513   .6233274    -0.44   0.663    -1.551341    1.002315
             |
        lnFR |
         --. |   .1208676   .2134118     0.57   0.576    -.3162868    .5580219
         L1. |  -.2361547   .1835552    -1.29   0.209    -.6121504     .139841
             |
      lnFDi2 |   .2958908    .325634     0.91   0.371    -.3711402    .9629218
       _cons |  -3.372931    2.26187    -1.49   0.147    -8.006163    1.260301
------------------------------------------------------------------------------

e(lags)[1,8]
      lnEF  lnRGDP    lnEU   lnTrd   lnDen   lnUrb    lnFR  lnFDi2
r1       1       0       0       0       0       0       1       0
```

AP3.5 AIC – Nigeria

```
ARDL(1,1,0,1,1,0,0,1) regression

Sample: 1985 thru 2022                                Number of obs =     38
                                                      F(12, 25)     = 223.78
                                                      Prob > F      = 0.0000
                                                      R-squared     = 0.9908
                                                      Adj R-squared = 0.9863
Log likelihood = 86.656298                            Root MSE      = 0.0305

------------------------------------------------------------------------------
        lnEF | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        lnEF |
         L1. |   .6708845   .1830459     3.67   0.001     .2938945    1.047875
             |
      lnRGDP |
         --. |  -.0036795   .0493316    -0.07   0.941    -.1052799    .0979209
         L1. |  -.0736954   .0461918    -1.60   0.123    -.1688291    .0214384
             |
        lnEU |   .3035851   .2492358     1.22   0.235    -.2097255    .8168958
             |
       lnTrd |
         --. |    .031023   .0253914     1.22   0.233    -.0212716    .0833175
         L1. |  -.0416022   .0255447    -1.63   0.116    -.0942124    .0110081
             |
       lnDen |
         --. |  -5.129839    3.20922    -1.60   0.123    -11.73935    1.479674
         L1. |   6.108087   3.495557     1.75   0.093    -1.091147    13.30732
             |
       lnUrb |  -.1047312   1.033014    -0.10   0.920    -2.232263    2.022801
        lnFR |   2.287914   .8801723     2.60   0.015     .4751653    4.100663
             |
      lnFDi2 |
         --. |  -.5529819   .6990041    -0.79   0.436    -1.992608    .8866441
         L1. |  -1.407167   .6939635    -2.03   0.053    -2.836412    .0220772
             |
       _cons |   .8074947   4.881289     0.17   0.870    -9.245708     10.8607
------------------------------------------------------------------------------

e(lags)[1,8]
      lnEF  lnRGDP    lnEU   lnTrd   lnDen   lnUrb    lnFR  lnFDi2
r1       1       1       0       1       1       0       0       1
```

AP3.6 AIC – Egypt

```
ARDL(1,0,0,1,1,1,1,0) regression

Sample: 1985 thru 2022                                Number of obs =     38
                                                      F(12, 25)     = 141.89
                                                      Prob > F      = 0.0000
                                                      R-squared     = 0.9855
                                                      Adj R-squared = 0.9786
Log likelihood = 87.781911                            Root MSE      = 0.0296

------------------------------------------------------------------------------
        lnEF | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        lnEF |
         L1. |  -.0117783    .165028    -0.07   0.944    -.3516597    .3281032
             |
      lnRGDP |   .1591589    .044611     3.57   0.001     .0672809     .251037
        lnEU |   .0543043   .1230578     0.44   0.663    -.1991381    .3077466
             |
       lnTrd |
         --. |   .2008643   .0696395     2.88   0.008     .0574391    .3442895
         L1. |  -.1342026    .046155    -2.91   0.008    -.2292606   -.0391446
             |
       lnDen |
         --. |   32.67571   8.605475     3.80   0.001     14.95241    50.39902
         L1. |  -32.60449    8.55202    -3.81   0.001     -50.2177   -14.99127
             |
       lnUrb |
         --. |  -4.685862   5.546857    -0.84   0.406    -16.10983    6.738104
         L1. |   7.699619   6.164476     1.25   0.223    -4.996357     20.3956
             |
        lnFR |
         --. |  -.6863565   .3659569    -1.88   0.072    -1.440059    .0673459
         L1. |  -.4759884   .2692955    -1.77   0.089    -1.030613     .078636
             |
      lnFDi2 |   .7912137   .3797653     2.08   0.048     .0090725    1.573355
       _cons |  -11.17411    5.33458    -2.09   0.046    -22.16088   -.1873363
------------------------------------------------------------------------------

e(lags)[1,8]
      lnEF  lnRGDP    lnEU   lnTrd   lnDen   lnUrb    lnFR  lnFDi2
r1       1       0       0       1       1       1       1       0
```

A4: PMG- ARDL RESULTS

AP4.1 PMG Results for All Countries

```
Pooled Mean Group Regression
(Estimate results saved as pmg)

Panel Vari able (i): Countryid                  Number of obs      =       114
Time Variable (t): Year                         Number of groups   =         3
                                                Obs per group: min =        38
                                                               avg =      38.0
                                                               max =        38

                                                Log Likelihood     =  242.1252
```

D.lnEF	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
__ec						
lnRGDP	.1886823	.0414694	4.55	0.000	.1074037	.2699608
lnEU	.2118039	.125296	1.69	0.091	-.0337718	.4573797
lnTrd	.1168806	.0677453	1.73	0.084	-.0158977	.2496589
lnDen	-.0839152	.1632654	-0.51	0.607	-.4039095	.236079
lnUrb	-.033436	.3521459	-0.09	0.924	-.7236294	.6567573
lnFR	-.8238388	.146518	-5.62	0.000	-1.111009	-.5366687
lnFDi2	.6086963	.4128316	1.47	0.140	-.2004387	1.417831
SR						
__ec	-.4623195	.2760206	-1.67	0.094	-1.00331	.0786709
lnRGDP						
D1.	.0067711	.0122231	0.55	0.580	-.0171857	.0307279
lnEU						
D1.	.3488375	.2306097	1.51	0.130	-.1031493	.8008242
lnTrd						
D1.	.0976623	.0331563	2.95	0.003	.0326772	.1626475
lnDen						
D1.	9.365421	8.147845	1.15	0.250	-6.604062	25.3349
lnUrb						
D1.	-3.050002	2.372473	-1.29	0.199	-7.699964	1.599959
lnFR						
D1.	.7593664	.3953446	1.92	0.055	-.0154947	1.534228
lnFDi2						
D1.	.1120551	.0337177	3.32	0.001	.0459696	.1781406

AP4.2 PMG Results for Individual Countries

Pooled Mean Group Regression
(Estimate results saved as PMG)

Panel Variable (i): Countryid	Number of obs = 114
Time Variable (t): Year	Number of groups = 3
	Obs per group: min = 38
	avg = 38.0
	max = 38
	Log Likelihood = 242.1252

D.lnEF	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
__ec						
lnRGDP	.1886823	.0414694	4.55	0.000	.1074037	.2699608
lnEU	.2118039	.125296	1.69	0.091	-.0337718	.4573797
lnTrd	.1168806	.0677453	1.73	0.084	-.0158977	.2496589
lnDen	-.0839152	.1632654	-0.51	0.607	-.4039095	.236079
lnUrb	-.033436	.3521459	-0.09	0.924	-.7236294	.6567573
lnFR	-.8238388	.146518	-5.62	0.000	-1.111009	-.5366687
lnFDi2	.6086963	.4128316	1.47	0.140	-.2004387	1.417831
Countryid_1						
__ec	-.4265649	.1523855	-2.80	0.005	-.7252351	-.1278948
lnRGDP D1.	.0311756	.0592004	0.53	0.598	-.0848549	.1472062
lnEU D1.	.3798729	.149432	2.54	0.011	.0869915	.6727542
lnTrd D1.	.1083011	.0884731	1.22	0.221	-.065103	.2817051
lnDen D1.	5.039051	1.972721	2.55	0.011	1.172588	8.905513
lnUrb D1.	-7.522482	8.011457	-0.94	0.348	-23.22465	8.179685
lnFR D1.	.3188928	.2285902	1.40	0.163	-.1291357	.7669214
lnFDi2 D1.	.0808108	.2681448	0.30	0.763	-.4447433	.6063649
_cons	-.0632932	.7851816	-0.08	0.936	-1.602221	1.475634
Countryid_2						
__ec	-.0031189	.0576407	-0.05	0.957	-.1160925	.1098548
lnRGDP D1.	-.0041953	.0374109	-0.11	0.911	-.0775194	.0691287
lnEU D1.	.7318422	.2824958	2.59	0.010	.1781605	1.285524
lnTrd D1.	.0356585	.0191809	1.86	0.063	-.0019354	.0732524
lnDen D1.	-2.077423	2.251466	-0.92	0.356	-6.490215	2.335369
lnUrb D1.	-2.186197	1.247278	-1.75	0.080	-4.630816	.2584222
lnFR D1.	1.548268	.9592569	1.61	0.107	-.3318413	3.428377
lnFDi2 D1.	.1794314	.4515946	0.40	0.691	-.7056777	1.064541
_cons	.1292493	.0881782	1.47	0.143	-.0435767	.3020754
Countryid_3						
__ec	-.9572746	.1479298	-6.47	0.000	-1.247212	-.6673376
lnRGDP D1.	-.0066669	.0863947	-0.08	0.938	-.1759973	.1626635
lnEU D1.	-.0652027	.104314	-0.63	0.532	-.2696543	.139249
lnTrd D1.	.1490275	.0639966	2.33	0.020	.0235965	.2744585
lnDen D1.	25.13464	7.448539	3.37	0.001	10.53577	39.7335
lnUrb D1.	.5586723	4.941461	0.11	0.910	-9.126413	10.24376
lnFR D1.	.4109388	.2472198	1.66	0.096	-.0736031	.8954807
lnFDi2 D1.	.075923	.4044942	0.19	0.851	-.7168711	.8687171
_cons	.0214886	1.648295	0.01	0.990	-3.209111	3.252088

.

A5: LINK TEST RESULTS

```
. linktest

      Source |       SS           df       MS      Number of obs   =       117
-------------+----------------------------------   F(2, 114)       =    872.05
       Model |  6.23722993         2  3.11861497   Prob > F        =    0.0000
    Residual |  .407683562       114  .003576172   R-squared       =    0.9386
-------------+----------------------------------   Adj R-squared   =    0.9376
       Total |   6.6449135       116  .057283737   Root MSE        =     .0598

------------------------------------------------------------------------------
        lnEF | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        _hat |   2.134633   1.013489     2.11   0.037      .126919    4.142346
      _hatsq |  -.1145711   .1023098    -1.12   0.265     -.317246    .0881039
       _cons |  -2.802697   2.505635    -1.12   0.266     -7.76634    2.160946
```