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The Environmental Impact of Trade Openness, Energy Consumption and Economic Growth in Malawi

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Abstract: **Carbon dioxide (CO_2) is a primary greenhouse gas and has been on an upward trend over the past four decades at global, regional, and country levels. It has significant economic, health, and environmental costs including global warming. In Malawi, CO_2 emissions have grown by 45% over the past four decades from 0.7 million tonnes in 1980 to 1.5 million in 2019. During the same period, exports and imports relative to gross domestic product (GDP) declined, and energy consumption and GDP increased. These trends do not explain the empirical relationship between trade, energy consumption, and GDP on one hand, and CO_2 emissions on the other hand. Therefore, this study was aimed at investigating the impact of trade, energy consumption and GDP on CO_2 emissions. The study used time series data from 1980 to 2020 and employed the Autoregressive Distributed Lag (ARDL) approach to cointegration to establish the short and long-run relationships. The study established that trade has a positive relationship with CO2 emissions both in the short and long run while GDP has a positive relationship with CO2 emissions the in short run only. The study further established that energy consumption has no significant impact on CO2 emissions. It is recommended that policy should focus on promoting the importation of environmentally friendly technologies rather than limiting the country's openness to trade.**

Keywords: **autoregressive distributed lag, carbon dioxide, energy consumption, gross domestic product, Malawi, trade openness.**

1. INTRODUCTION

1.1 Introduction and Background

Environmental pollution has been increasing lately which has become a major global concern. Environmental pollution affects the food, water and air humanity consumes. Approximately 16 million premature deaths occur annually from problems that emanate from the use of natural resources (United Nations Environment Programme, 2017). According to the United Nations Environment Programme, the World Health Organization (WHO) estimated that a quarter of deaths in 2012, about 12.6 million people, were attributed to environmental pollution. The majority of these deaths happened in low- and middle-income countries and mostly affected children. Pollution has significant economic costs that result from loss of human productivity, health care costs and damage to the ecosystem. It is estimated that about US$5.22 trillion was lost due to air pollution in 2013 (United Nations Environment Programme, 2017).

Environmental pollution has risen global temperature over the years which is causing rampant weather issues around the globe. Unpredictability in weather is negatively affecting agriculture and loss of life and property in some cases due to floods and drought. Pollution damages the ozone layer which negatively affects the growth and survival of tree seedlings, and increases the probability of being attacked by diseases, pests and harsh weather. Pollution can also cause acid rain that damages crops and vegetation, increases the acidity of the soil and water thereby damaging arable land and aquatic animals, and can damage property (Kelishadi, 2012)

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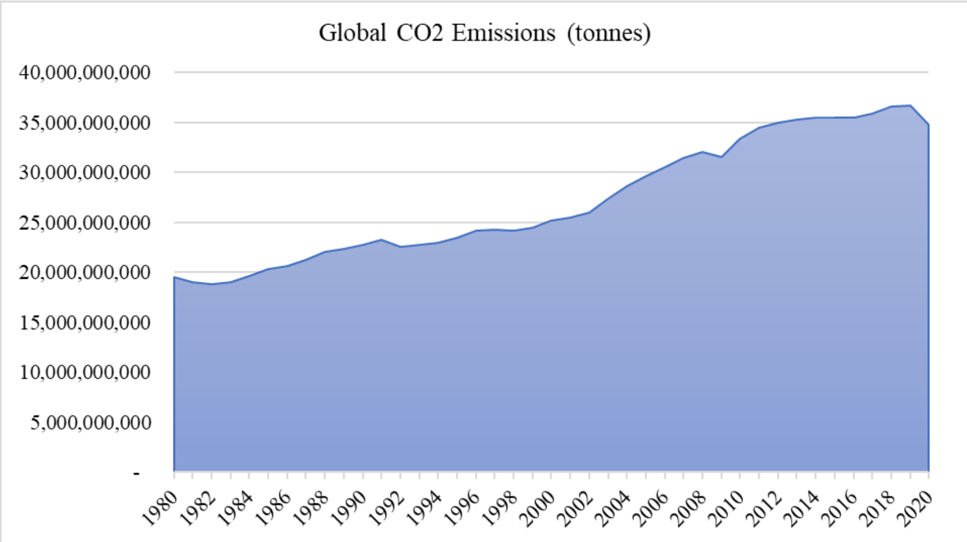
1.1.1 Carbon Dioxide (CO2) Emissions

Environmental pollution may be in form of air, land and water pollution. The main sources of air pollution are fossil fuel emissions from burning coal, transport, industrial furnaces, agriculture, and domestic solid fuel heating. Air pollution involves the emission of gases that pollute the environment including greenhouse gases which causes global warming. Carbon dioxide (CO_2) is the primary greenhouse gas (occupies 65% of the greenhouse gases) and has been on an upward trend over the past four decades at global, regional and country levels (Global Carbon Project, 2021). Figure 1.1 shows the trend in CO_2 emissions at the global level

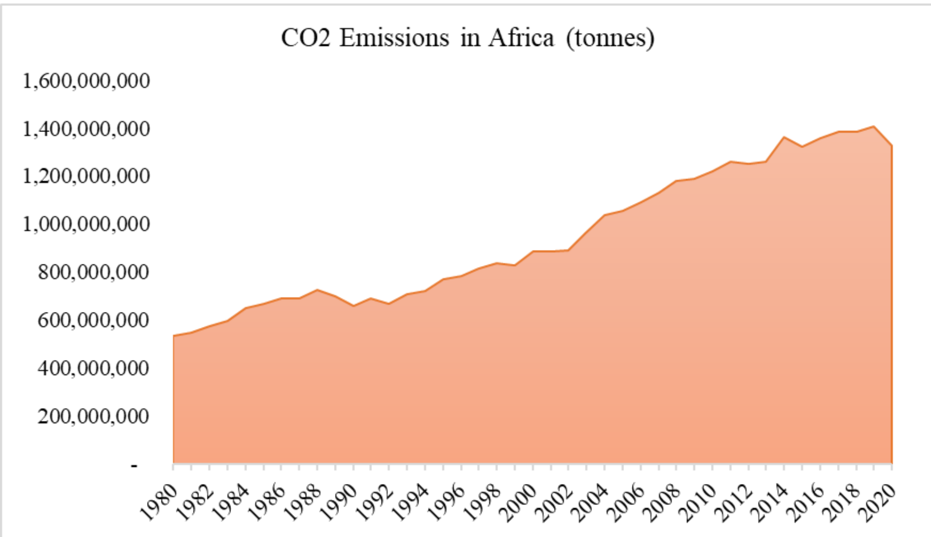


Source: Global Carbon Project (2021)

Figure 1.1: Trend in CO2 emissions at global level

World CO_2 emissions doubled over the past 4 decades, emitting 19 billion tonnes and 37 billion tonnes in 1980 and 2019 respectively (Global Carbon Project, 2021). This rapid increase is attributed to increased manufacturing, industrialization and urbanization across the globe. Meanwhile, there was a global reduction of 5.2% in CO_2 emissions in 2020 compared with 2019 (Liu, et al., 2022). The drop in CO_2 emissions resulted from reduced global economic activity due to the COVID-19 pandemic that caused lockdowns and a significant decrease in transportation activity.

The trend in global CO_2 emissions is similar to the trend in Africa. Figure 1.2 shows the trend from 1980 to 2020.

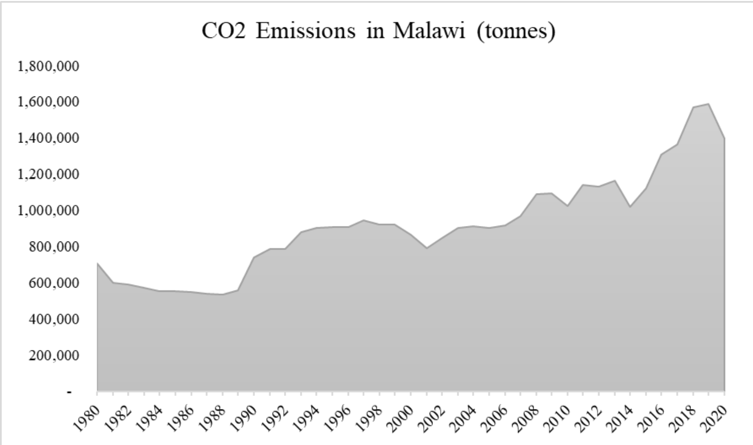


Source: Global Carbon Project (2021)

Figure 1.2: Trend in CO2 emissions in Africa

CO_2 emissions in Africa have increased by 38%, from 536 million tonnes in 1980 to 1.3 billion in 2019. This is below the global increase during the same period which was 53%. Developed countries emit more CO_2 than Africa and this explains the higher growth global level than at the regional level. Africa also registered a decline in CO_2 emissions in 2020 due to the COVID-19 pandemic.

In Malawi, CO_2 emissions have been fluctuating more that the African region average. The country registered a 45% increase in CO_2 emissions over the past four decades from 0.7 million tonnes in 1980 to 1.5 million in 2019. This implies that Malawi has been producing CO_2 at a faster rate than the African region. Figure 1.3 shows the trend in CO2 emissions in Malawi.



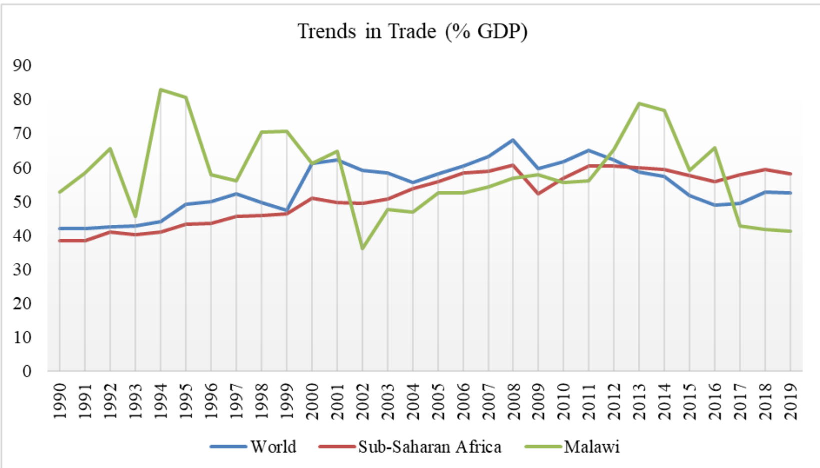
Source: Global Carbon Project (2021)

Figure 1.3: Trend in CO2 emissions in Malawi

Figure 1.3 shows that CO_2 emissions in Malawi declined in 2020 like in most countries due to the COVID-19 pandemic that slowed down economic activities (Global Carbon Project, 2021)

1.1.2 Trade

The relationship between CO_2 emissions and its associated factors including trade and energy use continues to attract attention worldwide in the context of increased globalization and the effects of pollution. Globalization, which can be observed through increased trade and foreign direct investment, can boost technical innovation, total productivity, environmental standards, and economic activities, and enable governments to access foreign efficient technologies to either import or export through international trade (Etokakpan, Adedoyin, Vedat, & Bekun, 2020). In the past decades, the world has registered a remarkable increase in trade which has transformed the world economy. Figure 1.4 shows trends in trade (exports and imports) as a percentage of GDP at global, regional and country levels.



Source: World Bank (2022)

Figure 1.4: Trends in the trade as percentages of GDP

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The figure shows that although trade volumes have been fluctuating, there has been an upward trend in trade at global and regional levels. Trade as a percentage of GDP has increased at the global level from 42% in 1990 to 52% in 2019 (World Bank, 2022). A similar trend can be observed in Sub-Saharan Africa where trade increased from 39% in 1990 to 58% in 2019. This happened during the period when the world has been experiencing an increase in CO_2 emissions. Meanwhile, Malawi's trade as a percentage of GDP has been significantly fluctuating over time. It has declined from 53% in 1990 to 41% in 2019 (World Bank, 2022). During this period, CO_2 emissions increased in the country which raises questions on whether the two variables are correlated or not.

The increase in trade at global and regional levels can be attributed to technological progress as well as a decline in trade barriers through various preferential trade agreements that have made it easier for countries to trade. These preferential trade agreements include the North American Free Trade Agreement (NAFTA), African Continental Free Trade Area, Southern Africa Development Community Free Trade Area and Common Market for East and Southern Africa (COMESA). The value of exported goods and services across the world is about one-fourth of the total world output (Benli, 2019).

The nexus between openness to trade and environmental outcomes is a long-standing debate among scholars. Various theories have been developed that successfully explain the links through which openness to trade may affect environmental quality but empirical verification of these theories has produced mixed outcomes. Among the theoretical explanations of the relationship between these variables are the Pollution Haven Hypothesis (PHH) and the Factor Endowment Hypothesis (FEH). The Pollution Haven Hypothesis suggests that less developed countries will worsen their environmental quality through trade while the Factor Endowment Hypothesis suggests that capital-intensive production processes that are harmful to the environment will relocate to developed countries which will increase environmental pollution (Antweiler, Copeland, & Taylor, 2001). Since Malawi is a less developed country, it is expected to fit into the PHH. Meanwhile, the trends in CO_2 and trade do not support this hypothesis.

1.1.3 Energy Consumption

Energy consumption is one of the crucial factors of production (Sepehrdoust, Javanmard, & Rasuli, 2022). Economic literature predicts that the development of the energy sector, which is one of the main producers of fossil fuels in the country, is associated with increased CO_2 emissions. Biomass is the major energy source in Malawi, contributing 89% while hydro-electricity contributes only 3% to the energy grid (Malawi Government, 2017) and the majority of the population in rural areas do not have access to electricity and rely on wood for energy which has the potential to increase environmental pollution. The total energy that is consumed in the country is not produced within, some is imported from other countries to increase the supply and reduce the unmet need for energy (Gamula, Hui, & Peng, 2013). The use of imported energy products including oil and coal hurts the environment.

1.1.4 Economic Growth

The Environmental Kuznets Hypothesis (EKH) proposes that an increase in per capita income is a crucial factor in redressing environmental problems. It says that early stages of economic growth are associated with environmental degradation but beyond some level of economic growth, the trend reverses itself (Callan & Thomas, 2013). Malawi's economy has been registering low and unstable economic growth during the past ten years. The gross domestic product (GDP) growth rate averaged around 1% per year over between 2011 and 2020 (World Bank, 2022). Figure 1.5 shows the trend in real GDP growth between 1980 and 2020.

Source: World Bank (2022)

Figure 1.5: Real GDP growth in Malawi

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Real GDP has been significantly fluctuating between 1980 and 2019 although there was a marginal upward trend. The average annual growth in this period was 0.7% which is low for a less developed country. The country has been implementing various policies and strategies that are aimed at growing the economy but they have not been successful. One of the strategies that the country is using is the Malawi Growth and Development Strategy (MGDS) III which is a successor of MGDS I and MGDS II. The MGDS III is the medium-term strategy for Malawi's long-term development agenda which runs from 2017 to 2022. Its objective is to move Malawi into a productive, competitive and resilient country by promoting sustainable agriculture, energy, economic growth, industrial and infrastructure development (Malawi Government, 2017). It also aims to address population growth, water, climate change and environmental management challenges.

1.2 Statement of the Problem

The trends in CO_2 emissions and trade in Malawi do not support the Pollution Haven Hypothesis which predicts that an increase in trade will increase environmental pollution in less developed countries. Firms in developed countries will attempt to avoid the cost of stern environmental regulations and high cost of energy by moving to less developed countries where environmental regulations are not severe. On one hand, Malawi's CO_2 emissions have significantly increased over the past forty years (figure 1.3). On the other hand, trade volumes relative to GDP have declined during this period (figure 1.4). No evidence indicates that technological transfer during this period has influenced CO_2 emissions.

The main source of energy in Malawi is biomass which is used by around 89% of the population and hydroelectricity contributes only 3% to the energy grid (Malawi Government, 2017). Between 1980 and 2020, the population of Malawi has been increasing by an average of 2.7% per annum which has increased the demand for energy (World Bank, 2022). During this period, CO_2 emissions grew by an average of 1.1% per annum (Global Carbon Project, 2021). The trends in energy use and CO_2 emissions fit into the theoretical explanation of the relationship between the two variables which predicts that an increase in energy consumption will increase CO_2 emissions. Meanwhile, there is no empirical evidence to support the existence of this relationship in Malawi.

Malawi's economy has been growing at a slow pace over the past four decades. The Environmental Kuznets Hypothesis predicts positive environmental effects at some level of economic growth but the low and unstable trend in economic growth does not support this proposition. It requires further analysis to establish the impact of this growth on the environment.

1.3 Main Objective

The study aims at investigating the impact of trade openness, energy consumption and economic growth on the environment in Malawi from 1980 to 2020.

1.4 Specific Objectives

Specifically, the study will pursue the following specific objectives.

i. To investigate the impact of energy consumption (Kg of oil equivalent per capita) on CO_2 emissions

ii. To find out if the sum of exports and imports relative to GDP influences CO_2 emissions

iii. To understand the impact of real GDP per capita on CO_2 emissions

1.5 Research Questions

The study will answer questions about the relationship between CO_2 emissions and the use of energy and the country's openness to trade. The following research questions will be of particular interest in the study.

ii. Does energy consumption increase CO_2 emissions in Malawi?

iii. What is the impact of the country's exports and imports on CO_2 emissions?

iv. Does an increase in real GDP reduces CO_2 emissions?

1.6 Research Hypotheses

The study will test the following hypotheses.

i. Energy consumption has an increasing effect on CO_2 emissions

ii. Exports and imports have an increasing effect on CO_2 emissions

iii. Real GDP reduces CO_2 emissions

1.7 Significance of the Study

Understanding the impact of trade and energy consumption on the environment and the direction of causality among the variables has significant policy implications. For instance, a positive causality running from energy consumption to environmental pollution would suggest the development of green energy technologies as compared to the current biomass to conserve the environment. In a situation where trade contributes to environmental pollution, regulation would be crucial to promote the importation of environmentally friendly energy sources and discourage the use of non-renewable energy in the country. There would also be a need to adopt new production strategies in favor of lower energy consumption and less CO_2 emissions into the environment. The study will also provide evidence on whether growing the economy will help to reduce environmental pollution.

The study will gather evidence for theories on the relationship between trade, energy use, economic growth and environmental pollution and deduce whether the theoretical relationships hold in Malawi. The study will also contribute to developing knowledge in the environmental and energy sector.

2. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Introduction

This chapter will dwell on the theories of trade openness that influence environmental pollution through the scale effect, composition effect and technology effect. According to the scale effect, an increase in trade increases production in a country which increases energy consumption (Antweiler, Copeland, & Taylor, 2001). Increased energy consumption increases the emission of carbon dioxide resulting in environmental pollution. The composition effect affects the environment by changing the production composition based on their comparative advantage (Jun, Mahmood, & Zakaria, 2020).

2.1.2 The Factor Endowment Hypothesis (FEH)

Swedish economist, Bertil Ohlin, developed the Factor Endowment Hypothesis (FEH) in 1933 based on the work of another Swedish economist, Eli Heckscher (Tang & Dou, 2021). The FEH argues that environmental pollution decreases if trade increases the demand for labor-intensive goods since the production of labor-intensive goods does not increase the emission of affluence. If it increases demand for capital-intensive goods, pollution will increase because capital-intensive goods increase emissions. The FEH implies that trade will increase pollution in developed countries as they are capital-intensive and decrease pollution in less developed countries as they are labor intensive. It assumes that there is free trade among countries. The hypothesis predicts that developed countries will benefit in terms of environmental quality from trade while developing countries will lose (Temurshoev, 2006). However, the hypothesis is criticized because it assumes free trade. In the real economy, there are always trade barriers.

2.1.3 Pollution Heaven Hypothesis (PHH)

In 1979, Ingo Walter and Judith Ugelow proposed the Pollution Heaven Hypothesis (PHH) to explain the transfer of pollution among countries (Tang & Dou, 2021). According to this hypothesis, demand for environmental quality is increasing in developed countries and have internalized negative externalities through strict legal regulations (Akin, 2014). These regulations increase the cost of production for firms that cause environmental pollution and they tend to transfer their production to less developed countries that usually do not have strict environmental regulations. The transfer of production to less developed countries leads to increased pollution in the recipient countries such that the more open the country is to trade, the more it imports pollution. According to the PHH, the effects of trade on the environment both locally and globally depend on the distribution of comparative advantages across countries and this comparative advantage is determined jointly by differences in pollution policy and among other influences by differences in factor endowments (Temurshoev, 2006). This hypothesis is criticized for its emphasis on comparative advantage based on pollution policy. The hypothesis assumes no barriers to entry which does not always hold as some countries with no strict pollution regulations have strict barriers to entry.

2.1.4 Environmental Kuznets Curve

Simon Kuznets developed an inverted U-curve which described the relationship between per capita income and income inequality. The curve was modified to represent the work done by Grossman and Krueger on the North Atlantic Free Trade Area (NAFTA) and its effects on the environment and was named the Environmental Kuznets Curve (EKC) (Tang & Dou, 2021). The EKC suggests that environmental quality changes with respect to income level. It states that environmental quality in terms of pollution declines steadily with an increase in income. After some level of income, the environmental quality increases with income (Antweiler, Copeland, & Taylor, 2001).

2.1.5 Technique Effect

Trade can affect the environment by spreading environment-friendly and energy-efficient technology between countries which will result in a reduction in environmental pollution. An increase in trade openness can accelerate the capital mobility for new technologies through technology transfer and increase environment-friendly technologies in a country (Jun, Mahmood, & Zakaria, 2020). The use of these technologies can decrease environmental pollution in the long term. This is the technique effect of trade on the environment. It is prominent in developed countries where the scale and composition effects are dominated by the technique effect (Jun, Mahmood, & Zakaria, 2020). Consequently, the net effect of trade in developed countries is beneficial to the environment unlike in less developed countries where the technique effect is dominated by the scale and composition effects.

2.2 Empirical Review

Several studies have investigated the relationships between environmental pollution, trade and energy use in various countries and mixed and controversial outcomes have come out of these studies. While exploring the relationship between trade and environmental pollution, some studies have established that trade is beneficial for the environment [He (2019); Antweiler, Copeland, & Taylor (2001); Akin (2014)] while others have shown that it is bad for the environment [Jun, Mahmood, & Zakaria (2020); Chebbi, Olareaga, & Zitouna (2011); Benli (2019)]. Various studies have established that energy consumption increases environmental pollution [Kahouli, Miled, & Aloui (2022); Akin (2014); Dogan & Turkekul (2016)] while other studies have shown that energy consumption may help to improve the environment (Magazzino & Cerulli, 2019). These mixed outcomes could be attributed to various factors such as different assumptions, econometric methods used, pollution variables, period of analysis, types of data used, single versus multi-country analysis country-specific context, etc.

Jun, Mahmood, & Zakaria (2020) investigated the impact of trade openness on pollution using Wavelet-coherence analysis, phase-difference technique and Breitung and Candelon's (2006) causality test. Having employed time series data from 1982 to 2016 for China, they established that trade increased pollution through carbon dioxide emission in the short, medium and long run. The results suggested the existence of the Pollution Haven Hypothesis in China.

Chebbi, Olareaga, & Zitouna (2011) carried out a similar study by investigating the impact of trade on carbon dioxide (CO_2) emissions in Tunisia using a VAR model covering the period of 1961-2005. The study established a direct positive relationship between trade and CO_2 emissions and an indirect negative relationship between the two variables. Trade directly affects CO_2 emissions by reallocating resources among more or less polluting sectors in both the short and long term. It indirectly affects CO_2 emissions by accelerating economic growth and increasing income levels.

Jan (2020) analyzed the impact of trade openness, energy consumption, gross domestic product (GDP) and urbanization on CO_2 emissions by using panel data from 50 Belt and Road countries in Asia, Europe and Africa from 1992 to 2014. Using Pooled OLS, Fixed effect, Random effect and GLS models, the study elicited that trade has a negative and significant impact on CO_2 emissions, implying that it mitigates CO_2 emissions. GDP was found to have a direct and significant impact on CO_2 emissions which implies that GDP per capita increases CO_2 emissions. The study further established that energy consumption contributed to CO_2 emissions significantly which signifies that fossil fuel energy dominated production activities in the countries under the study and this is also true for urbanization.

According to Benli (2019), trade openness and economic growth have a positive and significant effect on CO_2 emissions in developing countries. This was revealed by a study he conducted on the effect of trade growth and per capita income growth on long-run CO_2 emissions per capita using data on a sample of 79 developing countries from 1960-2017. The study used

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three different specifications which are standard panel ARDL, CS-ARDL and CS-DL to eliminate the problems related to panel data models.

Leitao & Shahbaz (2013) employed a GMM system estimator for dynamic panel data using data for selected 18 countries from 1990-2010 to investigate the existence of the Environmental Kuznets Curve (EKC) for CO_2 emissions and its relationship with economic growth, energy consumption and globalization. The study found a positive relationship between CO_2 emissions and energy consumption. The results show that energy consumption is harmful to the environment. Urbanization was found to have the opposite effect as it improves the environment by lowering CO_2 emissions.

A study by Leitao N. C. (2021) studied the relationship between trade intensity, energy consumption and income per capita on one hand, and CO_2 emissions on the other hand from 1970–2016 for the Portuguese economy. It employed the Autoregressive Distributed Lag (ARDL) model, quantile regression, and cointegration models including fully modified ordinary least squares (FMOLS), canonical cointegration regression, and dynamic ordinary least squares (DOLS) as an econometric analysis approach (Leitao N. C., 2021). It was found that trade intensity is beneficial to the environment as it reduces CO_2 emissions while energy consumption increases CO_2 emissions.

Akin (2014) assessed the impact of energy use, trade and economic growth on CO_2 emissions using panel cointegration techniques of Fully Modified Ordinary Least Squares (FMOLS) and DOLs focusing on 85 countries from 1990 to 2011. In the short run, energy consumption, trade openness and economic growth had a positive relationship with CO_2 emissions but trade openness had a negative relationship with CO_2 emissions in the long run. CO_2 emissions were found to have feedback effects on trade and economic growth in the short run.

Zakari, Adedoyin, & Bekun (2019) investigated the impact of energy use and economic policy on the environment using the pooled mean group-autoregressive distributed lag methodology (PMG-ARDL) and Dumitrescu and Hurlin causality test on 22 Organization for Economic Co-operation and Development (OECD) countries between 1985 and 2017. Energy use and uncertainties in economic policy had a positive relationship with CO_2 emissions both in the short and long run.

A study in China by Qu, Xu, Qu, Yan, & Wang (2017) tested the existence of long-run and short-run relationships between energy consumption, environmental pollution and public health using the Autoregressive Distributed Lag (ARDL) approach for the period of 1985-2014. The study found that environmental pollution and energy consumption have a significant positive relationship both in the long-run and short-run which indicates that environmental pollution worsens due to the use of fossil energy over time.

Kahouli, Miled, & Aloui (2022) explored the empirical relationship between energy consumption, environmental degradation, trade, industrialization, urbanization, and economic growth in Saudi Arabia for a time series of data spanning from 1971 to 2019. This was done using Autoregressive Distributed Lag (ARDL) and the Vector Error Correction Model approaches to cointegration. The results showed that energy consumption has a significant contribution to environmental pollution and environmental pollution granger causes energy consumption.

One study in China estimated the scale effect, technique effect, and trade-induced composition effects of trade on the environment using panel regression of the provincial level data from 1997 to 2008. The results showed that trade has significant positive effects on the environment and that the effects differ from pollutant to pollutant (He, 2019).

In 2013, Kanjilal and Ghosh conducted a study on the Environmental Kuznets's curve for India using time series data from 1971 to 2008 (Kanjilal & Ghosh, 2013). To investigate the relationship between economic growth and the environment, the study employed the Autoregressive Distributed Lag (ARDL) model. It was established that CO_2 emissions are highly elastic with respect to real per capita GDP and energy use in India.

3. METHODOLOGY

3.1 Data Sources and Measurements of Variables

The study will use time series data ranging from 1980 to 2020 which is a timeframe in which data for most of the variables of interest is available. This data will be gathered from the 2022 World Bank Development Indicators (WDI) for Malawi, Global Carbon Project (GCP) and British Petroleum (BP). The variables that will be used are carbon dioxide emissions, trade openness, energy consumption and GDP as defined below in Table 3.1.

Table 3.1: Definitions of variables

Variable	Acronym	Measure Source	Period
Carbon dioxide emission	CO_2	Metric tons per capita	GCP 1980 - 2020
Trade openness	TO	The sum of imports and exports relative to GDP	WDI 1980 - 2020
Energy consumption	EC	Kg of oil equivalent per capita	BP 1980 - 2020
Economic growth	GDP	GDP per capita in constant 2015 USD	WDI 1980 - 2020

CO_2 emissions were used to capture environmental pollution as it is a primary greenhouse gas. Trade openness was used to measure the volume of international trade between Malawi and other countries by considering both imports and experts.

3.2 Model Specification

The study will adopt the model used by Leitao (2021) hence the model is empirically determined. Leitao (2021) used the model to study the role of trade in carbon dioxide emissions in Portugal and specified his model by presenting carbon dioxide emissions as a function of trade openness, energy consumption and GDP. Equation 1 shows the econometric specification of the model.

$$CO_2 = f(TO, EC, GDP) \qquad 3.1$$

The variables will be transformed using logarithms and this study adopted the model specification without any modifications.

3.3 Cointegration Technique

Literature has various techniques that are used to test for the cointegration of variables. Some of these techniques are Engle-Granger, Phillips-Ouliaris, Johansen and Autoregressive Distributed Lag (ARDL). The empirical cointegration technique will be determined by the treatment of the time series.

3.4 Granger Causality

To test for the feedback effects of carbon dioxide emissions on trade and energy consumption, the Granger Causality test will be conducted. According to this test, if two variables are individually nonstationary and integrated of order one (I (1)) and are found to be cointegrated then there must exist a unidirectional or bidirectional causality between them.

3.5 Diagnostic Tests

To ensure the reliability of results from the model, various diagnostic tests will be carried out. This will be done to make sure that the model is satisfying various time series and econometrics assumptions which include stationarity of data, heteroscedasticity, no serial correlation and no omitted variables or model specification errors.

3.5.1 Stationarity Tests

The study will use the Augmented Dickey-Fuller (ADF) test to establish whether the data is stationarity or not and its order of integration. Testing for stationarity is important to ensure that the time series is independent of the point in time where it is observed. Under the ADF test, the null hypothesis is that there is a unit root in the time series sample. If the P-value of the ADF is statistically significant at a 5% significance level ($P<0.05$), the null hypothesis will be rejected in favor of the alternative hypothesis of no unit being present in the time series (Gujarati & Porter, 2009). The level of integration of the time series will be selected using Akaike Information Criterion (AIC)

3.5.2 Test for Serial Correlation

Serial correlation is the relationship between a given variable and a lagged version of itself over various time intervals (Gujarati & Porter, 2009). A time series that is serially correlated may not be random and therefore some econometric analysis may not be applied to such time series. The study will use the Breusch-Godfrey LM test to test for serial correlation.

The null hypothesis is that there is no serial correlation of any order up to a certain level (Greene, 2011). When the P-value of the Breusch-Godfrey LM test is statistically insignificant, it implies that there is no serial correlation problem.

3.5.3 Test for Heteroscedasticity

The classical linear regression model assumes that the variances of the error terms are homoscedastic. When the variances of the disturbance terms are not homoscedastic, the estimated coefficients are inefficient although they are consistent (Gujarati & Porter, 2009). In this study, the variances of the disturbance terms will be tested for homoscedasticity using the Breusch-Pagan heteroscedasticity test. The null hypothesis of the test is that the error variances are all equal (homoscedastic). When the P-value of the test is statistically insignificant (P>0.05), it implies that the data is homoscedastic (Gujarati & Porter, 2009).

3.5.4 Test for Omitted Variables

This study will use Ramsey RESET to test for the presence of omitted variables, incorrect functional form and specification errors. The test will be conducted against the null hypothesis of no omitted variables in the model. When the P>0.05, it implies that we cannot reject the null hypothesis of no omitted variables (Harris & Sollis, 2003).

3.5.5 Normality Test

Normality of data is a prerequisite for many statistical tests because normal data is an underlying assumption in parametric testing including Classical Linear Regression Models (Gujarati & Porter, 2009). The normality test will be conducted using the Jarque Bera test. Under this test, the null hypothesis states that the population is normally distributed. When P>0.05, it implies that the sample is from a normally distributed population.

3.5.6 Test for Multicollinearity

The Classical Linear Regression Model (CLRM) also assumes that there is no linear relationship among all or some of the explanatory variables (multicollinearity). When there is a perfect or near-perfect linear relationship among the explanatory variables, the regression coefficients are indeterminate and the standard errors are infinite (Gujarati & Porter, 2009). However, multicollinearity is not a serious problem since even in the presence of multicollinearity the OLS estimators are still BLUE. To test for the presence of multicollinearity, the study will use the Variance Inflation Factor (VIF). If the VIF of the time series is less than 10.0, it means that there is no perfect multicollinearity problem.

3.6 Apriori Expectations

Based on the Pollution Haven Hypothesis, trade is expected to worsen environmental pollution in Malawi. Since Malawi is a less developed country, this should happen through the scale effect as trade increases production which increases energy consumption. Increased energy consumption is expected to increase the emission of carbon dioxide resulting in environmental pollution. Real GDP growth is also expected to reduce pollution based on the Environmental Kuznets Curve.

4. DATA ANALYSIS AND RESULTS

4.1 Stationarity Test

Data analysis was conducted in E-Views. The Augmented Dickey-Fuller (ADF) test was used to test for the stationarity of the time series and determine the order of integration of the variables. Table 4.1 below shows the results of the test.

Table 4.1: ADF unit root test

	Levels		First Difference		
Variable	t-Statistic	P-value	t-Statistic	P-value	Order of integration
lnCO2	-3.8040	0.0165**			I (0)
lnTO	-3.2288	0.0255**			I (0)
lnEC	-1.7729	0.6990	-6.9655	0.0000*	I (1)
lnGDP	-2.6807	0.2496	-7.8603	0.0000*	I (1)

Note: H_0: the series is non-stationary. *, ** and *** means rejection of null hypothesis at 1%, 5% and 10% significance level respectively

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When testing for stationarity of the time series, the number of lags were automatically selected using Schwarz Information Criterion. The visual inspection of all the variables showed no trend in $lnCO_2$ and lnTO, and trends in lnEC and lnGDP, therefore, the ADF tests included trend terms for lnEC and lnGDP only. Meanwhile, the test included an intercept for all the variables. The ADF test rejects the hypotheses that $lnCO_2$ and lnTO are not stationary in levels at a 5 percent significant level as their Mckinnon P-values were statistically significant implying that the variables are stationary in levels and integrated at order zero [I(0)]. Meanwhile, lnEC and lnGDP were found to be nonstationary in levels and stationary at first difference [I(1)] at a 5% significance level.

The findings warrant the use of the Autoregressive Distributed Lag (ARDL) bounds test for cointegration because no variable is integrated of orders two and above, and the variables are integrated of different orders [I (0) and I (1)]. Autoregressive Distributed Lag (ARDL) has been a popular approach for testing the existence of cointegration. This test is based on work by Pesaran & Shin (1999) and Pesaran, Shin, & Smith (2001). The ARDL approach has several advantages over other cointegration techniques. According to Etokakpan, Adedoyin, Vedat, & Bekun (2020), the method is based on a single ARDL equation unlike Johansen which relies on a vector autoregressive process, therefore ARDL reduces the number of parameters to be estimated. ARDL technique is also advantageous because it does not require the variables to be integrated of the same order [I(0) or I(1)] provided none of the variables is I(2) or above. ARDL modeling is a better method because it allows for a sufficient number of lags to capture the data-generating process (Khalil & Dombrecht, 2011). Furthermore, the ARDL approach can address endogeneity problems. In this method, variables are assumed to be endogenous and this enables the estimation of both short-run and long-run parameters to be done simultaneously (Simwaka, Munthali, Chiumia, & Kabango, 2012). Lastly, the technique is suitable for small sample size estimation (Etokakpan, Adedoyin, Vedat, & Bekun, 2020). The sample size is small; therefore, the study has limited the number of variables to be included in the model in order not to reduce the degrees of freedom.

4.2 Estimation Results

4.2.1 Diagnostics Tests

The first step in the estimation of the Autoregressive Distributed Lag (ARDL) model was to decide the optimal lag length for each variable. Using Akaike Information Criterion (AIC), E-views automatically calculated the optimum combination of lags and found ARDL (4,3,0,1). The Breusch-Godfrey Lagrange Multiplier test did not reject the null hypothesis of no serial correlation in the chosen model up to lag two and the P-value was 0.3260, signifying no serial correlation problem. Additionally, the model was tested for heteroscedasticity, model specification and normality. Table 4.2 shows the results of these tests.

Table 4.2: Tests for heteroscedasticity, omitted variables and normality

Test	Null hypothesis	F-statistic	P-value
Breusch-Pagan Godfrey	Homoskedasticity	0.7035	0.7238
Ramsey RESET	The model has no omitted variables	0.1664	0.6869
Jarque Bera	Model is normally distributed	1.5043	0.4715

Note: H0: the series is non stationary. *, ** and *** means rejection of null hypothesis at 1%, 5% and 10% significance levels respectively.

The P-value of the Breusch-Pagan Godfrey test is not statistically significant which means that the null hypothesis of constant variance cannot be rejected. The P-value of the Ramsey RESET test is not statistically significant implying that the null hypothesis of no omitted variables in the model cannot be rejected. Lastly, the F-Statistic of the Jarque Bera test is not statistically significant. Therefore, we cannot reject the null hypothesis and conclude that the model is normally distributed. The VIF tests produced the VIFs of 5.8, 4.7 and 7.2 for lnTO, lnEC and lnGDP respectively. This shows that there is no perfect multicollinearity problem.

4.2.2 ARDL (4,3,0,1)

The diagnostics tests satisfied the conditions that are needed to estimate an ARDL model and tests for cointegration. Table 4.3 below shows the results of the ARDL (4,3,0,1) estimation.

Table 4.3: ARDL (4,3,0,1) estimation

Variable	Coefficient	t-Statistic	P-value
$lnCO2_{t-1}$	0.7296	4.1888	0.0003*
$lnCO2_{t-2}$	0.1054	0.4465	0.6591
$lnCO2_{t-3}$	-0.1415	-0.6335	0.5321
$lnCO2_{t-4}$	-0.2190	-1.3794	0.1800
lnTO	0.0118	0.1966	0.8457
$lnTO_{t-1}$	-0.1634	-2.1905	0.0380**
$lnTO_{t-2}$	0.1995	2.7178	0.0118*
$lnTO_{t-3}$	0.1481	2.0550	0.0505**
lnEC	-0.0275	-0.4330	0.6688
lnGDP	0.6486	2.4493	0.0217**
$lnGDP_{t-1}$	-0.7981	-3.1207	0.0045*
C	-0.0250	-0.0526	0.9585
R-Squared=	0.7957	Adj R-Squared=	0.7059
F-statistic=	8.8539	Prob (F-statistic)=	0.0000

Note: *, ** and *** means statistical significance at 1%, 5% and 10% significance level respectively

The adjusted R-square was found to be 0.7059 meaning that about 70% percent of the variations in $lnCO_2$ were being explained by the variables in the model. The results also show that the probability of the F-statistic of the model was 0.0000 which means the model is significant at a 5% significance level.

4.2.3 Bounds Test to Cointegration

The study employed an ARDL bounds test for cointegration to determine if the variables in the model are cointegrated. This was done by testing for the joint significance of the lagged variables in the ARDL model using an F-test/Wald test. Table 4.4 below shows the results of the F-test.

Table 4.4: Cointegration results (F-test)

F-Statistic	**5% Critical values**	
	I (0)	I (1)
4.83	2.79	3.67

Table 5.4 above shows the F-statistic from the F-test and the critical lower and upper bounds at a 5 percent significance level obtained from table C1.iii in Pesaran et al (2001). From the table, it can be seen that the F-statistic (4.83) is above the critical upper bound (3.67) which implies that the null hypothesis of no cointegration was rejected. In other ways, the results mean that there is cointegration among the variables in the model.

4.2.4 Long Run Relationship

The next step in the analysis of the long-run relationship was the computation of the long-run multipliers between $lnCO_2$ and each of the explanatory variables. Table 4.5 below shows the long run effects of the explanatory variables.

Table 4.5: Long-run effects

Variable	Coefficient	P-value
lnTO	0.3732	0.0230**
lnEC	-0.0524	0.6562
lnGDP	-0.2845	0.2729

Note: *, ** and *** means statistical significance at 1%, 5% and 10% significance level respectively

The long-run effects show that lnEC and lnGDP do not affect lnCO2 as their coefficients are not statistically significant. Energy consumption and real GDP have a negative relationship with CO_2 emissions but the relationship is not significant. lnTO has a significant positive impact on $lnCO_2$ at 5% significance level (P = 0.023). The estimated long-run equation means that a 1% increase in trade will increase CO_2 emissions by 0.37%. This outcome implies that trade increases environmental pollution in the country.

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4.2.5 Short Run Dynamics

The existence of a cointegration relationship among the variables warranted the estimation of an Error Correction Model (ECM). This was done to analyze the short-run dynamics of the variables in the model. The estimation of the ECM was also based on AIC. The ECM model was well specified (Ramsey RESET p-value = 0.6869), statistically significant at 5% significance level, there was no heteroscedasticity (Breusch-Pagan p-value = 0.7238), no multicollinearity and there was no serial correlation.

Table 4.6: Short-run effects

Variable	Coefficient	t-Statistic	P-value
$\Delta lnCO2_{t-1}$	0.2551	1.7371	0.0947***
$\Delta lnCO2_{t-2}$	0.3606	2.3609	0.0263**
$\Delta lnCO2_{t-3}$	0.2190	1.6202	0.1177
$\Delta lnTO$	0.0118	0.2259	0.8231
$\Delta lnTO_{t-1}$	-0.3478	-5.3255	0.0000*
$\Delta lnTO_{t-2}$	-0.1482	-2.4604	0.0211**
$\Delta lnGDP$	0.6486	2.8946	0.0078*
ECT	-0.5255	-5.2940	0.0000*

Note: *, ** and *** means statistical significance at 1%, 5% and 10% significance level respectively.

The error correction term (ECT) had the expected negative sign (-0.5255) and was statistically significant at 5% significance level (p-value = 0.0000). This confirms the validity of the bounds test for cointegration. The coefficient of the ECT suggests that approximately 52% of disequilibria from the previous year's shock converge back to long-run equilibrium in the current year. The short-run effects show that the first 2 lagged values of CO_2 statistically affect the current CO_2 emissions and the effect is positive. The first difference of lnTO does not affect $lnCO_2$ in the short term but the first 2 lagged values of lnTO in the first difference negatively affect $lnCO_2$. This result indicates that, unlike in the long term when trade positively affects CO_2 emissions, trade has a negative effect on CO_2 emissions in the short term. Lastly, the first difference of lnGDP statistically influences CO_2 emissions in the short run although its impact in the long-run is insignificant.

4.3 Stability Test

The long run coefficients were tested for structural stability. The structural stability test was conducted using the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of recursive residuals squared (CUSUMQ) (Simwaka, Munthali, Chiumia, & Kabango, 2012). Both the CUSUM and CUSUMQ lied within the 5 percent critical bounds as can be seen in figures 4.1 and 4.2 below.

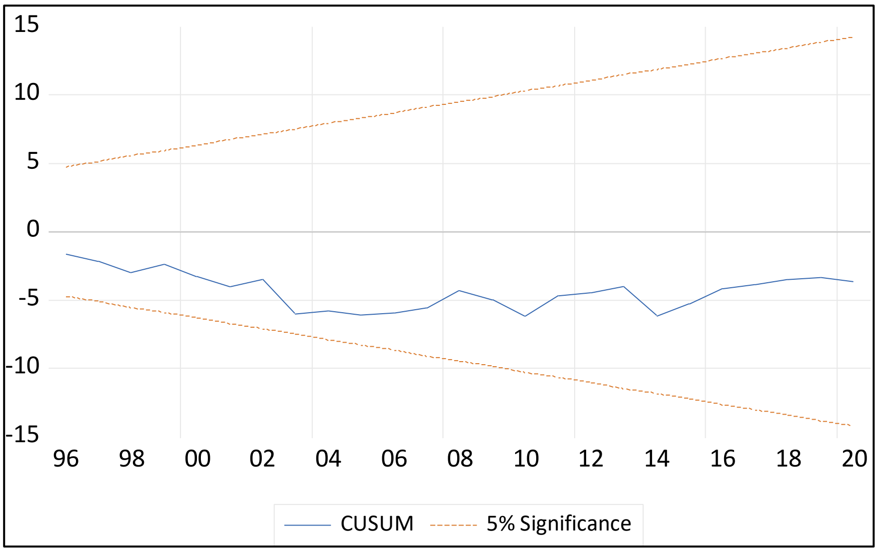

Figure 4.1: Cumulative Sum of Recursive Residuals (CUSUM)

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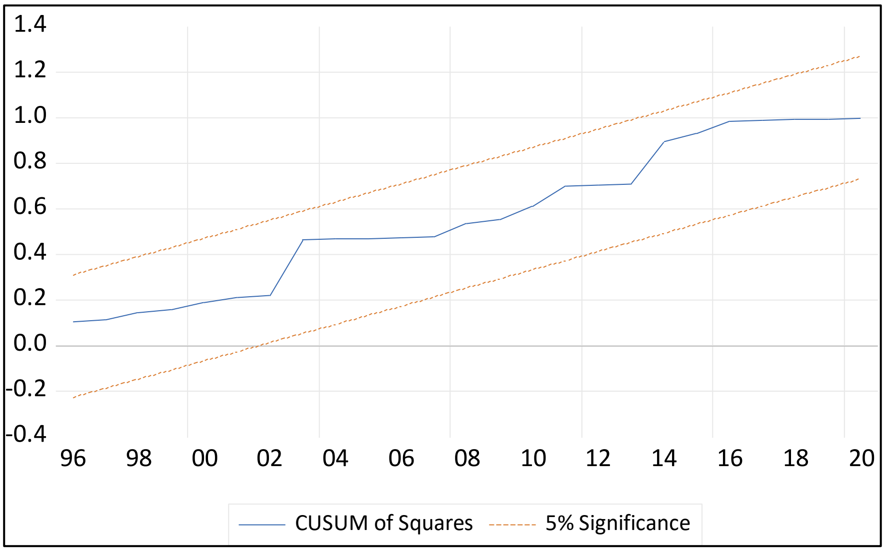

Figure 4.2: Cumulative Sum of Recursive Residuals Squared (CUSUMQ)

Since both CUSUM and CUSUMQ fall within the critical bounds, this implies that the estimated ARDL model was stable.

4.4 Granger Causality Test

The study was also aimed at checking the existence of a bi-causal relationship between the explanatory variables and the dependent variable. This was done by using the Granger causality test. Since the four variables were found to be integrated of different orders as can be seen in table 4.1, it means the VAR model on which the granger causality test was based is wrong. This is the case because the VAR model is used when the variables are integrated in the same order. This means the results of the granger causality test using the four variables are invalid. Therefore, another granger causality test was conducted using $\ln CO_2$ and lnTO because they are integrated of the same order, I (0). This test was credible compared to the first one because all the assumptions of the VAR model were satisfied. Table 4.7 below presents the results of the second granger causality test.

Table 4.7: Pairwise Granger causality test results

Null hypothesis	F-statistic	Probability
lnCO2 does not granger cause lnTO	1.5394	0.2291
lnTO does not granger cause lnCO2	2.2736	0.0989***

Note: *, ** and *** means statistical significance at 1%, 5% and 10% significance level respectively

From the table above, the hull hypothesis that $\ln CO_2$ does not granger cause lnTO was not rejected at the 5% significance level. This implies that $\ln CO_2$ does not granger cause $\ln CO_2$. Meanwhile, the null hypothesis that lnTO does not granger cause $\ln CO_2$ was rejected at 10% significance level implying that lnTO granger cause $\ln CO_2$, reinforcing the outcome of the ARDL model.

5. DISCUSSION AND RECOMMENDATION

5.1 Discussion

The major objective of the study was to assess the causal relationship between trade openness, energy consumption and economic growth on one hand and environmental pollution on the other hand. Using the Autoregressive distributed Lag (ARDL) bounds test approach, the study established that only trade openness has a significant short-run and long-run relationship with carbon dioxide emissions, a measure of environmental pollution.

International trade negatively affects the environment by increasing the emission of carbon dioxide both in the long and short run. The finding aligns with the studies that were conducted in China (Jun, Mahmood, & Zakaria, 2020), Tunisia (Chebbi, Olareaga, & Zitouna, 2011), and some most developing countries (Benli, 2019). The finding confirms the Pollution

Haven Hypothesis and the apriori expectation that trade increases CO_2 emission. Although the trends in trade and CO_2 emissions do not align, the effect of trade on CO_2 emission can be attributed to the technique effect of trade on pollution. Meanwhile, the result contradicts the findings of the study by Leitao N. C. (2021) on the Portuguese economy, Dogan & Turkekul (2016) in the USA, and Antweiler, Copeland, & Taylor (2001) which established that trade is beneficial to the environment as it reduced carbon dioxide emissions. The findings of this study imply that increasing the country's openness to trade will worsen the quality of the environment, ceteris paribas. Meanwhile, carbon dioxide emissions do not have any impact on trade.

The study established that energy use does not have significant effects on carbon dioxide emissions in the short and long run. The study fails to dispute or confirm the previous studies that found a positive relationship [(Kanjilal & Ghosh, 2013), (Dogan & Turkekul, 2016), (Udemba, Magazzino, & Bekun, 2020), (Qu, Xu, Qu, Yan, & Wang, 2017)] or a negative relationship between the two variables (Magazzino & Cerulli, 2019).

Real GDP growth increases carbon dioxide emissions in the short run and not in the long run. This confirms the findings from various studies that established a positive relationship between GDP and carbon dioxide emissions such as Akin (2014), Jan (2020), Benli (2019), and Bernard & Mandal (2016). The fluctuations in the real GDP that Malawi has been experiencing may partially explain the fluctuations in carbon dioxide emissions.

The results show that if the country's economy grows steadily, in the long run this will not contribute to increased carbon dioxide emissions.

5.2 Study Limitations

Environmental pollution is a broad term that consists of water, air and land pollution and each type of pollution has various measures. The study was limited in the choice of the environmental pollution variables due to lack of availability of data. It would be interesting to study the relationship between the explanatory variables and the other forms of pollution such as water and land pollution.

5.3 Policy Recommendations

The study suggests that limiting the country's openness to trade would help to improve the environment. However, this will hurt the economy as trade is beneficial to the country and the global economy. Trade is fundamental to ending global poverty and countries that are open to trade tend to grow faster, innovate, improve productivity and provide higher income and more opportunities to their people (World Bank, 2018). It also benefits lower-income households by offering them more affordable goods and services. Considering these benefits, Malawi needs to implement regulations that prevent pollutants or technologies that damage the environment from entering the country instead of reducing international trade. The country should put in place incentives that will motivate firms to import green technologies that do not damage the environment in the processing and manufacturing of goods. With such measures, an increase in trade and economic growth would not negatively affect the environment.

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