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The Impact of Trade Liberalization on Environmental Quality: Empirical Evidence from SADC Countries (1990-2016)

BY

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Declaration

I, the undersigned, do hereby declare that this Dissertation is a result of my own original research and that no part of it has been presented for examination in any other University.

Signed______________ Date_________________

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Dedication

To my dear parents, for their unwavering support, care and sacrifices throughout my educational life.

Acknowledgement

Writing this thesis has been an exciting journey of academic exploration which could not have been done without the support and encouragement from many. The completion of this thesis would have not been possible without the help of my supervisor Dr C. Pindiriri. I would like to express my extreme gratefulness for his guidance and advice during the course of this work. His consistent generosity, understanding, support and patience in working with me is greatly appreciated. Also, my deepest gratitude goes to my family, especially my parents, for the unconditional support they have provided me in pursuing my studies.

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Abstract

The impact of trade liberalization on environmental quality has received considerable attention, both in policy debate and in the theoretical literature. Nevertheless, the empirical evidence on the issue remains mixed and lagged. This study adds to the literature by unearthing the relationships and decomposing the effect into scale, technique and composition in the Southern African Development Community (SADC) region using OLS with Panel Corrected Standard Errors (PCSE) estimation technique. Aggregated panel data on carbon dioxide emission and on natural resource depletion spanning from 1990-2016 are used as proxies for environmental quality. The study findings provide evidence supporting the Environmental Kuznets Curve (EKC) hypothesis in the case of natural resource depletion. However, the EKC model is not present in the case of carbon dioxide emission. The results also indicate that trade liberalization has detrimental effect on environmental quality as a result of a positive scale effect of trade overriding the negative technique effect of trade. This finding appears to confirm the pollution haven hypothesis. Also, energy consumption is positively related with carbon dioxide emission and negatively related with natural resource depletion. Sustainable development assistance and urbanization have a negative relationship with carbon dioxide emissions. On the other hand, sustainable development assistance has a positive effect on natural resource depletion. Therefore, the study recommends that further trade liberalization policies in developing countries in Africa should be accompanied by strict enforcement of environmental regulations in order to avert the adverse impact of trade on the environment. The Member States should be mindful of the kind of multinational corporations allowed to produce and should allow corporations whose activities produce relatively less emissions or nearly produce no pollution.

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List of Acronyms

ARDL	Autoregressive Distributed Lag
BAU	Business as Usual
BOD	Biochemical Oxygen Demand
CAIT	Climate Analysis Indication Tool
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
DAC	Development Assistance Committee
DOLS	Panel Dynamic Ordinary Least Squares
EGS	Environmental Goods and Services
EIA	Environmental Impact Assessment
EKC	Environmental Kuznets Curve
EPI	Environmental Performance Index
FDI	Foreign Direct Investment
FEH	Factor Endowment Hypothesis
FEM	Fixed Effects Model
FGLS	Feasible Generalized Least Squares

FTA	Free Trade Area
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GLS	Generalized Least Squares
GMM	Generalised Methods of Moments
GNP	Gross National Product
IFIs	International Financial Institutions
INDC	Intended Nationally Determined Contribution
IP	Industrial Processes
IPCC	Intergovernmental Panel on Climate Change
IV	Instrumental Variable
LUFC	Land-Use Change and Forestry
$MtCO_2e$	Metric Tons of Carbon Dioxide Equivalent
NAFTA	North American Free Trade Area
NO_2	Nitrogen Oxide
NO_x	Nitrous oxides

ODA	Official Development Assistance
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
PCSE	Panel Corrected Standard Errors
PHH	Pollution Haven Hypothesis
PM_{10}	Particulate Matter
REM	Random Effects Model
RISDP	Regional Indicative Strategic Development Plan
SADC	Southern African Development Community
SADCC	Southern African Development Co-ordination Conference
SDA	Sustainable Development Assistance
SO2	Sodium Oxide
SO_2	Sulphur Dioxide
STIRPAT	Stochastic Impact by Regression on Population Affluence and Technology
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNFCC	United Nations Framework Convention on Climate Change

WRI	World Resource Institute
WTO	World Trade Organization

CHAPTER ONE
INTRODUCTION AND BACKGROUND OF THE STUDY

1.0 Introduction

The fifth assessment report on climate change by the Intergovernmental Panel on Climate Change (IPCC) in 2014 suggests that the planet earth is currently running a fever (Cook *et al*., 2016). According to the report, the global temperature is fast approaching the so-called tipping point level where a small increase in temperature will result in a dramatic change of the environment. Global environmental change has become a major policy concern for policy makers and scholars (Zamfir, 2014). Due to increasing globalization as well as growing pressure on the environment and the use of natural resources, there is an ever-growing interface between trade and environment (Zamfir, 2014). Worldwide deterioration of environmental quality has made many feel concerned about the issue and this has sparked efforts to understand more clearly the reasons for environmental degradation (Dinda, 2004). It is an important issue widely discussed during the Uruguay round of the General Agreement on Tariffs and Trade (GATT)[1] and the Doha round[2] of the World Trade Organization (WTO).

According to the comparative advantage theory, trade causes countries to become more efficient in their use of natural resources and avoiding waste. It may also involve removal of distortionary subsidies and pricing policies, improving the efficiency of resource allocation (Haris, 2004). In addition, trade enhances the spread of environmentally friendly technology, for example, in the energy sector where can it facilitates the replacement of old, inefficient and high polluting plants with modern, highly efficient combined cycle facilities or encourage a growing wind power sector. However, globalization can also create “boomerang” effects through the transboundary exchange of externalities (Haris, 2004).

Free trade has been questioned regarding its impacts, particularly in developing countries (Vishuphong, 2015). The proponents of environmental quality believe that although free trade has the capacity to lift nations out of poverty towards economic growth and prosperity, it has

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[1]International attention was first focused on these issues in 1991, when the Mexican government challenged a United States law banning imports of tuna from Mexico. According to the free trade principles that provided the basis for General Agreement on Tariffs and Trade (GATT), countries cannot restrict imports except in very limited cases such as protection of the health and safety of their own citizens.

[2] For the first time in multilateral trade negotiations, trade and environment issues were included in the round of WTO negotiations launched at Doha in November 2001 (UNCTAD, 2003).

also resulted in exporting countries increasing their exploitation of natural environment and resources beyond what would have been required to meet the local consumption need in autarky (Copeland, 2013). Moreover, with lax environmental policies, free trade also promote growth that is amenable to pollution-intensive industries that destroy local environments. This is due to the relocation of pollution intensive production from tightly regulated countries to countries with weak environmental regulations. This situation is referred to as Pollution Haven Hypothesis (PHH) (Vishuphong, 2015). Alternative to the PHH, the Factor Endowment Hypothesis (FEH) postulates that factor abundance and technology determine trade and specialization patterns, and that such countries relatively abundant in factors used intensively in polluting industries will on average get dirtier as trade liberalizes and vice versa (Mani &Wheeler, 1998).

Antweiler *et al*. (2001) first provide the theoretical framework to empirically explore the determinants of emissions and to successfully decompose them into scale, technique, and composition effects. The scale effect explains the negative environmental consequences after expansion of economic activity if the nature of the economic activity remains unchanged. The technique effect explains the positive environmental consequences of increases in income that call for cleaner production methods. The composition effects explain the trade-induced changes in the composition of output that affect pollution level. It can be an advantage or detrimental to the environment depending on how the production structure of each country change after freer trade.

The debate over the role of international trade in determining environmental quality has at times generated more heat than light (Antweiler *et al.*, 2001). A growing number of empirical works show evidence supporting both sides; positive and negative impacts. Studies by Grossman & Krueger (1991); Shahbaz *et al.* (2016) and Managi *et al*. (2009) found that trade liberalization is good for the environment whereas studies by Munir & Ameer (2018); Bernard & Mandal (2016) and Cole & Elliott (2003) among others showed that free trade damages the environment. Despite decades of research there is no consensus on how trade, growth and environment are linked and what factors determines what. Hence, this study adds to the debate by examining whether or not trade liberalization would improve environmental quality in the SADC[3] region.

1.1 Background

Regional integration within Africa is considered important for achieving sustained economic growth and development, including effective intra-African trade, enhanced global linkages and African unity. Several regional initiatives are pursued across Africa and the participation of South Africa in 1994 enhanced the viability of the SADC as an economic community (Chauvin & Gaulier, 2002). For now, SADC encompasses 16[4] members. One of the main features of the SADC is related to the sector coordination approach applied: every member is responsible for coordinating sector programs. SADC was created to enhance economic growth and development, eradicate poverty and to promote the free movement of goods and services, capital and labour amongst regional members (SADC, 2011). Trade openness has been one of the objectives of SADC as stipulated in the Regional Indicative Strategic Development Plan (RISDP) (Genesis Analytics, 2004). Furthermore, the Trade Protocol initiated in the year 2000 also sought to promote trade openness in goods and services in the region. The creation of SADC FTA in 2008 saw up to 85 per cent of intra-SADC trade flows duty free, with the remaining 15 per cent consisting of sensitive products[5] to be liberalized by 2012 (Secretariat SADC, 2013).

1.1.1 The state of SADC's Environment

Southern Africa supports significant biodiversity and is one of the world's most mineral-rich region (Tarr, 2003). Not surprisingly, the economic and social dependence on natural resources is high as evidenced by mining and its associated industries currently form the cornerstone of most economies. The increasingly important tourism sector is largely dependent upon natural capital, particularly healthy wildlife populations and beautiful scenery (Tarr, Ibid). Millions of families still rely on subsistence farming for their livelihoods, despite a highly variable rainfall and susceptibility to drought in many areas (Tarr, 2003). Traditionally, resource use activities

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[3] Originally known as the Southern African Development Co-ordination Conference (SADCC), the organisation was formed in Lusaka, Zambia on 1 April 1980, following the adoption of the Lusaka Declaration. The Declaration and Treaty establishing the Southern African Development Community (SADC) which has replaced the Co-ordination Conference was signed at the Summit of Heads of State or Government on 17 August 1992, in Windhoek, Namibia.

[4] Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia and Zimbabwe.

[5] Products that enjoyed significantly higher tariff rates and higher value of trade (Secretariat SADC, 2013).

in Southern Africa were largely sustainable, causing little, if any, harm to the environment. However, an increasing population, industrialisation and its accompanying environmental problems, and the evolution of market economies are placing enormous pressures on the natural capital. The increase in trade associated with growing agriculture, extraction of minerals, transportation and increased usage of energy put pressure on the environment in the form of pollution and increases the emission of carbon dioxide emissions (CO_2) (Opoku, 2013). The economic structures of SADC countries are heterogeneous, and fall into two broad groups, namely, those that rely on agriculture and those that are mineral based.

1.1.2 SADC greenhouse gases (GHG) emissions contribution

The sub-region’s climate over the last century has been characterised by oscillating wet and dry decades. Droughts have occurred during the periods: 1910; 1921-1930; 1947-48; 1967-73; 1981-82; 1991-92; 1994-95; 2001-03; and 2004-05 (Chishakwe, 2010). The sub-region has been experiencing a warming trend over the past few decades. This is consistent with the global trend of temperature rise in the 1970s, 1980s and 1990s making the sub-region more vulnerable to these climatic changes. This is so, because the region pre-dominantly dependent on climate-sensitive sectors, such as agriculture, water, infrastructure and transport, coastal zones, health, energy, urban planning and management, tourism, biodiversity and ecosystems, forests, fisheries, environment, and land and desertification (Chishakwe, 2010). Table 1 shows total greenhouse gases (GHG) emissions from SADC countries.

As shown in Table 1, South Africa has the highest GHG emissions, followed by Angola, Zambia, Zimbabwe, Mozambique, Madagascar, Botswana, Namibia, Malawi, Swaziland, Lesotho, and Seychelles. The total emissions from the region represent 2.2 per cent of global emissions. No country is responsible for emitting more than 1 per cent of global emissions. The average growth in per capita emissions of the whole region are also below the world average. However, the growth per capita emissions of Botswana, Angola, Namibia, Zambia, South Africa and Seychelles are above the world average. The Gross Domestic product (GDP) carbon intensity in the region is nearly triple the world average, with only the Seychelles’ GDP carbon intensity less than the world average (CAIT, 2015).

Table 1: Greenhouse gas emissions in Southern Africa (2011)

Country	Total GHG Emissions ($MtCO_2e$)[2]	% of global emissions	Population (thousands)	tCO_2e per capita	GDP (Billion US$)[3]	tCO_2e/ million US$ GDP	Change in GHG emissions (1990–2011) ($MtCO_2e$)
Angola	206	0.44%	20,180	10.22	$52	3,941	+101 (+96%)
Botswana	34	0.07%	1,987	16.89	$13	2,608	+11 (+50%)
Lesotho	2	0.00%	2,030	1.08	$2	1,221	+0.3 (+19%)
Madagascar	57	0.12%	21,679	2.65	$6	9,769	-3 (-6%)
Malawi	15	0.03%	15,458	0.98	$4	3,744	-1(-6%)
Mozambique	56	0.12%	24,581	2.28	$10	5,767	+1(+2%)
Namibia	22	0.05%	2,218	10.06	$10	2,345	+7 (+46%)
Seychelles	1	0.00%	87	7.58	$1	541	+0.5 (+285%)
South Africa	447	0.95%	51,553	8.67	$310	1,442	+125 (+39%)
Swaziland	3	0.01%	1,212	2.40	$3	1,004	-0.1 (-4%)
Zambia	120	0.26%	13,634	8.82	$13	8,943	+4 (+3%)
Zimbabwe	64	0.14%	13,359	4.77	$6	10,938	-7 (-10%)
Regional Total	1,027	2.19%	167,978	6.12 (weighted average)	$429	2,392 (weighted average)	+239 (+30%)
World	46,906	100%	6,964,618	6.73	$54,034	868	+12,969 (+38%)

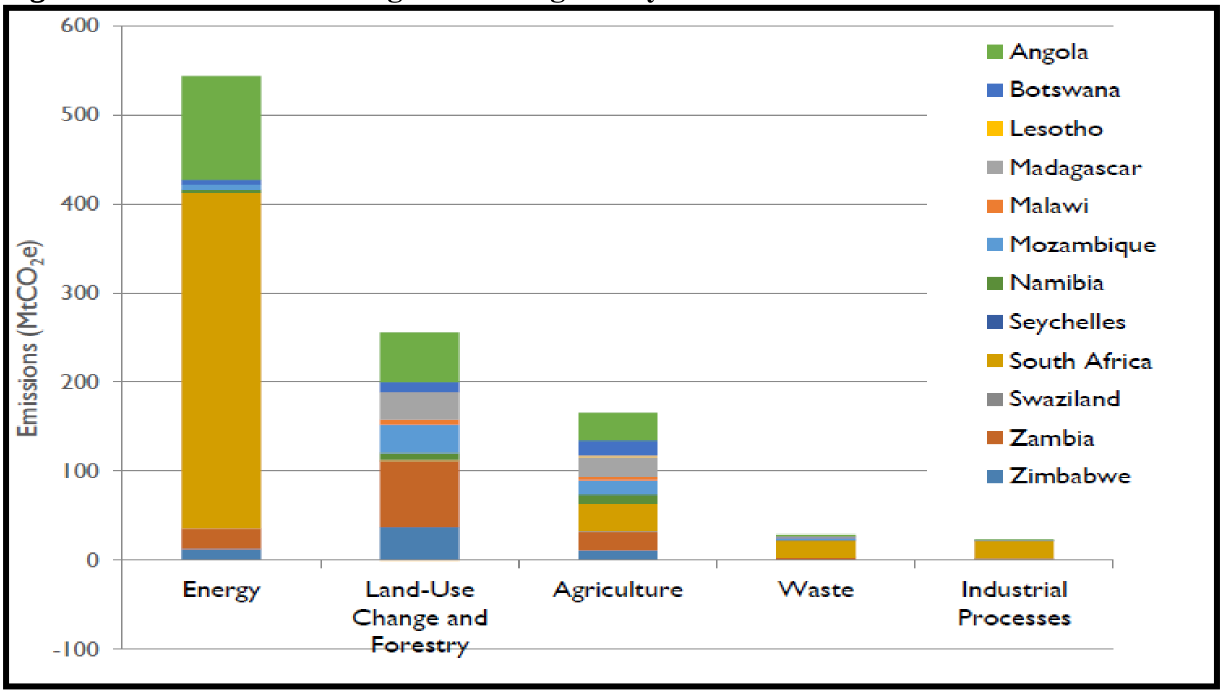
Source: CAIT (2015)[6]

Emissions from the 12 countries in Figure 1 are primarily from energy, land-use change and forestry (LUFCF), and agricultural sectors. Energy is considered the highest emitter with 166 metric tons of carbon dioxide equivalent (MtCO2e), followed by Land-Use Change and forestry (LUCF) with 255 MtCO2e, then Agriculture (166 MtCO2e). Greenhouse gases from waste and industrial processes (IP) are considered insignificant.

Though the leading emitting sector in the region is energy, it is only leading in two countries, that is, South Africa and Angola which account for 91 per cent of the region’s energy sector emissions (CAIT, 2015). The countries with the highest LUFC in 2011 were Zambia, Angola, Zimbabwe, Mozambique, and Madagascar with, LUFC emissions constituting 90 per cent of the region’s greenhouse gas emissions. The countries with the highest agriculture emissions were Angola, South Africa, Madagascar, Zambia, Mozambique, Botswana and Zimbabwe. Their emissions account for 90 per cent of the region’s greenhouse emissions from the agriculture sector.

[6] World Resources Institute (WRI) developed the Climate Analysis Indicators Tool (CAIT) which is — a data and analysis tool designed to help inform policy discussions and decisions under the United Nations Framework Convention on Climate Change (UNFCCC) and other forums.

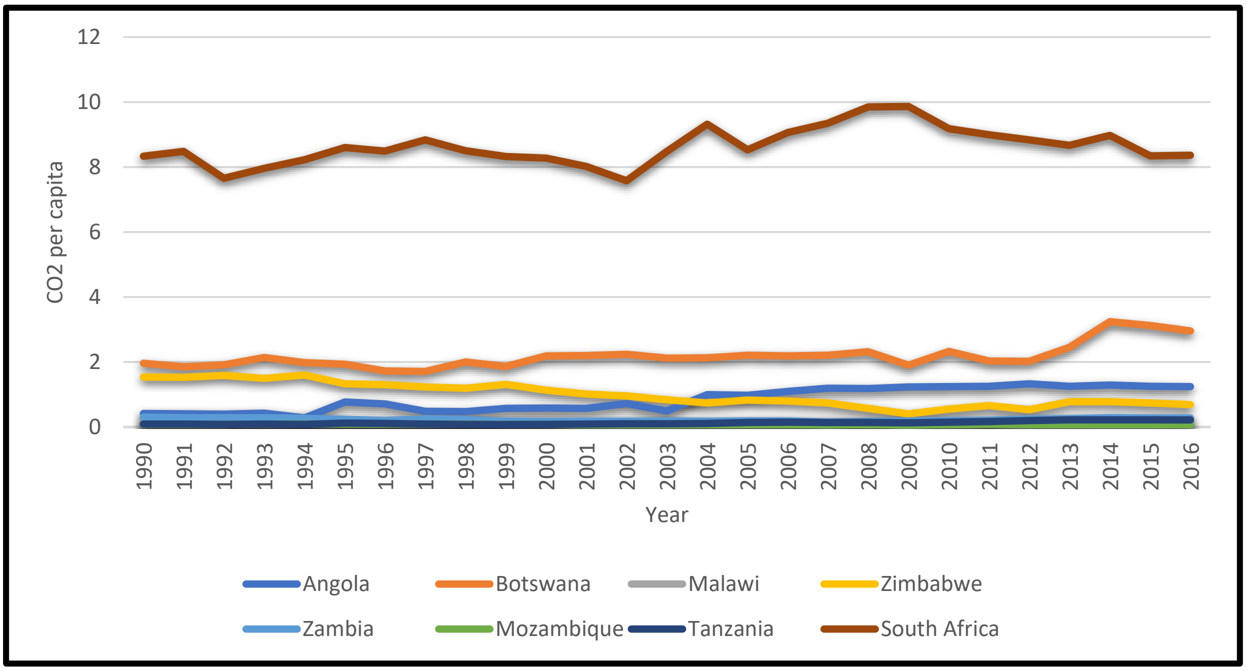
Figure 1: Southern Africa's greenhouse gases by sector



Source: CAIT (2015)

Figure 2 show the trends in carbon dioxide emissions per capita for the selected countries from 1990 to 2016.

Figure 2: Change in Carbon dioxide emissions in SADC countries (1990-2016)

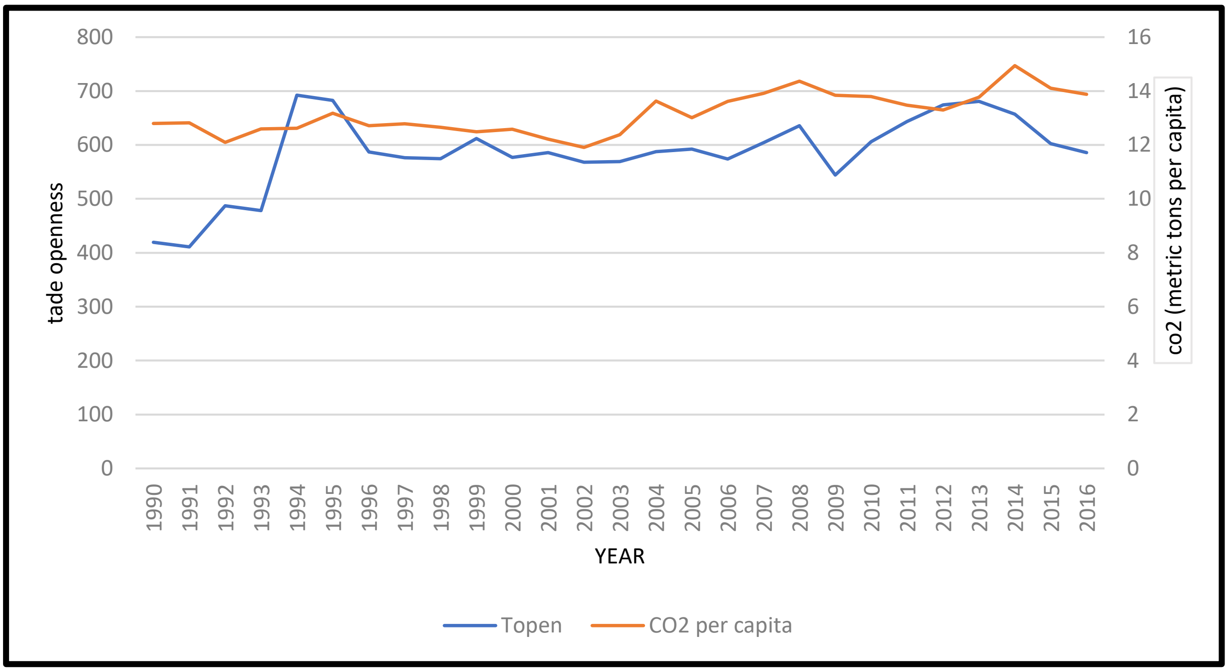


Source: Author's illustrations using World Bank data

Country total emissions are presented in Figure 2, with South Africa, Angola, and Botswana as high emitters over the period 1990-2016. Tanzania, Malawi and Mozambique have contributed low in relation to South Africa and others. Over the period in question, it can be shown that those countries with highest levels of trade volumes are also highest emitters of greenhouse gases. Probably their highest emissions levels are due to increased economic growth through international trade.

Figure 3 shows the change in carbon dioxide emissions and trade openness for the selected SADC countries.

Figure 3: Change in Carbon dioxide emissions and Trade Openness in Southern Africa



Source: Author's illustrations using World Bank data

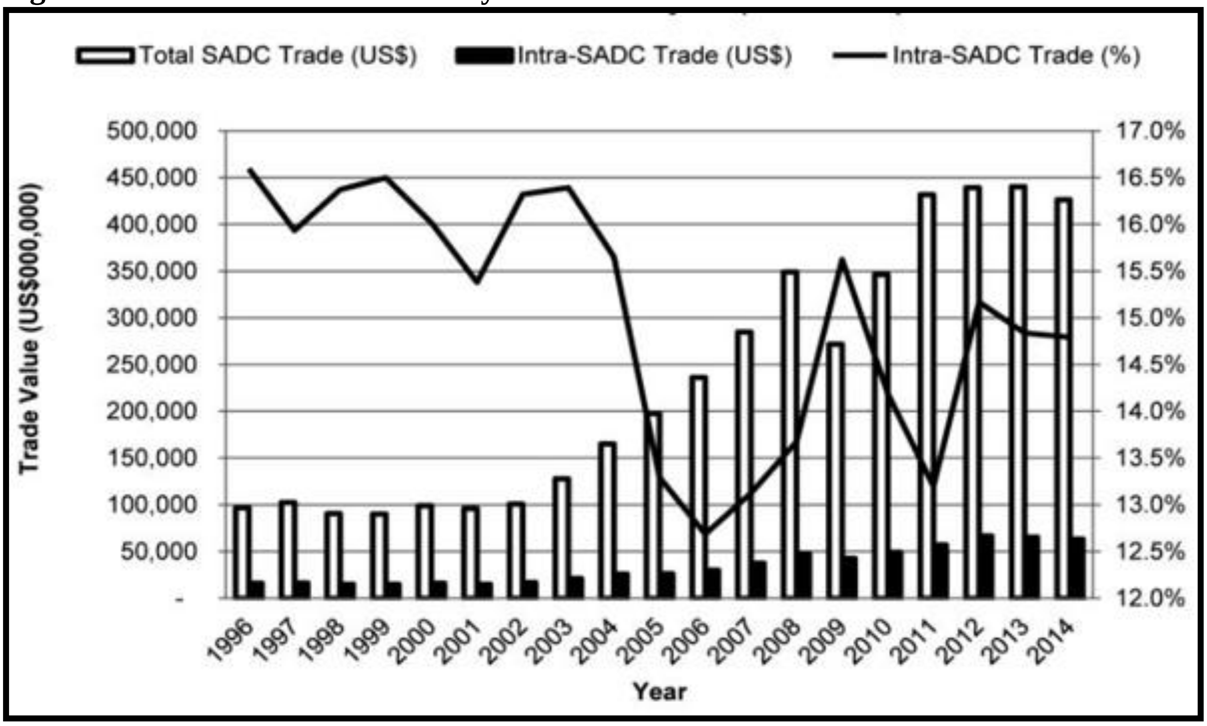
For the selected countries in total trade openness in 1990 was low and increased by 70 per cent in 1994 and from 1994 it decreased up to 57.8 per cent in 1998. The period between 1998 and 2006 witnessed a constant trend with small fluctuations. From 2006 to 2008 the value increased before decreasing in 2009 and for the period between 2009 and 2013 there was an upward trend before declining by 55.7 per cent in 2016. On the other hand, the response from carbon dioxide emissions increased 30 per cent from 1990 to 2016, the most recent year for which data are available for all countries in the region and for all sectors. On average, trends in figure 3 show that the emissions from various factors were increasing and fluctuating over the years. Carbon dioxide emissions per capita were constant between 1990 and 1991 with a slight decrease in year 1992. From 1992 emissions increased from 12 metric tonnes per capita up to 13, 5 metric tonnes per capita in 1995. For the period 1995 to 2001 the emissions were almost constant. The emissions increased over the period 2002 to 2014 and a slight decrease to 2016. These fluctuations are probably due to various factors which include the increased use of energy, urbanization, increased agricultural activities as well trade induced economic growth. This is so because the region's contribution is below the world average. However, it is the region itself that is experiencing increasing emissions and climate change. Both trade openness and carbon dioxide emissions witnessed a slight decrease from 2014 to 2016 which shows a kind of positive relationship between the two variables.

1.1.3 Environmental Policy and trade in Southern Africa

The relationship between trade in goods and services and the environment raised many concerns in various multilateral and regional trade agreements. Every country in the region has a contribution to make in order to achieve sustainable development policy and to combat environmental degradation. With regard to the key national climate change commitments and policies, all countries in the region submitted an Intended Nationally Determined Contribution (INDC) prior to the UN climate conference (COP 21) that culminated in the Paris Agreement (CAIT, 2015). The commitments were both unconditional and conditional upon the receipt of international support if this was stated in the INDC. For Angola the unconditional commitment was to reduce GHG emission by up to 35 per cent relative to the business as usual (BAU) scenario and the conditional was to reduce emission emissions by an additional 15 per cent below the BAU scenario by 2030. Sectors for mitigation in this case were reforestation and electricity power generation. Botswana committed to reduce GHG by 15 per cent by 2030 from 2010 base year, which are estimated to be 8,307 Gigagrams of carbon dioxide equivalent (CO_2e). The sectors for mitigation for Botswana include forestry, agriculture and energy. Malawi indicated combined unconditional and conditional action that could reduce per capita emissions from 1.4t CO_2e in 2010 to 0.7-0.8t CO_2e in 2030. Mozambique committed to reduce emissions by approximately 765 metric tons of carbon dioxide equivalent ($MtCO_2e$) in the period from 2020 to 2030, with 23.0$MtCO_2e$ by 2024 and 53.4$MtCO_2e$ from 2025 to 2030. Zimbabwe mainly targeted the energy sector to reduce emissions per capita by 2030 that are 33 per cent below the projected BAU level (CAIT, 2015).

In addition to these commitments, Member States implemented the Environmental Impact Assessment (EIA) programmes to monitor the environment and to promote sustainable development (Tarr, 2003). It is imperative to note that environmental policies in SADC countries were not created in response to local public pressure but were largely initiated by governments in response to international pressure regarding global environmental issues. However, although Member States are trying to reduce these problems, all countries have been trying to boost economic growth by regional and international trade integration. This is as a result of the signing of various regional trade agreements by member countries as indicated in the SADC Trade Protocol. In 1990's the region witnessed the International Financial Institutions (IFIs) structural adjustment programmes for which trade liberalization was one of its components. The implementation of a SADC Free Trade Area in 2008 and 2012 led to increase in intra-SADC trade as well as outside the bloc.

Figure 4: SADC Trade Trend Analysis



Source: (Erasmus& Hartzenberg, 2018) UNCTAD, WTO and SADC trade data statistics

Figure 4 shows that in relative terms trade among SADC countries started at US$16.1 billion before dropping to US$15.9 billion in 2000. Since 2000, intra-SADC trade recorded and posted a growth until 2009 when it dropped to US$42.5 billion from US$47.7 billion in 2008. Trade flows recovered and continued to grow to 2014 when intra-regional trade value was at US$63 billion. Between 2000 and 2014 when SADC Protocol on Trade was implemented, there was a 397% increase in the value of intra-regional trade whilst the region's trade grew by 430% (Hartzenberg & Erasmus, 2017). The recorded growth was however 33% lower than the growth of SADC trade in total to the world as shown in figure 4. In 1996 intra-SADC trade was 16.6% and from 1999 it has been as low as 12.7% before gaining momentum reaching 15.6% in 2009.

1.2 Problem Statement

A fundamental element of sustainable development is environmental sustainability. The environment is no other thing than a global public good, as countries, behaving on their self-interests would increase their production and pollution at the expense of other countries. Climate change is a serious and urgent problem, global in its cause and consequences (Zenghelis, 2006). Individual countries in SADC have their own environmental policies to protect the environment. Despite a common interest in the environmental preservation, countries also face economic interests and, push international negotiations to be able to increase their production and consequently their emissions.

Today developed world is in favour of opening economies for more trade, as trade openness has beneficial impact on economic growth. In developing countries, rapid economic growth is not an option but a need because of the starving population (Pindiriri & Chidoko, 2012). International trade raises questions about the environmental impact, especially in developing countries for which SADC region is not an exception. This is because every country is trying to increase economic growth by opening their economies for trade. However, pollution gases cross national borders. Trade network implies the transaction of not only goods but also the environmental responsibility for their production. Though every country should have a contribution in the reduction of environmental degradation, developing countries tend to prioritise economic growth via trade policy at the expense of environmental quality developments (Kleemann & Abdulai, 2013).

In addition, despite decades of research there is no consensus on how trade, growth and environment are linked and what factors determines what. A growing number of empirical works is increasingly showing evidence supporting both sides; positive impacts and negative impacts of international trade on the environment. It is clear from the research literature that beyond the basic links between trade and environment, the links between trade, environment and climate change are highly complex, multi-dimensional and dynamic, with ecological as well human-induced (economic, political and social) feedback effects, which are linked. Simply put, the links are far from straight forward; simple universally valid answers or truths are few.

To summarize, the core of the trade and environment problem lies in the ambiguity of environmental policy directions which are to be adjusted as a response to the trade liberalization and the resultant changes of politico-economic conditions. The ambiguity is spurred by the uncertainty about the degree of income elasticity of environmental demand, and also by the absence of a clear evidence that regulatory stringency hampers domestic industry's international competitiveness. Both pessimistic and optimistic hypotheses are theoretically plausible, but none is decisive and thus provoked a vast empirical research. Yet, the interplay of various associated factors has made it difficult to conclude that trade is either good or bad for the environment and the question is still up for debate. It is against this background that this study examines the impact of trade liberalization on environmental quality in SADC for the period 1990-2016.

1.3 Objectives of the study

The overall objective of the study is to find out the extent to which trade liberalization affect environmental quality in Southern Africa for the period 1990-2016. Specifically, the study seeks to:

- Examine the relationship between trade openness and greenhouse gases in SADC region;
- Determine the direction of the scale, composition and technique effects of trade on the environment in SADC; and
- Determine the impact of energy use intensity on the environment in SADC region.

1.4 Research questions

Research questions that arise are:

- What is the relationship between trade openness and environmental quality in SADC region?
- What are the directions of the scale, composition and technique effects of trade on the environment in SADC?

- What is the impact of energy use intensity on the environment in SADC?

1.5 Significance and Justification of the Study

Climate change is the major sustainable development challenge the international community has had to tackle to date. Measures to address climate change need to be fully compatible with the international community's wider ambitions for economic growth and human advancement. It is a challenge that transcends borders and requires solutions not only at national levels but at the international level as well. It is important to examine whether trade liberalisation policies are in fact in conflict with the environment as they accelerate economic growth. The collection of empirical evidence on the relative impacts of the scale, composition and technique effects of trade liberalization on the environment is scarce and largely limited to developed countries (Feridun *et al.,* 2006). More so, the few existing studies on the trade- environment relationship in developing countries obtained mixed results and, in most cases, contradicts the theoretical conclusions. Firstly, regarding this interrelation between international trade and emissions, many scholars have paid much attention to the volumes of pollutants generated to produce goods that later have been exported and imported, that is, emissions involved or 'embodied' in traded goods (Wiebe *et al.,* 2012).

Furthermore, many researchers have dealt with the issue of existing misbalances between emissions associated to imported and exported goods, and many considerations about the responsibility of those emissions have emerged in the academia (Munksgaard & Pedersen, 2001). Nevertheless, all this body of literature has only addressed the question of how much pollution is generated or involved in import and exports, but it has not addressed the question of how such emissions would increase or decrease if countries decided to enlarge or diminish their amounts of imported or exported goods, nor the question of how large is the impact that actual international trade finally has on emissions. While these studies provide insights into the trade-environment relationship in developing countries, they fail to properly measure the scale, composition and technique effects of trade on the environment. This study will therefore provide useful evidence on the relative impacts of the scale, composition and technique effects of trade intensity on the environment in the SADC region.

1.6 Organisation of the rest of the study

Chapter two reviews literature on the impact of trade liberalization on environmental quality while chapter three provides a detailed outline of the methodology used in the study. Estimation, presentations and interpretations are done in chapter four and chapter five gives a summary, conclusion and policy recommendations based on the study as well as areas of further study.

CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

This chapter reviews the relevant literature on the impact of trade on environment. The chapter is divided into two sections. The first section reviews the theoretical literature on trade and environment with emphasis on the trade-environment nexus and an elaborate description of the scale, composition and technique effects of trade on environment. The second section reviews empirical literature.

2.1 Theoretical Literature

2.1.1 Trade and Environment Nexus

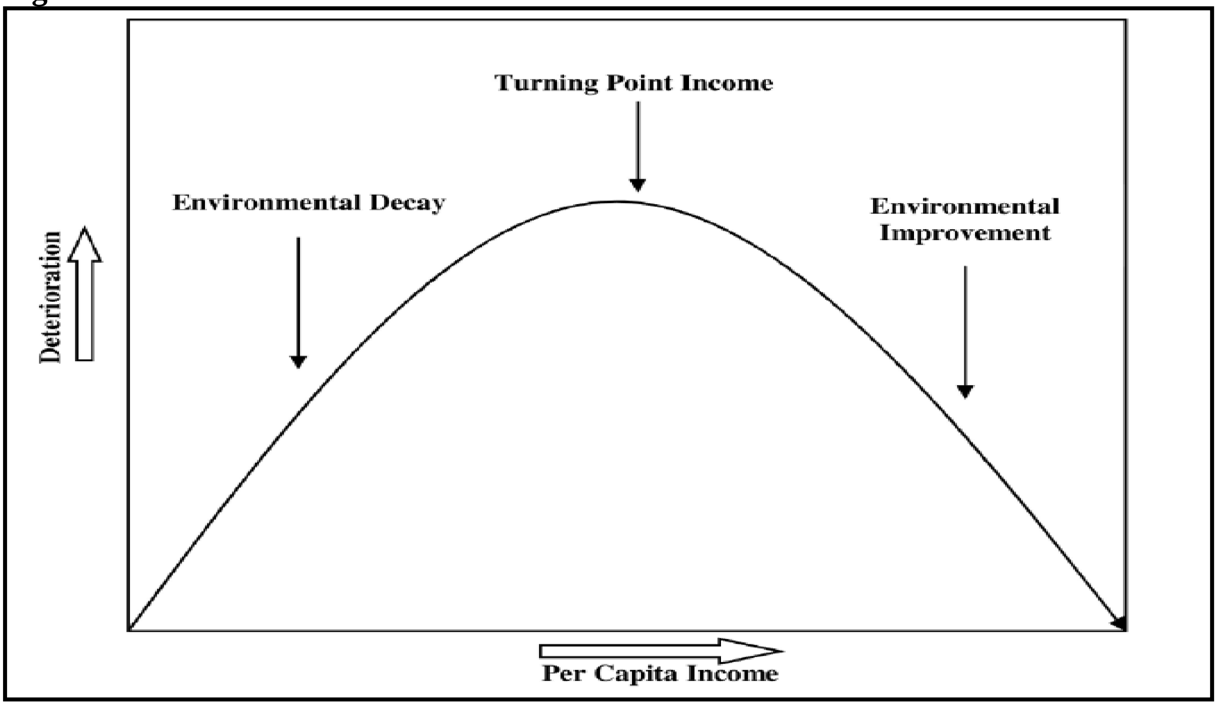
The theory of international trade predicts that trade and environment can be mutually compatible and perhaps even enforcing, whereas trade liberalization bring economic benefits that can be distributed so as to reduce poverty and protect the environment (De Alwis, 2015). Free trade proponents argue that trade will lead to increased world income. However, it is believed that intensive trade has environmental consequences that may outweigh the gains from income. It is argued that free trade worsens the already existing environmental problems of economic activity. This takes the form of depleted non-renewable resources or harmful emissions. Although comparative advantage is the hallmark of free trade, it is argued that seeking this advantage can promote further environmental degradation. In this review of the theoretical literature on the trade-environment nexus we continue with a discussion of main theories or hypotheses. These include the Environmental Kuznets Curve (EKC) theory, the Pollution Haven Hypothesis and the Factor Endowment Hypothesis.

2.1.1.1 The Environmental Kuznets Curve (EKC) theory

The Environmental Kuznets Curve (EKC) has become the fundamental economic theory underlying the relationship between economic growth and environmental degradation (Dinda, 2004). The Kuznets Curve dates back to Kuznets (1955), who used the inverted-U shaped framework to describe the relationship between income inequality and per capita income (Skaza & Blais, 2013). As per capita income increases, income inequality also increases, reaches a peak (turning point) and then starts to fall. Thus, both the EKC and the original

Kuznets Curve are premised on the fundamental idea that as an economy grows some measure of quality of life (that is the environment or income distribution) will initially worsen before improving (Skaza & Blais, 2013). The works of Grossman & Krueger (1991)[7] was the first to initiate the inverted U-shaped relationship between environmental degradation and per capita income. Their work showed that as income increases, environmental degradation (emissions) also increases but reaches a point and then starts to fall. This means that, at the early stages of economic growth, the awareness of environmental problems is low or negligible and environment friendly technologies are not available (Dinda, 2004). Beyond a threshold level environmental quality improves. This inverted U-shaped relationship between environmental degradation and per capita income is shown in figure 5. As per capita income increases deterioration of the environment increases, reaches a turning point and then starts to improve.

Figure 5: The Environment Kuznets Curve



Source: Dinda (2004)

International trade plays a significant role in the conceptual explanations of the EKC model (Dinda, 2004). In their paper, Grossman & Krueger (1991) cite three channels with which this relationship between economic growth and environment is portrayed. These include the scale effect, technique effect and the composition effect. These effects are also part of the

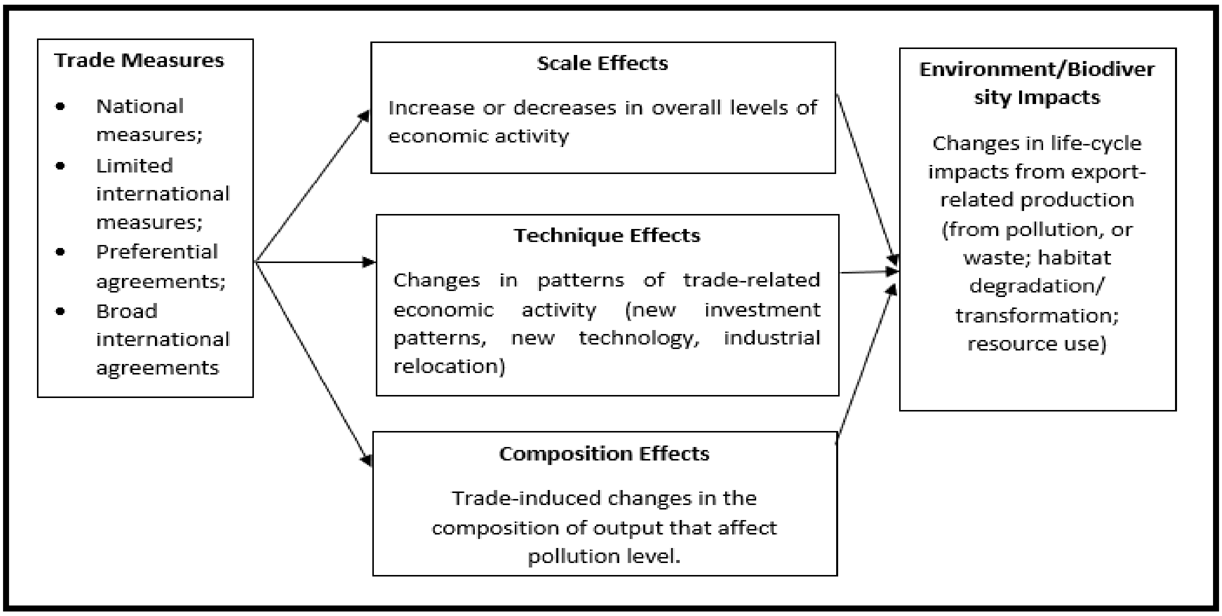
[7] One of the pioneering studies on the trade-environment nexus which examined the environmental impacts of North American Free Trade Agreement (NAFTA).

decomposition framework shown in Figure 6. The scale effect postulates that trade liberalization leads to an increase in output thereby worsening the existing environmental problems (Appiah, 2013). Increasing output requires more inputs and thus more use of natural resources in the production processes (Dinda, 2004). With more output, this implies more waste and emissions as by-product. Trade-induced growth, thus, exhibits a scale effect that has a negative impact on environmental quality. The scale effect, holding constant production techniques and the composition of goods produced constant, is likely to result in an increase in the level of both local and global pollution and natural resources depletion. To expand exports from agriculture, agricultural activities increase, which may result in water pollution from extreme fertilizer use and deforestation from increased demand for lands. It is also crucial to note that trade can directly influence pollution emission from through increases in air and road transport.

As shown in Figure 6, the technique effect refers to the tendency for emissions to decrease as income level increases (Dinda, 2004). The income effect from theory identifies the environment as a normal good whose demand increase as income rises. Higher income may facilitate stricter environment regulation[8]. As economic growth increases, a wealthy nation can afford to spend more on research and development, technological progress occurs, and the dirty and obsolete techniques are replaced by new and cleaner technology. Therefore, this improves environmental quality. Lastly, the composition effect implies an increase in trade-induced income growth that might cause changes in the economic structures and moves countries towards less polluting activities. Holding the scale of the economy and other production factors constant, an economy that shifts its production towards natural capital-intensive goods will pollute more. Those that shifts production away from natural capital-intensive goods will pollute less. Countries that are endowed with natural resources are likely to specialise in the resource-intensive industries and thus increase the extraction of natural resources when they open to trade. Given that most developing countries in the SADC region are endowed with natural resources, they are likely to export more minerals and natural resource-intensive products.

[8] Possible under the assumption that country governments are responsive to the citizens' demands for high environmental standards.

Figure 6: Conceptual Framework for decomposition of trade-environment nexus



Source: Author's illustrations, adapted from Dinda (2004).

However, although the EKC model has been successful in explaining the link between trade-induced income and environmental degradation, it faces some criticisms from various researchers. Firstly, there is no consensus in the literature on the turning points. Dinda (2004) sums it up to say that "there is no agreement in the literature on the income level at which environmental degradation starts to fall". Not all researchers agree on the same shape of the EKC model. The shape differs with different types of pollutants or environmental quality proxies.

2.1.1.2 Pollution Haven Hypothesis (PPH)

Theory on the trade-environment nexus has also recognised two main factors that influence the pollution intensity of production and hence trade. These two are known as the Pollution Haven Hypothesis (PHH) and the Factor Endowment Hypothesis (FEH). The PHH states that trade patterns will be influenced by the stringency of environmental regulation. It theorises that the choice of location for the manufacturing operation is significantly influenced by the environmental regulation enforced by the country. Given that the costs of compliance with environmental regulation differ across nations one may expect relocation of pollution intensive industries to locations where there are low compliance costs (Kirkpatrick & Scrieciu, 2008). According to the PHH, a country with weak stringent environmental policy will attract more manufacturers to set up their factory which gives them the privilege to emit pollution and other externalities (Mahidin, 2013). The insight of the PHH is that for poor countries, people are less concerned about the environmental standards compared to their desire to benefit from economic expansion. Thus, for developing countries, one may expect that due to lack of economic opportunity, the trade-led growth is vital in improving living standards. Therefore, most researchers maintain that developing countries have weaker environmental standards compared to developed countries (Mahidin, Ibid). Thus, trade liberalization will encourage relocation of factors from developed countries to developing countries.

However, this hypothesis is not free from criticisms. It is argued that PHH is too simplistic (Korves *et al.,* 2011). To say that developed countries do not do anything with the pollution and instead merely export their pollution industries to developing countries is subject to criticism. While at the same time the developing countries are assumed to voluntarily become home to pollution. These arguments show that it is very crucial to evaluate evidence provided by the empirical analysis.

2.1.1.3 Factor Endowment Hypothesis (FEH)

In contrast with the Pollution Haven Hypothesis (PHH), the Factor Endowment Hypothesis (FEH) postulates that, with trade liberalization, countries tend to produce and export goods for which they have large resource endowments. This is a foundation of the Heckscher-Ohlin theory of international trade. If comparative advantage exists due to factor endowment (capital-labour ratio), then the FEH suggest that high income countries with high capital-labour ratio will have comparative advantage in pollution-intensive goods and hence environmental degradation (Korves *et al.,* 2011). However, rich nations might have a higher willingness to pay for environmental quality and hence set higher environmental standards. From the overall principle that pollution intensive goods are relatively capital intensive (Antweiler *et al*., 2001 and Cole & Elliott, 2003), it is assumed that pollution-intensive (hereafter “dirty”) industries will relocate production from countries in the relatively labour abundant to those in the relatively capital abundant.

2.2 Empirical literature review

The empirical literature on trade-environmental quality nexus continues to accrue in terms of methodological techniques and key variables used. The studies have expanded in the three directions which includes model specification, indicators of environmental quality and measuring the strength of the impact.

One of the pioneering studies on the trade-environment nexus is a study by Grossman & Krueger (1991). Grossman & Krueger (1991) examined the environmental impacts of North American Free Trade Agreement (NAFTA) and they identify three effects which serve as the basis for the analyses of the effects of economic change on the environment. These effects are scale, technique and composition effects. The results from the study found lower emissions of sulphur dioxide (SO_2) due to trade liberalization. Ever since Grossman & Krueger (1991), a body of literature has emerged to investigate the impact of trade openness on the environment and usually, the early studies employed the EKC model with trade openness as one of the control variables. Stern (2004) argued that although employing the EKC model is simple and shows direct relationship between trade and environmental quality, the model is highly susceptible to econometric specification. Such a polynomial model is merely descriptive and arguably fail to provide answers as to whether trade actually changes environmental quality (Nektarios, 2009). In contrast to Grossman & Krueger (1991), Reinert & Roland-Holst (2001) used a general equilibrium model for the three countries under the NAFTA agreement and found that most types of pollution increased in the three countries due to NAFTA. Under the same NAFTA agreement, Yu *et al*. (2010) focused on the NAFTA effects on pollution in the United States and Mexico. The study found that US and Mexico greenhouse gases emissions increased due to the NAFTA passage, but the amount of this increment is larger in Mexico. The study also concluded that the Pollution Haven Hypothesis (PHH) hold for Mexico.

Extending their analysis by developing a theoretical framework to decompose the effect into scale, technique and composition effect for developed and developing countries, Antweiler *et al.* (2001) find evidence for positive scale effect, negative technique effect and negative composition effect. Antweiler *et al*. (2001) employed a general equilibrium approach via the use of Fixed effects and Random effects models by leveraging on panel data for the period 1971- 1996. Unlike Grossman & Krueger (1991) which concentrate on using growth, trade openness and pollution levels and then interpret the results as a signal of relative strength of scale and technique effects, Antweiler *et al.* (*Ibid*) estimated the scale, technique and composition effects on relative pollution concentration, GDP per square kilometre, relative income per capita and trade openness. The results showed that the technique effect dominated the scale effect. A 1 per cent increase in scale of production increases sulphur dioxide by 0.5

per cent, whilst for each 1 per cent increase in activity lead to a 1.25 per cent-1.5 per cent decrease in sulphur dioxide levels. The study concludes that trade is good for the environment. However, none of these studies considered greenhouse gases which are the initial concern for the environmental quality and climate change. This study will contribute to literature by including other environmental quality indicators such as carbon dioxide emissions and natural resource depletion.

Maintaining similar conclusions for SO_2 as Antweiler *et al.* (2001), Cole & Elliot (2003) found that when the analysis by Antweiler *et al*. (2001) is applied to NO_x and CO_2, trade may increase pollution. The study investigated trade openness on four environmental quality indicators which are: SO_2, CO_2, NO_x, and Biochemical Oxygen Demand (BOD) emissions. The fixed effects and random effects models were employed on longitudinal data for 32 developed countries and developing countries covering the period of 1975-1995. The study decomposed the effect into scale-technique and composition effect. The results from this study indicate that overall, trade openness increases CO_2 and NO_x emissions and energy use as a result of huge scale-technique effect that outweighs composition effect. This means that trade would increase production and output which would subsequently increase emissions, however, the pollution abatement technologies used are not large enough to counter such growth. Trade openness was, however, found to reduce BOD emissions.

Shahbaz *et al.* (2016) incorporated globalization and energy intensity in the CO_2 emissions function and investigated the presence of the EKC hypothesis in 19 African countries[9] for period 1971-2012. The study applied the ARDL bounds test for cointegration to examine the long run relationship in the variables. They argued that existing literature has neglected the effects of globalization, yet it has allowed highly polluting international companies to relocate to developing countries which have less stringent environmental standards. They found that globalization reduces carbon dioxide emissions at the panel level. Thus, fostering openness stimulating market integration with trading partners by lowering or removing the trade barriers, will improve environmental quality. Energy intensity was found to have a positive impact on African countries except for Zimbabwe and Zambia. In these two countries energy intensity was found to have a decreasing impact on emissions. The study also found that only seven

[9] Algeria, Angola, Cameroon, Republic, Côte d'Ivoire, Egypt, Gabon, Ghana, Kenya, Libya, Morocco, Nigeria, South Africa, Sudan, Tanzania, Togo, Tunisia, Zambia and Zimbabwe.

countries[10] follow the EKC hypothesis, which suggest that economic development improves environmental quality with higher levels of economic growth in these countries. On the other hand, for other countries which failed to show any evidence for EKC, there is no evidence of positive effect of economic activities on emissions. However, this study adds to the debate by introducing natural resource depletion as an environmental quality indicator. It also considers the role population growth play on the environment, which is regarded as one of the main determinants of environmental quality. This study also incorporates urban population growth as well as decomposing the effect of trade on environmental quality.

Maintaining the same results as Shahbaz *et al.* (2016), Lee & Min (2014) also found that globalization significantly reduces emissions. Within a panel framework they examined the impact of globalization on CO_2 for a larger panel data set for both developed and developing countries. In contrast, Al-Mulai *et al.* (2015) covered Central and Eastern Europe, Western Europe, America, East Asia, and the pacific, Sub-Saharan Africa, Southern Europe and South Asia in the study and employed non-stationary panel data technique. Their findings showed that opening up to trade has a positive effect on pollution in Sub-Saharan Africa and therefore recommend that the countries in the region should focus on trade-related policies so as to increase environmental quality. The study also found that renewable energy does not have an impact on the CO_2 emissions in Sub-Saharan Africa.

Kleemann & Abdulai (2013) contributed to the literature with a study on the impact of trade liberalization and economic growth on the environment. Panel data for developed and developing countries for the period 1980-2013 was used in the study. Carbon dioxide emissions and natural resource depletion were used as environmental quality indicators. Also, natural resources depletion in the form of adjusted net savings was used as a sustainability environmental indicator. The study supports the Pollution Haven Hypothesis and found that trade liberalization is not beneficial to sustainable development for poor countries as compared to developed countries. Hence, trade liberalization increases natural resource depletion. A distinguishing feature of this current study is that it adds other variables such as capital-labour ratio to decompose the effects of trade liberalization on environmental quality.

[10] Africa, Algeria, Cameroon, Congo Republic, Morocco, Tunisia and Zambia

Managi *et al*. (2009) argued that whether trade has a beneficial effect on the environment on average or not varies depending on the pollutant and the country. The study analysed the impact of trade openness on environmental quality in the Organisation for Economic Co-operation and Development (OECD) and non-OECD countries for the period 1980-2000. A dynamic panel model using the Instrumental Variable (IV) technique that controls for endogeneity of income and trade was employed in the study. The findings showed that the impact is large in the long term after the adjustment process, although it is small in the short term. It also indicated that trade benefits the environment in OECD countries. Trade was found to have detrimental effects on sulphur dioxide and carbon dioxide in non-OECD countries, although it does not lower biochemical oxygen demand (BOD) emissions in these countries. The study also found that both in the short term and long term, trade reduces emissions in OECD countries. Trade openness influence emissions through the environmental regulation effect and capital labour effect with the former being the larger.

In addition, Bernard & Mandal (2016) argued that the Environmental Performance Index (EPI) and CO_2 emissions increases with economic growth and trade openness. The study investigated the impact of trade openness on environmental quality in 60 emerging and developing countries from Asia, Latin America, Africa and Europe for the period 2002-2012. Fixed effects model and later the dynamic panel model following the EKC framework were employed. EPI and CO_2 emissions were used as two indicators of environmental quality. Explanatory variables include trade openness, per capita income, urbanization, energy consumption, population, financial development, political globalization and governance. Generalised Methods of Moments (GMM) results indicate that per capita income is negatively related with environmental quality. Trade openness was found to have no impact in the GMM model. Government effectiveness was found to have a positive impact on EPI which was expected since better political and social conditions are conducive to environmental sustainability. The coefficient of Foreign Direct Investment (FDI) was found to be insignificant and this renders the technique effect negligible. The study also found that energy consumption has a positive impact on CO_2 emissions in all models. However, the distinguishing feature of this study is that it is going to decompose the impact of trade liberalization on the environmental quality into scale, technique and composition effect.

Baek *et al.* (2009) did a study on the environmental consensus of trade liberalization on the quality of environment for 50 developed and developing countries for the period 1960-2000.

They found that trade liberalization improves environmental quality by lowering SO_2 emissions in developed countries, while it has a detrimental effect on the quality of environment in most developing countries. The study validated the EKC model and pollution haven hypothesis for both developed and developing countries and also found a unidirectional causality which runs from trade openness to SO_2 emissions for developed economies. In the case of most developing countries the study found a unidirectional causality from SO_2 emissions to trade openness, indicating that any change in the quality of the environment causes a consequential change in trade openness. However, it is also important to include other environmental indicators since the results may differ with different types of environmental quality indicators used in the empirical studies. The current study will, therefore, use natural resource depletion and carbon dioxide emissions as environmental quality indicators.

The study by Le *et al*. (2016) argued that trade have both negative and positive effects on environmental quality with respect to country characteristics. Le *et al.* (*Ibid*) used particulate matter (PM_{10}) as the basic indicator of environmental quality and found a long run relationship between PM_{10}, trade openness, GDP and GDP-squared for a cross-section of countries. The study examined the relationship between trade openness and the environment in a cross-country panel of 98 countries in the world for the period 1980-2013 and employed panel data model with cointegration test as well as fixed effects and random effects models. They also applied the GMM for estimating heterogenous cointegrated vectors and found that increased trade openness benefits the environment in high income countries. Thus, increased foreign trade increases income gains which enable some countries to specialize in relatively clean industries. Hence, increased investment in environmental protection. On the other hand, trade has detrimental effects in middle and low- income countries. However, this study will add to the existing literature by looking at both effects and not only the technique effect, and it will measure whether the pollution haven hypothesis hold in the case of SADC region.

Using the EKC model a study done by Munir & Ameer (2018) measures the environmental effects through Stochastic Impact by Regression on Population, Affluence, and Technology (STIRPAT) Framework. The study examined the impact of trade openness, urban population, technology and economic growth on environment of Asian countries[11]. Munir & Ameer (2018)

[11] Bangladesh, Sri Lanka, Hong Kong, India, Indonesia, Iran, Malaysia, Pakistan, Philippines, Singapore, and Thailand

employed the panel unit root test, panel cointegration, Panel Dynamic Ordinary Least Squares (DOLS) estimator and causality test in order to establish the association between the variables. The results support the cointegration relationship between urbanization, GDP, technology, free trade and CO_2 emissions. Urbanization was found to positively influence emissions in the long run. Economic growth also positively impacts CO_2 emissions. Better economic conditions increase the demand for goods and services that leads to the production of pollution intensive industries. The study measured technology in the form of energy consumption made by fossil oils and found that it has a positive impact on carbon dioxide emissions. The study also indicates that there is no relationship between trade openness and CO_2 emissions in the long run. However, trade openness was found to have a significant positive impact on sulphur dioxide (SO_2). With regards to SO_2 the presence of EKC was found. In developing countries imports of pollution intensive vehicles, machinery increase because developed nations exchange their pollution creating machines and vehicles to less developed countries and adopt environment friendly goods. However, the present study is not only limited to the EKC framework, but it decomposes the effects of trade liberalization on the environment. This study also adds to the debate by testing the Pollution Haven Hypothesis (PHH).

Employing the Zivot-Andrews unit root test with structural breaks and the bounds test for cointegration in the presence of structural breaks, Ertugrul *et al*. (2016) investigated the possible presence of the EKC[12]. Findings showed that the analysed variables are cointegrated for Thailand, Turkey, India, Brazil, China, Indonesia and Korea. EKC was validated for Turkey, India, China and Kore. An increase in energy consumption stimulates CO_2 emissions in all countries except Brazil and Indonesia. Trade openness was found to have a positive impact on carbon dioxide emissions for Turkey, India, China and Indonesia. The study also supports the Pollution Haven Hypothesis which claims that the demand for a cleaner environment increases as real income rises and the dirty industries in developed countries are looking for other places with lesser stringent environmental standards. These results are also confirmed by Bernard & Mandal (2016) who found that trade openness and GDP increase emissions in developing countries. However, although Ertugrul *et al*. (2016) was successful in testing the Pollution Haven Hypothesis, and finding the effects of the variables used, it focused on one environmental quality indicator. To assess the robustness of the results this study also

[12] Analysed countries are regarded as the top ten emitters: China, India, South Korea, Brazil, Mexico, Indonesia, South Africa, Turkey, Thailand and Malaysia.

included other environmental quality indicators such as natural resources depletion which is also a sustainability indicator.

Using panel data covering 114 countries in the world, Zugravu (2017) used the GMM estimation technique to examine the direct, indirect and total effects of trade flows in environmental goods on total CO_2 and SO_2 emissions. They study found support for the scale, technique and composition effect in the pollution regression. All else equal, any rise in total output (GDP) and capital-labour ratio increases CO_2 and SO_2 emissions, whereas income and stringency of the environmental regulation were found to reduce pollution. Ceteris paribus, trade openness was found to increase pollution in their pooled country sample model, mainly through an indirect channelled by per capita income. From the findings, the authors suggest that trade openness is increasing income inequality in an overall sample of heterogenous countries and may even decrease the average income in the developing countries that are unable to take advantage of knowledge accumulation and technology. It is also imperative to consider openness in all goods and services and not only environmental goods. Thus, this study will, look at openness on all goods and services as calculated by the total trade as a per cent of GDP.

Using similar trade in environmental goods and services as Zugravu (2017), De Alwis (2015) investigated the impact of opening trade of environmental goods and services (EGS) on environmental quality. The study used cross country data for 62 countries. The results for the estimated SO_2 pollution function revealed that the elimination of tariff on EGS trade result in falling SO_2 emissions in comparison to increasing SO_2 emissions as a result of elimination of tariffs on non EGS trade. The study concluded that falling pollution due to EGS trade liberalization has no relationship with the income level of the countries, but favour capital abundant countries in reducing the pollution emissions. However, developing countries may weaken their environmental policies to attract Foreign Direct Investment (FDI) and to be competitive internationally which may lead to developed countries export their dirty industries to developing countries. This study, therefore, adds to the debate by testing whether the Pollution Haven Hypothesis (PHH) hold in the case of developing countries only.

Related studies were also done in the African context (Pindiriri and Chidoko, 2012; Ziramba, 2015; Effiong, 2018). Pindiriri and Chidoko (2012) examined the impact of Sustainable

Development Assistance (SDA) on carbon dioxide emissions in Sub-Saharan Africa (SSA)[13]. The results from the random effects model showed that there is a weak negative relationship between SDA and carbon dioxide emissions. Per capita income and energy use were found to positively influence carbon dioxide emissions. Ziramba (2015) investigated the determinants of carbon emissions in six Southern African countries[14], using both individual time series and panel data models. From the Autoregressive Distributed Lag (ARDL) model, results indicated that the main driving force behind carbon emissions is income per capita in three countries (Botswana, Zambia and Zimbabwe). Ziramba (2015) also found that in a panel setting, trade openness, income and service share in GDP are significant determinants of carbon emissions. In addition, Effiong (2018) examined the impact of urbanization on environmental quality for 49 African countries through the Stochastic Impact by Regression on Population, Affluence and technology (STIRPAT) framework. Effiong (Ibid) found that urbanization negatively influence carbon emissions and ambient particulate matter (PM_{10}). Also, GDP and energy use were found to have a positive impact on environmental degradation. Although these related studies were successful in achieving their intended objectives, it is imperative to focus specifically on the trade-environment nexus, as trade coupled with economic development is increasingly becoming a threat to the environment.

2.3 Conclusion

From the reviewed literature both theoretical and empirical models, trade liberalization casts doubt on the well-known gains from trade argument particularly in the developing nations. The literature contains conflicting views on the long run impact of trade on the environment. They all have a common point that the immediate (short-term) effects will be negative. On one hand, some studies suggest that trade will increase demand for environmental quality. However, others question this view and argue that higher growth without environmental provisions will increase environmental degradation.

Overall, from the reviewed empirical literature the results are best described as mixed. This is due to the use of different environmental quality indicators such as SO_2, CO_2, BOD, and NOx among others. Differences in functional forms and different econometric techniques employed also contributes to mixed results. Another reason for varying results is different framework

[13] The study employed both static and dynamic panel models in the analysis.
[14] Botswana, Mozambique, Zambia, Zimbabwe, South Africa and Democratic Republic of Congo.

analyses used (panel data, cross-section, and time series regressions) and set of explanatory variables used. Apart from this, there is hardly enough empirical evidence and consensus that trade liberalization has a significant influence on the environment. From the empirical literature, the common variables used with regards to trade-environment nexus include GPD/Km^2, urbanization, capital-labour ratio, population growth, GDP per capita and trade openness. Finally, there is still lagged empirical evidence for the decomposition of the effects of trade on environmental quality.

CHAPTER THREE
METHODOLOGY

3.0 Introduction

This chapter presents the methodology used in the study. The chapter is further divided into two main sections. The first section focuses on the theoretical framework for the study. Section two contains the estimation procedure for the study. It mainly includes data type, specification of the model, explanation of variables, a priori expectation of signs, and statistical diagnostic tests that were carried out.

3.1 Theoretical Framework

The theoretical model for the decomposition of the impact of free trade on the environment in this study follows the one developed by Antweiler *et al*. (2001). Antweiler *et al*. (2001) decomposed the impact of free trade on the environment into scale, technique and composition effect. The model is highly intuitive, simple, with more realistic assumptions and resolves measurement problems and complexities surrounding trade and environmental quality (pollution).

Assume a small open economy with N agents that produces two goods X and Y, using two inputs capital (K) and labour (L). The production of good X is assumed to be capital-intensive and hence generates pollution as a by-product. The production of good Y is labour-intensive and generates no pollution. The model also assumes constant returns to scale and hence they used the iso-unit cost functions as the production technology of each sector. That is, $C_x\left(w,\ r\right)$ and $C_y\left(w,\ r\right)$ for both industries X and Y, respectively. Where w represents wages; reward for labour and r represents rent; reward for capital. Also important to the model is the assumption that countries differ in their sizes, distance, location, proximity to suppliers, and trade restrictions. Hence, by setting Y as the numeraire (that is, $P_y = 1$), we denote the relative price of X by P , while the common world price ratio is given as P^w. Therefore P can be written in terms of P^w as:

$$P = \lambda P^w \tag{3.1}$$

where λ measures the intensity of trade restrictions (trade friction) in the domestic economy. Also, crucial to note is that $\lambda > 1$ implies a country imports dirty good X while $\lambda < 1$

means a country exports dirt good X. The local economy is assumed to be a net exporter of commodity X.

An emission function which links environmental degradation to economic activity is therefore, specified as follows:

$$E = eX = e\theta S \qquad (3.2)$$

In equation (3.2) θ represents the share of X in total output. Equation (3.2) provides a simple decomposition: environmental degradation (E) depends on the pollution intensity of the dirty industry e, the relative importance of the dirty industry in the economy θ, and the overall scale of the economy S.

To estimate the overall effect of a change in trade restrictions on the environment, we account for the change created in the sale of output S, techniques of production e, and the composition of output by a unit change in trade restrictions λ. Differentiating equation (3.2) with respect to λ holding world prices and factor endowments constant gives the following:

$$\frac{dE.\lambda}{d\lambda.E} = \Pi 1 \frac{dS.\lambda}{d\lambda.S} + \Pi 2 \frac{d\theta.\lambda}{d\lambda.\theta} - \Pi 3 \frac{de.\lambda}{d\lambda.e} \qquad (3.3)$$

In equation (3.3), the dependent variable measures the total environmental impact of a unit change in trade restrictions. The first term to the right measures the trade-induced scale effect on the environment. The scale effect measures the change in environmental degradation resulting from an increase in the level of output, holding the mix of goods (θ) and production techniques (e) constant. The second term is the trade-induced composition effect on the environment. The composition effect measures the effect of a change in the output mix of the economy on the environment. Hence, holding the scale effect and intensities of emissions constant, an economy that devotes more of its resources to producing the pollution-intensive good X, will pollute more. The last term measures the trade induced technique effect on the environment. Therefore, a change in trade restrictions generates a scale, a technique, and a composition effect.

According to Antweiler *et al*. (2001), the overall impact of trade liberalization on the environment is determined by the interactions between scale, composition and technique effects. The scale effect is measured by the real Gross Domestic Product per square kilometre as well as GDP per capita. The technique effect is measured by the real gross national product per capita and the square of the GDP per capita. Composition effect is captured by the capital-labour ratio. The model, however, shows why the empirical evidence of trade on environment is mixed because there is no unique relationship between trade and environmental quality. Cole & Elliott (2003) argued that the effect is heavily dependent on a country's comparative advantage which is accounted for by the capital-labour ratio and pollution haven effect.

Due to differences in tax on emissions for countries, it implies that pollution intensive industries relocate to a laxer environmental regulation country. Because developing countries have weaker environmental regulations, they will have a comparative advantage in the production of pollution-intensive goods. Hence, a country's characteristics in terms of its relative factor abundance and relative income determine how trade affects the environment. Since the theoretical and conceptual analysis support the tendency for government policy and environment regulations to determine the effect of free trade on the environment, a positive effect of trade on environment shows the presents of the pollution haven effect in developing countries. Increased urbanization lead to improvement in environmental quality. In contrast, observational evidence suggests that in developing countries urbanization rather increases environmental degradation (Appiah, 2013). Urban population growth (percentage of total population) is therefore included in the model as an additional variable to control for the possible influence of urbanization in explaining the impact of free trade on environmental quality.

3.2 Model specification

To determine the effect of trade liberalization on environmental quality, the study employed the following mathematical model derived from theoretical framework:

$$ED_{it} = f(topen_{it}, gdpc_{it}, gdpkm_{it}^{2}, enrgy_{it}, urbp_{it}, k/l_{it}, fdapc_{it}) \qquad (3.4)$$

where ED_{it} represents environmental degradation that is, it represents all environmental indicators for country i in year *t*. *i* denotes the cross section, and *i* denotes the time period.

3.2.1 Empirical model specification

The empirical model estimated is based on the decomposition in equation (3.3) and empirical specification by Antweiler *et al.* (2001) with some modifications. For the purpose of this study, additional variables were included.

The empirical model takes the following form:

$$\ln co_{2it} = \sigma + \gamma_i + \beta_1 \ln topen_{it} + \beta_2 \ln gdpc_{it} + \beta_3 (\ln gdpc_{it})^2 + \beta_4 \ln enrgy_{it}$$
$$+\beta_5 \ln urbp_{it} + \beta_6 \ln gdpkm^2_{it} + \beta_7 \ln k/l_{it} + \beta_8 \ln fdapc_{it} + \varepsilon_{it} \qquad (3.5)$$

$$\ln nrd_{it} = \omega + \lambda_i + \alpha_1 \ln topen_{it} + \alpha_2 \ln gdpc_{it} + \alpha_3 (\ln gdpc_{it})^2 + \alpha_4 \ln enrgy_{it}$$
$$+\alpha_5 \ln urbp_{it} + \alpha_6 \ln gdpkm^2_{it} + \alpha_7 \ln k/l_{it} + \alpha_8 \ln fdapc_{it} + \mu_{it} \qquad (3.6)$$

where $i = 1,.........N$ and $t = 1,.........T$.

co_{2it} represents carbon dioxide emissions per unit of output for country i in year t; nrd_{it} is the natural resource depletion for country i in year *t*; $topen_{it}$ is trade openness for country i in year *t*; $gdpc_{it}$ is Gross Domestic Product per capita for country i in year *t*; $gdpsqr_{it}$ is the square of Gross Domestic Product per capita for country i in year *t*. $gdpkm^2_{it}$ represents Gross Domestic Product per square kilometre for country i in year *t*; $enrgy_{it}$ is energy use intensity for country i in year *t*; $urbp_{it}$ is urbanization for country i in year *t*; k/l_{it} represents capital-labour ratio for country i in year *t*; $fdapc_{it}$ is net official development assistant per capita for country i in year *t*. All independent variables in both models are assumed to be exogenous. σ , ω , β_i and α_i are constant parameters of the models (3.5) and (3.6) respectively. γ_i and λ_i represents country specific intercepts in equations (3.5) and (3.6), respectively. ε_{it} and μ_{it} in represents the error terms that satisfies, $\varepsilon_{it} \sim IID(0,\sigma^2_\varepsilon)$ and $\mu_{it} \sim IID(0,\sigma^2_\mu)$, respectively.

3.2.2 Definition and justification of variables

Carbon dioxide emissions per unit of output (co_{2it})

It is difficult to have a perfect environmental quality indicator, because there are several parts of the ecosystem that we care for which includes land, water and air. Various studies have produced different findings for different pollutants. Antweiler *et al*. (2001) specified that environmental quality can be measured by pollutants that have the following characteristics: have strong local effect; it should be a by-product from production of commodities; the pollutant should be in large quantities per unit of output produced in some industries; have readily available data; have well-known abatement technology available for implementation and should be subject to some regulations because if its noxious effect on the population. CO_2 emissions share many of these characteristics, and thus motivation for choosing this variable. It is a naturally occurring gas, by-product of burning fossil fuels and biomass and as a result of land use changes and other industrial processes (Florides & Christodoulides, 2009). However, by using CO_2 emissions as a dependent variable makes it difficult to compare the state of the environmental quality across countries overtime (Pindiriri & Chidoko, 2012). Therefore, this study used CO_2 emissions per unit of output in country i in year *t*. Carbon dioxide emissions per unit of output makes it possible to make a comparison of whether the 2000 output was cleaner than the 2010 output in country i or whether country i's output is cleaner than country *j*'s (Pindiriri & Chidoko, *Ibid*).

Natural resource depletion (nrd_{it})

Natural resource depletion enters the model as another indicator of environmental quality and one of the dependent variables. It is the sum of net forest depletion, energy depletion, and mineral depletion. Net forest depletion is unit resource rents times the excess of roundwood harvest over natural growth. Energy depletion is the ratio of the value of the stock of energy resources to the remaining reserve lifetime (capped at 25 years). It covers coal, crude oil, and natural gas. Mineral depletion is the ratio of the value of the stock of mineral resources to the remaining reserve lifetime (capped at 25 years). It covers tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate. The variable is captured in adjusted savings of natural resource depletion as a percent of gross national product (GNI) and it enters the model as a sustainability indicator. Kleemann & Abdulai (2013) also used natural resource depletion in their study.

Trade openness ($topen_{it}$)

Trade openness refers to the elimination of trade restrictions and it is measured as a ratio of the sum of exports and import to GDP. Trade openness is included in the model to capture the direct effects of trade liberalization on environmental quality. Based on the Pollution haven Hypothesis (PHH) argument, dirty goods industries in developed countries with stringent environmental policies will move to developing nations with weak environment policies. Therefore, the coefficient of trade openness has an ambiguous effect that is positive or negative depending on the stages of economic development. It is expected to have a negative sign for developed countries and a positive sign for developing countries. This is because developed countries' dirty industries move to developing nations which have weaker environmental policies. This may drastically reduce the extent of pollution in developed nations whilst increasing environmental degradation in the developing world. However, in this study the coefficient of trade openness was expected to be positive.

Real GDP per square kilometre ($gdpkm_{it}^2$)

Real gross domestic product per square kilometre measures the scale of economic activity. Real GDP for country i in year t is divided by the total land area of that country. This variable measure the trade-induced scale effect of economic activity on the environment. According to Antweiler *et al*. (2001) this measure has some benefits. It is measured in intensive form, as is our dependent variable. Therefore, to explain concentrations of pollution we need a measure of scale reflecting the concentration of economic activity within the same geographical area. Other possible proxies for scale fail this test: GDP per person makes no allowance for countries of different sizes. Thus, only GDP per square kilometre captures differences in the flow of economic activity per unit area across countries that vary in population size and density. This effect states that trade liberalization leads to increased scale of economic activity (output) and thereby worsening the existing environmental problems (Antweiler *et al*., 2001). Thus, the coefficient of GDP/km^2 was expected to be positive.

Urbanization ($urbp_{it}$)

This refers to the physical growth of urban areas as a result of rural migration and even suburban concentration into cities, particularly the very largest cities. Urbanization is measured by urban population as a percentage of total population. It is included in the model because the continent is urbanizing at a historically fast rate and this is likely to affect the environment (Effiong, 2016). An increase in urbanization is seen as a significant factor that increases citizens' demands for environmental quality and thereby leads to improved environmental standards when a nation opens up to trade (Effiong, 2016). It also supports the improvement in environmental quality by reducing atmospheric air pollutants through economies of scale in the provision of adequate and efficient public infrastructure. Thus, the coefficient of urbanization is expected to be negative.

Energy consumption ($enrgy_{it}$)

Energy intensity level of primary energy is the ratio between energy supply and gross domestic product measured at purchasing power parity. Energy intensity is an indication of how much energy is used to produce one unit of economic output. Lower ratio indicates that less energy is used to produce one unit of output. The study employed energy use intensity as a proxy for energy consumption. Energy Consumption can increase carbon emissions and affect the environment through the increase in emissions as well as improve living conditions (Munir & Ameer, 2018). This has been considered based on findings on the impact of energy consumption on environment through trade and economic growth. The sign of the coefficient of energy use is expected to be positive.

Gross Domestic Product per capita ($gdpc_{it}$)

Gross Domestic Product per capita is included in the model as another proxy for the scale effect. Although its prediction power is limited as compared to gross domestic product per square kilometre, GDP per capita as well as its squared term are important variables in the model as they measure the basic Environmental Kuznets Curve (EKC) hypothesis. Therefore, the coefficients were expected to be positive for GDP per capita and negative for GDP per capita squared. The negative sign of the coefficient of GDP per capita squared show the presents of the technique effect. The technique effect is the tendency for environmental quality to improve as income increases through increased trade. GDP per capita is measured in constant 200 US dollars as a measure for real income. The following authors have used this measure in a related work; Ertugrul *et al.* (2016), Antweiler *et al*. (2001), and Bernard & Mandal (2016).

Net Official Development Assistant ($fdapc_{it}$)

Net official development assistance (ODA) is included in the model to capture the effect of sustainable development assistance on environmental quality. ODA per capita consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries to promote sustainable economic development and welfare in countries and territories in the DAC list of ODA recipients; and is calculated by dividing net ODA received by the midyear population estimate. It includes loans with a grant element of at least 25 per cent. Developed countries are funding sustainable development in developing countries, assumed to have low willingness to pay for better environmental quality (Pindiriri & Chidoko, 2012). Hence development assistant funding is expected to improve environmental quality. Consequently, the coefficient is expected to be negative.

Capital-Labour Ratio (k / l_{it})

The composition effect is determined by the relative capital abundance to labour in a country. According to Tsurumi & Managi (2010) the composition effect explains how the environment in general is affected by the composition of output (structure of industry), which is determined by the degree of trade openness as well by the comparative advantage of a country. This effect could be positive or negative depending on a given country's resource endowments and the strength of the environmental policy. Therefore, countries that have large endowments of natural resources such as SADC countries are likely to relatively specialize in resource-intensive sectors and thus experience environmental degradation when they open to trade. The coefficient of capital-labour ratio is therefore expected to be positive.

3.3 Model estimation procedure

As OLS could lead to biased results in the presence of unobserved heterogeneity, either random effects or fixed effects could be employed to obtain consistent results to examine the impact of trade liberalisation on environmental quality in SADC countries. The panel data analysis has the advantage that it increases the observations which increase efficiency unlike the individual country time series analyses (Baltagi, 2008). Greenhouse gases emissions vary across and over time. Countries in the region have individual-specific characteristics such as infrastructure, period average climate, history and culture. Such individual-specific and period-specific variables require the use of panel data. Pure cross-sectional data does not contain information on period-specific variables or on the effect of period-specific variables and on the other hand, pure time series data does not contain information on individual differences or on effects of individual specific variables. With panel data it possible to avoid this problem while at the same time control for individual specific and time specific heterogeneity (Pindiriri & Chidoko, 2012).

Panel data can either be balanced or unbalanced. If the data set is balanced or not observations need to be made in both cross sectional and time series. It is considered to be a balanced panel data if the numbers of observations in the time series is the same for each cross-sectional unit. If the numbers of observations differ, it is unbalanced. Panel data can be dealt with by many methods which include, pooled regression, dynamic OLS, fixed effects model (FEM) and random effects model (REM). Given that OLS will yield biased results in the presence of unobserved heterogeneity, either random effects or fixed effects model could be employed to obtain consistent results (Baltagi, 2008).

3.3.1 Choosing between fixed and random effects models

The fixed and random effects models are both ways to address endogeneity problems, which can be described as correlation between the explanatory variables and the disturbance term. The important distinction between random and fixed effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not (Torres, 2007). Both models have potential advantages as well as disadvantages. The fixed effects model allows one to use panel data to establish relationship under weak assumptions than those needed to establish causation with models such as pooled and random effects (Cameroon & Trivedi, 2005). However, the fixed effects model is inappropriate when estimating the coefficient of any time-invariant regressor as it is absorbed in the individual specific effect.

3.3.2 Hausman Test

It may seem a daunting task to simultaneously incorporate these various theoretical considerations into model choice. The correlation between the unit effects and the explanatory variables determines to use one or the other. As a result, to choose between fixed effects (FEM) and random effects (REM) model, most researchers often use the Hausman (1978) specification test (Green, 2008). Hausman test is designed to detect the violation of the REM assumption that the independent variables are orthogonal to the unit effects (Clark & Linzer, 2015). If the explanatory variable(s) and the unit effects are not correlated, then estimates of β in the fixed effects model $(\hat{\beta}_{FE})$ should be similar to estimates of β in the in the REM $(\hat{\beta}_{RE})$ (Clark and

Linzer, *Ibid*). If the effects are correlated with the explanatory variables, the fixed effects estimator is consistent and efficient, but the random effects estimator will be inconsistent. By letting X_{it} as a 1 x K vector of K explanatory variables in models (3.5) and (3.6) corresponding to individual i at period t, the Hausman test statistic (H) is a measure of the difference between the two estimates:

$$H = \left(\hat{\beta}_{RE} - \hat{\beta}_{FE} \right)' \left[Var(\hat{\beta}_{FE}) - Var(\hat{\beta}_{RE}) \right]^{-1} \left(\hat{\beta}_{RE} - \hat{\beta}_{FE} \right) \quad (3.7)$$

The null and alternative hypothesis for model (3.5) is given as:

$$H_0 : Cov(X_{it}, \gamma_i) = 0$$
$$H_1 : Cov(X_{it}, \gamma_i) \neq 0$$

For model (3.6) the alternative and null hypothesis are given as:

$$H_0 : Cov(X_{it}, \lambda_i) = 0$$
$$H_1 : Cov(X_{it}, \lambda_i) \neq 0$$

Under the null hypothesis of orthogonality, H follows a chi-square (χ^2) distribution with degrees of freedom equal to the number of regressors (k) in the model. If the ($p < 0.05$) is taken to be evidence that at conventional levels of significance, the two models are different enough to reject the null hypothesis, and hence to reject the REM in favour of the FEM. On the other hand, if the test does not indicate a significant difference (that is, $p > 0.05$), it does not necessarily follow that the random effects estimator is safely free from bias, and therefore to be chosen over the fixed effects model. The random effects model is chosen because its estimator is more efficient than the fixed effects estimator. Following the Hausman test, the results confirm that the fixed effects model is more appropriate than the random effects model in modelling the impact of trade liberalization on environmental quality in SADC countries.

3.3.3 Fixed effects model

The fixed effects model explores the relationship between predictor and outcome variables within an entity (individuals, countries, among others). Each entity contains its own individual characteristic that may or may not influence the independent variables (Torres, 2007). Thus, when using the model, the assumption is that something within the individual may impact or bias the explanatory or dependent variables and we need to control for this. This is the rationale behind the assumption of the correlation between the time invariant variables (γ_i and λ_i) and some explanatory variables, that is:

$$Cov(X_{it}, \gamma_i) \neq 0 \text{, and}$$

$$Cov(X_{it}, \lambda_i) \neq 0 .$$

The fixed effects model removes the effect of those time-invariant characteristics so we can assess the net effect of the explanatory variables on the dependent variables. Using models (3.5) and (3.6), γ_i and λ_i in the fixed effects model are is treated as an unknown parameter to be estimated. The key insight is that if the unobserved variable does not change over time, then any changes in the dependent variable must be due to influences other than these fixed characteristics (Torres, Ibid). ε_{it} and μ_{it} in models (3.5) and (3.6) represents stochastic error terms for each country i and year t. These error terms satisfy, $\varepsilon_{it} \sim IID(0, \sigma_{\varepsilon}^2)$ and $\mu_{it} \sim IID(0, \sigma_{\mu}^2)$. One of the model's disadvantages is that they cannot be used to investigate time-invariant causes of the dependent variables. $X_{it}^{'}$ is assumed to be independently distributed for all *i* and *t*.

3.3.4 Panel unit root test

If a shock to a variable persists overtime, so that the variable does not revert back to its mean or trend-line, we say that the time series contains a unit root, or that it is non-stationary (Wooldridge, 2015). Therefore, running least squares -regressions on series containing unit root can lead to spurious results, and consequently it is not possible to make meaningful inference. The tests suggested by Levin, Lin and Chu (2002) (LLC hereafter), Im, Pesaran and Shin (2003) (IPS hereafter); Dickey and Fuller (1979); Fisher (1932); and Philips & Peron (1988) have been used to check for the existence of panel unit root test. All these tests depend on whether there exists cross-sectional dependence or not, hence they are categorised into two generations. The first generation assume that individual series are cross-sectionally independent. On the other hand, the second generation relax this assumption and capture the cross-sectional dependence through a factor structure. The null hypothesis that the series in the panel contains a unit root and the alternative hypothesis allows for the series to have no unit roots. This study used Im-Pesaran-Shin test for unit root test.

3.3.5 Multicollinearity test

Multicollinearity refers to a situation in which there exists an exact (or nearly exact) linear relation among two or more of the explanatory variables. The presence of perfect multicollinearity can make the usual least squares analysis of the regression model dramatically inadequate. Methods of analysis cannot fully distinguish the explanatory factors from each other or isolate their independent influence. This may lead to paradoxical results with misleading individual p-values. In this study, the correlation matrix was used to detect the presence of multicollinearity. The test contains values which ranges from zero to one with the main diagonal consist of ones indicating correlation of a variable against itself and the off-diagonals indicate some level of correlation. If the absolute value of the correlation coefficient exceeds 0.8, there is serious problem of multicollinearity and the results produced are biased due to large standard errors and covariance and this might as well lead to the acceptance of the false null hypothesis (type I error).

3.3.6 Post estimations tests conducted

After the fixed effects model has been estimated, some tests were performed to determine whether the estimates are unbiased and inconsistent. In the case that these estimates are biased and inconsistent, several adjustments have to be made to the method used for estimating the regression. The tests include the test for heteroscedasticity, test for cross-sectional correlation and test for autocorrelation. In many panel data sets, the variance among the cross-sectional units can differ. This can be due to differences in the scale of the dependent variable between units. Therefore, in this study, the researcher employed the modified Wald test to detect the presence of group wise heteroscedasticity in the residuals of our fixed effects regression. This is done under the null hypothesis that the variance of the error is same for all individuals. A second deviation from IID errors could result from the contemporaneous correlation of errors across units. Therefore, to test for cross-sectional dependence in the error term this study employed a Breusch-Pagan LM test. This is under the null hypothesis that the residual correlation matrix is an identity matrix of order N, which means that the error terms are not correlated across entities (Baum, 2001). Serial correlation is responsible for too optimistic standard errors (Torres, 2007). Therefore, to check for the presence of autocorrelation the study employed a Wooldridge test where the null hypothesis assumes no first- order autocorrelation.

If the panel structure is characterized by panel heteroscedasticity, autocorrelation and contemporaneous correlation (HPAC)[15], there is need to correct for these standard errors' complications. However, this depends upon the nature of the panel under study. In short panels (that is, T fixed and $N \to \infty$), the alternative covariance matrix estimates can be used to obtain valid standard errors (Cameroon and Trivedi, 2009). White's (1980) robust standard errors and Rogers's (1983) clustered standard errors are the most popular. However, in this study, time periods are more numerous than the cross-sectional units (T=27 and N=8). Thus, the data set is temporal dominant and can be characterised as a long panel (N fixed, $T \to \infty$). Given that T is relatively larger than N, the asymptotic behind the correct functioning of robust and cluster options is now violated. As a result, long panels cannot rely on these option methods and require putting some structure on the assumed error process, which is not the case in short panels (Cameroon and Trivedi, 2009).

The HPAC structure of the disturbance term in both models rules out the simple fixed effects estimates, which do have the appropriate options to deal with non-spherical errors. From various options to estimate the fixed effects model[16], this leaves two large T consistent covariance matrix estimators namely the Parks-kmenta's (1986) FGLS approach and the Beck-Katz (1983) PCSE method (Hoechle, 2007). The first uses an application of the GLS estimation that fits panel data models, namely the FGLS estimator. This structure contains the same optimal properties as GLS for panel data but avoids the GLS assumption that specifies the covariance matrix is known and instead it uses the variance-covariance matrix. However, Beck and Katz (1995) question the performance of FGLS in finite samples and they claim that this method tends to produce overconfident standard errors. Therefore, they suggest using a classic OLS estimation method with large T-based standard errors that are corrected for the HPAC complications, namely PCSE (Beck and Katz, 1995). Therefore, this study employed the PCSE estimation method.

3.4 Data Sources, Type and Period

The study used annual panel data on SADC member countries from reputable and credible sources for the period 1990 to 2016. The main shortcoming of secondary data gathering

[15] The HPAC acronym is taken over from Blackwell (2005).
[16] These are; feasible generalised least squares (FGLS) estimator, OLS with panel corrected standard errors (PCSE) estimator and FE (within, LSDV) estimator (Blackwell, 2005).

methods are that data may not be appropriate or sufficient for the study and issues of data quality, which is difficulty to check when using secondary data (Greene, 2008). Therefore, to minimise these shortcomings the best way was to ensure that there is credibility and professionalism of some institutions, rather than the data. Moreover, another step was to critically evaluate the research methods used to collect the data (Saunders *et al.*, 2009). Since the study was on SADC member countries, the study employed data from the World Bank Indicators and Penn World Tables 9.0. These sources have over the years proven to hold the highest value of professionalism and implement credible research methods to collect data. Data for all variables were gathered from the World Bank Indicators (WDI) except for capital- labour ratio. The data for capital-labour ratio was collected from the Extended Penn World Table 9.0.

3.5 Conclusion

This chapter presented the methodology that was used to examine the impact of trade liberalization on environmental quality for the period 1980 to 2016. A brief evaluation of the model specification as well as tests carried out were presented in this chapter. The chapter considered the definition and justification of variables and also shaded light on independent variables and their expected signs. The next chapter looks at the estimation, presentation and interpretation of results.

CHAPTER FOUR

ESTIMATION, PRESENTATION AND INTERPRETATION OF RESULTS

4.0 Introduction

This chapter presents the econometric estimations and discussion of results of the study. There are three sections in this chapter. Section one presents descriptive statistics of the data used for the study. The second section contains panel unit root test and multicollinearity test results of the data for the estimation. This is then followed by section three which presents the results of the OLS with Panel Corrected Standard Errors (PCSE) for equations (3.5) and (3.6), the interpretation and discussion of the empirical results of the study.

4.1 Descriptive statistics

Table 2 shows a summary of statistics with three different versions of test statistics namely the overall, between and within. Data for all variables are all made up of 216 observations ranging from the period 1990-2016. The between and within capture the cross-sectional and the time-series dimensions of the data, respectively. The study used data from 8 countries [17] due to lack of data for other countries in the region. The study used 8 cross-sectional units (n=8) and 27 time periods (T=27), and this gave a total of 216 observations (N=216).

Overall, by using the coefficient of variation, the variation of the carbon dioxide emissions (CO_2) is 0.821, for natural resource depletion the variation is 1.814. Variations on trade openness (topen), urbanization (urbp), energy use intensity (enrgy) and development assistant are relatively low as compared to the variation in the capital-labour ratio (6.392). For carbon dioxide emission per capita (co_2) and urbanization, the between and within standard deviations are nearly the same. This tells us that the variation in carbon dioxide emission per capita and urbanization across countries is nearly equal to that observed within a country over time. Energy use (enrgy), GDP per capita (gdpc), trade openness (topen), GDP per square kilometre, and natural resource depletion (nrd) have more between variations than within variations. Capital-labour ratio (k/l) varies more within the sampled countries than they are across countries as shown by a larger with variation (372739) than the between variation (66949.0) of K/L.

[17] Angola, Botswana, Malawi, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe.

Table 2: Summary of descriptive statistics

Variables	Variations	Mean	Std. Dev.	Min	Max	Obs.
co_2	Overall	.5022136	.4124873	.123573	1.556962	N=216
	Between		.4248004	.1981544	1.370086	n=8
	Within		.1072983	-.075058	.9364503	T=27
nrd	Overall	7.35881	13.34807	.0001445	84.3365	N=216
	Between		12.57429	.3022813	37.8949	n=8
	Within		6.259289	-21.79004	53.80041	T=27
topen	Overall	73.19217	29.32797	15.369	206.26	N=216
	Between		24.16889	47.21444	119.5707	n=8
	Within		18.61811	10.76143	159.8814	T=27
gdpc	Overall	1712.728	2031.959	120.6293	7976.466	N=216
	Between		1860.401	274.3144	4630.195	n=8
	Within		1042.266	-456.1122	5058.999	T=27
urbp	Overall	3.716418	1.575095	.5923367	10.97585	N=216
	Between		1.157762	2.305231	5.467096	n=8
	Within		1.141318	2.003523	11.28637	T=27
enrgy	Overall	11.51964	8.56233	3.040765	50.13474	N=216
	Between		7.925065	3.840432	28.5403	n=8
	Within		4.254652	-.438354	33.11409	T=27
$gdpkm^2$	Overall	55200.81	79345.04	2840.855	344959.8	N=216
	Between		80741.62	8702.902	252757.6	n=8
	Within		23765.41	-20733.13	147403	T=27
k/l	Overall	59134.71	377986.9	1108.446	5561024	N=216
	Between		66945.9	5658.333	208143.7	n=8
	Within		372739	-147900.6	5412015	T=27
fdapc	Overall	48.25814	36.70166	4.334526	371.5157	N=216
	Between		24.13339	14.26758	81.6782	n=8
	Within		28.89677	-1.250807	354.719	T=27

Source: Author's computations

Also, the official development assistance from developed countries to developing countries varies more within countries (28.896) than they are across countries (between variation of 24.133). Since the variables show higher differences in between and within variations, this justify the use of the log transformations.

4.2 Panel Unit Root test

To avoid spurious regression estimates as a result of the use of non-stationary variables, the variables in the study were tested for stationarity. The Im-Pesaran-Shin test for panel unit root results are presented in Tables 3 and 4.

Table 3: Panel Unit Root Test

Variable	Probability value	Order of integration
$logco_2$	0.0829	I (0)
lognrd	0.0224	I (0)
logtopen	0.0055	I (0)
logurbp	0.4752	Non-stationary
logenrgy	0.0007	I (0)
loggdpc	0.0787	I (0)
$(loggdpc)^2$	0.0787	I (0)
$loggdpkm^2$	0.0074	I (0)
logk/l	0.3906	Non-stationary
logfdapc	0.0325	I (0)

Table 3 indicates that carbon dioxide emission per output, natural resource depletion, trade openness, GDP per square kilometre, energy use, GDP per capita, official development assistance per capita and the square of GDP per capita are stationary (integrated to order zero). Capital-labour ratio and urbanization are non-stationary.

Table 4: Panel Unit Root test after differencing

Variable	Probability value	Order of integration
D.logurbp	0.0000	I(1)
D.logk/l	0.0000	I(1)

D means first difference.

Capital-labour ratio and urbanization variables are stationary after the first difference. This implies that they are integrated to order one, I (1), at 1% significance level.

4.3 Multicollinearity

Table 5: Muticollinearity test

	logtopen	D.logurbp	logenrgy	loggdpc	loggdpkm^2	D.logk/l	logfdapc
logtopen	1.0000						
D.logurbp	0.1500	1.0000					
logenrgy	-0.2359	-0.0087	1.0000				
loggdpc	0.1380	-0.0169	-0.5542	1.0000			
loggdpkm^2	-0.0916	0.0539	-0.3024	0.5592	1.0000		
D.logk/l	0.0698	0.0330	0.0419	-0.0200	-0.0499	1.0000	
logfdapc	-0.0562	0.0601	0.2360	-0.4077	-0.6166	0.0749	1.0000

From Table 5, all independent variables do not move in a systematic way since the absolute values are less than 0.8. Therefore, we can separate the effect of one variable from another.

4.4 Estimation results

Firstly, Table 6 presents the Hausman test results for model (3.5) with carbon dioxide emission per capita as a dependent variable. Other results for the Hausman test with natural resource depletion as a dependent variable are shown in Table 8. Table 7 presents the results with carbon dioxide per output (logco$_2$) as a dependent variable and Table 9 presents natural resource depletion (lognrd) as a dependent variable.

Table 6: Hausman (1978) specification test for model (3.5)

	Coef.
Chi-square test value	631.77
P-value	0.0000

Table 6 show that the overall statistic $\chi^2(k)$ has a p-value = 0.0000. This leads to reject the null hypothesis at 1% significance level. Therefore, the regression model should be Fixed

Effects model (FEM). From the test between fixed effects model and pooled OLS model a p-value of 0.0000 (shown in appendix E) show that the FEM is preferred. A p-value of 0.0000[18] for heteroscedasticity test strongly reject the null hypothesis for any confidence level and conclude that a phenomenon of heteroscedasticity is present. The presence of autocorrelation[19] is also detected which is shown by a p-value of 0.0003 as indicated by the Wooldridge test for autocorrelation. Finally, the errors exhibit cross-sectional correlation which is shown by p-value of 0.0000[20]. Hence, the study estimated the model for OLS with panel corrected standard errors (PCSE).

Table 7: Results with logco$_2$ as a dependent variable

Variables	Coefficient	Std. error	z-statistic	Prob > | z |
loggdpc	0.0487544	0.313011	0.16	0.876
$(\text{loggdpc})^2$	0.0053164	0.0055775	0.95	0.340
D.logk/l	0.0660293	0.0529985	1.25	0.213
logtopen	0.2910037	.0732295	3.97	0.000***
loggdpkm^2	.1840354	.0256251	7.18	0.000***
logenrgy	.7893775	.0401679	19.65	0.000***
D.logurbp	-.678297	.2634984	-2.57	0.010***
logfdapc	-.2690247	.0450535	-5.97	0.000***
Cons	-6.243046	1.250218	-4.99	0.000***

**** means that coefficients are significant at 1% Significance level.*

The estimated regression result for equation (3.5) which has carbon dioxide emission as the dependent variable indicate that trade openness, GDP per square kilometre (scale effect) and energy use have a positive relationship with carbon dioxide emissions whereas the urbanization and official development assistance have a negative relationship with carbon dioxide emission. The coefficients of GDP per capita, and GDP per capita squared are statistically insignificant which rejects the validity of the basic Environmental Kuznets Curve (EKC) hypothesis. Also, the coefficient of capital-labour ratio (composition effect) is statistically insignificant.

[18] Appendix F
[19] Appendix H
[20] Shown in appendix G

In line with the theoretical expectations, the coefficient of trade openness is statistically significant at 1% significant level. Specifically, a 1% increase in trade openness results in 0.29% increase in CO_2 emissions. This means that as trade increases the region is experiencing increases in carbon dioxide emissions. The finding conforms to the results found by previous studies (Munir & Ameer, 2018; Ertugrul *et al.*, 2016; Cole & Elliott, 2003). However, they are contrary to the results found by Shahbaz *et al.* (2016) who found that trade openness reduces carbon dioxide. In addition, the result is consistent with the assertion of the Pollution Haven Hypothesis (PHH) which suggest that regulations of environment will move polluting activities of tradable commodities in poorer countries. This hypothesis therefore expects trade openness to increase CO_2 emissions. This provides evidence for the developing countries becoming Pollution Havens with greater volumes of trade. This also conforms to the result found by Bernard & Mandal (2016).

Conforming to the results found by Antweiler *et al.* (2016) the coefficient of GDP per square kilometre is statistically significant at 1% significant level. This indicates that a 1% increase in the scale of economic activities, increases carbon dioxide emissions by 0.18%. Therefore, the trade-induced increases in output leads to rises in carbon dioxide emission in the SADC region. The positive effect sign show that trade liberalization leads to increased scale of economic activity (output) and thereby worsening the existing environmental problems. The direction of the scale effect is in line with the theoretical expectations.

The coefficient of energy consumption which is a control variable also conforms to the expected sign and is statistically significant at 1% level and positively influences carbon dioxide emissions in the SADC region. This reveals that a 1% increase in energy consumption increases carbon dioxide emissions by 0.79%. This means that increasing usage of energy is detrimental to the environment as it increases the emissions. Similar results were reported by Munir & Ameer (2018).

Urbanization coefficient is statistically significant at 1% level and negatively influences carbon dioxide emissions. This indicates that a 1% growth in urbanization is likely to reduce carbon dioxide emissions by 0.68%. This is also in line with the expectations and implies that high urbanization may lower environmental pressure through economies of scale in public infrastructure. The finding show that urbanization is seen as a significant factor that increases citizens' demand for environmental quality and thereby leads to the improvement in environmental standards when a nation opens up for trade. The same result was also found by Effiong (2016).

Last but not least is the negative relationship between official development assistant and carbon dioxide emissions. The coefficient of sustainable development assistant is statistically significant at 1% significant level. It means a 1% increase in sustainable development assistance reduces carbon dioxide emissions by 0.27%. This means that the funds from the developed World to the developing countries are being channelled towards reducing carbon dioxide emissions, hence improving environmental quality in the SADC region. This result is in line with the expected sign and it conforms to the one found by Pindiriri & Chidoko (2012).

Table 8: Hausman (1978) specification test for model (3.6)

	Coef.
Chi-square test value	98.21
P-value	0.0000

In Table 8, the overall statistic $\chi^2(k)$ has a p-value of 0.0000. This leads to reject the null hypothesis for any confidence level. So, the effects are fixed, and the regression model should be fixed effects model. The F-test for the choice between fixed effects model and pooled OLS provides a p-value of 0.0000[21] which rejects the null hypothesis and conclude that there is a significant fixed effect and the FEM is thus preferred than a Pooled OLS model. However, the use of the fixed effects model suffers from panel heteroscedasticity, autocorrelation and contemporaneous correlation (HPAC)[22]. This is evidenced by a p-value of 0.000[23] from the Wald test for heteroscedasticity, a p-value of 0.0003[24] for Wooldridge test for autocorrelation and a p-value of 0.000[25] from the Breusch-Pagan LM test for cross-sectional independence in the residuals, hence the need to correct for these standard error complications. Table 9 presents the results from OLS with Panel Corrected Standard Errors (PCSE).

[21] Shown in appendix K
[22] Shown in appendix
[23] Appendix L
[24] Shown in appendix N
[25] Appendix M

In the case of natural resource depletion GDP per capita (loggdpc) and its square $(\text{loggdpc})^2$ have a positive and negative relationship with natural resource depletion, respectively. Trade openness (logtopen), GDP per square kilometre (loggdpkm^2) and sustainable development assistant (logfdapc) positively influence natural resource depletion. Energy consumption (logenrgy) has a negative relationship with natural resource depletion (lognrd). The coefficients of capital-labour ratio (D.logk/l) and urbanization (D.logurbp) are statistically insignificant.

Table 9: Results with lognrd as a dependent variable

Variables	Coefficient	Std. error	z-statistic	Prob > | z |
loggdpc	6.994036	1.406589	4.97	0.000***
$(\text{loggdpc})^2$	-0.1349656	0.0243565	-5.54	0.000***
D.logk/l	0.0679268	0.2403351	0.28	0.777
logtopen	1.605469	0.3046656	5.27	0.000***
loggdpkm^2	1.779911	0.1807159	9.85	0.000***
logenrgy	-2.052241	0.1930672	-10.63	0.000***
D.logurbp	-.180453	0.9416213	-1.25	0.210
logfdapc	0.8588156	0.2331101	3.68	0.000***
Cons	-45.43622	6.195777	-7.33	0.000***

**** means that coefficients are significant at 1% Significance level.*

The results from Table 9 indicate that a scale effect has a positive and technique effect has a negative impact on natural resource depletion. The coefficients of GDP per capita (loggdpc) and its square $(\text{loggdpc})^2$ are statistically significant at 1 % level. The results indicate an income turning point of $17,515 which is significantly high. It shows that the relationship between linear (scale effect) and non-linear (technique effect) in terms of real GDP per capita and natural resource depletion is inverted U-shaped which further conforms the existence of Environmental Kuznets Curve (EKC) hypothesis. Increase in income increases natural resource depletion. However, when economic transition shifts due to technological change is considered, the positive effect turns into negative where increase in income reduces natural resource depletion. Results are consistent with the theoretical expectations and results found by Shahbaz *et al.* (2016) and Beak *et al.* (2009). The EKC is validated under natural resource depletion and it does not exist in the case of carbon dioxide emission.

Also confirming the results found by Antweiler *et al.* (2016)'s decomposition framework, the coefficient of GDP per square kilometre is statistically significant at 1% significant level. This reveals that while attaining the economies of scale, a 1% increase in economic activity (output) increases natural resource depletion by 1.78%. The finding is in line with the theoretical expectations. The magnitude of the Scale effect of trade far outweigh the favourable technique effects of, making the net effect of trade liberalization on forest resources unfavourable. This outcome is in line with the theoretical proposition that trade liberalization leads to depletion of natural resources in developing countries. The Composition effect does not have an impact on the depletion of natural resources.

The positive estimated coefficient of trade openness means that increased trade liberalization tends to increase the rate of natural resource depletion in the SADC region. The coefficient is statistically significant at 1% significant level and conforms to the theoretical expectations. A 1% increase in trade openness increases natural resource depletion by 1.6%. This conform to the theoretical assertion that increase in trade liberalization will further-up depletion of natural resources in the SADC region. Also, the positive sign conforms to the Pollution Haven Hypothesis in the case of SADC region. This suggest that weak-stringent environmental regulations in the post liberalization era could be a contributing factor to natural resource depletion. The study, therefore, concludes that trade liberalization has contributed to natural resource degradation in SADC as a result of relocation of environmentally sensitive industries into the region. In comparison to the impact of trade liberalization on carbon dioxide emission, the elasticity is higher in the case of natural resource depletion although they have the same direction. The finding is similar to the results found by Kleemann & Abdulai (2013) which shows that trade liberalisation increases the depletion of natural resources and this is not favourable to a sustainable development path.

The sign of the coefficient of energy consumption is negative, which is contrary to the expectations. It is statistically significant at 1% significant level. From the results a 1% increase in energy consumption reduces natural resource depletion by 2.05%. The response is high as indicated by a higher elasticity value. The result is in contrast to previous studies (Munir & Ameer, 2018; Ertugrul *et al.,* 2016) who found that energy consumption increases environmental degradation. The finding implies that, the intensity of energy use in the SADC region reduces the level of natural resources depletion. This is because, the governments are increasingly encouraging industries to produce output using renewable and cleaner energy, so that per every output produced the bigger percentage of energy being used is coming from renewable resources as a substitution to the degradation of natural resources. This means that energy use is favourable to a sustainable development path.

Also contrary to the prior expectations is the result on sustainable development assistance. The coefficient is statistically significant at 1% significant level. This reveals that a 1% increase in sustainable development assistant increases natural resource use by 0.86%. This result shows that the sustainable development assistance from the developed world to the SADC countries is not being channelled to the sustainable use of resources. As compared to the case of carbon dioxide emission, sustainable development assistance is negatively related to emissions, which shows that results may differ with different environmental indicators. This shows that sustainable development assistance does not lead to a sustainable development path when the resources are being extracted.

4. 5 Conclusion

This Chapter presented the estimation, presentation and interpretation of the results from empirical investigation on the impact of trade liberalization on environmental quality in the SADC region. The findings show that trade openness, GDP per square kilometre and energy consumption are positively related with carbon dioxide emissions. Urbanization and sustainable development assistance have a negative impact on carbon dioxide emission. All the coefficients of the variables are statistically significant at 1% level of significance. The coefficient of GDP per capita and its squared term and capital-labour ratio are statistically insignificant. On the other hand, trade openness, GDP per capita, sustainable development assistance and GDP per square kilometre have a positive relationship with natural resource depletion. Energy consumption has a negative relationship with natural resource depletion. The EKC model is valid in the in the case of natural resource depletion. The positive scale effect is relatively larger than the negative technique effect, which shows that trade liberalization is detrimental to the environment in the SADC region. This is because environmental policies and pollution abatement technologies used are not huge enough to counter the increasing growth of pollution-intensive goods caused by economic growth activities. The following chapter provides the summary of the study, policy implications and recommendations based on the results and the suggestion to areas of further studies.

CHAPTER FIVE
SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

5.0 Introduction

This chapter is divided into two sections. The first section presents a summary of the findings of the study. The second section provides policy recommendations based on the empirical results and identified areas for further research.

5.1 Summary of the findings and conclusion

This study has examined the impact of trade liberalization on environmental quality in the SADC countries. The main objective of the study was to assess the extent to which trade liberalization affect environmental quality in the SADC region. It also aimed to decompose the impact into scale, technique and composition effects. The analysis was conducted over a sample of 8 selected countries for the period 1990-2016. OLS with Panel Corrected Standard Errors (PCSE) estimation technique was used mainly to correct for heteroscedasticity, autocorrelation and contemporaneous correlation (HPAC) using Stata 14 statistical package. The findings provide a number of conclusions. First the study finds a strong link between trade liberalisation and environmental quality. There is evidence for Environmental Kuznets Curve (EKC) hypothesis in one model (in the case of natural resource depletion). This means that an increase in economic growth results in an initial increase in environmental degradation and subsequent fall with further growth. The results also render support for Pollution Haven Hypothesis (PHH). The study shows that generally, trade is detrimental to the environment (taking the two environmental indicators into consideration). Thus, the results support the alarmists claim that trade can harm the natural habitat.

Results reveal that trade openness is positively related to carbon dioxide emissions and natural resources depletion, respectively. Therefore, the study concludes that trade openness is detrimental to the environment. GDP per square kilometre was also found to have a positive impact on both carbon dioxide emission and natural resource depletion rendering a positive scale effect as expected. Urbanization and sustainable development assistance were also found to have a negative effect on carbon dioxide emission. However, contrary to the expectation's energy use and sustainable development assistance were found to have a negative impact on natural resource depletion which promotes a sustainable development path. In addition, GDP per capita and GDP per capita squared were found to have a positive and negative impact on natural resource depletion respectively which concurs with the EKC hypothesis. Overall, the study found no relationship between capital-labour ratio (composition effect) in all models. Given that the positive scale effect was found to have a greater magnitude compared to the negative technique effect, the study concludes that trade liberalization is detrimental to the environment.

5.2 Policy Implications and Recommendations

From the findings, it is shown that trade liberalization is detrimental to the environment. Therefore, the study recommends to policy makers of these developing countries to give more attention to the dramatic consequences of trade liberalization on the welfare of their citizens and to promote green trade liberalization instead. Therefore, further trade liberalization policies should be accompanied by significant investments in the development of the nations. Hence, it is crucial that policy makers in SADC member states set broader trade policies to encapsulate these environmental concerns. This can especially change the narrative of developing countries having a laxer regulatory environment and hence, pollution haven effect may break down completely.

Furthermore, the study recommends that nations engage in less polluting activities in their economic growth and trade expeditions since they are found to have a positive impact on carbon dioxide emissions and natural resource depletion. The Members States should be mindful of the kind of multinational corporations allowed to produce and should allow corporations whose activities produce relatively less emissions or nearly produce no pollution. Also, the study recommends that Member States import goods and services that are less carbon dioxide emitting. In addition, there is need for government support to exporters that should be explored to assist them in meeting international environmental challenges. This comprises investigations into the use of instruments available within current international standards, such as subsidies for environmental investment. This kind of support may be required by industries like the steel industry where there are still some plants with old stock requiring significant expenditure to meet new environmental requirements. Innovative instruments, such as making preferential finance available to exporters who are struggling to make the necessary environmental investments, should also be explored.

The study suggest that consumption of fossil fuels should be minimized and use of renewable energy for example, geothermal, solar and wind must be encouraged. The use of clean energy contributes significantly to a sustainable development path, hence less environmental degradation. This can only be possible if the governments provide resources to support research and development in the area. Further environmental assessment should be done before certain projects are implemented. Proper management in the use of sustainable development assistance is encouraged to embark on developments which are aimed at reducing pollution and promote a favourable sustainable development path on natural resources use. Urbanization is seen as a significant factor that increases citizens' demand for environmental quality and thereby leads to the improvement in environmental standards when a nation opens up for trade. Therefore, countries must be cautious about excess urbanization without proper planning and efficient public infrastructure as this will lead to more environmental degradation.

5.3 Suggestion for Further Research

The current study has not been comprehensive on the impact of trade liberalization on environmental quality in the SADC region as it used only static panel data analysis. This was due to data availability challenges. There is need for future research to focus on other advanced research methods and techniques such as the use of dynamic panel data analysis to cover the countries in the whole region. The study also could not account for the impact of trade openness on other measures of environmental degradation such as nitrogen oxide (NO2), sodium oxide (SO2) and Biochemical Oxygen Demand (a measure of pollution of water bodies) as a result of data limitations. Therefore, it is recommended that future studies on the trade-environment relationship in SADC should be focused on finding the impact of the nation's trade liberalization policies on NO2, SO2 and BOD.

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APPENDICES

Appendix A: Descriptive Statistics

```
. xtsum co2p nrd topen gdpc urbp enrgy gdpkm kl fdapc

Variable         |      Mean   Std. Dev.       Min        Max |    Observations
-----------------+--------------------------------------------+----------------
co2p     overall |  .5022136   .4124873    .123573   1.556962 |     N =     216
         between |             .4248004   .1981544   1.370086 |     n =       8
         within  |             .1072983   -.075058   .9364503 |     T =      27
                 |                                            |
nrd      overall |   7.35881   13.34807   .0001445    84.3365 |     N =     216
         between |             12.57429   .3022813    37.8949 |     n =       8
         within  |             6.259289  -21.79004   53.80041 |     T =      27
                 |                                            |
topen    overall |  73.19217   29.32797     15.369     206.26 |     N =     216
         between |             24.16889   47.21444   119.5707 |     n =       8
         within  |             18.61811   10.76143   159.8814 |     T =      27
                 |                                            |
gdpc     overall |  1712.728   2031.959   120.6293   7976.466 |     N =     216
         between |             1860.401   274.3144   4630.195 |     n =       8
         within  |             1042.266  -456.1122   5058.999 |     T =      27
                 |                                            |
urbp     overall |  3.716418   1.575095   .5923367   10.97585 |     N =     216
         between |             1.157762   2.305231   5.467096 |     n =       8
         within  |             1.141318   2.003523   11.28637 |     T =      27
                 |                                            |
enrgy    overall |  11.51964    8.56233   3.040765   50.13474 |     N =     216
         between |             7.925065   3.840432    28.5403 |     n =       8
         within  |             4.254652   -.438354   33.11409 |     T =      27
                 |                                            |
gdpkm    overall |  55200.81   79345.04   2840.855   344959.8 |     N =     216
         between |             80741.62   8702.902   252757.6 |     n =       8
         within  |             23765.41  -20733.13     147403 |     T =      27
                 |                                            |
kl       overall |  59134.71   377986.9   1108.446    5561024 |     N =     216
         between |              66945.9   5658.333   208143.7 |     n =       8
```

```
         within  |            372739  -147900.6    5412015 |     T =      27
                 |                                         |
fdapc    overall |  48.25814   36.70166   4.334526   371.5157 |     N =     216
         between |            24.13339   14.26758    81.6782 |     n =       8
         within  |            28.89677  -1.250807    354.719 |     T =      27
```

Appendix B: Panel Unit Root Test

```
. xtunitroot ips logco2p, trend lags(aic)

Im-Pesaran-Shin unit-root test for logco2p
------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     27

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.13 lags average (chosen by AIC)
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -1.3857        0.0829
------------------------------------------------------------------------------



. xtunitroot ips lognrd , trend lags(aic)

Im-Pesaran-Shin unit-root test for lognrd
-----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     27

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.13 lags average (chosen by AIC)
------------------------------------------------------------------------------
                   Statistic      p-value
```

```
------------------------------------------------------------------------------
 W-t-bar             -1.6246       0.0224
------------------------------------------------------------------------------

. xtunitroot ips logtopen , trend lags(aic)

Im-Pesaran-Shin unit-root test for logtopen
-------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     27

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.25 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -2.5429       0.0055
------------------------------------------------------------------------------

. xtunitroot ips logurbp , trend lags(aic)

Im-Pesaran-Shin unit-root test for logurbp
-------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     27

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.25 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -0.0621       0.4752
------------------------------------------------------------------------------

. xtunitroot ips d.logurbp , trend lags(aic)

Im-Pesaran-Shin unit-root test for D.logurbp
---------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
```

```
Ha: Some panels are stationary             Number of periods =     26

AR parameter: Panel-specific               Asymptotics: T,N -> Infinity
Panel means:  Included                                      sequentially
Time trend:   Included

ADF regressions: 0.00 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -8.6808        0.0000
------------------------------------------------------------------------------



. xtunitroot ips logenrgy , trend lags(aic)

Im-Pesaran-Shin unit-root test for logenrgy
-------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary             Number of periods =     27

AR parameter: Panel-specific               Asymptotics: T,N -> Infinity
Panel means:  Included                                      sequentially
Time trend:   Included

ADF regressions: 0.75 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -3.1904        0.0007
------------------------------------------------------------------------------



. xtunitroot ips loggdpc , trend lags(aic)

Im-Pesaran-Shin unit-root test for loggdpc
------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary             Number of periods =     27

AR parameter: Panel-specific               Asymptotics: T,N -> Infinity
Panel means:  Included                                      sequentially
Time trend:   Included
```

```
ADF regressions: 0.63 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -1.4141        0.0787
------------------------------------------------------------------------------

. xtunitroot ips loggdpsq , trend lags(aic)

Im-Pesaran-Shin unit-root test for loggdpsq
-------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     27

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.63 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -1.4141        0.0787
------------------------------------------------------------------------------

. xtunitroot ips loggdpkm , trend lags(aic)

Im-Pesaran-Shin unit-root test for loggdpkm
-------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     27

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.50 lags average (chosen by AIC)
------------------------------------------------------------------------------
```

```
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -2.4388        0.0074
------------------------------------------------------------------------------

. xtunitroot ips logkl , trend lags(aic)

Im-Pesaran-Shin unit-root test for logkl
----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     27

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.75 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -0.2778        0.3906
------------------------------------------------------------------------------

. xtunitroot ips d.logkl , trend lags(aic)

Im-Pesaran-Shin unit-root test for D.logkl
------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     26

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.13 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
```

```
------------------------------------------------------------------------------
 W-t-bar             -4.6753       0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot ips logfdapc , trend lags(aic)

Im-Pesaran-Shin unit-root test for logfdapc
-------------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     27

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Included

ADF regressions: 0.13 lags average (chosen by AIC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -1.8447       0.0325
------------------------------------------------------------------------------
```

Appendix C: Multicollinearity test

```
. corr logtopen d.logurbp logenrgy loggdpc loggdpkm d.logkl logfdapc
(obs=208)

             |                 D.                                   D.
             | logtopen  logurbp logenrgy  loggdpc loggdpkm    logkl logfdapc
-------------+---------------------------------------------------------------
    logtopen |   1.0000
     logurbp |
         D1. |   0.1500   1.0000
    logenrgy |  -0.2359  -0.0087   1.0000
     loggdpc |   0.1380  -0.0169  -0.5542   1.0000
    loggdpkm |  -0.0916   0.0539  -0.3024   0.5592   1.0000
       logkl |
         D1. |   0.0698   0.0330   0.0419  -0.0200  -0.0499   1.0000
    logfdapc |  -0.0562   0.0601   0.2360  -0.4077  -0.6166   0.0749   1.0000
```

Appendix D: Hausman test for model 3.5

```
  Test:  Ho:  difference in coefficients not systematic

                  chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =      631.77
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

Appendix E: Fixed effects model chosen by Hausman test

```
xtreg logco2p logtopen loggdpc loggdpsqr loggdpkm D.logurbp logenrgy  D.logkl
logfdapc, fe

Fixed-effects (within) regression               Number of obs     =        208
Group variable: id                              Number of groups  =          8

R-sq:                                           Obs per group:
     within  = 0.2203                                         min =         26
     between = 0.1581                                         avg =       26.0
     overall = 0.1600                                         max =         26

                                                F(8,192)          =       6.78
corr(u_i, Xb)  = -0.3235                        Prob > F          =     0.0000

------------------------------------------------------------------------------
     logco2p |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    logtopen |   -.005335   .0367122    -0.15   0.885     -.077746    .0670761
     loggdpc |  -.2312867   .2313312    -1.00   0.319    -.6875635    .2249902
   loggdpsqr |   .0013718   .0039662     0.35   0.730    -.0064512    .0091948
    loggdpkm |   .3730506   .1307619     2.85   0.005     .1151363    .6309649
             |
     logurbp |
         D1. |  -.2551179   .1040593    -2.45   0.015    -.4603642   -.0498716
             |
    logenrgy |   .6245362   .1696771     3.68   0.000     .2898657    .9592067
             |
```

```
       logkl |
         D1. |   .1214392   .0283594     4.28   0.000     .0655032    .1773751
             |
    logfdapc |  -.0226523   .0322411    -0.70   0.483    -.0862446      .04094
       _cons |  -4.810354   1.609599    -2.99   0.003    -7.985121   -1.635588
-------------+----------------------------------------------------------------
     sigma_u |  .70518811
     sigma_e |  .19979586
         rho |  .92569296   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(7, 192) = 77.05                     Prob > F = 0.0000
```

Appendix F: Heteroscedasticity test for model with CO_2

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (8)  =     1103.55
Prob>chi2 =      0.0000
```

Appendix G: Cross-sectional dependence test for model with CO_2

```
Correlation matrix of residuals:

         __e1      __e2      __e3      __e4      __e5      __e6      __e7      __e8
__e1   1.0000
__e2  -0.2183   1.0000
__e3  -0.3945   0.6075   1.0000
__e4  -0.2815   0.6323   0.5935   1.0000
__e5  -0.5310   0.5561   0.7680   0.7117   1.0000
__e6  -0.0990   0.3254   0.0027   0.2135   0.2690   1.0000
__e7   0.5257  -0.2407  -0.1668  -0.1748  -0.1487   0.3800   1.0000
__e8  -0.3184   0.5277   0.8318   0.4843   0.6073  -0.1858  -0.3770   1.0000
Breusch-Pagan LM test of independence: chi2(28) =   149.128, Pr = 0.0000
Based on 25 complete observations over panel units
```

Appendix H: Autocorrelation test for model with CO_2

```
. *testing for autocorrelation

. xtserial logco2p logtopen loggdpc loggdpsqr loggdpkm logurbp logenrgy logkl
logfdapc


Wooldridge test for autocorrelation in panel data

H0: no first-order autocorrelation

    F(  1,       7) =      5.097

           Prob > F =      0.0585
```

Appendix I: Corrected Model

```
. xtpcse logco2p logtopen loggdpc loggdpsqr loggdpkm d.logurbp logenrgy  d.logkl
logfdapc


Linear regression, correlated panels corrected standard errors (PCSEs)


Group variable:   id                             Number of obs     =        208

Time variable:    year                           Number of groups  =          8

Panels:           correlated (balanced)          Obs per group:

Autocorrelation:  no autocorrelation                           min =         26

                                                               avg =         26

                                                               max =         26

Estimated covariances      =        36           R-squared         =     0.7235

Estimated autocorrelations =         0           Wald chi2(8)      =    1219.57

Estimated coefficients     =         9           Prob > chi2       =     0.0000


------------------------------------------------------------------------------

             |           Panel-corrected

     logco2p |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]

-------------+----------------------------------------------------------------

    logtopen |   .2910037   .0732295     3.97   0.000     .1474765    .4345308

     loggdpc |   .0487544   .3130119     0.16   0.876    -.5647377    .6622465

   loggdpsqr |   .0053164   .0055775     0.95   0.340    -.0056153    .0162481

    loggdpkm |   .1840354   .0256251     7.18   0.000     .1338113    .2342596

             |

     logurbp |

         D1. |   -.678297   .2634984    -2.57   0.010    -1.194744   -.1618496
```

```
             |
    logenrgy |   .7893775   .0401679    19.65   0.000     .7106499    .8681052
             |
       logkl |
         D1. |   .0660293   .0529985     1.25   0.213    -.0378458    .1699043
             |
    logfdapc |  -.2690247   .0450535    -5.97   0.000     -.357328   -.1807215
       _cons |  -6.243046   1.250218    -4.99   0.000    -8.693429   -3.792663
------------------------------------------------------------------------------
```

Appendix J: Hausman test for model 3.6

```
Hausaman:

    Test:  Ho:  difference in coefficients not systematic

                  chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       98.21
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

Appendix K: Fixed effects chosen by Hausman test

```
. xtreg lognrd logtopen loggdpc loggdpsqr loggdpkm D.logurbp logenrgy D.logkl
logfdapc, fe

Fixed-effects (within) regression               Number of obs     =        208
Group variable: id                              Number of groups  =          8

R-sq:                                           Obs per group:
     within  = 0.3730                                         min =         26
     between = 0.0893                                         avg =       26.0
     overall = 0.1924                                         max =         26

                                                F(8,192)          =      14.28
corr(u_i, Xb)  = -0.2437                        Prob > F          =     0.0000

------------------------------------------------------------------------------
      lognrd |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
```

```
-------------+----------------------------------------------------------------
    logtopen |   .7093181    .289841     2.45   0.015     .1376366       1.281
     loggdpc |    4.97491   1.826348     2.72   0.007     1.372628    8.577192
   loggdpsqr |  -.0827457   .0313133    -2.64   0.009    -.1445078   -.0209835
    loggdpkm |   1.979925   1.032358     1.92   0.057    -.0562953    4.016145
             |
     logurbp |
         D1. |  -.9405533   .8215431    -1.14   0.254    -2.560962    .6798554
             |
    logenrgy |   1.012821   1.339592     0.76   0.451    -1.629385    3.655028
             |
       logkl |
         D1. |   .2286038   .2238958     1.02   0.309    -.2130074     .670215
             |
    logfdapc |   1.350769   .2545421     5.31   0.000     .8487112    1.852827
       _cons |  -48.51961    12.7077    -3.82   0.000    -73.58423   -23.45499
-------------+----------------------------------------------------------------
     sigma_u |  2.2589196
     sigma_e |  1.5773779
         rho |  .67222053   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(7, 192) = 15.56                     Prob > F = 0.0000
```

Appendix L: Heteroskedasticity test

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (8)  =      259.09
Prob>chi2 =      0.0000
```

Appendix M: Cross-sectional dependence test

Correlation matrix of residuals:

	__e1	__e2	__e3	__e4	__e5	__e6	__e7	__e8
__e1	1.0000							
__e2	-0.3510	1.0000						
__e3	0.6630	-0.3361	1.0000					
__e4	-0.4380	0.4937	-0.4209	1.0000				
__e5	-0.0346	0.3040	-0.2710	0.1050	1.0000			
__e6	-0.2107	0.4962	-0.4900	0.3145	0.7048	1.0000		
__e7	-0.5010	0.3248	-0.5628	0.3782	0.3838	0.6182	1.0000	
__e8	0.7016	-0.0982	0.4979	-0.2340	0.3124	0.1818	0.0059	1.0000

```
Breusch-Pagan LM test of independence: chi2(28) =   126.716, Pr = 0.0000
Based on 25 complete observations over panel units
```

Appendix N: Autocorrelation test

```
. *testing for autocorrelation
. xtserial lognrd logtopen loggdpc loggdpsqr loggdpkm logurbp logenrgy  logkl
logfdapc

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,       7) =     43.980
           Prob > F =      0.0003
```

Appendix O: Corrected Model

```
. xtpcse lognrd logtopen loggdpc loggdpsqr loggdpkm d.logurbp logenrgy  d.logkl
logfdapc

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   id                            Number of obs     =        208
Time variable:    year                          Number of groups  =          8
```

```
Panels:           correlated (balanced)        Obs per group:
Autocorrelation:  no autocorrelation                         min =         26
                                                             avg =         26
                                                             max =         26
Estimated covariances      =        36         R-squared         =     0.5526
Estimated autocorrelations =         0         Wald chi2(8)      =     229.51
Estimated coefficients     =         9         Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             |           Panel-corrected
      lognrd |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    logtopen |   1.605469   .3046656     5.27   0.000     1.008336    2.202603
     loggdpc |   6.994036   1.406589     4.97   0.000     4.237171      9.7509
   loggdpsqr |  -.1349656   .0243568    -5.54   0.000     -.182704   -.0872272
    loggdpkm |   1.779911   .1807159     9.85   0.000     1.425714    2.134107
             |
     logurbp |
         D1. |  -1.180453   .9416213    -1.25   0.210    -3.025997    .6650913
             |
    logenrgy |  -2.052241   .1930672   -10.63   0.000    -2.430645   -1.673836
             |
       logkl |
         D1. |   .0679268   .2403351     0.28   0.777    -.4031213    .5389749
             |
    logfdapc |   .8588156   .2331101     3.68   0.000     .4019281    1.315703
       _cons |  -45.43622   6.195777    -7.33   0.000    -57.57972   -33.29272
```