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FOREIGN DIRECT INVESTMENT, CLEAN DEVELOPMENT MECHANISM, AND ENVIRONMENTAL MANAGEMENT: A CASE OF SUB-SAHARAN AFRICA

Thesis for the degree of Doctor of Science (Economics and Business Administration) to be presented with due permission for the public examination and criticism in the Auditorium 1382 at Lappeenranta University of Technology, Finland on the 29th of May, 2015, at 12 pm.

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ABSTRACT

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Foreign Direct Investment, Clean Development Mechanism, and Environmental Management: A case of Sub-Saharan Africa

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This doctoral dissertation explores the contribution of environmental management practices, the so-called clean development mechanism (CDM) projects, and foreign direct investment (FDI) in achieving sustainable development in developing countries, particularly in Sub-Saharan Africa. Because the climate change caused by greenhouse gas emissions is one of the most serious global environmental challenges, the main focus is on the causal links between carbon dioxide (CO_2) emissions, energy consumption, and economic development in Sub-Saharan Africa. In addition, the dissertation investigates the factors that have affected the distribution of CDM projects in developing countries and the relationships between FDI and other macroeconomic variables of interest.

The main contribution of the dissertation is empirical. One of the publications uses cross-sectional data and Tobit and Poisson regressions. Three of the studies use time-series data and vector autoregressive and vector error correction models, while two publications use panel data and panel data estimation methods. One of the publications uses thus both time-series and panel data. The concept of Granger causality is utilized in four of the publications.

The results indicate that there are significant differences in the Granger causality relationships between CO_2 emissions, energy consumption, economic growth, and FDI in different countries. It appears also that the causality relationships change over time. Furthermore, the results support the environmental Kuznets curve hypothesis but only for some of the countries. As to CDM activities, past emission levels, institutional quality, and the size of the host country appear to be among the significant determinants of the distribution of CDM projects. FDI and exports are also found to be significant determinants of economic growth.

The doctoral dissertation consists of five research papers employing different empirical methodologies.

Keywords: Sustainable development, environmental management, clean development mechanism, FDI, Granger causality, Sub-Saharan Africa

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Pendo Teresia Kivyiro

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To my dear Husband David Koloseni, and my beloved Parents Oswald Kivyiro and Winfrida Mvugusi

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PART II: PUBLICATIONS:

[1] Kivyiro, P., and Arminen, H., 2014. Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa**.** Energy 74, 595-606

[2] Kivyiro, P., and Arminen, H., 2014. Carbon dioxide emissions, energy consumption and economic development in Sub-Saharan Africa: Panel cointegration and causality analysis. Conference paper: presented at International Association for Management of Technology (IAMOT) 2014.

[3] Kivyiro, P., and Arminen, H., "Exploring the factors affecting the Clean Development Mechanism in the developing countries," *European Energy Market (EEM), 2013 10th International Conference on the European Energy Market*, vol., no., pp.1-8, 27-31 May 2013

[4] Kivyiro, P., and Arminen, H., 2013. GDP, FDI, and Exports in East and Central African Countries: A Causality Analysis. *International Journal of Business Innovation and Research*, Vol.9, No.3, pp.329-350

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The contribution of Pendo Kivyiro to the publications:

[1] Made the research plan. Synchronized the writing of the paper. Wrote most of the manuscript. Interpreted the empirical results together with the co-author

[2] Made the research plan. Synchronized the writing of the paper. Wrote most of the manuscript. Interpreted the empirical results together with the co-author

[3] Synchronized the writing of the paper. Wrote most of the manuscript. Interpreted the empirical results together with the co-author.

[4] Made the research plan. Synchronized the writing of the paper. Wrote most of the manuscript. Interpreted the empirical results together with the co-author

[5] Sole author

LIST OF ABBREVIATIONS

AIC	Akaike information criterion
ADF	Augmented Dickey-Fuller
ARDL	Autoregressive distributed lag
CO_2	Carbon dioxide
CDM	Clean development mechanism
DF	Dickey-Fuller
DF-GLS	Dickey-Fuller generalized least squares
EBA	Extreme bound analysis
ELG	Export-led growth
EKC	Environmental Kuznets Curve
FDI	Foreign direct investment
FE	Fixed effects
FIML	Full information maximum likelihood
FPE	Final prediction error
GDP	Gross domestic product
GHGs	Greenhouse gases
HQ	Hannan-Quinn information criterion
IPCC	Intergovernmental panel on climate change
IID	Independent and identically distributed
IPS	Im-Pesaran-Shin
IRFs	Impulse response functions
IV	Instrumental variables
KP	Kyoto Protocol
LLC	Levin-Lin-Chu
MNCs	Multinational corporations
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary least square

PP	Phillips-Perron
RE	Random effects
SIC	Schwarz information criterion
2SLS	Two stage least squares
3SLS	Three stage least squares
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework on Climate Change
VAR	Vector autoregressive
VECM	Vector error correction model

PART I: OVERVIEW OF THE DISSERTATION

1. INTRODUCTION

1.1 Background of the study

The concept of sustainable development has been a subject of debate among different groups of stakeholders as countries strive to improve the living conditions of poor people. Sustainable development can be defined as “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (WCED, 1987, p.43). The three dimensions of the concept are economic growth, social development, and environmental quality and protection. Achieving sustainable development requires thus developing countries to catch up with the more developed economies in terms of the level of economic development. However, even if neoclassical growth models predict convergence, the actual evidence is more in favor of divergence (Cheshire and Magrini, 2000). In fact, it seems to be the case that many countries particularly in Sub-Saharan Africa have ended up in poverty traps (Lin, 2014). The development can be partly explained by the factors of production but it is also associated with the other two dimensions of sustainable development. In this dissertation, the focus is on environmental quality.

Environmental degradation also has drawn the attention of numerous policy-makers as it continues to be a threat in the current era. There are three main aspects of environmental degradation, and these include land degradation, water pollution, and air pollution. Land degradation has been defined as a process that makes land lose its productive capacity due to numerous factors, such as overgrazing, poor farming techniques, deforestation, overexploitation of vegetation for domestic and industrial use, and mining activities (Bugri, 2008; Muchena et al., 2005; Van Niekerk and Viljoen, 2005). Water pollution has been defined as a process of contaminating water bodies such as oceans, lakes, and rivers by chemical, physical, and biological factors. These factors include, among others, poor fishing methods and mining activities. In this dissertation, the focus is on the third type of environmental degradation, namely air pollution. It has been defined as contamination of air due to a persistent increase in the level of greenhouse gases (GHGs), dusts, fumes, or odors, usually in larger quantities. The main causes of contamination in the air include, among others, the combustion of fossil fuels, emissions from motor vehicles, industrial production, and deforestation. The adverse effects of this phenomenon include, among others, climate change and poor human health, most specifically for poor families. Human activities have been pointed out to be a major contributor to environmental degradation (Falkenmark and Widstrand, 1992; Kasum, 2010; Rapport et al. 1998; Stern et al., 1996).

Global warming has been pointed out as one of the threats of the current era that is plaguing the globe as a whole, and also as one of the causes of the climate change (see e.g., Cox et al., 2000; Houghton et al. 1992; Markner-Jäger, 2008; Parmesan and Yohe, 2003; Vitousek, 1994). The main cause of this predicament is the increase in the concentration of greenhouse gases (GHGs) that trap heat from the sun (Deaton and Winebrake, 2000; MacKay and Khalil, 2000; Meinshausen et al., 2009; Shine et al., 2005; Wallington et al., 2004). These gases intercept and absorb long-wave radiation (most specifically infrared radiation) being emitted from the surface of the Earth. These gases then re-radiate some of this energy back down to the surface, thus lowering the amount that would be lost to space. As a result, the surface is kept warmer than it would otherwise be if these gases were not present. However, the adverse effect of GHGs is pervasive as they increase beyond limit. The consequences of global warming include, among others, the potential rise in the sea level, floods, drought, and long-term erosion of sandy beaches (Douglas et al., 2000; Vellinga and Leatherman, 1989).

Some of GHGs are naturally present in the atmosphere, while others are man-made. Human activities are pointed out to be the main contributors to both types of these gases, and hence the levels of these gases in the atmosphere keep on increasing more often (Houghton, 1996; Karl and Trenberth, 2003; Mahlman, 1997; Oreskes, 2004; Raval and Ramanathan, 1989). Apart from increasing the global warming potential, some of these gases are the main cause of the depletion of the ozone layer. The ozone layer is crucial in preventing the sun's ultraviolet light from reaching the Earth's surface (Andersson and Wallin, 2000; Penner, 1999; Ravishankara et al., 2009). Water vapor and carbon dioxide (henceforth CO_2) are the major concentration of the GHGs. CO_2 is mainly generated from the combustion of fossil fuels (coal, oil, and natural gases), the extraction of methane from landfill, and deforestation. Cutting down trees and killing some plants spur environmental problems, since these living organisms use CO_2 for photosynthesis and also give out oxygen that is crucial for the survival of human beings. Hence, deforestation is also one of the causes of the concentration of CO_2 in the atmosphere (Cox et al., 2000; Lashof and Ahuja, 1990; Vitousek, 1994). Of the other GHGs, nitrous oxide is mainly used in fertilizers, while hydrochlorofluorocarbons are used in refrigeration and air-conditioning equipment and industrial aerosols. Therefore, we observe that human activities have contributed much to global warming. Moreover, trying to attain the highest level of industrial development has triggered more demand for the consumption of large amounts of energy than before. Because fossil fuels are the prime source of energy globally, global warming continues, creating a catastrophe for the future environment.

There have been various initiatives put in place by international organizations to reduce the concentration of the GHGs in the atmosphere, in order to offset the effect of global warming (see e.g., Nordhaus, 1992; Stainforth et al., 2005; Van Vuuren et al., 2007; Watson et al., 1992). In 1988, the intergovernmental panel on climate change (IPCC) was established by two entities: the United Nations Environment Programme (UNEP) and the World Meteorological Organization. The IPCC consists of leading scientists and experts in the area of global warming, and it aims to assess the impacts of climate change and to provide policy-makers with authoritative scientific information concerning climate change (Agrawala, 1998; Joos et al., 2001; Smith et al., 2009). In 1992, the United Nations general assembly established the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro, Brazil, which entered into force in March 1994. The main objective of the convention was to reduce the concentration of GHGs in the atmosphere. In subsequent periods, there have been conferences of parties to UNFCCC held every year in different countries, and these include, among others, the Kyoto Protocol (KP), Japan 1997; Montreal Canada 2005; the Nairobi Framework, Kenya 2006; the Bali Action Plan, Indonesia 2007;

Poznan Poland 2008; the Copenhagen Accord, Denmark 2009; the Cancun Agreement, Mexico 2010; the Durban platform for enhanced action, South Africa 2011; and Doha, Qatar 2012. However, the KP is the most fundamental engine to other sessions held afterwards. The KP is a protocol to the UNFCCC, adopted in Kyoto, Japan, in 1997 (UNFCCC, 1998). The main objective of the KP was to find coherent strategies that could be used by international communities to reduce the concentration of GHGs in the atmosphere (Breidenich et al., 1998; Manne and Richels, 2000; Nordhaus, 2006). Under the KP, three market-based project mechanisms were proposed: joint implementation, international emission trading, and the clean development mechanism (CDM) (Hepburn, 2007; Springer, 2003). These mechanisms are well defined in article 12 of the KP (Protocol, 1997). Furthermore, the KP divided countries into two main categories. These are Annex I countries, which include the industrialized countries and other countries in a transition stage, and non-Annex I, which include all developing countries. The Annex 1 countries were obliged to accept a legally binding agreement under the KP to reduce their emission level to at least 5.2% below the 1990 level, while the developing countries (non-Annex 1) did not have a binding commitment with the KP. The emission reductions required of Annex 1 countries under the KP are supposed to represent the difference between business-as-usual emissions and the maximum emission levels specified in the protocol. The joint implementation program allows any Annex 1 country to claim carbon credits from the reduction of emissions from low-carbon investments in other industrialized countries. The international emission trading allows industrialized countries to transfer part of their assigned amount of units to other countries. The CDM has two main objectives; the first one is to assist Annex 1 countries in meeting their KP binding commitments of reducing the emission level by using cost-effective ways. The second objective is to assist developing countries in achieving sustainable development (Alexeew et al., 2010; Brown et al., 2004; Nussbaumer, 2009). Under the CDM, all the emission reduction projects are to be invested in developing countries, and the certified emission reductions generated from the projects are to be bought by industrialized countries. The first commitment period of the KP was between 2008 and

2012, and the second commitment was agreed in Doha, Qatar 2012, which is expected to last for eight years (2012-2020).

Despite the environmental benefits associated with the KP, the full benefits have not been realized. One of the possible reasons is that some countries have not yet ratified the protocol, for example the United States. By June 2012, only 159 countries had ratified the KP. Another obstacle to the protocol is associated with endless negotiations that are, to some extent, poor and not productive. Although the second commitment period has commenced, as we have pointed out previously, we do not see the viability of the protocol if giant countries like the United States are not committed to the KP like other western countries. Furthermore, some developing countries, like China, Brazil, and India, that are not obliged to reduce the emission levels under the KP, have been pointed out to be net emitters, and this has triggered a lot of concern.

1.1.1. Environmental degradation in Sub-Saharan Africa

Sub-Saharan Africa has been pointed out to contribute to global environmental degradation as well, but to a lesser extent when compared to other regions. However, land degradation and water pollution are pervasive in the region, due to numerous factors, such as poverty, population growth, poor technology, deforestation, overgrazing, urbanization, poor farming practices, and poor mining activities. The major sources of energy in many countries in Sub-Saharan Africa include biofuel, wood fuel, hydroelectric power, natural gas, coal reserves, wind, and solar energy. However, due to poor living conditions, wood fuel has been exploited more than any other source of energy. This is because the majority of citizens live in rural areas, and wood fuel can more easily be accessed in the countryside than in urban areas, and it is also cheap. Other sources of energy, although abundant, have not been fully tapped due to poor technology. Wood fuel accounts for 70% of the total energy consumption (Kebede et al., 2010). Energy consumption has been pointed out to have a direct impact on the quality of the environment, most specifically when the energy efficiency policies of a particular state are flouted. Some sources of energy have also been pointed out to increase the level of CO_2

emissions in the atmosphere. Hence, even if energy use is imperative for the viability of economic activities, the source of energy should be examined critically. For example, energy from fossil fuels, and most specifically coal, has been a major source of CO_2 emissions. Wood fuel causes deforestation, hence since the majority of countries in Sub-Saharan Africa are poor, and civilians rely more heavily on wood fuel, appropriate energy conservation policies should be constructed to enable the people in this region to use alternative energy, in order to offset the impacts of environmental degradation.

Stern et al. (1996) pointed out that although Sub-Saharan Africa is the region least responsible for global climate change, it is acutely vulnerable to its adverse effects, most specifically on economic growth and sustainable development, poverty reduction, human security, and the prospects for achieving the Millennium Development Goals (MDG). Numerous explanations have been given for why low-income countries are more prone to the adverse effects of climate change than high-income countries. Some studies point out that the lack of coherent adaptation measures to climate change and the higher exposure to climate risk are some of the reasons (Bowen et al., 2012; Le Dang et al., 2014; Fankhauser and McDermott, 2014). There is plenty of evidence suggesting that the consequences of climate change for Sub-Saharan Africa include persistent increase in the intensity of heat waves, floods and droughts, changes in the distribution of vector-borne diseases such as malaria, malnutrition, and increased vulnerability of food crop systems (e.g., Challinor et al., 2007; Cooper et al., 2008; Haines et al., 2006; Hole et al., 2009). These phenomena indicate that the region is already facing the adverse effects of climate change. Hence, the countries in this region are obliged to find coherent ways to tackle environmental degradation. The means to offset the effects of environmental degradation should also include capacity building in mitigation and adaptation to climate change. However, the sustainable ways should include, among others, the use of renewable sources of energy, afforestation and reforestation activities, empowering small-scale miners by giving them more advanced extractive tools, and educating people about legitimate methods of environmental management (FAO, 2007; Van Straaten, 2000). Furthermore, since the region's agricultural sector – an important source of stable food supply in the region is entirely dependent on rainy seasons, policies designed to attract more investors to this sector should be enforced.

1.1.2. Economic structure of Sub-Saharan Africa

Sub-Saharan Africa has been lagging behind other developing regions of the world in terms of economic development (Janik, 2014). However, according to a report by the IMF (2014), the region has recently experienced strong economic performance, most specifically in 2013. The region's GDP in 2013 increased by 4.9%, and this surge has been attributed to various factors, such as the investment in natural resources and infrastructure, private investment in mining activities, infrastructure improvement, energy production, and improvements in the agricultural sector. Despite this good news, the region is still facing many challenges that have been pointed out to impede the region from attaining sustainable socio-economic development compared to other developing regions. The challenges that have been pointed out to affect the region, both economically and socially, include issues related to political instability, environmental problems, lack of skilled manpower, lack of public-private partnerships, poor technological adaptation through innovation, lack of well functioning and intergrated market and poor institutions (Anyanwu, 2014). Figures 1 to 3 indicate the trend of three macroeconomic indicators: GDP per capita, FDI, and exports in five developing regions of the world. The regions include only **developing countries** from East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean, the Middle East and North Africa, and Sub-Saharan Africa. This classification is based on the World Bank's country classification system. The World Bank classifies countries into different categories for the purpose of facilitating its operations and also for analytical purposes, using the measures of gross national income (GNI) per capita per previous year, and other world development indicators (World Bank, 2013b). According to the World Bank (2013b), a developing country is one whose GNI per capita per year is US$1036 or less. The European countries included in the list according to this classification are Albania, Armenia, Bosnia and Herzegovina, Georgia, Macedonia, Moldova, and Serbia.

Figure 1 depicts the time series of GDP per capita for the five regions for the period between 1980 and 2012. GDP per capita captures the level of economic development of a particular region. The figure shows that the GDP per capita in Latin America and the Caribbean is the highest of all, followed by Europe and Central Asia. The third ranked region was the Middle East and North Africa until 2011. However, a dramatic change over the period between 2011 and 2012 in this specific region can be observed. The GDP per capita of East Asia and Pacific surpasses that of the Middle East and North Africa. The fourth ranked region over the period between 1980 and 1993 was Sub-Saharan Africa. However, a reverse change from 1994 until 2012 can be observed. East Asia and Pacific GDP per capita surpassed that of Sub-Saharan Africa. In fact, Sub-Saharan Africa is the only region where GDP per capita did not depict a clear increasing trend between 1980 and 2012. The poor performance of Sub-Saharan Africa with respect to economic growth, in comparison to the rest of the developing countries, has been attributed to numerous factors, such as poor infrastructure in many sectors, a persistent increase in the unemployment rate, a lack of technological advancement, the quality of institutions, and the global financial crisis (Cohen, 2004; Collier and Gunning, 1999; Kessides, 2006).

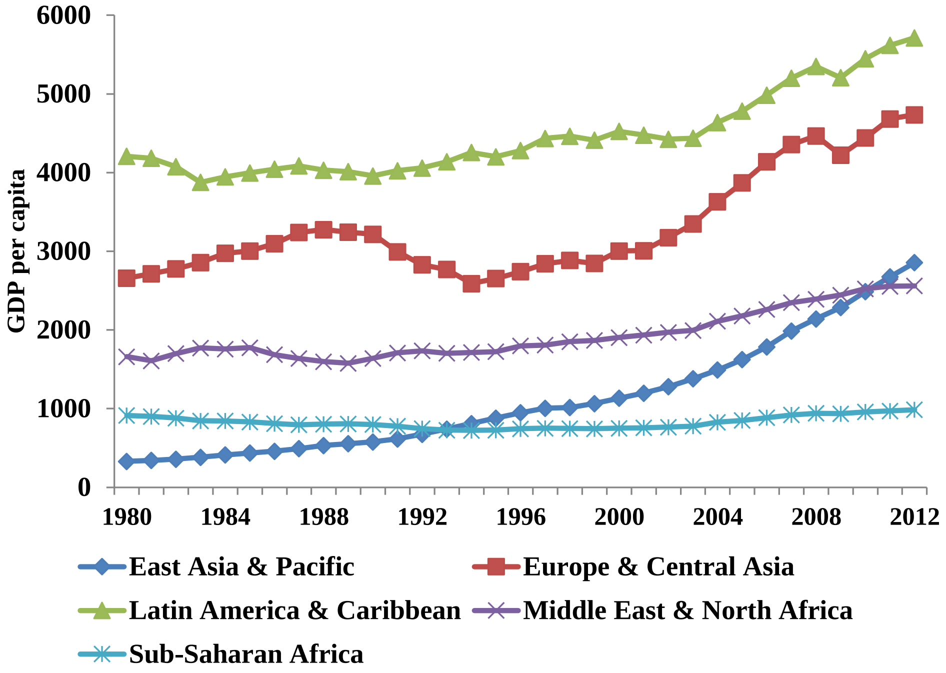


Figure 1. GDP per capita (constant 2005 United States dollar)

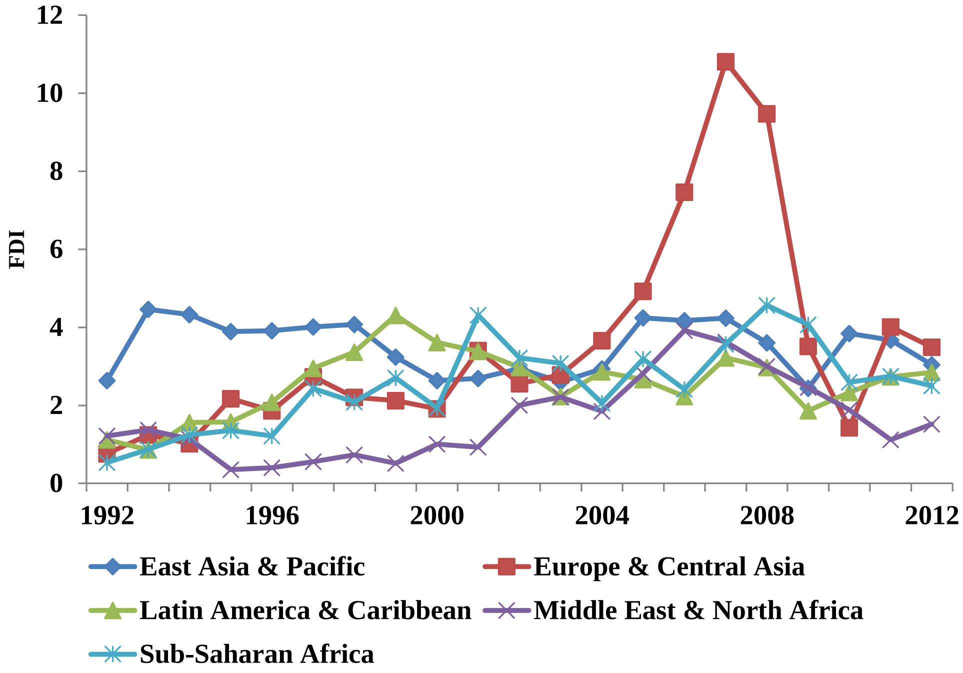


Figure 2. FDI, net inflows (% of GDP)

Figure 2 depicts the time series of foreign direct investment, net inflows as a percentage of GDP, over the period between 1992 and 2012 in the five regions. No clear trend can be observed with reference to this macroeconomic variable. However, over the period between 1992 and 1998, the East Asia and Pacific region managed to attract more FDI than other developing regions. We also observe a significant overshoot of FDI inflows in the case of Europe and Central Asia between 2004 and 2008. Generally, Sub-Saharan Africa and Middle East and North Africa have been lagging behind in terms of attracting FDI, as compared to other regions. This effect might be associated with the low GDP per capita, specifically in Sub-Saharan Africa, as depicted in Figure 1, within a specified period. This is because, although FDI has been pointed out to be one of the engines of economic development, the region has not managed to attract a substantial amount of it. Some of the factors that have been pointed out as hindering the FDI in these regions are, among others, political instability, poor institutional quality, and investor risk aversion (Asiedu, 2006; Chan and Gemayel, 2004; Onyeiwu, 2003). The next section will cover FDI in Sub-Saharan Africa in more detail.

Figure 3 depicts a time series of the exports of goods and services as a percentage of GDP, over the period between 1989 and 2011. We observe an upward trend of the series in almost all the regions. There has been a fluctuation of exports over the years in these regions; however, the last ranked region is Latin America and the Caribbean. Furthermore, we also observe poor performance in terms of exports in the case of Sub-Saharan Africa over the period between 2001 and 2013. The region is the last but one in the rankings. This, again, can be one of the factors in the last ranking in terms of GDP per capita of this region. This is because exports have been pointed out to be one of the determinants of economic development. However, the literature has also pointed out the causal links between FDI and exports: either complementarity or substitutability. Hence, the poor performance of exports can also be a major factor for poor FDI inflow in the region.

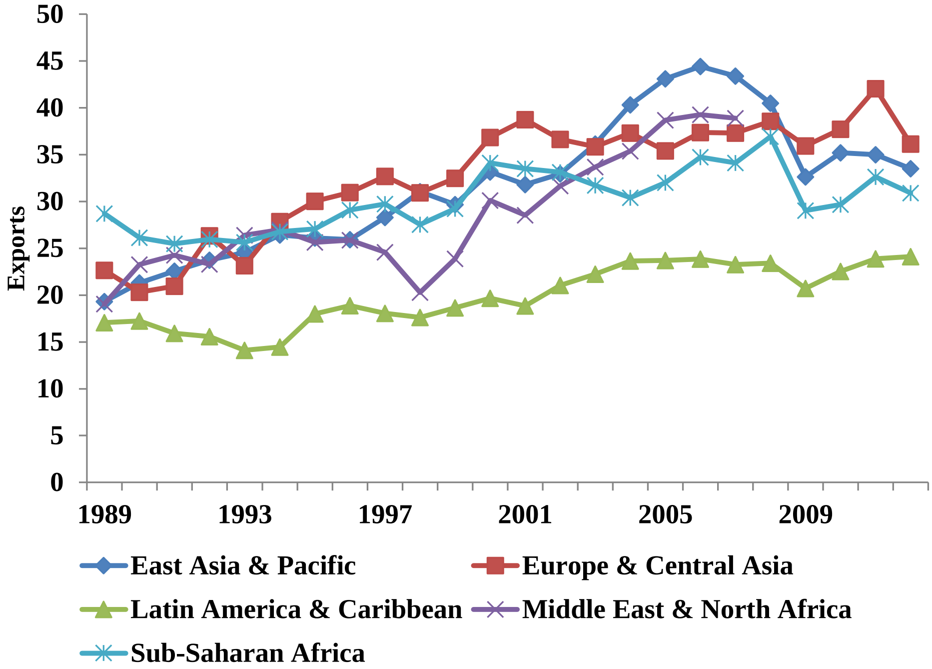


Figure.3. Exports of goods and services (% of GDP)

1.1.3. Foreign direct investment in Sub-Saharan Africa

The trend in FDI in the Sub-Saharan region started to pick up pace in the mid-1990s, as the result of economic reform in various countries in the region. Nevertheless, the stagnation in attracting FDI is still a major threat in the region, due to various factors. Odenthal (2001) contended that factors such as political instability, the lack of economic dynamism, and poor infrastructure, particularly in the areas of telecommunications, transport, and power supply, hinder FDI flow in developing countries. Hence, it can be revealed that despite the initiatives taken by the region to attract FDI, investors are still reluctant to invest in the region. According to Ajayi (2006), explanations vary, from a bias against Africa because of its risks and inappropriate environment. Furthermore, the amount of FDI that comes to Africa is concentrated in a few countries. The top 10 African countries in terms of magnitude of FDI inflows in 2008/9 were Angola, Egypt, Nigeria, South Africa, Sudan, Algeria, Libya, Congo, Tunisia, and Ghana (UNCTAD, 2009). However, in 2009/10, the trend keeps on changing in some of the countries; for example, South Africa is the last among the top 10 countries, despite its effort in attracting foreign investors (UNCTAD, 2010). According to the UNCTAD (2013) world investment report, South Africa was ranked third among the top 5 as indicated in 2012 (see Figure 4). In 2013, South Africa was a leading country. Likewise, there have been similar fluctuations in other countries. This indicates that there have been fluctuations in the distribution of FDI inflow in this particular region.

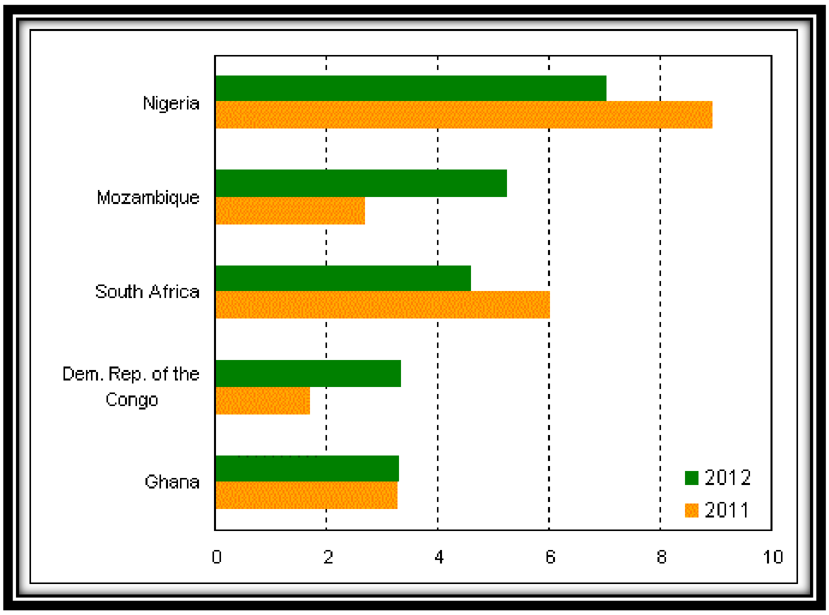


Figure 4. Africa: Top 5 recipients of FDI inflows, 2011 and 2012 (billions of US dollars) Source: UNCTAD, World Investment Report 2013

Based on a review of previous studies, we observe that the impact of FDI on the level of economic development is diverse, and hence the current dissertation focuses on the causal links between FDI, exports, imports, emissions, and economic development in Sub-Saharan

African countries. This is because studies that examined the causal relations among the mentioned macroeconomic variables are very scant in the region, and we aim to fill this gap. Furthermore, the region is still lagging behind in terms of its attractiveness to FDI, despite numerous reforms taken by the governments in this region. The factors that have contributed to this phenomenon have been pointed out in the previous literature. However, there is very little empirical research that focuses specifically on the causal link between FDI, exports, imports, emissions, and economic growth in the region. This topic is analyzed in three out of five publications, in which both individual time series data and panel data methodologies were employed.

1.1.4. Clean Development Mechanism (CDM) projects

The dual objectives of CDM activities have been a subject of debate among researchers and other environmental policy-makers. The main objectives of the CDM, as we have pointed out from above (see section 1.1), is first to assist Annex 1 countries in reducing the concentration of GHGs by employing cost-effective ways, and second to assist developing countries (non-Annex 1 countries) in achieving sustainable development. UNEP (2004) pointed out that the CDM can achieve the latter objective through the transfer of climate-friendly technologies and financial resources, sustainable methods of energy production, increased energy efficiency and conservation, poverty alleviation through income and employment generation, and local environmental actions.

In terms of technology transfer, the CDM investment in developing countries has been pointed out to complement other sources of technology transfer in developing countries. These include, among others, licensing, international trade, and FDI (Heller and Shukla, 2003; Schneider et al., 2008; Stern, 2007; UNFCCC, 2007). It has been pointed out that technology transfer to host countries can be in the form of knowledge, skills, and know-how. However, it can also be in terms of transfer of equipment, or both (OECD, 2005; Dechezleprêtre et al., 2008; Seres et al., 2009; Costa-Júnior et al., 2013). However, the technology used in CDM activities can also be originally from the host countries, or from domestic and foreign partnerships (Dechezleprêtre et al., 2009; Seres et al., 2009).

Costa-Júnior et al. (2013) investigated the CDM as an instrument for technology transfer and the promotion of cleaner technology in the case of Brazil. The study employed documentary analysis of the project design documents of 75 projects, which is a portion of the projects already approved by the CDM executive board. They focused on technology transfer embedded in end-of-the pipe projects and in projects involving cleaner technology. The end-of-pipe projects are projects designed to get rid of or reduce the adverse effects of emissions that already prevail in the atmosphere. These include, among others, HFCs, N_2O, and methane destruction projects. The cleaner technology projects are defined to be projects that do not involve any kind of emissions. For example, energy efficiency projects and renewable energy projects are categorized as cleaner technology projects. The study by Costa-Júnior et al. (2013) found that only 28% of the projects investigated claim transfer of technology. Dechezleprêtre et al. (2008) investigated technology transfer through the CDM by employing the data from 644 registered CDM projects. They found that transfer of technology is more pervasive and common in large projects than in small projects. A similar conclusion has also been drawn by Seres et al. (2009). Furthermore, the results from the econometric analysis pointed out that the probability of transfer is almost 50% in subsidiary companies, and the technological capabilities of the host country also have a significant and positive influence on the technology transfer. Seres et al. (2009) investigated the technology transfer in the CDM by going through the project design documents for 3296 registered and other proposed projects in the pipeline. They found that 36% of these projects claim technology transfer, and this is noticeable in large projects.

It has also been pointed out that technology transfer in CDM projects is somehow reliant on the type of the project and the technological capability of the host country (Dechezleprêtre et al., 2009). For example, wind energy projects, N_2O destruction projects, HFC-23 destruction projects, landfill gas recovery, and fugitive gas recovery rely heavily on technology imported from abroad. This evidence is found in the cases of Brazil, China, India, and Mexico. However, projects such as hydro power, biomass energy, and energy efficiency do not entail transfer of technology, as they normally depend on local technology.

However, generally, it has been pointed out in the previous studies that the CDM has not been fully successful in promoting sustainable development so far (Olsen, 2007; Paulsson, 2009; Nussbaumer, 2009; Liu, 2008; Parnphumeesup and Kert, 2011). According to UNFCCC (2011), sustainable development consists of three dimensions, and these are economic development, social development, and environmental protection. Economic development consists of indicators such as employment creation, diffusion of local or foreign technology, and infrastructure development. Sustainable development in terms of social development involves indicators such as labor conditions, protection of human rights, education promotion, health and safety, poverty reduction, engagement of the local population, and empowerment of women. Environmental development involves efficient utilization of natural resources, reduction of noise, odors, dusts, and other pollutants, and the promotion of renewable energy. The area that has been somehow successful since the implementation of CDM activities is the environmental development dimension.

According to the data from the CDM pipeline, the total number of registered CDM projects by March 2014 was 8753. However, as indicated in Figure 5, it can be observed that the Asia and Pacific region has been most successful, followed by Latin America, and the third ranked region is Africa, followed by Europe and the Middle East. The European countries that have hosted CDM projects so far are Albania, Armenia, Bosnia and Herzegovina, Georgia, Macedonia, Moldova, and Serbia (UNEP Risoe, 2014). The number of CDM projects going to Africa has improved compared to early 2009, when the region was the last, in relation to other regions, in the number of CDM projects attracted.

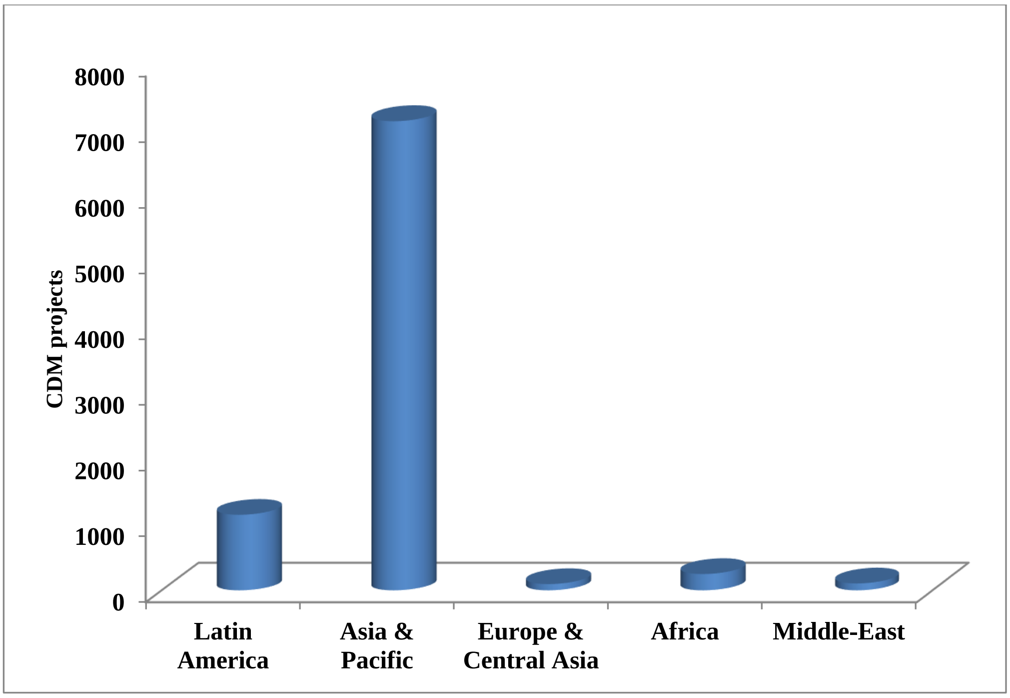


Figure 5: Regional distribution of CDM projects (Source: CDM pipeline, UNEP Risoe, 2014)

Countries in the Middle East, which are Iran, Israel, Jordan, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen, have been relatively unsuccessful in attracting CDM projects. This might be due to the issues related to political stability and the geographical location of the countries.

Figure 6 shows the top 10 countries in attracting CDM projects. The first country is China, which has almost 4023 projects registered by the CDM Executive Board, followed by India with 2325 projects in the CDM pipeline. The third-ranked country is Brazil, with a total of 499 projects in the pipeline, followed by Vietnam, which has 275 projects. The fifth-ranked country is Mexico, which has 239 projects, followed by Indonesia, with a total number of 185 projects. The seventh-ranked country is Thailand, with a total 181 projects in the pipeline. The last three countries, with the number of CDM projects already registered by Executive Board in brackets, are Malaysia (175), Chile (125), and South Korea (122). Therefore, it can be concluded that big countries have been able to attract more CDM projects than smaller countries, as measured by either the number or volume of the projects.

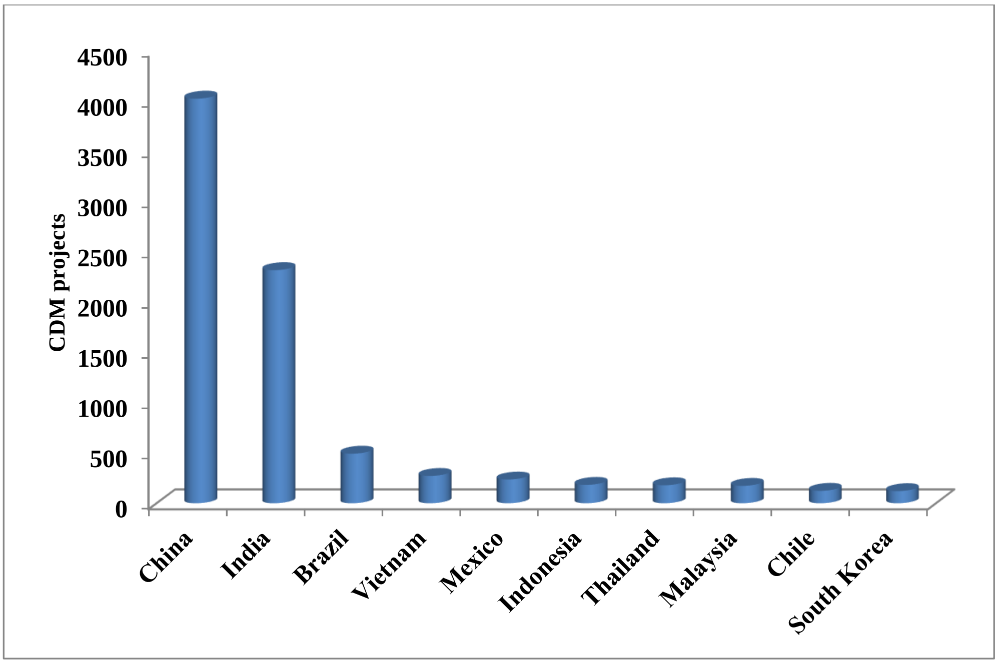


Figure 6: Top 10 host countries for CDM projects (Source: CDM pipeline, UNEP Risoe, 2014)

1.2 Research framework and objectives

The overall objective of this study is to investigate the contribution of environmental management practices, the so-called clean development mechanism (CDM) projects, and foreign direct investment (FDI) in achieving sustainable development in developing countries. According to the World Commission on Environment and Development (WCED, 1987, p.43), sustainable development has been defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The concept focuses on three dimensions: economic growth, social development, and environmental quality and protection. The spirit of this form of development relies on a stable relationship between human activities and the natural world, which does not diminish the prospects for future generations to enjoy a quality of life at least as good as our own (Mebratu, 1998). Figure 7 illustrates the basic framework of the study and how the concept of sustainable development has been discussed in this dissertation using the five publications attached.

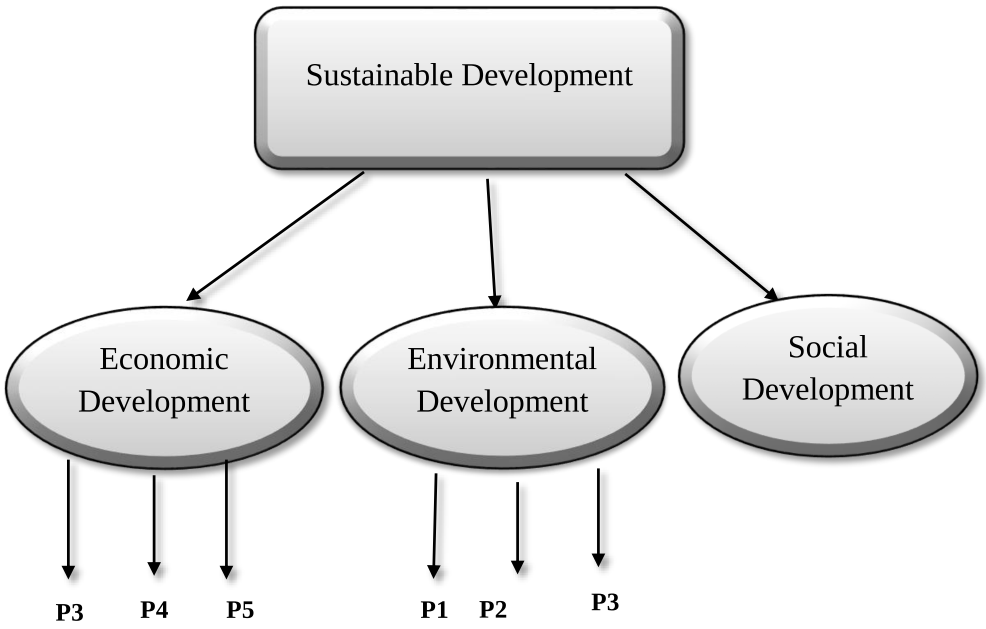


Figure 7: The basic framework used to meet the objectives of the study (Ps stand for publications)

The aims of this study are mainly derived from previous research, which extensively stresses the importance of FDI in enhancing economic growth, as well as a positive externality for improving the environmental quality of various economies. Foreign investors are believed to have more advanced green technology when compared to their domestic counterparties.

Hence, it is expected that the presence of multinational corporations (MNCs) will not harm the environmental quality of the host countries. On the hand, CDM activities are required to assist the developing countries in achieving sustainable development. However, because there has been an uneven distribution of these kinds of projects in developing countries, this study aims specifically to investigate the factors that affect the distribution of CDM projects in host countries. Furthermore, with a persistent increase in global warming potential, there has been a vast amount of literature that focuses on the determinants of this dilemma. It is believed that the identification of the possible determinants of global warming will assist policy-makers in coming up with appropriate policies that will enable a reduction in the adverse effects of this problem. Therefore, the current study also aims to investigate the causal links between emissions levels, energy consumption, and economic development. There have been few studies that employ up-to-date statistical methods to investigate the issues at hand, most specifically in Sub-Saharan Africa, so we aim to fill this gap.

The general objectives are further distributed across multiple sub-goals, and each goal was pursued at a more detailed level, using the five publications that accompany this study. Hence, the specific aims of the respective five publications are as indicated below (see Table 1 for more details):

- [1] To investigate the causal relations between CO_2 emissions, energy consumption, FDI, and economic growth in Sub-Saharan African countries, using time series data.
- [2] To investigate the causal links between CO_2 emissions, energy consumption, and economic development in Sub-Saharan Africa, using panel data.
- [3] To explore the factors affecting the CDM in developing countries.
- [4] To investigate the causal links between FDI, exports, and economic growth in East and Central African countries, using individual country studies and panel data approaches.
- [5] To investigate the causal links between FDI, exports, imports, and economic growth in South Africa.

Table 1: The research objectives and the corresponding publications

The main Research Objective: *To investigate the contribution of environmental management practices, clean development mechanism projects, and foreign direct investment in achieving sustainable development in developing countries.*		
***Publication 1**: Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa*	***Objective 1**: To investigate whether the variables of interest move together in the long-run.* ***Objective 2**: To test whether there are any Granger causality relationships among the variables of interest.*	***Data:** Time series over the period [1971-2009]*
***Publication 2:** Carbon dioxide emissions, energy consumption, and economic development in Sub-Saharan Africa: Panel cointegration and causality analysis*	***Objective 1:** To investigate whether the variables of interest move together in the long-run* ***Objective 2**: To test whether there are any Granger causality relationships among the variables of interest in the sample of Sub-Saharan African countries on average, and to explore whether the causality relationships between the variables have changed over time.*	***Data:** Panel data over the period [1971-2009]*
***Publication 3**: Exploring the factors affecting the Clean Development Mechanisms in developing countries*	***Objective :** To explore the economic, environmental, and institutional factors responsible for the uneven distribution of CDM projects in developing countries.*	***Data:** Cross-sectional data (predictor variables were measured in 2004, dependent variable 2012*
***Publication 4**: GDP, FDI, and exports in East and Central*	***Objective 1:** To investigate whether the variables of*	***Data:** Time series and panel data over the period [1989-2010]*

African countries: A causality Analysis	*interest move together in the long-run* ***Objective 2**: To test the direction of causality among the variables of interest using the concept of Granger causality.*	
***Publication 5:** Foreign direct investment, exports, imports and economic growth of South Africa: Granger causality analysis*	***Objective 1**: To test the direction of causality among the variables of interest using the concept of Granger causality.* ***Objective 2:** To examine the responsiveness and proportions of movement of one the variables with respect to shocks/changes given to other variables.*	***Data:** Time series over the period [1985-2010]*

1.3 Structure

The dissertation consists of two main parts. The introduction presents an overview of the study, and the second part comprises the five research publications. The introduction has five chapters. Chapter 1 introduces the background of the study, the scope, and the main objectives. Chapter 2 presents the theoretical point of departure, the basic concepts, related research, and the overall framework. The third chapter describes the research methodology employed, and Chapter 4 summarizes the main findings reported in the publications, and presents their main contributions. We present the conclusions and the limitations of the study in Chapter 5. The second part of the dissertation consists of the five publications. For the details of part one of the dissertation, see Figure 8.

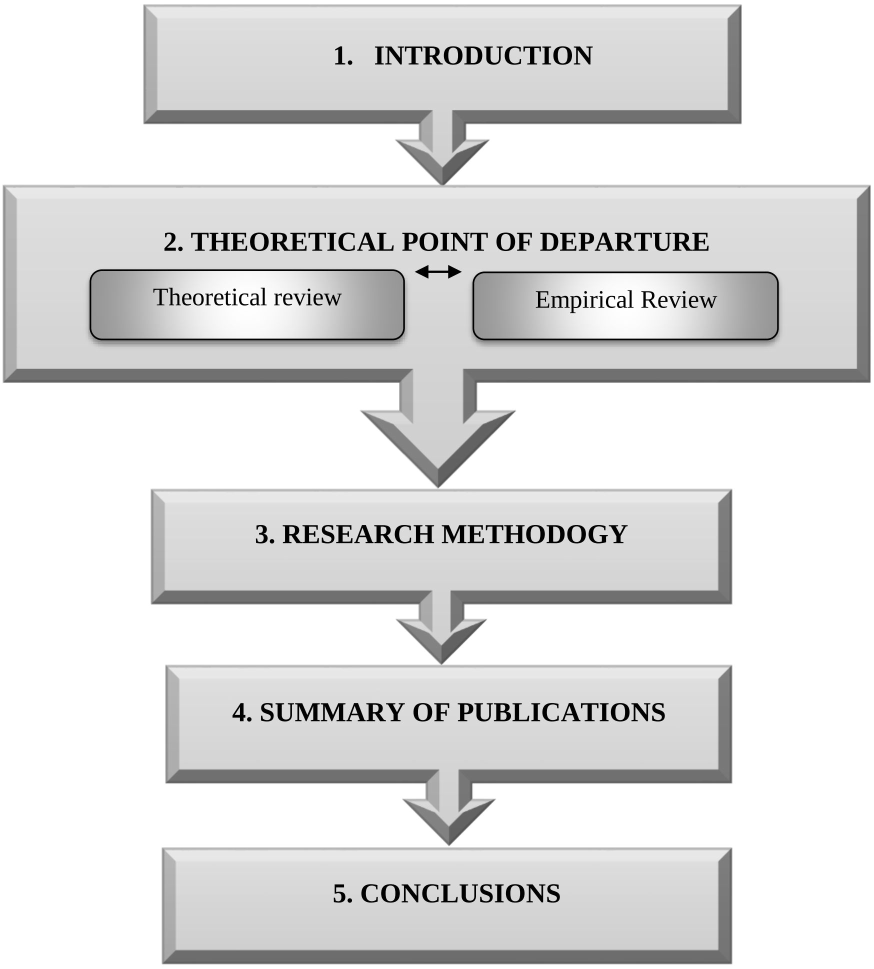


Figure 8: Outline of the study

2. THEORETICAL BACKGROUND AND PREVIOUS LITERATURE

This chapter first introduces the theoretical framework of the study, in which the theories related to FDI, environmental issues, and economic growth are discussed. Second, the chapter reviews both the theoretical and empirical parts of previous studies: their main findings, methodologies employed, and the limitations encountered.

2.1. Theories of FDI

Foreign direct investment (FDI) has been defined as an investment made to acquire a lasting management interest (10% or more of voting stock) in enterprises operating outside the economy of the investor (UNCTAD, 2014). The investor´s purpose is to gain an effective voice in the management of the enterprise. FDI has been pointed out to supplement other deep determinants of economic growth in numerous economies. Some of the positive impacts of FDI, among others, include the formation of foreign capital, employment creation, the expansion of the export base by raising efficiency and enhancing market opportunities, and technological and knowledge spillovers that improve the productivity of domestic firms inter alia (Borensztein, 1998; Blomström et al., 1997; De Mello, 1999; Greenaway and Kneller, 2007; Konings, 2001; Javorcik, 2004; Markusen and Venables, 1999). The negative impacts of FDI have also been articulated in the previous academic literature, and these include, among others, the crowding out of domestic investment and the enhancement of environmental degradation (Acharyya, 2009; Aitken and Harrison, 1999; Buckley et al., 2002; Jian-guo, 2007; Li-yan, 2008; Miao-zhi, 2005; Weiqing, 2010). Hence, there have been differing views with regard to the impacts of FDI in recipient countries, and the empirical results are still mixed. However, it is generally thought that the positive impacts outweigh the corresponding negative impacts (Sinani and Meyer, 2004; Barrios et al., 2005; Carstensen and Toubal, 2004; Te Velde, 2002).

The emergence of capitalist economies and their generation of investible surplus capital gave rise to several forms of international capital investment and mobility. Levi (1996) contends that multinational corporations (MNCs) today not only participate in most national markets, but are also increasingly coordinating their activities across those markets to gain advantages of scale, scope, and learning on a global basis. These motives behind MNCs have been achieved through numerous forms of foreign investment, most specifically foreign direct investment. The theories that explain the basic motivations that cause MNCs to engage in FDI have been pointed out in the previous literature. These include, among others, market imperfections theory (Hymer, 1970, Morgan and Katsikeas, 1997), internalization theory (Buckley, 1982, 1988; Buckley and Casson 1976, 1985), international production theory (Dunning, 1980), and globalization.

According to Morgan and Katsikeas (1997), **market imperfections theory** states that firms constantly seek market opportunities, and their decision to invest overseas is explained as a strategy to capitalize on certain capabilities not shared by competitors in the foreign countries. It includes product differentiation, market skills, proprietary technology, managerial skills, better access to capital, economies of scale, and government-imposed market distortions. Buckley (2004) observes that foreign firms must possess advantages over local firms to make such investment viable, and usually the market for the sale of the product or service is imperfect. FDI is a direct outcome of imperfect markets. It is the financial effects of this that underpin FDI. This theory suggests that foreign investment is undertaken by those firms that enjoy some monopolistic advantages. Sodersten (1994) concludes that potential gains from these advantages must outweigh the disadvantages of establishing and operating in a foreign country.

Hill (2001) writes that **internalization theory** explains why firms prefer FDI over licensing when entering foreign markets. The theory was first pioneered by Buckley and Casson (1976) and later extended by Hennart (1982). FDI is profitable when the firm needs tight control over a foreign entity to maximize its market share and earnings in that country. The theory centers on the notion that firms aspire to develop their own internal markets whenever transactions can be made at lower cost within the firm, through integration. As suggested by

Eiteman et al. (2004), the decision to invest abroad for the first time is often a stage in a firm's development process. It means, therefore, that the firm first develops a competitive advantage in its domestic market, and eventually finds that it can grow profitably by exporting to a foreign market.

According to Dunning (1980), **international production theory** suggests that the ability of a firm to initiate foreign production depends on the specific attraction of its home country compared to the resource advantages of locating in another country. This theory makes it explicit that not only do resource differentials and advantages for the firm play a part in determining overseas investment activities, but foreign government actions may significantly influence the attractiveness and entry conditions for firms.

Hill (2001) defines **globalization** as the shift towards a more integrated and interdependent world economy. It is divided into globalization of markets and globalization of production. The globalization of markets refers to the merging of historically distinct and separate national markets into one huge global marketplace. The globalization of production refers to the tendency among firms to source goods and services from different locations around the globe, to take advantage of national differences in the costs and quality of aspects of production (such as labor, energy, land, and capital). There are two widely used measures of globalization in empirical research: trade as measured by the ratio of the sum of world trade to the sum of world GDP, and capital flows as measured by the ratio of the sum of the absolute values of the current account gap to the sum of world GDP (Dutt and Mukhopadhyay, 2005; O'Rourke, 2002).

However, some more recent studies have come up with another explanatory variable that also explains the motive behind FDI. The variable is somewhat missing in the extant literature; this variable is the **measure of environmental stringency** in the host countries. The proponents of this measure, and some environmentalists, posit that foreign investors tend to flock more to countries whose environmental regulations are less stringent. Two confronting hypotheses have been formulated in the extant literature: the pollution haven hypothesis and the halo effect hypothesis. These hypotheses have been discussed in more detail in section 2.5. List and Co (2000) proposed four indicators to capture the environmental stringency of host countries, and these are the Council of State Government expenditure per capita, and the Council of State Government expenditure per manufacturer. The first two indicators, above, refer to the cost (monies) spent by the host countries to control, prevent, and abate pollution. The third indicator is firm-level pollution abatement costs, and the fourth indicator is the Environmental Protection Index (EPI). It is postulated that higher regulatory expenditure may lead to a tighter constraint on production activity (List and Co, 2000).

Furthermore, the role of **institutions** in the host country has also been noted to complement the other deep determinants of locational advantage for MNCs in the extant literature (Narula and Dunning, 2000). Bénassy-Quéré et al. (2007) emphasize the importance of institutional quality in attracting foreign investors. The study posits that poor institutions can bring additional costs to investors, while good institutions may reduce the costs of investment. Busse and Hefeker (2007) show that government stability, internal and external conflict, corruption and ethnic tension, law and order, democratic accountability of government, and quality of bureaucracy are highly significant determinants of FDI. Generally, the concept of institutions as one of the determinants of FDI has drawn the attention of many researchers, but the results are, however, inconclusive (see, e.g., Asiedu, 2006; Bengoa and Sanchez-Robles, 2003; Bevan et al., 2004; Henisz, 2002; Jensen, 2003; Jun and Singh, 1996). Based on the theories of FDI, the previous literature has identified the potential determinants of FDI as specified in Equation (1)

$$FDI_{it} = \alpha_0 + \alpha_1 Y_{it} + \alpha_2 GLOB_{it} + \alpha_3 ENV_{it} + \alpha_4 INST_{it} + \alpha_4 HC_{it} + \alpha_5 X_{it} + \varepsilon_{it} \qquad (1)$$

Where $GLOB_{it}$ denotes the measure of globalization (the most widely used measures include trade and capital flows, as mentioned in the previous paragraph); Y_{it} stands for the GDP of the host country i in period t, which is also used as a proxy for the market size; ENV_{it} is the measure of environmental stringency; INS_{it} is the measure of institutions of the host country; and HC_{it} stands for human capital, and this variable measures the absorptive capacity of the host country. X_{it} stands for a set of other explanatory variables that might have a significant influence on FDI, and these include, among others, inflation rate, interest rate, exchange rate fluctuation, wage rate, the black market premium, infrastructure, and other dummy variables.

2.2. FDI and economic growth

The causal relationships between economic growth and FDI have been investigated in the previous studies, and they have been a subject of debate. Theoretically, FDI complements the other deep determinants of economic growth through the boosting of capital formation, technology transfer, employment creation, enhancement of business competition, and improvement of technological and management spill-over. According to neoclassical growth models, FDI increases the capital stock and thus growth in the host country, by financing capital formation (Brems, 1970). However, it has been pointed out that the impact is only in the short-term. In contrast, in endogenous growth models, FDI can promote long-term growth effects due to the advanced technology embedded in it (De Mello, 1997).

Nevertheless, it has also been argued that the economic growth of a host country can be one of the factors that has a direct influence on the level of FDI inflow into the host country. Hence, these variables can be simultaneously determined. However, the results from the extant empirical literature are found to be empirically mixed and inconclusive (see, e.g., Adams, 2009; De Mello, 1999; Hansen and Rand, 2006; Li and Liu, 2005; Mencinger, 2003). According to Hansen and Rand, FDI has a positive and significant long-term effect on economic growth. Some other studies (e.g., Hsiao and Hsiao, 2006; Nair-Reichert and Weinhold, 2001; Zhang, 2001) reported a unidirectional causal relationship between the two variables, while others observed a bidirectional causal relationship (Basu et al., 2003; Chowdhury and Mavrotas, 2006; Hansen and Rand, 2006; Mencinger, 2003). However, different methodologies, data, and samples used are pointed out to be major causes of such contradictory results. While others, such as Adams (2009), Azman-Sain (2010), Herzer et al. (2008), Nair-Reichert and Weinhold (2001), Alfaro et al. (2004), Borensztein et al. (1998), Carkovic and Levin (2002), Durham (2004), and Alfaro (2003), employed an ordinary least square (OLS) regression model, the second group of researchers employed the Granger causality framework (see, e.g., Chowdhury and Mavrotas, 2006; Dash and Parida, 2011, 2013; Kholdy and Sohrabian, 2005; Mencinger, 2003). However, the OLS regression technique has been pointed out to trigger serious endogeneity problems, which makes results somehow unreliable. Furthermore, others have employed the Cobb-Douglas production function, where FDI is assumed to complement other factors of production in influencing the output (see, e.g., Fedderke and Romm, 2006; Vu and Noy, 2009). There have also been different views with regard to the impact of FDI on the level of economic development. The first views point out that FDI has a direct impact on the level of economic growth. The second views claim that FDI has indirect impact on the level of economic growth when in interaction with the absorptive capacities of the host country. The variables that have been singled out in the previous literature as capturing the absorptive capacities include, among others, the level of human capital, the level of financial development, economic freedom, the quality of institutions, efficient trade policy, and the initial level of economic growth captured by gross domestic product. Borensztein et al. (1998) investigated the effect of FDI on economic growth using a cross-country regression framework. According to their results, FDI inflow only had a minimal direct impact on economic growth, but in countries where human capital was above a certain threshold, it did positively contribute to growth. Hence, the human capital of the host country is a crucial factor affecting the impact of FDI, indicating that FDI only increases productivity, and hence fosters economic development, when the host country has reached a minimum threshold stock of human capital. Moreover, Alfaro (2003) found that FDI has an ambiguous impact on economic growth: FDI in the primary sector appears to have a negative effect on growth, while FDI in the manufacturing sector seems to have a positive impact. Furthermore, other studies indicate that FDI has a significant effect on economic growth when in interaction with a financial market variable (Alfaro et al., 2004;

Adjasi et al., 2012; Carkovic and Levine, 2005). Moreover, FDI has a positive impact on economic growth via its influence on private domestic investment (Ali-Sadig, 2013; Dash and Parida, 2013; Xu and Ruifang, 2007). Azman-Sain et al. (2010) investigated the links between economic freedom, FDI, and economic growth in a panel of 85 countries. Their results revealed that FDI by itself has no direct positive impact on the growth of output. Instead, the impact of FDI is dependent on the level of economic freedom in the host country. Blomstrom et al. (1994) found that FDI affects economic growth positively in countries with a higher level of development. Balasubramanyam et al. (1996) investigated the link between FDI efficiency and trade policy of the host country, and found that the impact of FDI was stronger in countries with export promotion policies than in countries that promote import substitutions policies. The role of the institutions of the host country in the promotion of FDI activities has also been pointed out in the literature (see Barro, 2000; North 1990; Demetriades and Law 2006; Knack and Keefer, 1995; Rodrik et al., 2004).

2.3. Exports and economic growth

Another strand of the literature examines the nexus between exports and growth, with the intention of testing the validity of either the export-led growth (ELG) hypothesis or the growth-led export hypothesis. The so-called 'ELG' hypothesis was pioneered by the classical economists Smith and Ricardo, who emphasized the importance of international trade as an engine for economic development (Ricardo, 1817; Smith, 1776). The ELG hypothesis considers exports as the primary determinant of overall economic growth, while the growth-led export hypothesis believes that the level of economic growth has a significant influence on the expansion of the export base of the host county. The intuition behind this strand of the literature is that a particular country's level of economic development does not simply depend on the accumulation of physical and human capital, but also on the trade openness of the economy. Numerous studies have investigated the causal links between exports and economic growth empirically, by employing different methodologies and techniques, and the results are mixed (see, e.g., Ahmad and Harnhirun, 1996; Babatunde, 2011; Chen, 2007;

Dollar and Kraay, 2003; Dreger and Herzer, 2013; Frankel and Romer, 1999; Furuoka, 2007; Huang and Wang, 2007; Thangavelu and Rajaguru, 2004; Siliverstovs and Hertzer, 2006). For example, Chen (2007) employed the Granger causality test to examine the relationship between exports and growth in Taiwan, and concludes that there is a long-term causal relationship between exports and growth. The relationship appears to run only in one direction: from exports to growth and not vice versa. Furuoka (2007) examined the relationship between exports and economic development in Malaysia, and found a unidirectional, short-term causal relationship running from GDP to exports. Dreger and Herzer (2013) examined empirically the ELG hypothesis for 45 developing countries, using panel data, and found bidirectional causality between exports and GDP in the short run. In the long run, exports affect GDP negatively on average. Various studies have focused on developing countries and have tested the ELG hypothesis, with mixed results. In particular, some of the time series studies (e.g., Hsiao and Hsiao, 2006) fail to support the hypothesis, while most cross-sectional studies report a significant relationship between exports and growth (see, e.g., Kunst and Marin, 1989). Overall, the direction of causality between exports and GDP remains unresolved.

2.4. GDP, FDI, and exports

Theoretically, it has been pointed out that both exports and FDI complement the other deep determinants of economic growth through boosting capital formation, technology transfer, employment creation, enhancement of business competition, and improvement of technological and management spill-over. However, it has also been argued that the economic growth of a host country can be one of the factors that have a direct influence on the level of exports, as well as on FDI. Hence, these variables can be simultaneously determined. Numerous empirical studies have investigated the validity of the FDI-led growth (FLG), export-led growth (ELG), and FDI-led export hypotheses for the past three decades, within a single multivariate model (see, e.g., Berthélemy and Demurger, 2000; Basu et al., 2003; Chen, 2007; Chow, 1987; De Mello, 1999; de Mello, 1997; Feder, 1983; Henriques and Sadorsky, 1996; Kavoussi, 1984; Kunst and Marin, 1989; Li and Liu, 2005; Marin, 1992; Xu, 1996). However, there are no unanimous conclusions so far. Hsiao and Hsiao (2006) explicated how exports may boost FDI by providing information on the host country, which helps to reduce investors' transaction costs. They also noted that FDI may reduce exports by serving the foreign market through the establishment of production facilities in the host country. However, FDI has been regarded as both complementary to and a substitute for international trade. For example, Liu et al. (2001) emphasize that trade can substitute for the international movement of factors of production, including FDI.

As can be learned from above, the previous literature has examined bivariate causality between the following pairs of macroeconomic variables: exports and GDP, GDP and FDI, and exports and GDP. However, few published works have examined the relationships among all three variables in a single multivariate model. Liu et al. (2002) examined the relationships among economic growth, FDI, and exports in China, and reported bidirectional causality between each pair of real GDP, real exports, and real FDI, using seasonally adjusted quarterly data from January 1981 to December 1997. Kohpaiboon (2003) examined the relationships among the three economic variables and finds unidirectional causality running from FDI to GDP in the case of Thailand. The author used annual data for the period between 1970 and 1999. According to Hsiao and Hsiao (2006), FDI has a unidirectional effect on GDP directly and indirectly, through exports, in the case of East and Southeast Asian economies. Their results also support bidirectional causality between exports and GDP for East and Southeast Asian economies. They used time series and panel data over the period between 1986 and 2004 in their analysis. Miankhel et al. (2009) examined the relationships among FDI, exports, and economic growth in the case of South Asia and other emerging economies. Their results support the validity of the ELG hypothesis. In the long run, they found that GDP has an influence on other variables, such as exports in the case of Pakistan, and FDI in India. For Mexico and Chile, they found that exports Granger-cause FDI and growth in the long run. They also observed bidirectional causality between GDP and FDI in the case of Thailand. In Malaysia, there was no evidence of any relationship among the three variables.

The causal links among FDI, exports, and economic growth in Africa have been examined in some previous studies (e.g., Ahmad and Ghanbarzadeh, 2011; Akoto, 2012; Hansen and Rand, 2005). The results of Ahmad and Ghanbarzadeh (2011) support bidirectional causality among all three variables for the sample used in their study (Middle East and North African countries). Hansen and Rand (2006) conclude that FDI has a significant long-term impact on economic growth. Akoto (2012) examined the nature of the relationship among FDI, exports, and GDP in South Africa. The results show that FDI has a significant impact on exports. To summarize, the previous literature indicates that there are important interlinkages between GDP, FDI, and exports. The issue is thus important from the point of view of developing economies attempting to improve their socio-economic conditions.

2.5. FDI and CO_2 emissions

The impact of FDI on the host country's environment has also been a subject of debate. Two conflicting hypotheses have been presented in previous studies: the pollution haven hypothesis and the halo effect hypothesis. According to the halo effect hypothesis, the presence of foreign investors will spur positive environmental spill-overs to the host country (Albornoz et al., 2009) because multinational corporations (MNCs) have more advanced technology than their domestic counterparts and will tend to disseminate cleaner technology that will be less harmful to the environment (Görg and Strobl, 2005). In contrast, the pollution haven hypothesis postulates that MNCs will flock more into countries where environmental regulations are less strict (Cole and Elliott, 2005). This strategy might harm the environment in the host country if the issue is not taken seriously (Cole et al., 2006). The results are both theoretically and empirically mixed (see, e.g., Goldenman, 1999; Xing and Kolstad, 2002; Zarsky et al., 1999). However, there is plenty of evidence suggesting that foreign MNCs tend to relocate dirty industries to developing countries with lax environmental regulations, rather than to developed countries, where the environmental regulations are very strict (Blanco et al., 2011; Copeland and Taylor, 2003; Levinson, 1996). Therefore, depending on the nature of and the motives behind the MNCs, FDI can cause more emissions in the host countries. The effect of FDI on GHG emissions in particular has also been a subject of debate in the extant literature. The conclusion by Hoffman et al. (2005) posits that there is evidence of the pollution haven hypothesis most specifically in low-income countries, while in in the case of middle and high-income countries, the halo effect can be proved.

2.6. CO_2 emissions and economic growth

The environmental pollution-economic growth nexus has been a subject of debate for the past two decades. This nexus is closely related to the testing of the Environmental Kuznets Curve (EKC) hypothesis, which was first proposed by Grossman and Krueger (1991, 1995). Grossman and Krueger adjusted the idea of Kuznets (1955) to investigate the relationship between economic development and environment. According to the hypothesis, the relationship between environmental degradation and the level of economic development resembles an inverted U-shape. This means that environmental degradation increases with an increase in income up to a certain turning point, after which the pollution level decreases with an increase in income. The notion of ECK was made popular by the World Bank in the World Development Report of 1992 (IBRD, 1992), which argued that: “The view that greater economic activity unavoidably hurts the environment is based on static assumptions about technology, tastes and environmental investments” (p. 38) and that “As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment” (p. 39). The advocates of this theme vindicate the factors that are responsible for rising or declining environmental degradation over the course of economic development. These include, among others, the scale effect, changes in the structure of the economy, product mix, changes in input mix, and improvement in the state of technology (Andreoni and Levinson, 2001; Grossman and Krueger, 1993; Kijima et al., 2010; Cole, 2004; Stern et al., 1996; Stern, 2004). Kijima et al. expound that “The most common explanation for EKC is the notion that, when a country achieves a sufficiently high standard of living, people assign an increasing value to environmental amenities" (p.1189). Grossmann and Krueger (1993) explicate how environmental degradation tends to increase as the structure of the economy changes from agricultural to industrial, but decreases with another structural change from energy intensive industry to service. Furthermore, because rich countries can manage to spend more on R&D, technological progress increases with economic growth, and hence there is the possibility of replacing dirty and obsolete technologies with cleaner technology, which eventually improves the environmental quality. Scale of production implies increasing production at given factor-input ratios, output mix, and state of technology. Therefore it is pointed out that, as output increases, waste and emissions as by-products also increase, and hence contribute more to environmental degradation. However, this effect can be short-term, because as people within a certain society become richer, the demand for a cleaner and healthier environment increases. Therefore, they are willing to pay more for cleaner products (Dinder, 2004; Kijma et.al, 2010; Stern, 2004).

There have been numerous studies that have tested empirically the validity of the Environmental Kuznets Curve hypothesis using different environmental indicators (e.g., Apergis and Payne, 2009; Borhan and Ahmed, 2012; Dietz et al. 2012; Dinda and Coondoo, 2006; Dinda, 2004; Duarte et al., 2013; Fodha and Zaghdoud, 2010; Friedl and Getzner, 2003; Lee and Lee, 2009; Martínez-Zarzoso and Bengochea-Morancho, 2004; Narayan and Narayan, 2010; Pao and Tsai, 2010; Stern, 1996). Although some of the studies support the Environmental Kuznets Curve, the results of others (e.g., Holtz-Eakin and Selden, 1995; Lise, 2006; Shafik, 1994) indicate that the level of environmental pollution increases monotonically with the income level. A survey by Kijima et al. (2010), Dinda (2004), and the study by Stern (2004) posit that the model specification and methodologies employed by various studies have been singled out to be a major cause of such controversies. Narayan and Narayan (2010) test the Environmental Kuznets Curve hypothesis for 43 developing countries, based on short-term and long-term income elasticity. According to their results, long-term income elasticity estimates for the Middle East and South Asia are smaller than their corresponding short-term elasticity estimates. Hence, the countries have managed to reduce their level of emissions in the long run, which is in line with the Environmental Kuznets Curve hypothesis. Fodha and Zaghdoud (2010) investigate the causal links between economic growth and pollutant emissions in the case of Tunisia, with the aim of testing the validity of the Environmental Kuznets Curve. The study employs two environmental indicators (SO_2 and CO_2), and their results support the Environmental Kuznets Curve hypothesis with reference to SO_2. However, they find a monotonically increasing function between economic growth and CO_2, and hence fail to support the Environmental Kuznets Curve in this case. Duarte et al. (2013) investigate the relationship between per capita water use and per capita income for 65 countries. Their results also support the existence of the Environmental Kuznets Curve hypothesis with reference to the sample studied. The previous studies, such as Hoffmann et al. (2005) and Hassaballa (2013), have provided coherent justifications for using GHG (particularly CO_2) emissions as a proxy for pollution in general. According to them, CO_2 is a primary source of global warming, and the variable is also highly correlated with local pollutants such as nitrogen oxide and sulfur dioxide.

2.7. Energy consumption and economic growth

The energy consumption-economic growth nexus is another strand of literature that has drawn the attention of numerous researchers for the past three decades. It has been pointed out that energy consumption complements the other key determinants of economic growth, such as labor and capital. However, there have been different views regarding the direction of causality between the two variables. The first category of the literature posits that it is economic growth that triggers the demand for energy consumption. This is because, as the country grows, the demand for energy in numerous sectors increases as well, and various economic activities consume substantial amounts of energy. Hence, in this case, economic growth is said to influence energy consumption positively. Furthermore, a well-developed country is perceived to be able to use energy more efficiently than a less-developed country.

The second view emphasizes that energy consumption is crucial for any economy to realize a certain level of economic development. Hence, it is energy consumption that increases the level of economic growth and not vice versa. Another view posits that the two variables are simultaneous with each other. Therefore, based on these arguments, there has been a lot of research on this topic.

Since the seminal study of Kraft and Kraft (1978), a number of studies have investigated the causal link between the two variables, by employing different empirical methodologies (e.g., Akinlo, 2008; Masih and Masih, 1996; Narayan et al., 2008; Narayan and Singh, 2007; Odhiambo, 2009; 2010; Wolde-Rufael, 2005; 2006; 2009). Some of these studies focus on Africa. For example, Odhiambo (2009) employs an autoregressive distributed lag (ARDL) model and Granger causality test to examine the link between energy consumption and economic growth in Tanzania. The study shows that there is a long-term relationship between the two variables. In addition, there seems to be a one-way causality running from energy consumption to economic growth. In a related study, Odhiambo (2010) finds a one-way Granger causality running from energy consumption to economic growth in the case of Kenya and South Africa. A reverse causality seems to exist in the case of the Democratic Republic of the Congo. According to Akinlo (2008), energy consumption has a significant positive long-term effect on economic growth in the case of Ghana, Kenya, Senegal, and Sudan. Furthermore, the results from a Granger causality analysis reveal bidirectional causality between the two variables in the case of Gambia, Ghana, and Senegal, and a unidirectional causality running from economic growth to energy consumption in the case of Sudan and Zimbabwe. A neutral hypothesis between the pair of variables gets support in the case of Cameroon, Ivory Coast, Nigeria, Kenya, and Togo. Bashiri Behmiri and Pires Manso (2013) examine how crude oil consumption affects the economic growth of Sub-Saharan African countries by employing a vector error correction model (VECM). The results reveal bidirectional Granger causality between the two variables in the oil-importing region, while there seems to be a one-way causality running from crude oil consumption to economic growth in the oil-exporting region. In the long run, the results indicate bidirectional causality between the two variables in both regions.

2.8. CO_2 emissions, energy consumption, FDI, and economic growth

Another strand of the literature incorporates the four macroeconomic variables (CO_2 emissions, energy consumption, FDI, and economic development) in a single multivariate model. Recently, a substantial number of studies have examined the causal links among CO_2 emissions, energy consumption, FDI, and economic growth by employing different methodologies and case studies. Despite the vast amount of literature, only a few studies have examined the causal links between these variables in the case of Sub-Saharan Africa. The study by Al-mulali and Binti Che Sab (2012) is the only study that has focused specifically on the Sub-Sahara region. The first line in this strand of literature comprises individual country studies (e.g., Alam et al., 2011; Jahangir Alam et al., 2012; Ang, 2007, 2008; Chang, 2010; Halicioglu, 2009; Pao and Tsai, 2011; Pao et al., 2011; Soytas et al., 2007; Zhang and Chen, 2009). The results from these studies are, however, mixed and cannot be generalized because each country seems to behave differently. The second and more recent line employs a panel data approach (e.g., Kofi Adom et al., 2012; Al-mulali and Binti Che Sab, 2012; Arouri et al. 2012; Hossain, 2011; Niu et al. 2011; Pao and Tsai, 2010, 2011). It has been pointed out that panel data techniques enhance the reliability of the results, especially when the time span of the data is very short (Bashiri Behmiri and Pires Manso, 2013; Narayan and Smyth, 2008). In some countries, particularly in Sub-Saharan Africa, the time span of many macroeconomic variables is short, because of which using simple time series data might lead to spurious results. In a rare study conducted with panel data for Sub-Saharan Africa, Al-mulali and Binti Che Sab (2012) investigated the impacts of energy consumption and CO_2 emissions on economic growth and financial development in the region. They find causality running from both directions in the case of total primary energy consumption and CO_2 emissions, and also between GDP per capita and investment. The authors are not interested in the validity of the Environmental Kuznets Curve hypothesis in their case study. Moreover, we find some of the conclusions made in this study problematic, since despite the claims made by Al-mulali and Bint Che Sab, Granger causality only indicates that changes in one variable precede changes in another variable, not whether the variables are positively or negatively related. Another strand in this category adds FDI to the analysis (Pao and Tsai, 2011). One of the publications in this dissertation addresses the issue.

2.9. Factors affecting the distribution of CDM projects

The previous literature has identified various factors as necessary for successful CDM project registration. Issues to consider include, for example, property rights, quality of other institutions, political stability and predictability, transaction costs, and the date of Kyoto Protocol ratification (e.g., see Dinar et al., 2008; Niederberger and Saner, 2005; Winkelman and Moore, 2011). Essentially, the CDM host countries can be seen as competing to attract foreign capital or FDI. Therefore, the factors that affect CDM projects are closely associated with the factors that influence FDI (see Section 2.1). In addition, as highlighted by Niederberger and Saner (2005) and Jung (2006), CDM investors base their decisions on the business environment, potential volume of cheap emission reductions, and local institutional capacity to organize CDM projects.

First, Byigero et al. (2010) pointed out that the general business environment is closely associated with the investment climate, which is one of the most important factors in initiating a CDM project. Therefore, factors that have been found to impact FDI also affect the number of successfully registered CDM projects. There is a vast amount of literature assessing such factors. In recent years, it has been recognized that institutional quality is one of the most important determinants of the general investment climate. The role of long-lasting institutions, such as property rights and rule of law, is particularly important (Knack and Keefer, 1995; Rodrik et al., 2004). Political stability also matters. These general-level measures of institutional quality are important because, even if well-functioning and efficient CDM institutions are a key element in attracting CDM projects, they have a very limited impact on the general investment climate (Jung, 2006; Schneider et al., 2008). For example, it is virtually impossible to impact political stability through CDM institutions (Paulsson, 2009).

In particular, the level of corruption may play a role: for example, Shleifer and Vishny (1993) and Bardhan (1997) find that corruption inhibits productive investment. More generally, corruption lowers investment relative to GDP by increasing risks (for example, by lowering the security of property rights) and by increasing costs. Mauro (1995) was the first to verify empirically, in a cross-section of countries, that corruption lowers investment, a result that has later gained further support, for example from Dreher et al. (2007), Knack and Keefer (1995), and Mauro (1997). The detrimental effects of corruption do not depend solely on the level of overall corruption, but also on its predictability: countries with more predictable corruption tend to have higher investment rates (Campos et al., 1999 and Wei, 1997 for FDI). If domestic investors are sensitive to the level of corruption, it should not come as a surprise that foreign investors are equally or even more sensitive.

Second, the supply of cheap and feasible emission reduction projects is also important. It is at least partly dictated by the level of economic development of the host country. Therefore, GDP per capita, urbanization, and industrialization can be used to measure the range of opportunities for the CDM. Of course the size of the country plays a role, too: there tend to be more opportunities in large countries. It might thus be necessary to control for population size in the empirical estimations. The level of greenhouse gas emissions also reflects the CDM potential of a country and may thus be used as an indicator for the emission reduction potential of CDM host countries (Jung, 2006).

Third, the local institutional capability to organize CDM projects plays a significant role. This requires that the CDM host country has invested in domestic CDM capacity by increasing CDM awareness, by offering training programs, and by facilitating project identification (Niederberger and Saner, 2005). Jung (2006) uses the following indicators to measure CDM capacity: ratification of the Kyoto Protocol, participation in the Activities Implemented Jointly pilot phase, timely establishment of a designated national authority, and completion of a national strategy study . The national strategy study is a program designed by the host country to build its capacity toward the flexible mechanisms of the Kyoto Protocol (including the CDM). Another aspect is that the size of the CDM activities is likely to depend on transaction costs in host countries to a significant degree (Michaelowa and Jotzo, 2005). The magnitude of transaction costs impacts which projects are economically viable. Because the multiple stages of the CDM require careful monitoring, transaction costs are unavoidable, but might decline when more experience is gained (Chadwick, 2006). Furthermore, transaction costs have been pointed out to shift the supply curve for certified emission reductions from CDM projects upward and hence reduce the number of permits traded in the carbon markets (Jotzo and Michaelowa, 2002; Michaelowa et al., 2003; Michaelowa and Jotzo, 2005). Therefore, the more efficient the local CDM institutions are, the lower the transaction costs are. The level of transaction costs also depends on institutional quality: the more inefficient the regulatory framework, the higher the transaction costs (Michaelowa and Jotzo, 2005).

It has been shown that a lack of human capital is associated with an increase in transaction costs that could be avoided if the level of human capital could be sufficient enough within a particular country hosting CDM projects (Winkelman and Moore, 2011). Many researchers have investigated the determinants of CDM projects theoretically, without testing the hypotheses using empirical data (see, e.g., Cosbel et al., 2006; Lecocq and Ambrose, 2007; Nussbaumer, 2009; Silayan, 2005). In addition, some researchers have focused on the case studies of projects registered in some specific countries, which hinders the generalization of the results (see, e.g., Zhang, 2006; Kim, 2003). Theoretically, it has been pointed out that the necessary conditions for participation in the CDM markets include, among others, the ratification of the Kyoto Protocol, establishment of the designated national authority by the host county, the existence of baseline data, and the local capacity of the host country (see Silayan, 2005).

Winkelman and Moore (2011) empirically investigated the differential distribution of CDM projects among the host countries and found that factors such as human capital, greenhouse emission levels, and the quality of host countries' institutions influenced which countries hosted projects. They used two regression models: a probit model, in which the dependent variables were binary for a country that hosts one or more projects; and a truncated regression model, with the number of certified emission reductions created acting as a dependent variable.

Jung (2006) conducted a cluster analysis to investigate host country attractiveness for CDM non-sink projects and found that very few potential host countries are able to attract CDM activities, due to their credibility and general investment climate. The variables used in the analysis are grouped in three different factors, and these include mitigation potential, institutional CDM capacity, and general investment climate. The mitigation potential of the host county was measured by absolute greenhouse gas emissions, which differed from the work investigated by Frankhauser and Lavric (2003). Kyoto ratification and establishment of a designated national authority are the proxy for institutional CDM capacity, and they indicate whether the country has participated in capacity building programs. The quality of institutions was examined by government indicators for political stability, rule of law, and regulatory quality.

Dinar et al. (2008) investigated factors affecting levels of international cooperation in carbon abatement projects and found out that factors such as economic development, institutional development, the energy structure of the economies, the level of country vulnerability to various climate change effects, and the state of international relations between the host country and investors country are the most prominent predictors of the level of cooperation in CDM projects.

Nevertheless, as we pointed out earlier, there has been an uneven distribution of CDM projects in developing countries. Despite the initiatives taken by developing countries to attract CDM projects, few projects have been registered and implemented in some countries

(Silayan, 2005). According to UNFCCC (2009), it has been clearly stated that a country is eligible to host a CDM project if, first, it has ratified the Kyoto Protocol; and second, if it has established a designated national authority. By June 2013, 192 parties had committed themselves to both steps, which means they have ratified the Kyoto Protocol and at the same time have designed a designated national authority (UNFCCC, 2014). On top of that, 21 countries had ratified the protocol but had not designed a designated national authority.

2.10. FDI and CDM projects

Previous studies have not documented clear links between FDI and CDM projects. It has been however pointed out that the partition between these kinds of investments most specifically in the case of developing countries is difficult to make (Muller, 2007). Nevertheless, they differ in terms of ownership and operations. In the case of FDI, 10% of the voting stock must be owned by the foreign investor, which is not the case with CDM investment. In the case of CDM, the owner can be either a foreign or domestic entity. Furthermore, the CDM executive board should approve the project before it is implemented, which is contrary to FDI. Moreover, CDM investments are mainly focused on projects related to renewable energy technology, energy efficiency, waste management, and fuel switching, while FDI focuses on numerous diverse projects in different sectors.

Furthermore, the evidences to substantiate that countries that have been successful in attracting FDI are also the mainstream for hosting the CDM projects are mixed. For instance, Muller (2007) did not find any positive correlations between FDI and CDM projects in the case of India. However, in the case of China, Cosbey et al. (2005) and Niederberger and Saner (2005) found a positive correlation between these two types of investments. China has managed to attract more of both FDI and CDM projects than any other developing country. In addition, the factors that have been pointed out to affect the distribution of FDI are also found to be responsible for distribution of CDM projects in developing countries (Schroeder, 2009; Zang and Wang, 2011). These factors include, among others, institutional quality, ease of doing business indicators, and market size which have mentioned in the previous section.

3. EMPIRICAL STUDY

This chapter discusses (i) the data collection and the experimental set-up used in this study, (ii) the research methodologies employed, and the merits and demerits of the techniques used. It also includes the econometric models employed in the five publications

3.1. Data sources and experimental set-up

This dissertation consists of five publications, and each publication employs its own data set and methodologies. *The first publication* had the objective of examining the causal links among CO_2 emissions, energy consumption, FDI, and economic development in six Sub-Saharan African countries. The countries under investigation were the Republic of the Congo, the Democratic Republic of the Congo, Kenya, South Africa, Zambia, and Zimbabwe. The study employed the annual time series data covering the period 1971-2009. The energy consumption per capita measured by the kilogram of oil equivalent per capita, GDP per capita in constant 2000 USD, and CO_2 emissions per capita were all taken from the World Development Indicator database (World Bank, 2013a). The FDI series as a percentage of gross fixed capital formation was obtained from the United Nations Conference on Trade and Development (UNCTAD, 2013). The sample used was dictated by the availability of the data for all four macroeconomic variables. The main objective was further divided into three goals. The first goal focused on testing the validity of the so-called Environmental Kuznets Curve (EKC) hypothesis, which claims an inverted U-shaped relationship between environmental degradation and economic development. The second goal in this specific publication was to test for cointegration among the series, meaning to examine whether the series of interest moves together in the long run. It is imperative to test the existence of co-integration within the series under investigation, in order to decide on the appropriate econometric model to be used in further analysis. Lise and Montfort (2007) point out that there is a great advantage in finding co-integration relationships, as the series need no longer to be transformed and, hence, the forecasting power increases substantially. The third goal was to examine the Granger causality within the series. We employed bounds testing procedures for testing co-integration, which is based on a conventional autoregressive distributed lag (ARDL) model. This approach has become popular among scholars due to some useful advantages that are embedded in it. One of the merits of this technique is that it can be used irrespective of whether the series are in level form or integrated in order one, or fractionally co-integrated (Phillips and Hansen, 1990; Wolde-Rufael, 2010). The ARDL modeling technique for testing the co-integration was initially introduced by Pesaran and Shin (1999), and was later extended by Pesaran et al. (2001). However, the traditional ARDL models have been used for a long time, and this is a new application of them for the new purpose of testing co-integration among the series.

The second publication examined the causal links among CO_2 emissions, energy consumption, and economic development using panel cointegration and the vector error correction model, in 13 countries from the Sub-Saharan Africa region. The panel of the sample, which was dictated by data availability, consisted of the following countries: Benin, Cameroon, the Democratic Republic of the Congo, the Republic of the Congo, Ivory Coast, Gabon, Ghana, Kenya, Nigeria, Senegal, Togo, Zambia, and Zimbabwe. The study employed the annual data extracted from the World Band development indicators (World Bank, 2013) covering the period 1991-2010. In order to examine whether the causal relationships between the variables have changed over time, the data was further divided into two periods: 1971-1990 and 1991-2010. The objectives of the study were (1) to test whether the variables of interest move together in the long run (cointegration test), and (2) to examine whether there are dynamic Granger causality relationships between the variables. In addition, we estimated the long-term elasticity estimates of CO_2 emissions with respect to other variables, for the purpose of testing the validity of the Environmental Kuznets Curve hypothesis.

The third publication, whose main objective was to explore the factors affecting the clean development mechanism (CDM) in developing countries, took data for the number of registered CDM projects from the CDM pipeline (http://www.cdmpipeline.org/). The analysis was restricted to 159 non-Annex 1 countries that had already ratified the Kyoto

Protocol and established a designated national authority by June 2012. The response variable was the number of CDM projects, and the explanatory variables were emission level (captured by CO_2 emissions), institutional quality, human capital, the level of economic development, infrastructure, and transaction costs (captured by the ease of doing business indicator). The institutional quality was captured by the six dimensions of good governance, as proposed by Kaufmann et al. (2009). Some other variables were collected from the World Bank development indicators (World Bank, 2012). Human capital was measured by the average years of total schooling, and this proxy was taken from the Barro-Lee Education Attainment Dataset (Barro and Lee, 2001). The level of infrastructure was measured by the electric power consumption (kWh per capita) of the host country, and the data was taken from the World Bank development indicator database (World Bank, 2012). We employed the Poisson and Tobit regression models. This was because, apart from having an integer response variable, the same variable was also censored and had a limiting value. However, in order to check for the robustness of the results, we also employed the number of certified emission reductions generated by the CDM projects as the dependent variable. Furthermore, the extreme bound analysis (EBA) was also used to test the robustness of the explanatory variables.

The fourth publication had the objective of examining the causal links among GDP, FDI, and exports in the case of seven East and Central African countries, by employing both individual time series and panel data methodologies. The countries are Burundi, the Republic of the Congo, the Democratic Republic of the Congo, Kenya, Tanzania, Rwanda, and Uganda. The study employed a Granger causality analysis in a vector error correction model (VECM) framework, to investigate the interrelationship among the variables for the case of Tanzania, while we used a vector autoregression (VAR) model for the other countries. The data were extracted from the World Bank Development Indicator database (World Bank, 2013), covering the period 1989-2010. All the series were measured in constant United States dollars (USD).

The fifth publication aimed to examine the causal links among GDP, FDI, exports, and imports in South Africa. The study employed Granger causality techniques and the vector autoregression correction (VAR) model approaches. Moreover, the study employed the forecast error variance decomposition and the impulse response function, to see how the variables of interest respond to their own shocks and to the shocks imposed on the other remaining variables in the system. These techniques are also known as innovation accounting techniques. The data used in this particular study were also taken from the World Development Indicator database (World Bank, 2013), covering the period 1985-2010. All the series were measured in constant USD. The summary of the variables used, their corresponding proxies, and the data source of each variable are presented in Table 2.

Table 2: Summary of the variables used and the corresponding data source

Article	Variable	Proxies used	Data source
Publication 1	1) CO_2 emissions 2) Energy consumption 3) FDI 4) Economic development	1) CO_2 emissions per capita 2) Kilograms of oil equivalent 3) Percentage of gross fixed capital formation 4) GDP per capita in constant 2000 USD	1) WDI 2) WDI 3) UNCTAD, 2013 4) WDI
Publication 2	1) CO2 emissions 2) Energy consumption 3) Economic growth	1) CO2 emissions per capita 2) Kilograms of oil equivalent 3) GDP per capita	1) WDI 2) WDI 3) WDI
Publication 3	1) Number of CDM projects 2) Emission levels 3) Institutional quality 4) Economic development 5) Infrastructure 6) Transaction cost 7) Human capital	1) CDM projects 2) CO_2 emissions 3) Corruption 4) GDP per capita in constant 2000 USD 5) Electricity capacity 6) Ease of doing business indicator 7) Average years of total schooling	1) CDM pipeline 2) WDI 3) Kaufmann et al. 2009 4) WDI 5) WDI 6) WDI 7) Barro and Lee, 2001
Publication 4	1) Economic growth 2) FDI 3) Exports	1) GDP 2) FDI inflows 3) Exports of goods and services	1) WDI 2) WDI 3) WDI
Publication 5	1) Economic growth 2) FDI 3) Exports 4) Imports	1) GDP 2) FDI inflows 3) Exports of goods and services 4) Imports of goods and services	1) WDI 2) WDI 3) WDI 4) WDI

3.2 Research methodologies

In the following section, we discuss in more detail the methodologies employed in this dissertation. As we have pointed out in the previous section, the data used in four publications out of five were the time series data and panel data. The time series data differs from cross-sectional data in the sense that they are recorded over a period of time for one or more variables, hence they behave differently. Furthermore, when dealing with time series data, issues related to stationarity of the data and the autocorrelation among the series of interest should be taken into consideration, in order to avoid spurious regression results. The panel data have the dimensions of both the time series and cross-sections. Therefore, we started testing the features of the time series data and panel data. These include a test for stationarity and cointegration among the variables of interest. We then proceeded to test the causal links among the variables and other specifications. However, in the other publication, we employed the cross-sectional data. The cross-sectional data are the data on one or more variables recorded at a single point in time.

3.3. Testing for stationarity

Using time-series data in an econometric analysis generally requires the series of interest to be stationary. This is because, if the series are non-stationary, the corresponding results in some of the analysis may be spurious, or misleading. However, numerous macroeconomic series are far from stationary, and hence need to be transformed into other forms in order to induce stationarity before further analysis can take place. Hence, the first step in using time-series data is to test whether the series under consideration are stationary or not (i.e. using a unit root test). This will enable the researcher to define the order of integration of the series in the analysis (i.e. to find how many times the series need to be differenced in order to make them stationary). Furthermore, identification of the order of integration will enable the researcher to choose the appropriate method for testing cointegration, which is a sequel to the stationary test.

There are numerous techniques available to test for the presence of a unit root in time-series variables. The most commonly employed techniques are the Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF), and Phillips-Perron (PP) tests (see Dickey and Fuller, 1979, 1981; Said and Dickey, 1984; Phillips and Perron, 1988) in the case of individual time series analysis, and the Breitung (2000), Levin-Lin-Chu (LLC) (Levin et al., 2002), Im-Pesaran-Shin (IPS) (Im et al., 2003), Fisher-AFD and Fisher-PP (Dickey and Fuller, 1979), and Hadri (2000) tests in the case of a panel data framework. In this dissertation, we employed the ADF and PP approaches in the case of individual country study, and in the case of panel data analysis, we used LLC, Breitung, and IPS techniques.

3.3.1 Dickey-Fuller test

The Dickey-Fuller (DF) is an econometric test used to test whether the time-series data has an autoregressive (AR) unit root. The test procedures were pioneered by Dickey and Fuller (1979). Given a series Y_t whose autoregressive process of order one, or AR(1), is as indicated in Equation (2):

$$Y_t = \alpha Y_{t-1} + \varepsilon_t \qquad (2)$$

and since $\Delta Y_t = Y_t - Y_{t-1}$, then $Y_t = \Delta Y_t + Y_{t-1}$, then by substituting these two small equations in Equation (1) we obtain Equations (3) to (5):

$$\Delta Y_t = \phi Y_{t-1} + \varepsilon_t \qquad (3)$$

$$\Delta Y_t = c_0 + \phi Y_{t-1} + \varepsilon_t \qquad (4)$$

$$\Delta Y_t = c_0 + \delta T + \phi Y_{t-1} + \varepsilon_t \qquad (5)$$

where ϕ is the autoregressive coefficient to be estimated, Δ is the first difference operator, c_0 stands for the constant term, δ is the coefficient of trend component, T stands for trend term, and ε_t is the error term assumed to be independent and identically distributed. The DF tests are based on the forms of regression, Equations (3) to (5). The test Equation (3) includes neither the constant (drift) nor the trend components. Equation (4) includes the constant term only, and Equation (5) includes both the constant (drift) term and the time trend components. The choice of the test equation is determined by the nature of the time series. This can be achieved by plotting the graph of the given series. If the series appears to be fluctuating or wandering around a zero mean, then neither a constant term nor a time trend should be included. But if the series appears to be fluctuating or wandering around a non-zero sample mean, then a constant term should be included. Otherwise, if the series fluctuates around a linear trend, then both the constant and deterministic time trend should be included in the test equation (Hill et al., 2008). In all three cases, the distribution of parameters to be estimated is subject to change. The null hypothesis states that the series has a unit root (i.e., is non-stationary), and if the Dickey-Fuller generalized least squares (DF-GLS) test statistic is greater (i.e. less negative) than the corresponding critical value, we should not reject the null hypothesis, implying that the series is non-stationary. However, if the DF-GLS test statistic is less (i.e. more negative) than the corresponding critical value, then the series is said to be stationary.

3.3.2 Augmented Dickey-Fuller (ADF) test

The Augmented Dickey-Fuller test is also a unit root test for the time series data. It is an extension of the DF test in such a way that it encompasses both the lag one level series and the lagged values of the first difference series. The test was pioneered by Said and Dickey (1984). This approach eliminates the problem associated with serial correlation, which is pervasive in the DF test. The ADF test has been proved to be an appropriate test for large and complicated time series models. The ADF test equations are as indicated in Equations (6) to (8).

$$\Delta Y_t = \phi Y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \varepsilon_t \qquad (6)$$

$$\Delta Y_t = \delta_0 + \phi Y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \varepsilon_t \qquad (7)$$

$$\Delta Y_t = \delta_0 + \delta_1 T + \phi Y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \varepsilon_t \qquad (8)$$

Here, Y_t denotes the series whose stationarity property is to be tested, p is the optimal lag length, and the other variables have already been defined above. The test Equation (6) includes neither the constant nor the trend components. Equation (7) includes the constant term only, and Equation (8) includes both the constant term and the time trend component. The null hypothesis in all cases states that the series has a unit root, or nonstationarity. If the ADF test statistic is greater (i.e. less negative) than the corresponding critical value, then the series is said to be non-stationary, and if the ADF test statistic is less (i.e. more negative) than the corresponding critical value, then the series is stationary.

3.3.3 Phillips-Perron (PP) tests

Phillips and Peron (1988) developed a number of unit root tests that have been used more often in the extant literature to analyze financial and economic time-series data. Phillips and Perron's test statistics can be viewed as modified Dickey-Fuller statistics. They both employ the same estimation equations. However, the PP test corrects for any serial correlation and heteroscedasticity in the errors of the test regression. They do this by directly modifying the test statistics so that the autocorrelation does not affect the asymptotic distribution of the test statistic (Newey-West, 1987). One of the great advantages of this test for the unit root is that it assumes no functional form for the error process of the variables (i.e. it is a non-parametric test), and this means that it is applicable to a very wide set of financial and economic problems. Its disadvantage is that it relies on the asymptotic theory, and hence is not recommended for small samples. The PP tests involve fitting the regression of the form as indicated in Equations (3) to (5).

3.3.4 Testing for stationarity with panel data

There have been vast techniques used to test the presence of a unit root in the case of panel data statistical analysis. The tests make different assumptions about the heterogeneity of the cross-sectional units and may give different results. Some of the tests can only be performed with balanced panel data. The tests include, among others, the Levin-Lin-Chu (LLC) tests (Levin et al., 2002), the Breitung test (Breitung, 2000), the Im-Pesaran-Shin (IPS) test (Im et al., 2003), the Hadri (2000) test, and the Fisher-type test (Maddala and Wu, 1999). For example, the IPS, Hadri, and Fisher-Type tests can be used with unbalanced panel data, while the remaining tests require mainly balanced panel data. The general structure used by most panel unit root testing approaches is as specified in the following Equation (9):

$$\Delta Y_{it} = \rho_i Y_{it-1} + \sum_{l=1}^{pi} \gamma_{i,l} \Delta Y_{it-l} + \alpha_i d_{it} + \varepsilon_{it} \qquad (9)$$

where i indexes unit and t time, d_{it} are the deterministic components (constant and time trend), and $\rho_i = \alpha_i - 1$ are the autoregressive coefficients. $\rho_i = 0$ denotes that Y_{it} has a unit root for individual i, while $\rho_i < 0$ means that the process is stationary around the deterministic part. The null hypothesis in a panel data setting states that the series has a unit root (i.e. is nonstationary); however, the corresponding alternative hypothesis can be a single common dominant stationary root, or heterogeneous stationary roots. Levin et al. (2002) propose a test that has an alternative hypothesis in which ρ_i is identical and negative across all the cross-sections. That is, they assume homogeneity across the cross-sections. The Breitung (2000) test also proposes homogeneity across the cross-sections' unit root and that all cross-sections have a common unit root process; the null hypothesis according to Breitung (2000) is that the series has a unit root, i.e. $H_0 : \rho = 0$ and the corresponding alternative hypothesis is that the series has no unit root, i.e $H_1 : \rho < 0$. The main difference between the Breitung and LLC tests is that Breitung uses an unbiased estimator rather than biased-corrected ones. Im et al. (2003) allow heterogeneity across the cross-sections' unit roots and that each cross-section has an individual unit root process; the null hypothesis is that the series has a unit root, i.e. $H_0 : \rho_i = 0$ and the corresponding alternative hypothesis is that some cross-sections do not have unit roots, $H_1 : \rho_i < 0$. Bashiri Behmiri and Pires Manso (2013) posited that this test is more trustworthy with country data, due to differences in characteristics and economic structures across countries. Maddala and Wu (1999) and Choi (2001) proposed a Fisher-type test as a panel unit root test that combines the probability values from individual unit root tests. The Fisher-type test neither requires a balanced panel nor identical lag lengths in the individual regressions (Hamit-Haggar, 2012). However, one of the shortcomings of Fisher-type test is that the probability values need to be drawn from Monte Carlo simulations. The Hadri (2000) test is constructed as a residual based Lagrange multiplier test.

3.5 Co-integration analysis

According to Brooks (2008), cointegration is defined as the long-term relationship between non-stationary time series whose linear combination is stationary. Hence, if the series are non-stationary at one level, but stationary after being differenced once, then we continue testing for cointegration. Instead, if the above conditions are not fulfilled, there will be no need to test for cointegration among the variables under investigation. Several methods have been developed for testing for cointegration among macroeconomic variables with individual time-series data (Engle and Granger, 1987; Johansen, 1988, 1991; Johansen and Juselius, 1990) and recently with panel data (e.g., Kao, 1999; Maddala and Wu, 1999; Pedroni, 1999; 2004). Another cointegration test technique, as discussed earlier, is bounds testing based on an ARDL approach. In this dissertation, we employed an ARDL bounds testing approach and Johansen in the case of individual time series studies, and in the case of panel data analysis, we used the residual-based procedures proposed by Pedroni. Pedroni cointegration approaches have been used frequently in recent studies (see, e.g., Al-mulali and Binti Che Sab, 2012; Pao and Tsai, 2011). We also used Johansen-type panel cointegration test procedures developed by Maddala and Wu (1999), in order to check for the robustness of the results. The results of the cointegration test can be used to model the long-term relationship among numerous finance and economic series. Furthermore, realization of the cointegrated system will rule out the possibility of the regression results being spurious.

3.5.1. Cointegration test based on ARDL model

The autoregressive distributed lag (ARDL) modeling technique for testing for cointegration was initially introduced by Pesaran and Shin (1999) and was later extended by Pesaran et al. (2001). Although conventional ARDL models have been used for a long time, this is a new application of them for the new purpose of testing cointegration among variables. The critical values generated by Pesaran et al. are valid for large sample sizes, while Narayan (2004a, 2004b) and Narayan (2005) propose critical values that are appropriate for small sample sizes. There are also other univariate cointegration approaches, such as the methodology by Engle and Granger (1987) and the fully modified OLS procedures developed by Phillips and Hansen (1990). However, ARDL has been more used recently, due to some useful advantages that are embedded in it. One of the main merits of this technique is that it can be used irrespective of whether series are level, meaning I(0), or integrated of order one, meaning I(1), or fractionally cointegrated (Wolde-Rufael, 2010; Kofi Adom et al., 2012). Another advantage is that both short-term and long-term estimates can be obtained simultaneously. In addition, endogeneity problems and an inability to test the hypothesis on the estimated coefficients in the long run, as associated with the Engle-Granger method, are avoided (Halicioglu, 2009). An illustration of the ARDL model for two series is specified in Equations (10) and (11).

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 X_{t-1} + \sum_{i=1}^{p} \alpha_{3i} \Delta Y_{t-i} + \sum_{i=1}^{p} \alpha_{4i} \Delta X_{t-i} + \mu_t \tag{10}$$

$$\Delta X_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 X_{t-1} + \sum_{i=1}^{p} \beta_{3i} \Delta X_{t-i} + \sum_{i=1}^{p} \beta_{4i} \Delta Y_{t-i} + \mu_t \tag{11}$$

where Y_t and X_t are the series we need to test for the presence of cointegration, α_0 , β_0 are drift components, μ_t stands for white noise error term, and Δ is the first difference operator.

Our task is to test whether the coefficients of the first lags of the level series of Equations (10) and (11) are jointly significantly different from zero against the corresponding alternative hypothesis. For example, in Equation 10, we test whether α_1 and α_2 are jointly statistically significantly different from zero, while in Equation 11, we test whether β_1 and β_2 are jointly statistically significantly different from zero. We achieve this test by means of Wald statistics.

3.5.2. Johansen cointegration test

The Johansen cointegration test is carried out under the vector autoregressive (VAR) model framework. The technique was first pioneered by Johansen (1988) and later extended by Johansen and Juselius (1990) and Johansen (1991). The approach is based on asymptotic distribution, and hence is more appropriate for a large sample. Suppose that a set of n variables ($n \geq 2$) are integrated of order one, i.e. I(1), and are thought to be cointegrated, then the VAR with *p* lags containing these variables could be specified as indicated in Equation (14). In order to employ the Johansen test, the VAR model (14) needs to be turned into a vector error correction model of the form specified in Equation (15). The test for cointegration between the variables is calculated by observing the rank of the Π matrix in Equation (15) through its eigenvalues. The rank of the matrix is equal to the number of its characteristic roots (eigenvalues) that are significantly different from zero (see, Brooks, 2008). The Johansen approach uses two test statistics for testing the cointegration, and they are indicated in Equations (12) and (13).

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i) \qquad (12)$$

$$\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1}) \qquad (13)$$

where r stands for the number of cointegration vectors, and $\hat{\lambda}_i$ is the estimated value for the *i*th ordered eigenvalue from the Π matrix. λ_{trace} is a joint test where the null hypothesis is that the number of cointegrating vectors is less than or equal to r against the alternative hypothesis that there are more than r cointegration vectors. $\lambda_{\max}$ conducts a separate test on each eigenvalue, and has its own null hypothesis that the number of cointegration vectors is λ_{trace} against the alternative hypothesis that there are more than $r+1$ cointegration vectors. The critical values for the two test statistics are provided by Johansen and Juselius (1990), and the distributions of these tests statistics are not given by the usual chi-squared distributions.

3.6 Vector autoregression (VAR) and vector error correction models

The VAR model is a multivariate time series model initially popularized by Sims (1980) as the extension of the univariate autoregressive model and simultaneous regression models. In the VAR system of equations, all the variables are treated as endogenous and independent, although sometimes exogenous variables can also be included (see, e.g., Ramey and Shapiro, 1998). Endogenous variables are the economic variables that are determined within the specified models, while exogenous variables are usually assumed to be determined by factors outside the model of interest. Furthermore, all variables to be included in estimating VAR need to be stationary (see Brooks, 2008). The VAR(*p*) model involves the estimation of a system of equations as indicated in Equation (14).

$$y_t = \beta + \Gamma_1 y_{t-1} + \Gamma_2 y_{t-2} + \ldots + \Gamma_p y_{t-p} + \mu_t \tag{14}$$

where y_t is a ($m \times 1$) column vector of the endogenous variables, p is the number of lags in each equation, β is a ($m \times 1$) constant vector, μ_t is a ($m \times 1$) vector of random error terms in the system, and Γ_i for $i = 1, 2, \ldots, p$ are ($m \times m$) matrices of regression coefficients. According to Granger (1988), the VAR framework is only valid when the variables under consideration are not cointegrated. VAR captures only the short-term effects among the variables, while the vector error correction (VECM) model takes into account the short-term and long-term causal relationships. The VECM of lag *p* is specified in Equation (15).

$$\Delta y_t = \Pi ECT_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \ldots + \Gamma_p \Delta y_{t-p} + \mu_t \qquad (15)$$

where y_t is a column vector of the endogenous variables as previously stated, Π is the long-term coefficients matrix, ΠECT_{t-1} is the long-term error correction term, which captures the speed of adjustment to the long-term equilibrium after a short-term shock, and Δ is the difference operator. The VECM indicates that the differenced dependent variables are affected by the long-term error correction term and the short-term first differenced lagged variables ($\Delta y_{t-1}, \ldots, \Delta y_{t-p}$). There are numerous criteria that have been used in selecting the optimal lag length, and these include, among others, the Akaike (1974) information criterion (AIC), the Schwarz (1978) information criterion (SIC), the Hannan-Quinn (1979) information criterion (HQ), the sequential modified likelihood ratio test (LR), and the final prediction error (FPE). Mathematically, these criteria are defined in Equation (16).

$$\begin{aligned}
AIC_m &= \log\left|\hat{\Omega}\right|) + \frac{2m}{T} \\
SIC_m &= \log\left|\hat{\Omega}\right| + \frac{m}{T}\log(T) \\
HQ_m &= \log\left|\hat{\Omega}\right| + \frac{2m}{T}\log(\log(T)) \\
FPE_m &= \log\left|\hat{\Omega}\right|(T+m)(T-m)^{-1} \\
LR &= T\left[\log\left|\hat{\Omega}_r\right| - \log\left|\hat{\Omega}_u\right|\right]
\end{aligned} \qquad (16)$$

where T denotes the number of observations, $\hat{\Omega} = (T-m-1)^{-1}\sum_{t=1}^{T}\mu_t^2$ is the variance-covariance matrix of residuals, $m = p^2 k$ is the total number of parameters, k denotes the number of lags, p stands for the number of variables in the given VAR system, which is also equal to the total number of equations, $\hat{\Omega}_r$ is the variance-covariance matrix of the residuals for the restricted model, and $\hat{\Omega}_u$ is the variance-covariance matrix of the residuals for the unrestricted model. Some of these criteria, such as AIC and SIC, are applicable to general classes of models, while others, such as HQ, are only applicable in fairly restrictive circumstance, such as in autoregressive models or autoregressive moving average models (Akaike, 1981; Hannan, 1980). For a more theoretical review of these criteria, see Sin and White (1996).

3.7. Panel data models

Panel data models describe individual behavior both across time and across individuals. There are different kinds of panel data estimation techniques, and these include, among others, the pooled panel model, the random effects model, the fixed effects model, and difference and system generalized method of moment (GMM) models. The panel data techniques have an advantage over the other methods due to their flexibility in controlling the unobserved individual heterogeneity (Baltagi, 2001; Baltagi, 2005). The general notion behind this is that there are individual-specific characteristics that are difficult or even impossible to observe or measure (e.g., intelligence/ability, family-specific characteristics, specific skills). However, it is assumed that these unobserved individual-specific characteristics vary across individuals but are constant over time.

3.7.1 The pooled model

The pooled model assumes that both the intercept and slope terms are constant across individuals and over time. This is the usual assumption for cross-sectional analysis. The general pooled regression model with cross-sections $i = 1,\ldots,N$, and time $t = 1,\ldots,T$ is specified in Equation (17).

$$Y_{it} = \alpha + X_{it}\beta + \varepsilon_{it} \qquad (17)$$

where Y_{it} is a ($k \times 1$) column vector of continuous dependent variables; X_{it} is a *K*-dimensional vector of explanatory variables; α is both a time and an individual-invariant constant term, independent of time and cross-section; β is a ($k \times 1$) vector of coefficients of regression, which are also assumed to be independent of i and t; and ε_{it} is the error terms that are assumed to be independent and identically distributed with a mean of zero and constant variance. In other words, all the classical linear regression assumptions are assumed to be valid, and hence the OLS estimator for β will be efficient in this situation. However, the estimator will be biased, hence the pooled OLS estimation technique is not much used in the literature when compared to individual-specific panel models.

3.7.2 Fixed effects model

When using the fixed effects (FE) model, we assume that each country has its own individual characteristics. Because of this, the intercept term of the regression model is allowed to vary over individual countries, but is constant over time. However, the slope coefficients are assumed to be the same for all cross-section units. Generally, the FE model is as specified in Equation (18)

$$Y_{it} = \alpha_i + X_{it}\beta + \varepsilon_{it} \tag{18}$$

where Y_{it} is the dependent variable; i stands for a specific cross-section; t stands for time; β is the slope coefficient, which is considered to be constant for all cross-section units; X_{it} is a vector of all explanatory variables, as previously defined; α_i is the individual-specific unobserved constants (individual effects), taking into account the heterogeneity impact from unobserved variables, which may be different across countries; and ε_{it} is the error term. In addition to the unobserved individual-specific effects, the unobserved time-specific effects can also be incorporated into the model. There are some explicit assumptions. First, ε_{it} is assumed to be uncorrelated with X_{it}, meaning strict exogeneity $E[\varepsilon_{it}|X_{it}] = 0$, and there is also correlation between individual-specific effects and the explanatory variables, $E[\alpha_i|X_{it}] \neq 0$.

3.7.3 Random effects model

The main difference between the FE and random effects (RE) models is that, in the RE model, the individual specific effects η_i are random variables, as specified in Equation (19), and these individual-specific effects are added to the error term to form a composite error $\varepsilon_{it} = \eta_i + \upsilon_{it}$

$$Y_{it} = \beta_0 + \beta X_{it} + (\eta_i + \upsilon_{it}) \tag{19}$$

where $\eta_i \approx IID\left(0, \sigma_\eta^2\right)$ are individual specific random errors and $\upsilon_{it} \approx IID\left(0, \sigma_\upsilon^2\right)$ depict the remaining random error, also known as an idiosyncratic error. This implies that the individual-specific effects are independent and identically distributed random variables with a mean of zero and constant variance, and their distributions are assumed to be not too far from normal distribution. However, another different feature of the two models is that, in the case of the RE model, there is no correlation between the individual-specific effects η_i and the regressors X_{it}. The general mean is captured in β_0. Generally, the moment conditions as specified in Equation (20) should be met.

$$\begin{aligned}
&E\left[\upsilon_{it} \middle| X_{it}\right] = 0 = E\left[\eta_i \middle| X_{it}\right] = 0 \\
&E\left[\upsilon_{it}^2 \middle| X_{it}\right] = \sigma_\upsilon^2 \\
&E\left[\eta_i^2 \middle| X_{it}\right] = \sigma_\eta^2 \\
&E\left[\varepsilon_{it}^2 \middle| X_{it}\right] = Var(\varepsilon_{it}) = \sigma_\eta^2 + \sigma_\upsilon^2 \\
&E\left[\upsilon_{it}\eta_i \middle| X_{it}\right] = 0 \ for\ all\ i, and\ t \\
&E\left[\eta_i\eta_j \middle| X_{it}\right] = 0 \ \ if\ \ i \neq j
\end{aligned} \tag{20}$$

In order to choose between the two estimation methods, the Hausman (1978) test can be used. The null hypothesis states that the individual-specific effects are uncorrelated with explanatory variables, meaning that the RE model is consistent. If the null hypothesis is rejected, the FE model has to be used.

3.8. Tobit, probit and Poisson regression models

3.8.1 Tobit model

The Tobit regression model (aka the censored normal regression model) is often appropriate when the dependent variable of the regression model is incompletely observed. However, the model is also used when the dependent variables have limiting values. This specific situation indicates that an observation y^* can be censored either from above or from below. However, the Tobit model can be generalized to take into account the censoring both from below and/or from above. It can also take account of interval censored data. Therefore, if the data used in the analysis are constrained with these features, then employing OLS regression will result in biased and inconsistent estimators. The general Tobit model is as indicated in Equation (21).

$$y_i^* = X_i \beta + \varepsilon_i \quad i = 1, \ldots, N \tag{21}$$

where y^* stands for a latent variable that is observed for values greater than or less than the limiting point τ. β denotes a vector of parameters to be estimated, X stands for a vector of independent variables, and ε_i is the error terms assumed to be independent and identically distributed with a mean of zero and constant variance. The corresponding observed y is defined as specified in Equation (22):

$$y_i = \begin{cases} y^* \ \ if \ y^* > \tau \\ \tau_y \ \ if \ \ y^* \le \tau \end{cases} \tag{22}$$

In the case of the typical Tobit model, where the data are censored at 0, Equation (22) becomes as indicated in Equation (23):

$$y_i = \begin{cases} y^* \ if \ y^* > 0 \\ 0 \ if \ \ y^* \le 0 \end{cases} \tag{23}$$

The Tobit model has been widely used in the previous academic literature (see, e.g., Adesina and Zinnah, 1993; Amemiya, 1979; Blundell and Meghir, 1987; Johnston and Dinardo, 1972; Greene, 1981; Smith and Blundell, 1986; Suits, 1984).

3.8.2 Probit model

Probit models have been widely used in academic literature (see, e.g., McCulloch and Rossi, 1994; Hausman and Wise, 1978; Ai and Norton, 2003; Amemiya, 1978; Keane, 1992) to model numerous economic phenomena. The model is often used in cases in which the dependent variable of the regression equation is binary (dichotomous), and hence is appropriate for social science research. The general probit model is as specified in equation (24).

$$y_i^* = X_i \beta + \varepsilon_i$$
$$y_i = \begin{cases} 1 & if \;\; y_i^* \geq 0, \\ 0 & otherwise \end{cases} \qquad (24)$$

where i indexes individuals, X is a vector of independent variables, and β is a vector of regression coefficients. In a probit model, the value of Xβ is taken to be the Z-value of a normal distribution, and higher values of Xβ mean that the event is more likely to happen. In other words, the probit model estimates the probability that $y = 1$ is the function of the independent variables as specified in Equation (25).

$$p = \Pr\left[y = 1 \;|X \right] = F(X'\beta)$$
$$F(X'\beta) = \phi(X'\beta) = \int_{-\infty}^{x'\beta} \phi(Z)dZ \qquad (25)$$

where $F(X'\beta)$ is the cumulative density function of the standard normal distribution.

3.8.3 Poisson regression model

Poisson regression models have been widely used to model count data. A random variable Y is said to have a Poisson distribution with parameter μ if it takes integer values $Y = 0,1,2,\ldots$ with a probability as indicated in Equation (26).

$$\Pr[Y = y] = \frac{e^{-\mu}\mu^{y}}{y!} \tag{26}$$

for $\mu > 0$. The population mean and variance of this distribution are said to be the same, meaning E(Y) = Var(Y) = μ, and since the mean is equal to the variance, any factor that affects one will also affect the other. Thus, the usual assumption of homoscedasticity would not be appropriate for Poisson data. We employed Poisson regression in one of the publications. This was because the dependent variable in our model entailed integer values.

3.9. Statistical causality analysis

The concept of causal inference between the variables has been widely used in scientific research for a long period of time. The most commonly used methods in previous studies include, among others, regression analysis, the causal Markov Chain condition, and Granger causality techniques (see, e.g., Chatterjee and Cohen et al., 2013; Hadi, 2013; Kiiveri et al., 1984; Granger, 1969; Holland, 1986; Montgomery et al., 2012; Pearl, 1995, 2000; Robert and Casella, 2004; Rubin, 1978; Sims, 1986; Spirtes et al., 1993; Swanson and Granger, 1997). Others have employed the so-called Directed Acyclic Graph and innovation accounting techniques (see, e.g., Bernanke, 1986; Jayech and Zina, 2013; Pearl, 2000; Spirtes et al., 2000). In regression analysis, the objective of the researcher is to estimate the influence that explanatory variables have on an outcome variable, and it is assumed that if the relations among the variables of interest are linear, then the rate of change in the outcome variable with respect to a unit change in one of the explanatory variables can be represented by regression coefficients. In a Markov process, knowing the current state of a system is relevant to its future, but knowing how it got to its current state is completely irrelevant (Reichenbach, 1956). This notion is somewhat different from the idea proposed by Granger (1969), as we see in the next subsection. However, in this study, we employed Granger causality approaches and the innovation accounting framework to investigate the causal links among the variables of interest, so the next sections discuss these two concepts in more detail.

3.9.1 Granger causality

In this dissertation, we used the Granger causality test developed by Granger (1969) and Wiener (1956) to analyze the relationships among the variables of interest. According to Granger (1969), a variable x is said to Granger-cause another variable y, if the variable y can be better predicted by the past or lagged values of both x and y than by the lagged values of y alone. Granger causality is not causality in the traditional sense, when compared with other causal inference methods mentioned in the previous section, and it cannot be used to deduce whether changes in a variable have a positive or negative impact on another variable. In fact, Granger causality is a kind of misnomer process: instead of indicating directly that the movement of one variable causes the movement of another variable, it shows the chronological ordering of movements (Tang, 2008). However, by applying the Granger causality test, the complicated and difficult issues related to the endogeneity of explanatory variables, which would arise in many other econometric approaches due to interlinkages among the variables of interest, can be eliminated (Granger, 1988; Masih and Masih, 1996; Masih and Masih, 1997). Furthermore, the Granger causality test method has been embraced in the literature more than other alternative approaches, due to its flexibility for both large and small samples (see, e.g., Guilkey and Salemi, 1982; Geweke et al., 1983). Other alternative techniques that have been proposed in the academic literature for causality analysis include Sims (1972), Pierce and Haugh (1977), and Geweke (1982), inter alia. However, the Granger causality test has been used more often than the other methods, despite the limitations described above. The test for bilateral Granger causality can be performed by estimating Equations (27) and (28).

$$Y_t = \alpha_{10} + \sum_{i=1}^{n} \alpha_{1i} Y_{t-i} + \sum_{i=1}^{n} \beta_{1i} X_{t-i} + \mu_{1t} \quad (27)$$

$$X_t = \alpha_{20} + \sum_{i=1}^{n} \alpha_{2i} Y_{t-i} + \sum_{i=1}^{n} \beta_{2i} X_{t-i} + \mu_{2t} \quad (28)$$

where μ_{1t} and μ_{2t} are assumed to be mutually uncorrelated white noise processes and n denotes the number of lagged variables. Furthermore, X is said to Granger-cause Y if the estimated coefficients of the lagged values of X in Equation (27) are statistically significantly different from zero as a group, and Y is said to Granger-cause X if the estimated coefficients of lagged Y in Equation (28) are statistically different from zero as a group.

There have been numerous arguments regarding the validity of Granger causality analysis in investigating the causal links between the variables of interest. As we have pointed out earlier, Granger causality only shows chronological ordering of movement between the causal and effect variables, and not how the movement of one variable causes the movement of another variable. It centers on the notion that changes in the causing variables should precede changes in the effect variables. Furthermore, the theory behind Granger causality lies in the fact that the future cannot cause the past, but rather the past values are relevant determinants of the present values, and hence the stochastic nature of variables and the direction of flow of time are the central features in Granger causality. The theory is not relevant for non-stochastic variables (Granger, 1969). However, despite the limitations behind Granger causality methodologies, it has been used more often in recent years to analyze the cause and effect relationship between variables in numerous fields, such as economics and finance (see, e.g., Ashenfelter and Card, 1982; Gelper and Croux 2007; Hamilton, 1983; Hiemstra and Jones 1994; Lee 1992; Renault and Werker, 2005; Sims, 1972), neuroscience (see, e.g., Brovelli et al., 2004; Seth 2008), gene networks (see, e.g., Fujita et al., 2009), geophysics (see, e.g., Reichel et al., 2001), sociology (Deane and Gutamann, 2003), and health science (see, e.g., Devlin and Hansen, 2001; Dreger and

Reimers, 2005; Erdil, and Yetkiner, 2009; Farahani et al., 2009; French, 2012; Frijters et al., 2005; Hansen, 2012).

3.9.2 Causality analysis based on simultaneous equation modeling

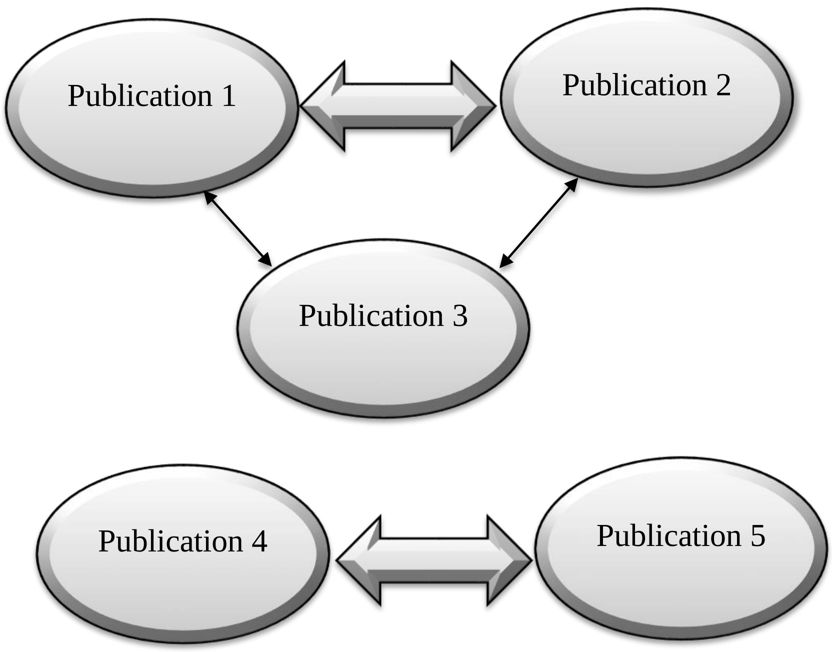
The alternative econometric models that are also employed in empirical research in investigating the causal links between the variables of interest are the simultaneous equations models. Unlike the more conventional multivariate linear model, in simultaneous equations, the response variable of one of the regression equations may appear as a regressor in another equation. Generally, the variables are simultaneously determined, and they may affect each other either directly or indirectly. This implies that, in the case of simultaneous equations models, the variables are treated as endogenous variables, and can therefore also be used to overcome the problems related to endogeneity. Furthermore, these kinds of models can be employed to examine the endogenous relationships among the economic and finance variables. There are numerous techniques used to estimate the simultaneous equations models, such as indirect least squares (ILS), two stage least squares (2SLS), three stage least squares (3SLS), instrumental variables (IV) techniques, full information maximum likelihood, and limited information maximum likelihood (for more discussion on these techniques, see Brooks, 2008). However, as Emirmahmutogle and Kose (2011) point out, simultaneous equations techniques do not take into account the dynamic effects, cointegration tests, and exogeneity in examining the causal links between the variables. This is because, in simultaneous equations, we normally include the instantaneous variables, and the variables of interest are endogenous, even though the model can include other exogenous variables.

3.9.3 Innovation accounting techniques to causality analysis

The Granger causality analysis in the VAR framework is limited in the sense that the Chi-square or block F-tests from the Wald tests do not provide information about the sign of the relationship or how long these effects need to take place (Brooks, 2008). Furthermore, it does not indicate the relative importance between variables that simultaneously affect each other. To respond to these questions, some of the previous studies have utilized the so-called forecast error variance decomposition and impulse response functions to analyze the causal links between economic variables of interest within the VAR framework (see, e.g., Enders, 1995; Pesaran and Shin, 1998; Shahbaz, 2012; Shan, 2002). These approaches together are termed innovation accounting techniques. Impulse response functions identify the responsiveness of each of the dependent variables (endogenous variables) in the VAR system to one standard deviation positive shock/innovation/impulse imposed on the very same variable, as well as to the shock given to the other variables in the system over time. According to Brooks (2008), for each variable from each equation, a unit shock is applied to the error term separately. The significance of the impulse response function is that it is used to show whether there is a positive or negative relationship between the variables in the VAR framework. On the other hand, forecast error variance decomposition provides an inference of the proportion of the movements or fluctuations in a time series subject to their own shocks, versus shocks to other variables in the system (Brooks, 2008). In other words, variance decomposition breaks down the variance of the forecast error for each dependent variable into components that can be attributed to each of the other endogenous variables.

4. SUMMARY OF THE FINDINGS IN THE FIVE PUBLICATIONS

This chapter gives a short summary of the publications attached to this dissertation. The first publication investigated the causal links among CO_2 emissions, energy consumption, FDI, and economic development in the case of six Sub-Saharan African countries. The publication employed the autoregressive distributed lag model (ARDL) and VECM to examine the cointegration among the variables of interest, and tests Granger causality between the variables. The second publication incorporated three variables, CO_2 emissions, energy consumption, and economic development, in a panel of 13 countries from Sub-Saharan Africa. These first two publications differ in terms of the sample used, the span of the data used, and the methodologies employed. The third publication explored the factors that affect the so-called clean development mechanism (CDM) in the case of developing countries. The publication employed cross-sectional data, and Tobit and Poisson regression models. This study differs somewhat from the rest of the publications, which employed time-series data. However, the first three publications are somehow related, because they all focus on environmental development. The fourth publication investigated the causal links between GDP, FDI, and exports in seven East and Central African countries, by employing the vector error correction model (VECM) and the vector autoregressive model (VAR). The fifth publication incorporated imports as an additional variable and focuses merely on the case of South Africa. It also employed the VAR model framework to test the Granger causality among the variables of interest. Furthermore, the publication used impulse response functions and variance decomposition to examine the responsiveness of the variables with respect to the shock given to the other variables within a given VAR system of equations. Hence, there is a slight difference in terms of case studies and methodologies between these last two publications. Figure 9 depicts the links among the five publications in more details.



Key

Partially related (in terms of variables employed)

Related in such that they all focus on environmental development

Figure 9: The links between the five publications

4.1 Publication 1: Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: causality analysis of Sub-Saharan Africa

General objective

There has been great interest in the causal links among the level of greenhouse emissions, energy consumption, FDI, and economic development in the extant literature. Only a few of the existing studies focus on Sub-Saharan Africa, although the issue could be thought to be particularly important there, because the countries in this particular region are struggling to improve their living standards. As it has been pointed out, energy consumption and FDI are two of the determinants of economic growth. But the issue of environmental protection is imperative, since energy use can cause more emissions. Therefore, understanding the causal links among the mentioned macroeconomic variables will enable policy-makers in this region to construct the appropriate policies. Hence, the current study aims to provide new insights with regard to the causality relationships among the mentioned economic variables in the case of six Sub-Saharan African countries. Since CO_2 is probably the most important greenhouse gas, it was used as an indicator of emission levels. For example, Hoffmann et al. (2005) and Hassaballa (2013) have provided justifications for using CO_2 emissions as an indicator for pollution in general. According to these scholars, the increase in the level of CO_2 is a primary source of global warming, and the level of CO_2 emissions is also highly correlated with local pollutants such as nitrous oxide and sulfur dioxide.

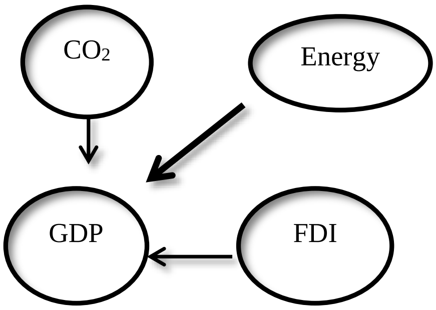
Main contribution

The results, based on an autoregressive distributed lag (ARDL) model, imply that the variables are cointegrated; in other words, they move together in the long run. The results also support the Environmental Kuznets Curve hypothesis in the case of the Democratic Republic of the Congo (DRC), Kenya, and Zimbabwe. Moreover, FDI appears to increase CO_2 emissions in some of the countries, while the opposite effect is pervasive in others. The most common unidirectional Granger causality relationships run from the other variables to CO_2 emissions, with different variables Granger-causing CO_2 emissions in different countries, and from GDP to FDI. Granger causality running to CO_2 emissions appears more likely in the countries where the evidence supports the Environmental Kuznets Curve hypothesis. Otherwise, the causality relationships vary greatly between the countries. This is the first study to investigate the causal links among the variables of interest in this sample of countries. The summary of results of the Granger causality analysis in the short run is reported in Figure 10.

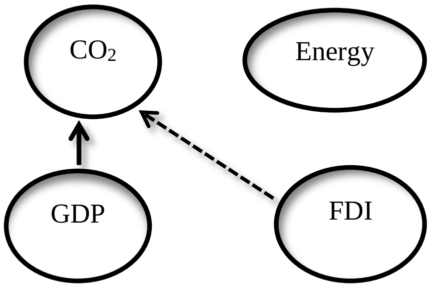
The results pose some policy implications for policy-makers in the countries investigated. For instance, the causality running from FDI to CO_2 emissions might support the pollution haven hypothesis or the halo hypothesis. This means that the presence of multinationals in the host countries could either increase or decrease the level of emissions, implying that the host countries must try to assess the environmental impact of FDI before welcoming foreign investors into the country. Another crucial result is the Granger causality running from energy consumption to GDP. If energy consumption is one of the determinants of economic development, attempts to curb energy consumption may have an adverse effect on the economic development of the country in question. On the other hand, if GDP Granger-causes energy consumption in Zambia, and not the other way round, it might be the case that energy-saving policies could be implemented in the country with little or no adverse effect on the level of economic development.

Moreover, the results showing that energy consumption and GDP Granger-cause CO_2 emissions are associated with the fact that, as a country develops, it tends to consume more energy than before. As a result, its emissions increase as well. Such countries should encourage the use of renewable sources of energy in order to minimize the adverse effects of emissions. In addition, the author would like to recommend that the countries should invest more in energy-efficiency projects, in order to continue protecting the environment. Furthermore, the results showing that FDI Granger-causes GDP indicate that FDI is one of the determinants of economic development. Hence, the potential host countries should continue with strategies of attracting more FDI. For other countries, the reverse causality from GDP to FDI seems to hold. In such cases, the level of economic development of the host country is one of the determinants of FDI. This has been the case especially in the market seeking FDI. The potential host countries should encourage other determinants of economic development, such as institutional quality, expansion of the export base, persistent improvements in domestic investments, and improvement in infrastructure, in order to attract more foreign investors.

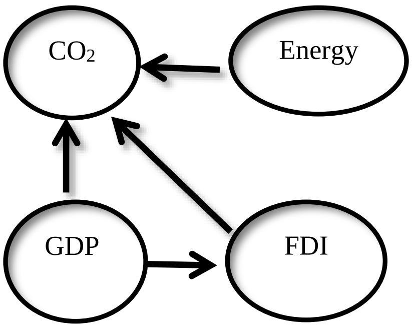
(1) The Republic of the Congo



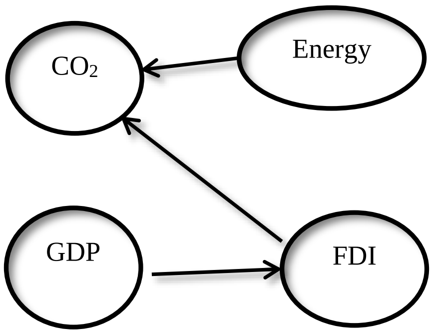
(2) DRC



(3) Kenya



(4) South Africa



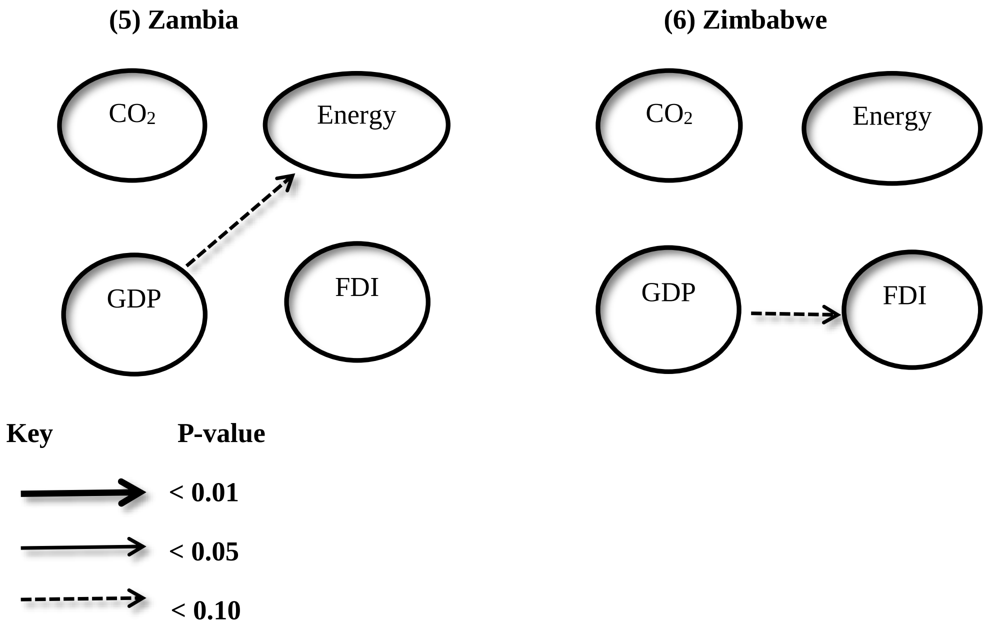


Figure 10: Granger causality relations between CO2, energy consumption, FDI, and GDP

4.2. Publication 2: Carbon dioxide emissions, energy consumption, and economic development in Sub-Saharan Africa: panel cointegration and causality analysis

General objectives

Previous research has investigated the causal links between CO_2 emissions, energy consumption, and economic growth. However, the results are mixed, and so no consensus has been reached with regard to the direction of causality among these three economic variables. Moreover, only a few studies have focused on the Sub-Saharan African region. The current study aims to provide a new way of looking at the interrelationships among the variables, by employing the panel cointegration analysis and Granger causality in a vector error correction framework.

Main contribution

The sample consists of 13 countries from Sub-Saharan Africa. In order to examine whether the causal relationships between the variables have changed over time, the data is divided into two periods: 1971-1990 and 1991-2010. The results show that there is a long-term relationship between the variables of interest. The results also support the Environmental Kuznets Curve hypothesis in the latter period, but not in the first period, where a linear monotonic relationship seems to prevail between CO_2 emissions and economic development. The short-term Granger causality tests results revealed some differences between the two periods: there is evidence for bidirectional causality between economic development and energy consumption over the first period, whereas causality seems to run from economic development to energy consumption over the second period. This indicates that causality may change over time. Furthermore, the periods also have some common features: there is evidence of Granger causality running from economic development to energy consumption in both periods in the short run, while in the long run, there is bidirectional causality between economic development and CO_2 emissions in the first period, and bidirectional causality between energy consumption and CO_2 emissions in the latter period. The summary of the results in the short run is depicted in Figure 11.

Moreover, the results imply that reducing CO_2 emissions and conserving energy should not hamper economic growth in Sub-Saharan Africa (on average), meaning that these tools could help the region to achieve sustainable development. More specifically, energy efficiency should be increased and the adverse impacts of electricity generation should be reduced, but without decreasing electricity supply to the end-users. In addition, Sub-Saharan African countries should invest in energy infrastructure and initiate energy conservation policies to reduce CO_2 emissions. According to the results, energy-efficiency projects can also mitigate the impact of economic growth on environmental quality.

All in all, and particularly since Sub-Saharan African countries have not committed to reducing CO_2 emissions under the Kyoto Protocol, the results imply that the emissions are likely to increase in the region in the future, as the countries aim for a higher level of economic development. Hence, energy-efficiency projects and emissions reduction policies can be the most effective and feasible policies to be implemented, in order to mitigate the adverse impacts of economic growth on environmental quality. Furthermore, renewable sources of energy can be promoted. Although renewable energies tend to be more expensive than other sources of energy, the countries can try to attract investments most specifically in the form of clean development mechanism (CDM) projects. These do not aim solely at reducing the emissions into the atmosphere, but also assist developing countries in achieving sustainable development. Moreover, if a high enough level of economic development is achieved, the result for the validity of the Environmental Kuznets Curve hypothesis during recent years indicates that the state of the environment should start to improve.

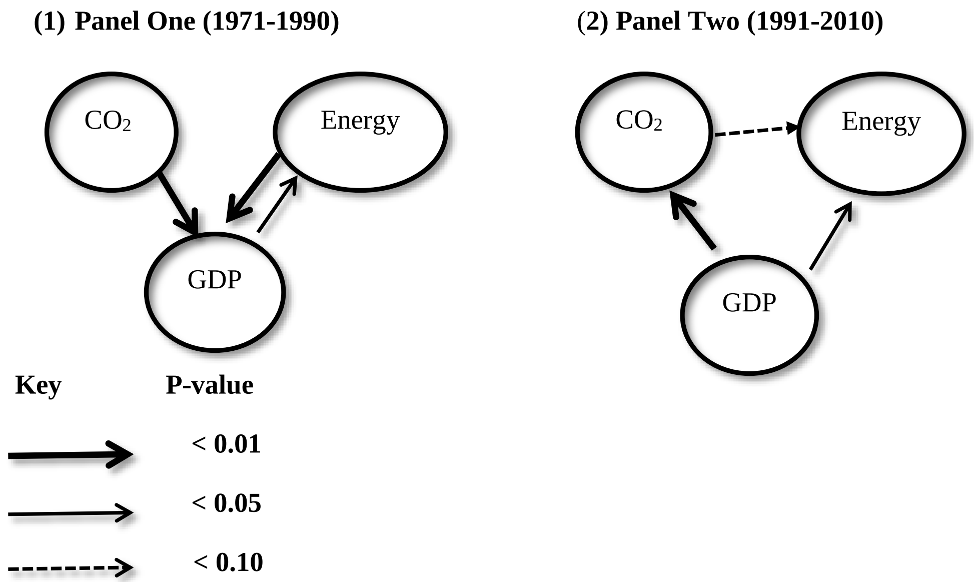


Figure 11: Granger causality relations between CO_2, energy consumption, and GDP

4.3 Publication 3: Exploring the factors affecting the clean development mechanism in developing countries

General objective

The clean development mechanism (CDM) of the Kyoto Protocol aims not only to reduce the level of greenhouse gases (GHG) in the atmosphere in a cost-effective way, but also to assist developing countries in achieving sustainable development in all respects. However, there has been an uneven distribution of these types of projects in developing countries, with a huge number of projects going to very few developing countries in Asia and Latin America. The countries with an enormous number of projects are China, India, Brazil, Vietnam, Mexico, and Indonesia. Therefore, the current study aims to investigate the factors that affect the distribution of CDM projects in developing countries by employing statistical analysis.

Main contribution

The results show that the emission level, the quality of institutions, and the size of the potential host country have been particularly important determinants of the number of CDM projects hosted so far in developing countries. The main policy implications include, among others, the importance of increasing the pace for fulfilling the institutional requirements of the CDM, improving the government structure to become free from corruption, and engaging more with capacity building in order to be able to attract more of these kinds of projects. Furthermore, infrastructure improvements, most specifically in electricity capacity, are imperative in order to make economic activities more viable in the developing countries. This is among the first studies to employ statistical analysis and regression techniques to identify the statistical significance of the explanatory variables that might have impacted the distribution of the CDM projects. There are also some problems with the previous literature; for example, Winkelman and Moore (2011) employed the same set of explanatory variables, but put more emphasis on the level of past greenhouse gases without controlling for the size of the host countries. Therefore, their results are somewhat misleading. However, this study argues that the emission level is closely associated with the size of the potential host country because large countries also have more CDM investment opportunities.

4.4 Publication 4: GDP, FDI, and exports in East and Central African countries: a causality analysis

General objective

Previously, scholars have investigated the causal links between GDP, FDI, and exports by employing different methodologies. The results are, however, still inconclusive. Hence, the current study aims to complement the existing literature in this strand by focusing on countries situated in the East and Central African region. The countries are Burundi, the Republic of the Congo, the Democratic Republic of the Congo (DRC), Kenya, Uganda, and Tanzania. The study employs both individual time series analysis and panel data techniques.

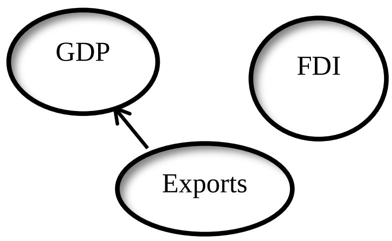
Main contribution

The results show that there is a unidirectional causality running from exports to GDP in Burundi, Tanzania, and Uganda. The findings also suggest a unidirectional causality running from FDI to GDP in Rwanda, Tanzania, and Uganda, while GDP appear to Granger-cause FDI in the case of Rwanda and Tanzania. Furthermore, FDI Granger-causes exports in Uganda, while exports Granger-cause FDI in Rwanda and GDP Granger-cause exports in the case of DRC. There is also bidirectional causality between FDI and GDP in the case of Rwanda and Tanzania. The results from the panel data analysis indicate that there is bidirectional causality between FDI and exports, and unidirectional causality from exports and FDI to GDP. To the best of our knowledge, this is the first study to examine the causal links among the variables of interest within the sample selected. Our causality findings are summarized in Figure 12.

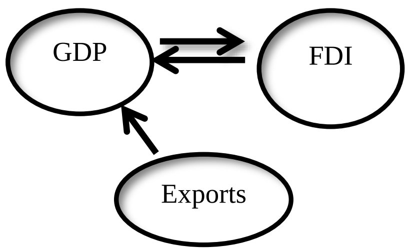
The results present some policy implications. First, a one-way causality running from FDI to GDP implies that the changes in FDI precede the changes in the level of economic development, and hence FDI complements other deep determinants of economic development in this particular country. The results also imply that any policy that can hinder foreign investments will also have impacts on the level of economic development. Hence, the country should find a way of attracting more FDI in order to realize the highest level of economic development. Second, causality running from FDI to exports indicates that changes in FDI precede the changes in exports, hence FDI causes exports and not the other way around. This implies that, since FDI is one of the determinants of exports, a particular state should find the means of attracting more FDI in order to be able to influence its export-base. The bidirectional causality between FDI and GDP per capita implies that both FDI and GDP are simultaneous with each other.

All in all, the countries should place greater emphasis on other deep determinants of economic growth, as a well-developed country is more likely to attract additional foreign investors, and more specifically the market seeking FDI. Furthermore, since FDI and exports are simultaneous with each other in some of the countries, we expect that if this particular country attracts more FDI, the share of exports will also eventually change.

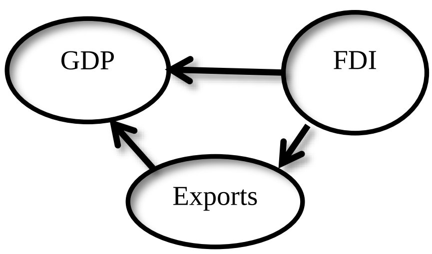
(1) Burundi



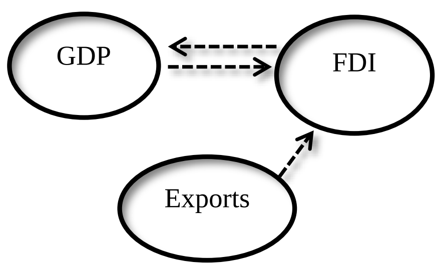
(2) Tanzania



(3) Uganda



(4) Rwanda



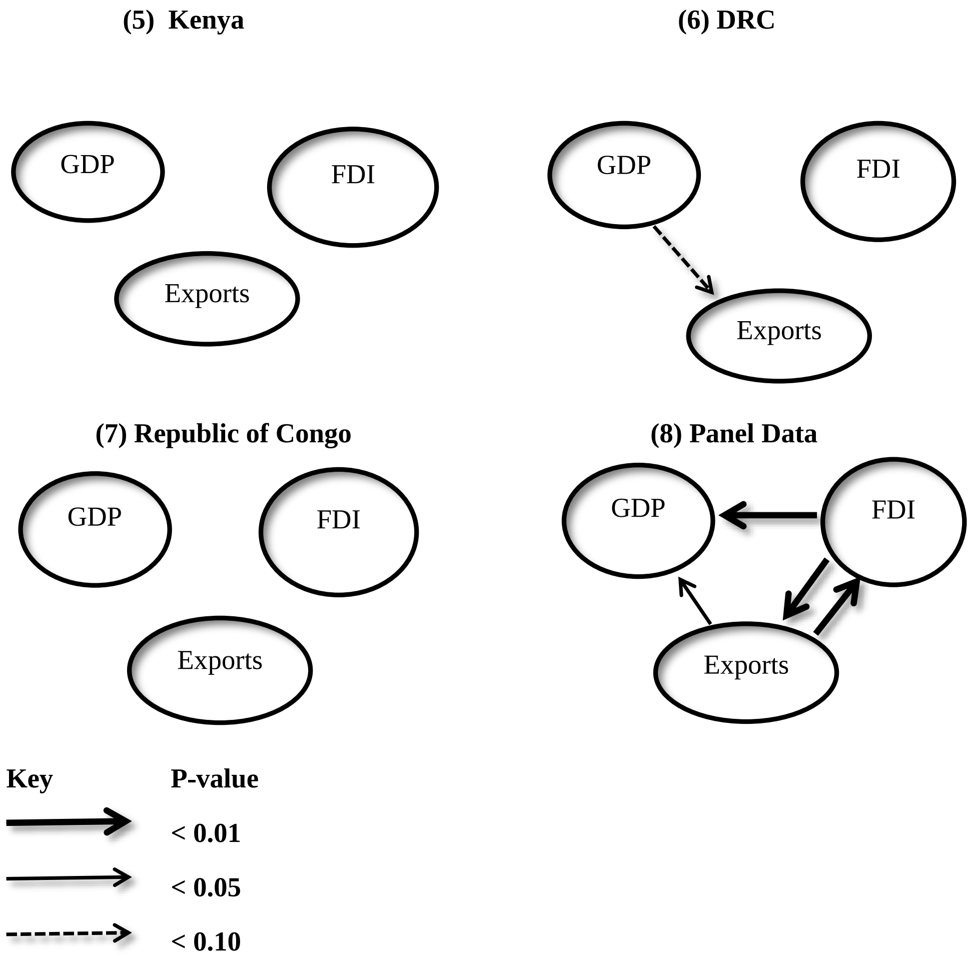


Figure 12: Granger causality relations of the seven countries

4.5 Publication 5: FDI, exports, imports, and economic growth of South Africa: Granger causality analysis

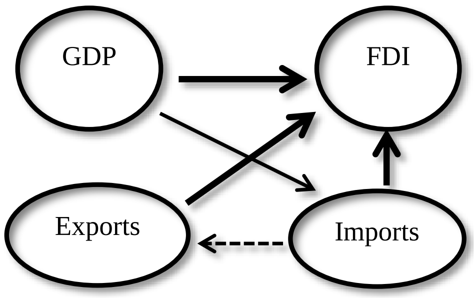
General objective

The previous studies have investigated the causal links between FDI, exports, imports, and economic growth by employing numerous econometric techniques. However, the results are still mixed and therefore cannot be generalized. However, differences in methodologies, samples selected, and the span of the data used have been pointed out to be major catalysts of such contradictions. The current study aims to investigate the interrelationship between the mentioned economic variables in South Africa, by employing the Granger causality analysis and the so-called innovation accounting techniques. The innovation accounting techniques used in the previous studies are forecast error variance decomposition and the impulse response functions techniques. We decided to complement the Granger causality results with these innovation accounting techniques, because Granger causality does not indicate how the movement in one variable causes the movement in another variable and in what direction.

Main contribution

The results show that GDP, exports, and imports Granger-cause FDI. The results are strengthened by the graphs of impulse response functions, which show that FDI responds positively to the positive shocks given to GDP and exports, and negatively with respect to the shocks given to imports. Furthermore, variance decomposition analysis shows that the variations in FDI are mainly explained by GDP rather than the other two variables. The results also show a one-way causality running from imports to exports, and the graph of impulse response functions also shows that exports respond negatively to import shocks. We also find that GDP Granger-causes imports. A summary of the findings is reported in Figure 13.

The results present some policy implications. Since the level of economic development captured by GDP per capita, exports, and imports, all seem to Granger-cause FDI in the case of South Africa, the country has to find the means to increase its GDP per capita, by embracing other deep determinants of economic development. The country should also improve its export-base, as well as encouraging import substitution in order to be in a good position to attract more FDI in the country.



Key	**P-value**
	< 0.01
	< 0.05
	< 0.10

Figure 13: Granger causality relations between FDI, exports, imports, and GDP in South Africa

5. CONCLUSIONS

5.1 Empirical contribution

The main objective of this dissertation was to investigate the contribution of environmental management practices, clean development mechanism (CDM) projects, and FDI in achieving sustainable development in developing countries, particularly is Sub-Saharan Africa. The general objective was further distributed across specific objectives as indicated below, and each specific objective was pursued at a more detailed level, using the five publications that accompany this study.

Objective 1*: To investigate whether CO_2 emissions, energy consumption, economic growth, and FDI move together in the long-run, and also to test whether there are any Granger causality relationships among the variables in the sample of Sub-Saharan African countries*

The dissertation investigated the causal links between emissions level captured by CO_2 emissions, energy consumption, FDI, and economic growth. The focus was mainly on the Sub-Saharan region, as there have been very few studies in this region. However, the countries in the region have also been aspiring strongly to improve the living conditions of poor people, hence there is a need to assess the environmental impact that can be triggered by the urge to achieve higher levels of economic development. This is because demand for energy tends to increase, as a country develops economically, and because increased consumption of energy is likely to cause more emissions if effective measures to protect the environment are missing. Hence, much has to be done to control environmental degradation at some stages of economic development. The dissertation employed Granger causality analysis to identify the direction of causality among the variables of interest. The direction of causality between energy consumption, emissions level, and economic growth cannot be determined in advance, and numerous empirical studies in this strand have come up with mixed conclusions. Since no unanimous conclusion has been reached so far, the author was motivated to further the discussion, and focus more on the Sub-Saharan region.

Furthermore, it is arguable that, since foreign investors have significant financial, political, and negotiating power, their presence in a host county can cause environmental damage if the environmental regulations of the host countries are less stringent than they tend to be in more developed countries. However, another group of scholars emphasizes that multinational corporations have more advanced technology, and hence their presence can be beneficial to the quality of the environment of the host country. The two conflicting hypotheses have been coined the pollution haven hypothesis and the halo effect hypothesis.

The results, based on an autoregressive distributed lag model, implied that the variables are cointegrated; in other words, they move together in the long run. The results also supported the Environmental Kuznets Curve hypothesis for the Democratic Republic of the Congo, Kenya, and Zimbabwe. Moreover, FDI appeared to increase CO_2 emissions in some of the countries, while the opposite effect is pervasive in others. Thus, the results supported both the pollution haven hypothesis and the halo effect hypothesis but in different countries within the study. The results are somehow similar to a few previous studies (Acharyya, 2009; Cole et al., 2006; Hassaballa, 2013; Hoffmann et al., 2005; Kretschmer et al., 2013; Merican et al., 2007).

The most common unidirectional Granger causality relationships were found to run from the other variables to CO_2 emissions, with different variables Granger-causing CO_2 emissions in different countries, and from GDP to FDI. Granger causality running to CO_2 emissions appeared more likely in the countries where the evidence supports the Environmental Kuznets Curve hypothesis.

Objective 2: *To investigate whether CO_2 emissions, energy consumption, and economic growth move together in the long-run, to test whether there are any Granger causality relationships among the variables of interest, and to explore whether the causality relationships between the variables have changed over time in a panel of 13 countries from Sub-Saharan Africa*

The results indicated that there is a long-term relationship between the variables of interest. The results also supported the Environmental Kuznets Curve hypothesis in the latter period (1991-2010), but not in the first period (1971-1990), where a linear monotonic relationship seems to prevail between CO_2 emissions and economic development. The short-term Granger causality tests results revealed some differences between the two periods: there is evidence for bidirectional causality between economic development and energy consumption over the first period, whereas causality seems to run from GDP per capita to energy consumption over the second period. This indicates that causality may change over time. Furthermore, the periods also have some common features: there is evidence of Granger causality running from economic development to energy consumption in both periods in the short run, while in the long run, there is bidirectional causality between economic development and CO_2 emissions in the first period, and bidirectional causality between energy consumption and CO_2 emissions in the latter period.

Objective 3*: To explore the economic, environmental and institutional factors responsible for the uneven distribution of CDM projects in developing countries.*

The CDM is one of the market-based mechanisms of the Kyoto Protocol, which has twin objectives. The first objective is to assist industrialized countries in reducing the greenhouse gas emissions level in cost-effective ways, and the second objective is to assist developing countries in achieving sustainable development. With a persistent increase in the global warming and environmental degradation as a whole around the globe, the current dissertation also aims to investigate the good environmental management practices that need to be initiated by policy-makers in order to combat the adverse effects of this dilemma. There have been numerous proposals suggested by the international community, and one of these initiatives is the implementation of CDM activities in developing countries. However, there have been numerous concerns with regard to the distribution of CDM projects among the developing countries, with the vast majority of the projects going to a few countries, like China, India, Brazil, and Vietnam. Factors such as previous emissions level, infrastructure, transaction costs, institution quality, and the local institutional capability to organize CDM projects have been pointed out to be among the factors that cause the current geographical distribution of CDM projects. However, there are also some problems with the previous literature. Hence, we aimed to explore the determinants of CDM in developing countries, in order to complement the previous literature and suggest coherent ways that will assist the other developing countries, particularly in Africa, to be able to host more CDM projects. The results indicated that the emissions level, the quality of institutions, and the size of the corresponding host country are significant determinants of the distribution of CDM projects. The study differs from the previous few studies employing statistical methods to investigate the distribution of CDM activities. For example, the study by Winkelman and Moore (2013) puts a large emphasis on the level of past greenhouse gas emissions, but neglects to control for the size of the country with any other explanatory variable. According to results of this study, the exclusion of the size of a country biases the conclusions drawn based on the other explanatory variables (particularly emissions).

Objective 4*: To investigate whether GDP, FDI, and exports move together, and also test the direction of causality among the variables of interest using the concept of Granger causality.*

The study investigated the causal links between GDP, FDI, and exports in the case of seven countries of East and Central Africa, using again the Granger causality approach. The results indicated a unidirectional Granger causality running from exports to GDP in some of the countries under investigation. Furthermore, the results reveal that a change in FDI precedes a change in GDP in some of the countries. The results from panel data indicated that there is bidirectional causality between FDI and exports, and unidirectional causality from exports and FDI to GDP. The results are somehow similar to other previous studies (see., e.g., Ahmadi and Ghanbarzadeh, 2011; Hsiao and Hsiao, 2006), but we also differ in terms of the focus of the study and the data employed. The contributions of each study have been explicated in more detail in Section 4 of this dissertation.

Objective 5*: To test the direction of causality among FDI, exports, imports, and economic growth in the case of South Africa; to examine the responsiveness and proportions of movement of one of the variables with respect to innovations/shocks given to other variables.*

Furthermore, the study aimed to test the causal relationships between FDI, exports, imports, and economic growth in South Africa. There has been a lot of research in this strand with the notion of testing the validity of the FDI-led growth hypothesis, the export-led growth hypothesis, and the import-led growth hypothesis in a single multivariate model. However, very few studies have focused on Sub-Saharan African countries, with the exception of the study by Ahmed et al. (2007). The results show that GDP, exports, and imports Granger-cause FDI. The results are strengthened by the graphs of impulse response functions, which show that FDI responds positively to the positive shocks given to GDP and exports, and negatively with respect to the shocks given to imports. Furthermore, variance decomposition analysis shows that the variations in FDI are mainly explained by GDP rather than the other two variables. The results also show a one-way causality running from imports to exports, and the graph of impulse response functions also shows that exports respond negatively to import shocks. We also find that GDP Granger-causes imports.

5.2 Policy implications

In the case of the first publication, the results pose some policy implications for policy-makers in the countries investigated. For instance, the causality running from FDI to CO_2 emissions might support the pollution haven hypothesis or the halo hypothesis. This means that the presence of multinationals in the host countries could either increase or decrease the level of emissions, implying that the host countries must try to assess the environmental impact of FDI before welcoming foreign investors into the country. Another crucial result is the Granger causality running from energy consumption to GDP. If energy consumption is one of the determinants of economic development, attempts to curb energy consumption may have an adverse effect on the economic development of the country in question. On the other hand, if GDP Granger-causes energy consumption in Zambia, and not the other way round, it might be the case that energy-saving policies could be implemented in the country with little or no adverse effect on the level of economic development. Moreover, the results showing that energy consumption and GDP Granger-cause CO_2 emissions are associated with the fact that, as a country develops, it tends to consume more energy than before. As a result, its emissions increase as well. Such countries should encourage the use of renewable sources of energy in order to minimize the adverse effects of emissions. In addition, the author would like to recommend that the countries should invest more in energy-efficiency projects, in order to continue protecting the environment. Furthermore, the results showing that FDI Granger-causes GDP indicate that FDI is one of the determinants of economic development. Hence, the potential host countries should continue with strategies of attracting more FDI. For other countries, the reverse causality from GDP to FDI seems to hold. In such cases, the level of economic development of the host country is one of the determinants of FDI. This has been the case especially in the market seeking FDI. The potential host countries should encourage other determinants of economic development, such as institutional quality, expansion of the export base, persistent improvements in domestic investments, and improvement in infrastructure, in order to attract more foreign investors.

The panel data results for 1991-2010 in publication 2 imply that investing in pollution abatement technologies and emissions reduction policies should not hurt economic growth in Sub-Saharan Africa (on average), meaning that these tools could help the region to achieve sustainable development. Because GDP seems to Granger cause energy consumption as well, the results imply also that, on average, energy conservation policies could be followed without impeding economic growth in Sub-Saharan Africa during 1991-2010. However, as Wolde-Rufael (2009) points out, in many Sub-Saharan African countries the state of the energy infrastructure is such that some energy conservation policies are not an option because economic growth, which is necessary for raising the living standards of the people, requires energy. It is nevertheless possible to reduce electric power transmission and distribution losses in countries like Nigeria and Senegal. All in all, the objective should be to improve energy efficiency while reducing the adverse impacts of electricity generation, without reducing electricity supply to the end-users (Wolde-Rufael, 2009). In the long-run, energy consumption and GDP per capita appear to influence CO_2 emissions per capita in both 1971-1990 and 1991-2010 samples. Hence, energy-efficiency projects can mitigate the impact of economic growth on environmental quality. Furthermore, the bidirectional long-run Granger causality between CO_2 emissions and energy consumption in 1990-2010 indicates that improving energy efficiency of e.g. energy equipment and reducing the losses in power transmission and distribution could be useful instruments in controlling the level of CO_2 emissions. Therefore, Sub-Saharan African countries should invest in energy infrastructure and step up energy conservation policies in order to reduce CO_2 emissions. But also the presence of multinationals in the host countries could either increase or decrease the level of emissions, implying that the host countries must try to assess the environmental impact of FDI before welcoming foreign investors into the country.

With regard to the factors affecting the CDM projects, the results imply that the developing countries should increase the pace for fulfilling the institutional requirements of the CDM, improving the government structure to become free from corruption, and engaging more with capacity building in order to be able to attract more of these kinds of projects. Furthermore, infrastructure improvements, most specifically in electricity capacity, are imperative in order to make economic activities more viable in the developing countries

With respect to the causal relationships between FDI and other macroeconomic variables (see, publication 4), the results pose also some policy implications. First, a one-way causality running from FDI to GDP implies that the changes in FDI precede the changes in the level of economic development, and hence FDI complements other determinants of economic development in this particular country. The results also imply that any policy that can hinder foreign investments will also have impacts on the level of economic development. Hence, the country should find a way of attracting more FDI in order to realize the highest level of economic development. Second, causality running from FDI to exports indicates that changes in FDI precede the changes in exports. This implies that a particular state should find the means of attracting more FDI in order to be able to influence its export-base. The bidirectional causality between FDI and GDP per capita implies that FDI and GDP are determined simultaneously with each other.

In publication 5, the results imply that, since the level of economic development, exports, and imports, all seem to Granger-cause FDI in the case of South Africa, the country has to find the means to increase its GDP per capita, by embracing other deep determinants of economic development. The country should also improve its export-base, as well as encouraging import substitution in order to be in a good position to attract more FDI in the country.

Generally, although Sub-Saharan Africa is the region least responsible for global climate change as pointed out earlier, it is acutely vulnerable to its adverse effects on economic growth and sustainable development, human security, and the prospects of improving living conditions of poor people. Hence, the countries in this region need to find coherent ways to tackle environmental degradation. The means to offset the effects of environmental degradation as mentioned earlier should include capacity building in mitigation and adaptation to climate change. They should include, among others, the use of renewable sources of energy, afforestation and reforestation activities, empowering small-scale miners by giving them more advanced extractive tools, and educating people about legitimate methods of environmental management (FAO, 2007; Van Straaten, 2000). Moreover, the sources of energy should be examined critically. For example, fossil fuels, most specifically coal, are a major source of CO_2 emissions. Therefore, the use of fossil fuels should be reduced in order to decrease CO_2 intensity. To do this, the countries with extensive hydro-electric capacity should improve their institutional quality and reduce political uncertainty to attract investors to the country (Odhiambo, 2010). Furthermore, since Sub-Saharan African civilians rely heavily on wood fuel, which causes deforestation and health problems, expansion of electricity supply through a more efficient electricity sector that is made available to a larger part of the population is necessary to enable them to use alternative sources of energy (Wolde-Rufael, 2006; 2009)

5.3 Limitations and further research

The dissertation is subject to a number of limitations. First, it employed cross-sectional data in one of the publications, in order to avoid problems caused by reverse causality. The cross-sectional research setting does not take into consideration the individual country-specific effects. Furthermore, it provides only a snapshot of the phenomenon, and the analysis may provide different results if another time frame is selected. Therefore, it is difficult to make a causal inference with cross-sectional data.

The second limitation is based on the properties of the data used. The time span of the data was relatively short for time series analysis. This might affect the reliability of the results. Furthermore, the dissertation employed aggregated macroeconomic variables. The aggregate data only encompasses the averages of all individuals, hence cannot show the individual attributes; hence in future research, one needs to employ more disaggregate data. Moreover, the data from Sub-Saharan Africa can be considered somewhat unreliable.

The other limitations are based on the methodologies used: first, the dissertation employed Granger causality in four publications attached to this study. The goal was to investigate the causal links among the variables of interest. However, Granger causality analysis indicates only the chronological ordering of the movement of the variables, and not how or even whether the movement of one variable causes the movement of another variable. For instance in publications 1 and 2, one of the tasks was to study the causal links between energy consumption and economic growth using the concept of Granger causality. In reality, energy is one of important inputs at different stages of production of goods and services, at the same time no energy will be used in production if nothing viable is produced, and therefore I would expect this notion be sufficient enough to prove causality among the two macroeconomic indicators. But since Granger-causality analysis does not show whether one variable has a significant positive or negative influence on the other variable, such conclusions can not be drawn. Hence, in future research, one needs to employ other causal inference methods. Second, some of the methods employed could be more appropriate for larger samples. For instance variance decomposition and impulse response function techniques are more appropriate when the sample size is large enough. As we pointed out earlier, the samples used in our case were somewhat small. For example, in testing the cointegration between the variables, we employed the Johansen cointegration in one of the publications, but we think that the bounds testing procedures as proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) could be more appropriate. Hence, in future research, one should observe this limitation.

Another limitation is related to the omitted variable bias. Some variables that could be relevant in explaining the phenomena examined were not included in the analysis. For example, the institutional quality of the host country is very important in influencing investment decisions in the host countries. Foreign investors are more reluctant to invest in countries whose economic freedom, protection of property rights, and rule of law are not enforced (Knack and Keefer 1995; Rodrick et al., 2004; Virta, 2008). However, we did not include these measures, due to difficulties in getting the data, and most specifically the time series data. Therefore, in future research, this variable should be included, together with other control variables.

Furthermore, the use of secondary data in all the five publications might have restricted the scope of the empirical analysis and findings in general because a researcher has no full autonomy in controlling such data. Hence the data might not provide answers to each question constructed by the researcher. Moreover, some data sources do not unveil the modality and obstacles encountered during the extraction of the data

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PART II: PUBLICATIONS

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Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa

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ABSTRACT

This study investigates the causal links between CO_2 (carbon dioxide) emissions, energy consumption, economic development and FDI (foreign direct investment) in six Sub Saharan African countries: the Republic of the Congo, the DRC (Democratic Republic of the Congo), Kenya, South Africa, Zambia and Zimbabwe. The results based on an autoregressive distributed lag model imply that the variables move together in the long run (cointegration) in all of the countries. The results also support the environmental Kuznets curve hypothesis in the cases of DRC, Kenya and Zimbabwe. Moreover, FDI appears to increase CO_2 emissions in some of the countries, while the opposite impact can be observed in others. The most common unidirectional Granger causality relationships run from the other variables to CO_2 emissions, with different variables Granger causing CO_2 emissions in different countries, and from GDP (gross domestic product) to FDI. Granger causality running to CO_2 emissions appears more likely in the countries where the evidence supports the environmental Kuznets curve hypothesis. Otherwise, the causality relationships vary greatly between the countries, making it impossible to give any universal policy recommendations.

1. Introduction

Global warming has been a subject of debate among researchers and politicians for the past two decades. The GHG (greenhouse gas) emissions resulting from human activities have been claimed to be the major cause of this development [1–3]. The potential consequences of global warming are so severe that researchers and policy practitioners have devoted much time and many resources to investigating its causes. Despite the differences of opinion, some initiatives have been put in place to curb the adverse effects of climate change. For example, the KP (Kyoto protocol) imposed a binding agreement between developing and developed countries, with the objective of reducing GHG emissions. The KP is linked to UNFCCC (United Nations Framework Convention on Climate Change) and was adopted in December 1997, in Kyoto, Japan, and it came into force in 2005. The first commitment period ended in December 2012, and the second commitment period (2013–2020) has been put in place but has not entered into force, because the countries are still in the process of ratification following the amendment made in the 8th session of COP (conference of parties) in Qatar. The CA (Copenhagen Accord), which was adopted at the 15th session of the conference of parties (COP 15) in Copenhagen, December 2009, is another treaty put in place that requires the countries to pledge a reduction in their GHG emission levels voluntarily. However, there have been mixed perceptions with respect to KP and CA [4–8]. Hence, the effects and causes of global warming are still a hot topic that needs special attention.

According to the previous literature, energy consumption and the level of economic development are among the most important causes of increased GHG emissions. Moreover, the impact of FDI (foreign direct investment) on the environment of the host countries has also been a subject of debate: despite the fact that FDI has been seen as an engine of economic growth in many developing countries, it might also cause environmental degradation. In this study, we employ all the four variables to investigate the direction of causality among them, but also to see whether the variables move together in the long run.

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As to the previous literature focussing on developing countries, most of the studies have concentrated on countries from Asia, Latin America, the Middle East, and North Africa. In contrast, studies considering Sub-Saharan African countries are scant, apart from a study conducted by Odhiambo [9] investigating the causal link between energy consumption and economic development in South Africa. We thus focus on the causal links between GHG emissions, energy consumption, economic development, and FDI in six Sub-Saharan African countries: the Republic of the Congo, the Democratic Republic of the Congo, Kenya, South Africa, Zambia, and Zimbabwe. To our knowledge, this is the first study to explore the causal links between the four variables in these countries. The issue is particularly important because the majority of developing countries are in desperate need of economic development, which is believed to improve the living conditions of the people. Hence, understanding the causality relationships between the variables will assist policy-makers in designing the appropriate policies.

The study is structured as follows: Section 2 reviews the previous literature, Section 3 presents the methodologies employed in this study, Section 4 reports and discusses the empirical findings, and finally, Section 5 concludes.

2. Literature review

The causality relationships between carbon dioxide emissions, energy consumption, FDI and economic growth have been a subject of debate in empirical and theoretical literature for the past two decades. Some of the extant studies are cross-country panel studies [10–13], while others have focused on individual countries [14–17]. Al-mulali and Binti Che Sab [2] and Bashiri Behmiri and Pires Manso [18] present an excellent overview of the existing literature.

The first category of the literature focuses on the causal links between environmental pollution and economic development. Different methodologies have been employed and the results have also been mixed see, for example, [14,17,19–25]. It is likely that the differences in econometric methodologies, time span of the data, and model specification explain some of the conflicting results [26,27]. Some of the indicators that have been employed as proxies for environmental pollution are CO_2 (carbon dioxide) and SO_2 (sulphur dioxide) emissions [28]. In general, the relationship between environmental pollution and economic development can be modelled by the so-called EKC (environmental Kuznets curve), indicating that pollution increases together with increases in the income level up to a certain turning point, after which increases in the income level result in a decline in the level of pollution. In other words, there is an inverted-U-shaped relationship between environmental pollution and economic development. The EKC originates from the seminal work of Grossmann and Krueger [29,30], who adjusted the idea of Kuznets [31] to investigate the relationship between economic development and environment.

The second category of the literature investigates the link between energy consumption and economic development. The topic has also been a very hot subject of debate among researchers and policy-makers. In theory, the larger the scale of economic activities (i.e., the higher the level of economic development), the more energy is needed. However, a well-developed country is also expected to use energy more efficiently than a less developed country. Thus, the relationship between the two variables can be either positive or negative. However, the first channel can be expected to dominate the relationship between the two variables. Since the seminal paper by Kraft and Kraft [32], who examined the link between energy consumption and economic development in the USA, a number of studies have come up with mixed conclusions regarding the nature of the relationship between the two variables [23,33–39].

The impact of FDI (foreign direct investment) on the host country's environment has also been a subject of debate. Two conflicting hypotheses have been presented in previous studies: the pollution haven hypothesis and the halo effect hypothesis. According to the halo effect hypothesis, the presence of foreign investors will spur positive environmental spill-overs to the host country [40] because MNCs (multinational companies) have more advanced technology than their domestic counterparts and will tend to disseminate cleaner technology that will be less harmful to the environment [41]. In contrast, the pollution haven hypothesis postulates that MNCs will flock more into countries where environmental regulations are less strict [19]. This strategy might harm the environment in the host country if the issue is not taken seriously [42]. The results are both theoretically and empirically mixed [43–45]. However, there is plenty of evidence suggesting that foreign MNCs tend to relocate the dirt industries in developing countries with lax environmental regulations rather than in developed countries, where the environmental regulations are very strict [46–48]. Therefore, depending on the nature of and the motives behind the MNCs, FDI can cause more emissions in the host countries. The effect of FDI on GHG emissions in particular has also been a subject of debate in the extant literature. The previous studies see, e.g., Hoffmann et al. [49] and Hassaballa [50] have provided coherent justifications for using GHG (particularly CO_2) emissions as a proxy for pollution in general. According to them, CO_2 is a primary source of global warming, and the variable is also highly correlated with such local pollutants as nitrogen oxide and sulphur dioxide.

The last category of the literature employs a multivariate framework to examine the causal links between the variables by incorporating all the variables of interest in a single equation. The first strand of this literature focuses on the links between CO_2 emissions, energy consumption, and economic development, with mixed results [16,17,34,51,53]. Another strand in this category adds FDI to the analysis [13]. Some of the previous studies are cross-country panel studies [10–12], while other studies focus on individual countries [14–17]. Due to the vast amount of literature, we focus here on the specific country studies. Table 1 presents an overview of some of the studies.

Alam et al. [54] employ a Johansen cointegration test and an ARDL (autoregressive distributed lag model) to examine the causal links between energy consumption, electricity consumption, CO_2 emissions, and economic development in Bangladesh. They find one-way causality running from energy consumption to economic development, both in the short run and the long run. Furthermore, the results show bidirectional causality between energy consumption and CO_2 emissions, and also between electricity consumption and economic development. In the case of Malaysia, a study by Ang [34] reveals that CO_2 emissions and energy use are positively related in the long run. In a related study, Lotfalipour et al. [55] investigate the causal links between economic growth, CO_2 emissions, and energy consumption in Iran. They use three proxies for energy consumption: total fossil fuel consumption, consumption of petroleum products, and natural gas consumption. Their results suggest three unidirectional causality relationships: one running from GDP to CO_2 emissions, the second from the consumption of petroleum products to CO_2 emissions, and the third from natural gas consumption to CO_2 emissions. Interestingly, total fossil fuel consumption does not seem to Granger-cause CO_2 emissions in the long run.

Several studies have been conducted for China. First, Zhang and Cheng [39] find that GDP Granger-causes energy consumption and that energy consumption Granger-causes CO_2 emissions in the country in the long run. According to Ang [15], research intensity, technological transfer, and absorptive capacity are the main

Table 1
A summary of some of the empirical studies investigating the causal links between energy consumption, CO_2 emissions, and economic growth in individual countries.

Article	Period	Country	Methodology	Results
Alam et al. [54]	1972–2006	Bangladesh	ARDL, VECM, Granger causality	EN → Y EN ↔ CO_2 CO_2 → Y
Alam et al. [51]	1971–2006	India	Augmented VAR model of Toda and Yamamoto [52]	EN ↔ CO_2 EN … Y
Ang [34]	1971–1999	Malaysia	Johansen cointegration test, Granger causality test based on VECM	Y → EN Through running the cointegration equation, the results show that both CO_2 and energy consumption are positively related to economic growth.
Ang [14]	1960–2000	France	Johansen cointegration test, ARDL bound test procedures, VECM	Y → EN long-run Y → CO_2 EN → Y short-run
Chang [16]	1981–2006	China	Johansen cointegration test, Granger causality test based on VECM	Y ↔ CO_2 Y ↔ EN
Pao and Tsai [59]	1980–2007	Brazil	Johansen cointegration test, Granger causality based on VECM, Grey prediction model	Supports EKC hypothesis EN → Y Y ↔ CO_2 EN ↔ CO_2
Pao et al. [57]	1990–2007	Russia	Johansen cointegration test, Granger causality tests based on VECM	Does not support EKC hypothesis CO_2 → Y CO_2 → EN
Soytas et al. [63]	1960–2004	USA	VAR model based on Toda and Yamamoto [52] procedures	Y … CO_2 EN → CO_2
Wolde-Rufael [72]	1969–2006	India	ARDL approach, Toda and Yamamoto [52] procedures, variance decomposition	EN → Y
Zhang and Cheng [39]	1960–2007	China	VAR model based on Toda and Yamamoto [52] procedures	Y → EN EN C → CO_2 EN … Y CO_2 … Y

Note: 1) →, ↔, and … denote unidirectional causality relationships, bidirectional causality relationships, and no causality relationships, respectively; 2) CO_2, EN, and Y are abbreviations for carbon dioxide emissions, energy consumption, and GDP, respectively.

determinants of CO_2 emissions in China. In addition, Chang [16] employs different indicators of energy, which are crude oil, natural gas, electricity consumption, and coal, to study the causal link between CO_2 emissions, energy consumption, and economic growth in China. The results imply that both energy consumption and GDP cause more CO_2 emissions in the country.

Ang [14] employs a multivariate VECM (vector error correction model) to study the causal links between CO_2 emissions, energy consumption, and output in France. The results show that energy use increases CO_2 emissions, and also that CO_2 emissions and output have a quadratic relationship in the long run. The study by Halicioglu [17] shows that there is bidirectional causality between CO_2 emissions and income both in the short and long run in the case of Turkey.

As to the studies conducted for Sub-Saharan Africa, Menyah and Wolde-Rufael [56] examine the links between energy consumption, pollutant emissions, and economic development in South Africa and find that there is a long-term relationship between the underlying variables. The results also show that there is one-way causality running from both energy consumption and CO_2 emissions to economic development. Similar results are found for Russia in a study by Pao et al. [57]. As to other research on African countries, Adom et al. [58] find bidirectional causality between economic growth and CO_2 emissions in the case of Morocco and one-way causality running from economic growth to CO_2 emissions in Senegal.

Pao and Tsai [59] examine the causal link between CO_2 emissions, energy consumption, and economic growth in Brazil by employing a Granger causality analysis. The results reveal three bidirectional causality relationships: one between GDP and CO_2 emissions, the second between GDP and energy consumption, and the last one between energy consumption and CO_2 emissions. In addition, for the US, Menyah and Wolde-Rufael [60] investigate the causal links between CO_2 emissions, renewable energy consumption, nuclear energy consumption, and GDP, by employing a modified Granger causality VECM. According to the results, energy consumption Granger-causes CO_2 emissions. In a related study, De Freitas and Kaneko [61] find that CO_2 emissions have a positive significant effect on GDP and also that GDP and population have a significant positive effect on CO_2 emissions in Brazil.

Ozturk and Acaravci [62] examine the relationships between GDP, CO_2 emissions, energy consumption, and employment in Turkey, by employing ARDL. The results do not reveal any causality relationships between energy consumption, GDP, and CO_2 emissions. In contrast, employment seems to Granger-cause GDP in Turkey. Table 1 summarises some of the studies that empirically examine the causal links among the variables of interest.

Finally, as to the studies interested in FDI, Merican et al. [64] investigate the causal link between FDI and pollution by employing the ARDL model approach. According to their results, FDI increases emissions in Malaysia, Thailand, and the Philippines, while there seems to be an inverse relationship between the variables in Indonesia. Hoffmann et al. [49] find one-way causality running from FDI to CO_2 emissions. Pao and Tsai [13] examine the causal links between CO_2 emissions, energy consumption, FDI, and GDP in the BRIC (Brazil, Russia, India and China) countries, using a multivariate Granger causality approach. According to the results, there is bidirectional causality between emissions and FDI, and a one-way causality running from output to FDI.

3. Model and econometric methodology

3.1. Model

In accordance with the EKC (environmental Kuznets curve) hypothesis, the long-term relationship between CO_2 emissions, energy consumption, economic development, and FDI can be modelled as indicated by Equation (1) below. According to the hypothesis, there is an inverted-U-shaped relationship between environmental pollution and economic development, which can be captured mathematically by including the squared value of GDP per capita in the set of regressors. We follow the same procedures as employed by previous studies (see, e.g., [1,13,17]), where the model used is:

$$\mathrm{CO}_t = \alpha_0 + \alpha_1 \mathrm{EN}_t + \alpha_2 \mathrm{FDI}_t + \alpha_3 Y_t + \alpha_4 Y_t^2 + \mu_t \quad (1)$$

where CO represents the CO_2 emissions per capita, EN stands for energy consumption per capita, FDI stands for FDI per capita, Y is GDP per capita, and Y^2 stands for GDP per capita squared. μ_t is the error term. All the variables are in their natural logarithmic form. Theoretically, we expect the regression coefficient α_1 to be positive because energy consumption is expected to spur more emissions. The impact of FDI on the environment of the host country has been mixed in the literature; hence we expect the sign of coefficient α_2 to be either positive or negative. The relationship between economic development and the emission level is based on the EKC hypothesis; hence we expect the sign of α_3 to be positive and α_4 to be negative.

3.2. Testing for cointegration

We start our analysis by testing whether the variables move together in the long run, that is, whether they are cointegrated. First, we need to find out the order of integration of each series, in order to decide the appropriate method for testing cointegration. As a result, we employ the most recently developed ARDL (autoregressive distributed lag) bound testing approach. The ARDL modelling technique for testing for cointegration was initially introduced by Pesaran and Shin [65] and was later extended by Pesaran et al. [66]. Although conventional ARDL models have been used for a long time, this is a new application of them for the new purpose of testing cointegration among the variables. The critical values generated by Pesaran et al. are valid for large sample sizes, while Narayan [67,68] and Narayan [69] propose critical values that are appropriate for small sample sizes.

There are also other univariate cointegration approaches, such as the methodology by Engle and Granger [70] and the fully modified OLS (ordinary least squares) procedures developed by Phillips and Hansen [71]. However, ARDL has been more used recently, due to some useful advantages that are embedded in it. One of the main merits of this technique is that it can be used irrespective of whether series are I(0) or I(1) or fractionally cointegrated [72,73]. Another advantage is that both short-term and long-term estimates can be made simultaneously. In addition, endogeneity problems and an inability to test the hypothesis on the estimated coefficients in the long run, as associated with the Engle-Granger method, are avoided [17].

We thus use the ARDL bounds cointegration testing approaches in our study. The model used is as specified in Equations (2)–(6):

$$\begin{aligned}\Delta \mathrm{CO}_t = {} & \alpha_0 + \alpha_1 \mathrm{CO}_{t-1} + \alpha_2 \mathrm{EN}_{t-1} + \alpha_3 \mathrm{FDI}_{t-1} + \alpha_4 Y_{t-1} + \alpha_5 Y_{t-1}^2 \\ & + \sum_{i=1}^{p} \alpha_{6i} \Delta \mathrm{CO}_{t-i} + \sum_{i=1}^{p} \alpha_{7i} \Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} \alpha_{8i} \Delta \mathrm{FDI}_{t-i} \\ & + \sum_{i=1}^{p} \alpha_{9i} \Delta Y_{t-i} + \sum_{i=1}^{p} \alpha_{10i} \Delta Y_{t-i}^2 + \mu_t \end{aligned} \quad (2)$$

$$\begin{aligned}\Delta \mathrm{EN}_t = {} & \beta_0 + \beta_1 \mathrm{EN}_{t-1} + \beta_2 \mathrm{CO}_{t-1} + \beta_3 \mathrm{FDI}_{t-1} + \beta_4 Y_{t-1} + \beta_5 Y_{t-1}^2 \\ & + \sum_{i=1}^{p} \beta_{6i} \Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} \beta_{7i} \Delta \mathrm{CO}_{t-i} + \sum_{i=1}^{p} \beta_{8i} \Delta \mathrm{FDI}_{t-i} \\ & + \sum_{i=1}^{p} \beta_{9i} \Delta Y_{t-i} + \sum_{i=1}^{p} \beta_{10i} \Delta Y_{t-i}^2 + \mu_t \end{aligned} \quad (3)$$

$$\begin{aligned}\Delta \mathrm{FDI}_t = {} & \delta_0 + \delta_1 \mathrm{FDI}_{t-1} + \delta_2 Y_{t-1} + \delta_3 Y_{t-1}^2 + \delta_4 \mathrm{CO}_{t-1} + \delta_5 \mathrm{EN}_{t-1} \\ & + \sum_{i=1}^{p} \delta_{6i} \Delta \mathrm{FDI}_{t-1} + \sum_{i=1}^{p} \delta_{7i} \Delta Y_{t-i} + \sum_{i=1}^{p} \delta_{8i} \Delta Y_{t-i}^2 \\ & + \sum_{i=1}^{p} \delta_{9i} \Delta \mathrm{CO}_{t-i} + \sum_{i=1}^{p} \delta_{10i} \Delta \mathrm{EN}_{t-i} + \mu_t \end{aligned} \quad (4)$$

$$\begin{aligned}\Delta Y_t = {} & \lambda_0 + \lambda_1 Y_{t-1} + \lambda_2 Y_{t-1}^2 + \lambda_3 \mathrm{CO}_{t-1} + \lambda_4 \mathrm{EN}_{t-1} + \lambda_5 \mathrm{FDI}_{t-1} \\ & + \sum_{i=1}^{p} \lambda_{6i} \Delta Y_{t-i} + \sum_{i=1}^{p} \lambda_{7i} \Delta Y_{t-i}^2 + \sum_{i=1}^{p} \lambda_{8i} \Delta \mathrm{CO}_{t-i} \\ & + \sum_{i=1}^{p} \lambda_{9i} \Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} \lambda_{10i} \Delta \mathrm{FDI}_{t-i} + \mu_t \end{aligned} \quad (5)$$

$$\begin{aligned}\Delta Y_t^2 = {} & \varpi_0 + \varpi_1 Y_{t-1}^2 + \varpi_2 Y_{t-1} + \varpi_3 \mathrm{CO}_{t-1} + \varpi_4 \mathrm{EN}_{t-1} \\ & + \varpi_5 \mathrm{FDI}_{t-1} + \sum_{i=1}^{p} \varpi_{6i} \Delta Y_{t-i}^2 + \sum_{i=1}^{p} \varpi_{7i} \Delta Y_{t-i} + \sum_{i=1}^{p} \varpi_{8i} \Delta C_{t-i} \\ & + \sum_{i=1}^{p} \varpi_{9i} \Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} \varpi_{10i} \Delta \mathrm{FDI}_{t-i} + \mu_t \end{aligned} \quad (6)$$

where α_0, β_0, δ_0, ϖ_0 are drift components; μ_t stands for white noise error term; Δ is the first difference operator and other variables are as defined earlier Our task is to test whether the coefficients of the first lags of the level series of Equations (2)–(5) are jointly significantly different from zero against the corresponding alternative hypothesis. For example, in Equation (2), we test whether α_1, α_2, α_3 and $\alpha 4$ are jointly statistically significantly different from zero, while in Equation (3), we test whether β_1, β_2, β_3 and $\beta 4$ are jointly statistically significantly different from zero. We achieve this test by means of Wald statistics.

3.3. Granger causality

A variable x is said to Granger-cause a variable y if the past values of x can be used to predict the current value of y in collaboration with past values of y [74]. Granger causality is not causality in the traditional sense, and it cannot be used to deduce whether changes in a variable have a positive or negative impact on another variable. If the variables of interest are cointegrated, we expect to observe causality among the variables at least in one direction [70]. Granger [75] explicates that if the variables are cointegrated, a VECM (vector error correction) model should be estimated rather than a conventional VAR (vector autoregression model).

4. Empirical results

4.1. Data description

As discussed above, the objective of this study is to examine the causal links between energy consumption, CO_2 emissions,

Table 2
Descriptive statistics (before data transformation), 1971–2009.

	CO_2		EN		Y		FDI	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Rep. Congo	0.504	0.207	323.459	41.113	1062.954	171.876	25.317	29.570
DRC	0.093	0.043	322.272	17.352	194.359	92.339	12.336	24.600
Kenya	0.282	0.056	448.524	10.581	418.064	23.179	2.432	2.493
South Africa	8.844	0.954	2541.890	261.374	3236.994	224.118	3.933	7.480
Zambia	0.419	0.256	707.083	82.782	417.361	85.048	21.691	19.084
Zimbabwe	1.261	0.285	857.257	77.620	491.387	77.278	17.042	28.416

economic development, and FDI. The data used are the annual time series data covering the period between 1971 and 2009. The energy consumption per capita (measured in kg of oil equivalent per capita), GDP per capita (in constant 2000 USD), and CO_2 emissions per capita (in metric tons per capita) are taken from the WDI (World Bank Development Indicators) [76]. The FDI series (in percentage of gross fixed capital format) are obtained from the UNCTAD (United Nations Conference on Trade and Development) [77]. The sample used was dictated by the availability of the yearly data for all the four macroeconomic variables. Also the differences in the level of economic development of the countries were considered important. Table 2 shows descriptive statistics of the actual variables used in the analysis, for each country.

Fig. 1 depicts the time series of GDP per capita, which marks the level of economic development of the country. The GDP per capita in South Africa is the highest of all by a large margin, followed by the Republic of the Congo. The difference in the level of economic development between South Africa and the rest of the Sub-Saharan African countries has been attributed to numerous factors such as natural resource endowment, the quality of financial institutions, and differences in the efficiency of energy usage. Hence, South Africa can also be expected to differ from the other countries with respect to the causality relationships between CO_2 emissions, energy consumption, economic growth, and FDI. However, the development of GDP per capita in South Africa has been all but steady during the observation period: after a steady increase between 1971 and 1980, a reverse trend could be observed between 1981 and 1991, after which an increasing trend can be observed again. In fact, in comparison to the other countries in the sample, South Africa shows the highest variation in terms of not only GDP per capita, but also CO_2 emissions and energy consumption, as shown by the standard deviations of the series depicted in Table 2. The highest pick of GDP per capita is observed in 2008 for South Africa and in 1983 for the Republic of the Congo. For some countries (most notably DRC and Zimbabwe), a decreasing trend in GDP per capita is visible.

Fig. 2 depicts the time series of CO_2 emissions per capita for all six countries. In some of the countries (the Republic of the Congo, Zambia, and Zimbabwe), the level of emissions has been on the decrease especially since 1995. In contrast, a persistent increase in the emissions level can be observed in South Africa. This is not surprising, because the country is very rich in terms of coal, which has been proved to be a major source of CO_2 emissions. In addition, the South African economy has been growing faster than those of most of the other countries in the sample during the last decades (see Fig. 1). This indicates that the factors that have prompted the persistent increase in CO_2 emissions are somehow related to the increase in economic activities. Hence, increases in emissions are probably unavoidable during some stages of the economic development of a country.

Fig. 3 shows the time series of energy consumption per capita for all six countries. Again, South Africa shows unique characteristics in terms of energy use. There has been a steady increase in energy use in South Africa, with the highest pick revealed in 2008. Together with Fig. 2, this implies that there is a positive relationship between energy consumption and emissions level in South Africa. In the other countries, we do not notice significant trends.

Fig. 4 shows the time series of FDI per capita for all six countries. The overall variation in the series is much larger for the FDI series than for the other series.

4.2. Unit root rest results

Because most of the macroeconomic variables are likely to be non-stationary, we start by testing for the presence of unit roots in our variables. Even if the ARDL cointegration test approach can be used regardless of whether the series are stationary in the level form, that is, whether they are I(0) or are integrated of order one, I(1), some of the variables may have higher orders of integration that may prevent the use of this model.

There are different ways of testing for the presence of the unit root in time series data. In this study, we use ADF (Augmented

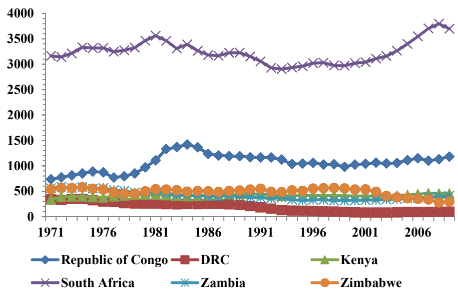

Fig. 1. GDP per capita (constant 2000 USD (United States dollar)).

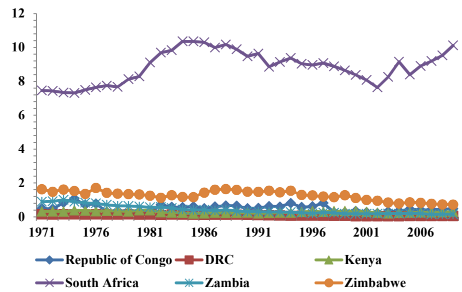

Fig. 2. CO_2 emissions per capita (measured in metric tons per capita).

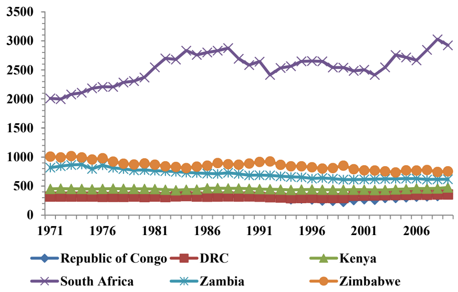

Fig. 3. Energy consumption per capita (measured in kg of oil equivalent).

Dickey-Fuller) [78] and Phillips-Peron [79] unit root testing procedures. The results are reported in Table 3.

The results in Table 3 show that most of the series become stationary after being differenced once. We may thus conclude that most of the series are integrated of order one, meaning that they are I(1). The exception is the FDI series, which seems to be stationary at the level in the Republic of the Congo, DRC, South Africa, Zambia, and Zimbabwe, at least according to the Phillips–Perron test. Because the highest order of integration is one, the ARDL is appropriate in testing the cointegration among the variables.

4.3. ARDL cointegration test results

In order to apply the ARDL cointegration test procedure, we used the following steps. Our first task was to select the optimal lag lengths of the first difference terms of Equations (2)–(5). To do this, we ran the unrestricted VAR (vector autoregressive) model and selected the number of lags by means of the Akaike information criterion and Schwarz Bayesian criterion. The same approach was used by Halicioglu [17]. The second step was to apply bound F-test statistics, as first proposed by Pesaran et al. [66]. However, we employed the procedures according to Narayan [69] because the number of observations in our sample was small (39 observations). The results are reported in Table 4 and the corresponding asymptotic critical values are reported in Table 5.

Pesaran et al. (2001) computed two sets of critical values for a given level of significance: lower bound I(0) and upper bound I(1). One set assumes that all the series are stationary at the level, and the other set assumes that all the series are integrated of order one. If the calculated F-statistic is greater than the upper critical value,

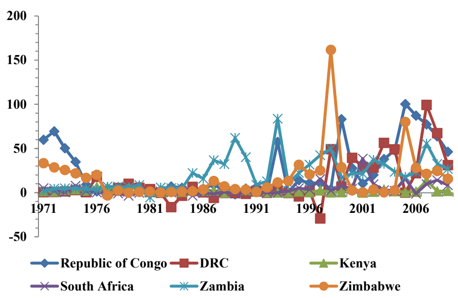

Fig. 4. Inward FDI per capita (measured as percentage of gross fixed capital formation).

Table 3
Unit root test results.

Country	Variable	Level series		First difference series	
		ADF test statistics	PP test statistics	ADF test statistics	PP test statistics
Republic of the Congo	CO_2	−2.700	−2.899	−6.367***	−6.366***
	EN	−0.444	−0.598	−6.430***	−6.532***
	FDI	−4.155**	−4.080**	−7.025***	−10.492***
	Y	−2.313	−1.974	−3.495**	−3.546**
	Y^2	−2.313	−1.961	−3.484**	−3.488**
DRC	CO_2	−1.857	−2.017	−5.589***	−5.587***
	EN	−1.311	−1.325	−5.999***	−5.999***
	FDI	−3.784**	−3.874**	−10.175***	−13.035***
	Y	−2.242	−1.442	−2.132**	−2.172**
	Y^2	−2.149	−1.394	−2.219**	−2.248**
Kenya	CO_2	−2.408	−2.154	−2.725*	−6.105***
	EN	−1.304	−0.839	−4.609***	−4.609***
	FDI	−0.497	−1.686	−5.819***	−17.224***
	Y	−1.929	1.385	−5.686***	−5.686***
	Y^2	−1.933	1.357	−5.591***	−5.591***
South Africa	CO_2	−1.415	−1.648	−5.555***	−5.663***
	EN	−1.868	−1.883	−5.997***	−5.999***
	FDI	−1.851	−3.347**	−6.121***	−11.166***
	Y	−1.594	−0.537	−3.592**	−3.577**
	Y^2	−1.596	−0.535	−3.593**	−3.578**
Zambia	CO_2	−1.364	−0.815	−7.101***	−9.882***
	EN	−2.643	−0.758	−9.099***	−9.917***
	FDI	−2.487	−5.281***	−4.293***	−12.310***
	Y	0.650	1.081	−5.803***	−5.870***
	Y^2	0.619	1.092	−5.925***	−5.984***
Zimbabwe	CO_2	−1.540	−1.469	−7.421***	−7.439***
	EN	−2.392	−2.443	−6.211***	−6.274***
	FDI	−3.474*	−3.403*	−8.204***	−8.243***
	Y	−0.472	−0.647	−4.805***	−4.804***
	Y^2	−0.523	−0.714	−4.771***	−4.771***

Notes: 1) The test equations in the level series include the constant and the linear trend components. 2) In the first difference series, the test equations include only the constant term, except in DRC, where neither constant nor trend components are included. 3) The optimal lag length is selected automatically based on the Akaike Information Criterion in ADF approach. 4) In the PP test technique, the optimal lag is selected based on Newey–West (using a Bartlett kernel). 5) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively.

the null hypothesis of no cointegration is rejected. In contrast, if the statistic falls below the lower critical values, then the null hypothesis of no cointegration is not rejected. Finally, if the computed F-statistic falls between the lower and upper critical values, the test is inconclusive [17]. Our test equation includes a constant but no time trend, because the trend component was statistically insignificant.

According to our results, the number of cointegration relationships is three for the Republic of the Congo (with energy consumption, GDP, and GDP squared as the dependent variables) and Zambia (with GDP, GDP squared, and FDI as the dependent variables), two for Kenya (with CO_2 emissions and energy consumption as the dependent variables), and one for the DRC and South Africa (for both countries with FDI as the dependent variable) and Zimbabwe (with energy consumption as the dependent variable). Because we have now established a long-term relationship among the variables through the cointegration test, the next step is to estimate the long-term and short-term regression coefficients with the purpose of testing the validity of the environmental Kuznets curve hypothesis.

4.4. Long-term Elasticity

In this subsection, we report the long-term elasticity estimates of CO_2 emissions with respect to energy consumption, economic development, and FDI. Specifically, we report whether the EKC gets

Table 4
Bounds cointegration Test – ARDL approach.

The equation used (based on Equations (2)–(5))	Computed F-statistics	Lags
$F(\mathrm{CO}_{\mathrm{COG}}\|\mathrm{EN}_{\mathrm{COG}}Y_{\mathrm{COG}}Y^2_{\mathrm{COG}}\mathrm{FDI}_{\mathrm{COG}})$	1.88	
$F(\mathrm{EN}_{\mathrm{COG}}\|\mathrm{CO}_{\mathrm{COG}}Y_{\mathrm{COG}}Y^2_{\mathrm{COG}}\mathrm{FDI}_{\mathrm{COG}})$	3.76*	
$F(Y_{\mathrm{COG}}\|\mathrm{EN}_{\mathrm{COG}}\mathrm{CO}_{\mathrm{COG}}Y^2_{\mathrm{COG}}\mathrm{FDI}_{\mathrm{COG}})$	296.46***	5
$F(Y^2_{\mathrm{COG}}\|\mathrm{EN}_{\mathrm{COG}}Y_{\mathrm{COG}}\mathrm{CO}_{\mathrm{COG}}\mathrm{FDI}_{\mathrm{COG}})$	279.46***	
$F(\mathrm{FDI}_{\mathrm{COG}}\|\mathrm{EN}_{\mathrm{COG}}Y_{\mathrm{COG}}Y^2_{\mathrm{COG}}\mathrm{CO}_{\mathrm{COG}})$	0.42	
$F(\mathrm{CO}_{\mathrm{DRC}}\|\mathrm{EN}_{\mathrm{DRC}}Y_{\mathrm{DRC}}Y^2_{\mathrm{DRC}}\mathrm{FDI}_{\mathrm{DRC}})$	1.91	
$F(\mathrm{EN}_{\mathrm{DRC}}\|\mathrm{CO}_{\mathrm{DRC}}Y_{\mathrm{DRC}}Y^2_{\mathrm{DRC}}\mathrm{FDI}_{\mathrm{DRC}})$	2.95	
$F(Y_{\mathrm{DRC}}\|\mathrm{EN}_{\mathrm{DRC}}\mathrm{CO}_{\mathrm{DRC}}Y^2_{\mathrm{DRC}}\mathrm{FDI}_{\mathrm{DRC}})$	0.48	4
$F(Y^2_{\mathrm{DRC}}\|\mathrm{EN}_{\mathrm{DRC}}\mathrm{CO}_{\mathrm{DRC}}Y_{\mathrm{DRC}}\mathrm{FDI}_{\mathrm{DRC}})$	0.49	
$F(\mathrm{FDI}_{\mathrm{DRC}}\|\mathrm{EN}_{\mathrm{DRC}}Y_{\mathrm{DRC}}Y^2_{\mathrm{DRC}}\mathrm{CO}_{\mathrm{DRC}})$	8.75***	
$F(\mathrm{CO}_{\mathrm{KEN}}\|\mathrm{EN}_{\mathrm{KEN}}Y_{\mathrm{KEN}}Y^2_{\mathrm{KEN}}\mathrm{FDI}_{\mathrm{KEN}})$	29.18***	
$F(\mathrm{EN}_{\mathrm{KEN}}\|\mathrm{CO}_{\mathrm{KEN}}Y_{\mathrm{KEN}}Y^2_{\mathrm{KEN}}\mathrm{FDI}_{\mathrm{KEN}})$	59.34***	
$F(Y_{\mathrm{KEN}}\|\mathrm{EN}_{\mathrm{KEN}}\mathrm{CO}_{\mathrm{KEN}}Y^2_{\mathrm{KEN}}\mathrm{FDI}_{\mathrm{KEN}})$	1.89	5
$F(Y^2_{\mathrm{KEN}}\|\mathrm{EN}_{\mathrm{KEN}}\mathrm{CO}_{\mathrm{KEN}}Y_{KEN}\mathrm{FDI}_{\mathrm{KEN}})$	1.90	
$F(\mathrm{FDI}_{\mathrm{KEN}}\|\mathrm{EN}_{\mathrm{KEN}}Y_{\mathrm{KEN}}Y^2_{\mathrm{KEN}}\mathrm{CO}_{\mathrm{KEN}})$	2.41	
$F(\mathrm{CO}_{\mathrm{ZAF}}\|\mathrm{EN}_{\mathrm{ZAF}}Y_{\mathrm{ZAF}}Y^2_{\mathrm{ZAF}}\mathrm{FDI}_{\mathrm{ZAF}})$	1.03	
$F(\mathrm{EN}_{\mathrm{ZAF}}\|\mathrm{CO}_{\mathrm{ZAF}}Y_{\mathrm{ZAF}}Y^2_{\mathrm{ZAF}}\mathrm{FDI}_{\mathrm{ZAF}})$	0.45	
$F(Y_{\mathrm{ZAF}}\|\mathrm{EN}_{\mathrm{ZAF}}\mathrm{CO}_{\mathrm{ZAF}}Y^2_{\mathrm{ZAF}}\mathrm{FDI}_{\mathrm{ZAF}})$	1.58	5
$F(Y^2_{\mathrm{ZAF}}\|\mathrm{EN}_{\mathrm{ZAF}}\mathrm{CO}_{\mathrm{ZAF}}Y_{\mathrm{ZAF}}\mathrm{FDI}_{\mathrm{ZAF}})$	1.59	
$F(\mathrm{FDI}_{\mathrm{ZAF}}\|\mathrm{EN}_{\mathrm{ZAF}}Y_{\mathrm{ZAF}}Y^2_{\mathrm{ZAF}}\mathrm{CO}_{\mathrm{ZAF}})$	4.28**	
$F(\mathrm{CO}_{\mathrm{ZMB}}\|\mathrm{EN}_{\mathrm{ZMB}}Y_{\mathrm{ZMB}}Y^2_{\mathrm{ZMB}}\mathrm{FDI}_{\mathrm{ZMB}})$	0.17	
$F(\mathrm{EN}_{\mathrm{ZMB}}\|\mathrm{CO}_{\mathrm{ZMB}}Y_{\mathrm{ZMB}}Y^2_{\mathrm{ZMB}}\mathrm{FDI}_{\mathrm{ZMB}})$	3.06	
$F(Y_{\mathrm{ZMB}}\|\mathrm{EN}_{\mathrm{ZMB}}\mathrm{CO}_{\mathrm{ZMB}}Y^2_{\mathrm{ZMB}}\mathrm{FDI}_{\mathrm{ZMB}})$	8.3588***	5
$F(Y^2_{\mathrm{ZMB}}\|\mathrm{EN}_{\mathrm{ZMB}}\mathrm{CO}_{\mathrm{ZMB}}Y_{\mathrm{ZMB}}\mathrm{FDI}_{\mathrm{ZMB}})$	8.8862***	
$F(\mathrm{FDI}_{\mathrm{ZMB}}\|\mathrm{EN}_{\mathrm{ZMB}}Y_{\mathrm{ZMB}}Y^2_{\mathrm{ZMB}}\mathrm{CO}_{\mathrm{ZMB}})$	5.9387***	
$F(\mathrm{CO}_{\mathrm{ZWE}}\|\mathrm{EN}_{\mathrm{ZWE}}Y_{\mathrm{ZWE}}Y^2_{\mathrm{ZWE}}\mathrm{FDI}_{\mathrm{ZWE}})$	2.7618	
$F(\mathrm{EN}_{\mathrm{ZWE}}\|\mathrm{CO}_{\mathrm{ZWE}}Y_{\mathrm{ZWE}}Y^2_{\mathrm{ZWE}}\mathrm{FDI}_{\mathrm{ZWE}})$	23.6827***	
$F(Y_{\mathrm{ZWE}}\|\mathrm{EN}_{\mathrm{ZWE}}\mathrm{CO}_{\mathrm{ZWE}}Y^2_{\mathrm{ZWE}}\mathrm{FDI}_{\mathrm{ZWE}})$	1.7128	5
$F(Y^2_{\mathrm{ZWE}}\|\mathrm{EN}_{\mathrm{ZWE}}\mathrm{CO}_{\mathrm{ZWE}}Y_{\mathrm{ZWE}}\mathrm{FDI}_{\mathrm{ZWE}})$	1.6463	
$F(\mathrm{FDI}_{\mathrm{ZWE}}\|\mathrm{EN}_{\mathrm{ZWE}}Y_{\mathrm{ZWE}}Y^2_{\mathrm{ZWE}}\mathrm{CO}_{\mathrm{ZWE}})$	1.3628	

Notes: 1) The test equation includes only the constant term. 2) The lag length was selected based on AIC and SC. 3) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively. 4) COG, DRC, KEN, ZAF, ZMB, and ZWE are country codes for the Republic of the Congo, DRC, Kenya, South Africa, Zambia, and Zimbabwe, respectively.

Table 6
Long-term elasticity estimates for CO_2 with respect to the other variables.

Country	Variable	Coefficient	Standard error
Republic of the Congo	EN	3.160	3.063
	FDI	0.052	0.329
	Y	206.969	223.848
	Y^2	−14.815	15.982
DRC	EN	−2.105***	0.639
	FDI	−0.004**	0.014
	Y	5.596***	1.649
	Y^2	−0.456**	0.163
Kenya	EN	0.170	1.227
	FDI	0.354***	0.041
	Y	681.126**	101.148
	Y^2	−56.685**	8.425
South Africa	EN	0.856***	0.164
	FDI	−0.030*	0.018
	Y	−30.047	138.223
	Y^2	1.876	8.588
Zambia	EN	7.004	5.519
	FDI	−0.020	0.070
	Y	−5.836	15.408
	Y^2	0.363	1.173
Zimbabwe	EN	2.080***	2.080
	FDI	0.169**	0.019
	Y	0.019**	33.306
	Y^2	−13.662**	2.744

Notes: 1) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively. 2) All the variables are lag one.

support in the sample countries. These elasticity estimates are computed based on the ARDL model estimates, which are available upon request. The technique used is that we divide the estimated coefficients of lag one of the independent level variables (in this case: energy consumption, FDI, GDP, and GDP squared) by the coefficient of the lag one of the dependent level variable (CO_2) [80]. The elasticity estimates are reported in Table 6, while the diagnostic tests based on ARDL estimates are reported in Table 7. The test results reported in Table 7 indicate that serial correlation is not a problem in the estimations, and that heteroscedasticity might only affect the results for South Africa.

The results in Table 6 show that in the case of the Republic of the Congo, all the coefficients have the expected sign (bearing in mind that the sign of FDI could be either positive or negative) but are statistically insignificant even at the 10% level. In contrast, in DRC energy consumption, FDI, GDP, and GDP squared are all statistically significant either at the 1% or 5% level of significance. The coefficient for energy consumption is negative, which is contrary to our expectations because energy consumption is expected to cause more CO_2 emissions unless the country is utilising mostly renewable sources of energy. The elasticity of CO_2 emissions with respect to GDP is 5.596−0.912Y, which supports the EKC hypothesis. The negative coefficient of FDI is in line with the halo effect theory, implying that FDI might be associated with cleaner technology spill-overs in DRC. In the case of Kenya, the coefficients have the expected signs but energy consumption is statistically insignificant. The results support the EKC. Furthermore, the positive coefficient of FDI supports the pollution haven hypothesis. In South Africa, energy consumption and FDI are statistically significant at the 1% and 10% levels of significance, respectively. The results imply that as energy consumption increases by 1%, the level of emissions increases by 0.856%; and that as FDI inflows increase by 1%, the level of emissions decreases by 0.03%. Hence there is also evidence for the halo effect in South Africa. In the case of Zambia, all the coefficients are statistically insignificant. For Zimbabwe, all the coefficients have the anticipated signs, and energy consumption is statistically significant at the 1% level, while FDI, GDP, and GDP squared are statistically significant at the 5% level. Therefore, the results for Zimbabwe also support the EKC hypothesis. The positive coefficient of FDI is, again, in line with the pollution haven hypothesis.

To summarise, there is some evidence for the EKC, but only in DRC, Kenya, and Zimbabwe. As to the impact of FDI, evidence is even more mixed (as expected): the variable seems to increase CO_2 emissions in Kenya and Zimbabwe, while the opposite effect can be observed in DRC and South Africa. Thus, it appears to be the case that the pollution haven hypothesis dominates in some countries, while the halo effect is stronger in other countries. A potential explanation for the differences between the countries could be whether the countries import or export oil [18]. However, our results do not reveal any generalizable differences between the oil-exporting countries (the Republic of the Congo and DRC) and the oil-importing countries (Kenya, South Africa, Zambia, and Zimbabwe). In contrast, Bashiri Behmiri and Pires

Table 5
Narayan (2005) asymptotic critical value bounds.

1% significance level		5% significance level		10% significance level	
Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
3.657	5.256	2.734	3.920	2.306	3.353

Note: The critical values are according to Narayan (2005) case III page 1988.

Table 7
Residual Diagnostic Tests based on the estimated ARDL model.

Diagnostic tests	Republic of the Congo	DRC	Kenya	South Africa	Zambia	Zimbabwe
Serial correlation LM test (Breusch-Godfrey)	0.148 (0.766)	4.867 (0.170)	10.000 (0.218)	0.624 (0.574)	0.395 (0.642)	0.519 (0.865)
Heteroscedasticity test (Breusch-Pagan-Godfrey)	0.149 (0.996)	0.096 (1.000)	2.970 (0.149)	28.800 (0.008)	0.156 (0.995)	1.362 (0.459)

Note: *P*-values in parentheses.

Manso [18] find evidence for a bidirectional causality relationship between energy consumption (proxied by crude oil consumption) and economic growth in the oil-importing region and for one-way causality running from energy consumption to GDP in the oil-exporting region. However, the sample and the time span of the data used in their study are quite different from ours, and they focus on only two variables. To our knowledge, this is the first study to examine the causality links among the four stated macroeconomic variables in as many as six Sub-Saharan African countries.

4.5. Results and discussion for Granger causality analysis

In this subsection, we present the results of the Granger causality analysis. According to Engle and Granger [64], the appropriate model for examining Granger causality is the VECM (vector error correction model) if the variables move together in the long run, because the VAR (vector autoregressive model) in the first difference terms will be misleading in such cases. The VECM incorporates the first difference terms and an error correction term that captures the speed of adjustment to long-term equilibrium values after a short-term shock. The model is as indicated in Equations (7)–(11):

$$\Delta \mathrm{CO}_t = c_1 + \sum_{i=1}^{p} c_{11i}\Delta \mathrm{CO}_{t-i} + \sum_{i=1}^{p} c_{12i}\Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} c_{13i}\Delta \mathrm{FDI}_{t-i} + \sum_{i=1}^{p} c_{14i}\Delta Y_{t-i} + \sum c_{15i}\Delta Y^2_{t-i} + \lambda_1 \mathrm{EC}_{t-1} + \mu_{1t} \tag{7}$$

$$\Delta \mathrm{EN}_t = c_2 + \sum_{i=1}^{p} c_{21i}\Delta \mathrm{CO}_{t-i} + \sum_{i=1}^{p} c_{22i}\Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} c_{23i}\Delta \mathrm{FDI}_{t-i} + \sum_{i=1}^{p} c_{24i}\Delta Y_{t-i} + \sum c_{25i}\Delta Y^2_{t-i} + \lambda_2 \mathrm{EC}_{t-1} + \mu_{2t} \tag{8}$$

$$\Delta \mathrm{FDI}_t = c_3 + \sum_{i=1}^{p} c_{31i}\Delta \mathrm{CO}_{t-i} + \sum_{i=1}^{p} c_{32i}\Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} c_{33i}\Delta \mathrm{FDI}_{t-i} + \sum_{i=1}^{p} c_{34i}\Delta Y_{t-i} + \sum c_{35i}\Delta Y^2_{t-i} + \lambda_3 \mathrm{EC}_{t-1} + \mu_{3t} \tag{9}$$

$$\Delta Y_t = c_4 + \sum_{i=1}^{p} c_{41i}\Delta \mathrm{CO}_{t-i} + \sum_{i=1}^{p} c_{42i}\Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} c_{43i}\Delta \mathrm{FDI}_{t-i} + \sum_{i=1}^{p} c_{44i}\Delta Y_{t-i} + \sum c_{45i}\Delta Y^2_{t-i} + \lambda_4 \mathrm{EC}_{t-1} + \mu_{4t} \tag{10}$$

$$\Delta Y^2_t = c_5 + \sum_{i=1}^{p} c_{51i}\Delta \mathrm{CO}_{t-i} + \sum_{i=1}^{p} c_{52i}\Delta \mathrm{EN}_{t-i} + \sum_{i=1}^{p} c_{53i}\Delta \mathrm{FDI}_{t-i} + \sum_{i=1}^{p} c_{54i}\Delta Y_{t-i} + \sum c_{55i}\Delta Y^2_{t-i} + \lambda_5 \mathrm{EC}_{t-1} + \mu_{5t} \tag{11}$$

where λ is the speed of adjustment parameter, which also captures the long-term relationship between the underlying variables. EC_{t-1} is the first lag error correction term, which is a residual term obtained by running the long-term cointegration equation (1). All the variables are again measured in per capita terms. The error correction term is included in the equation only when cointegration exists. The lag length was determined by the unrestricted VAR framework, and each country had its own lag length. The optimal lags were selected by means of the Akaike information criterion and the Schwarz Bayesian criterion. The same procedures have been employed by recent studies [81,17,1]. The results are reported in Table 8.

The first country under investigation is the Republic of the Congo. For this country, we found cointegration relationships with energy consumption per capita, GDP per capita, and GDP per capita squared as the dependent variables. Hence the error correction terms are only included in these three equations [17]. The results depicted in Table 8 reveal three unidirectional Granger causality relationships in the short run: (1) from CO_2 emissions to GDP, (2) from energy consumption to GDP, and (3) from FDI to GDP. Therefore, the results indicate that changes in CO_2 emissions, energy consumption, and FDI precede changes in the level of economic development in the Republic of the Congo. Granger causality is a kind of misnomer process: instead of indicating directly that the movement of one variable causes the movement of another variable, it shows the chronological ordering of movements [82]. Here the result that changes in CO_2 emissions precede changes in the level of economic development indicates thus that increases in CO_2 emissions could jumpstart economic development. We did not find any bidirectional feedback relationships between the variables in the short run. The statistically significant coefficients of the error correction terms complement the bounds testing results discussed above. Generally, the results imply that attempts to lower energy consumption may have an adverse effect on the level of economic development, implying that the country needs to be prudent enough when formulating the energy use policies.

In the case of DRC, we found only one cointegration relationship with FDI as a dependent variable. Hence the error correction term was only included in this equation. The results reveal two unidirectional Granger causality relationships: one from FDI to CO_2 emissions, and another from GDP to CO_2 emissions. This implies that changes in both FDI and GDP precede changes in CO_2 emissions. However, in the long run, we did not find any significant relationship between any pair of variables. This effect is supported by the coefficient of the error correction term, which seems to be insignificant.

Table 8
Results of Granger causality analysis.

Country	Dep. Var.	ΔCO_t F-statistic	ΔEN_t F-statistic	ΔFDI_t F-statistic	ΔY_t F-statistic	ΔY_t^2 F-statistic	ΔEC_{t-1} t-statistic
Republic of Congo	ΔCO_t	–	1.33(0.30)	1.99(0.15)	0.97(0.45)	0.96(0.46)	–
	ΔEN_t	1.37(0.30)	–	0.91(0.48)	0.28(0.88)	0.28(0.87)	−0.09(0.05)**
	ΔFDI_t	0.38(0.81)	0.76(0.56)	–	1.39(0.29)	1.39(0.28)	–
	ΔY_t	4.21(0.02)**	4.77(0.01)***	3.65(0.03)**	–	0.96(0.46)	−0.11(0.00)***
	ΔY_t^2	4.09(0.02)**	4.63(0.01)***	3.57(0.03)**	0.90(0.49)	–	−1.66(0.00)***
DRC	ΔCO_t	–	0.42(0.73)	2.59(0.09)*	4.74(0.01)***	4.14(0.02)***	–
	ΔEN_t	1.25(0.32)	–	0.20(0.89)	0.30(0.81)	0.20(0.88)	–
	ΔFDI_t	1.13(0.37)	1.30(0.31)	–	0.59(0.63)	0.54(0.66)	9.03(0.42)
	ΔY_t	0.91(0.45)	0.92(0.45)	1.27(0.31)	–	0.69(0.57)	–
	ΔY_t^2	0.99(0.42)	0.84(0.49)	1.27(0.31)	0.80(0.50)	–	–
Kenya	ΔCO_t	–	10.4(0.01)***	7.67(0.01)***	8.90(0.01)***	8.95(0.01)***	0.47(0.01)***
	ΔEN_t	0.33(0.87)	–	0.38(0.84)	1.09(0.44)	1.10(0.44)	0.57(0.29)
	ΔFDI_t	0.71(0.63)	1.82(0.21)	–	5.32(0.01)***	5.37(0.01)***	–
	ΔY_t	0.99(0.47)	0.79(0.58)	0.30(0.89)	–	0.57(0.71)	–
	ΔY_t^2	0.98(0.48)	0.79(0.58)	0.29(0.90)	0.51(0.75)	–	–
South Africa	ΔCO_t	–	3.89(0.05)**	4.29(0.04)**	4.74(0.03)	4.73(0.03)	–
	ΔEN_t	1.26(0.37)	–	1.91(0.20)	0.77(0.59)	0.77(0.59)	–
	ΔFDI_t	1.89(0.22)	0.42(0.81)	–	3.97(0.06)**	3.96(0.06)**	1.36(0.00)***
	ΔY_t	0.40(0.83)	0.74(0.61)	1.02(0.47)	–	0.15(0.97)	–
	ΔY_t^2	0.40(0.83)	0.74(0.61)	1.02(0.46)	0.15(0.97)	–	–
Zambia	ΔCO_t	–	0.16(0.95)	0.18(0.90)	0.18(0.90)	0.15(0.92)	–
	ΔEN_t	0.37(0.76)	–	0.81(0.49)	2.40(0.09)*	2.39(0.10)*	–
	ΔFDI_t	0.20(0.88)	0.45(0.71)	–	0.31(0.81)	0.33(0.80)	−5.02(0.31)
	ΔY_t	0.30(0.81)	0.56(0.64)	0.63(0.60)	–	0.19(0.89)	−0.17(0.28)
	ΔY_t^2	0.34(0.79)	0.60(0.62)	0.66(0.58)	0.19(0.89)	–	−2.16(0.27)
Zimbabwe	ΔCO_t	–	0.18(0.90)	0.97(0.42)	1.66(0.20)	1.66(0.20)	–
	ΔEN_t	0.21(0.88)	–	0.63(0.60)	1.89(0.16)	1.91(0.16)	−0.01(0.88)
	ΔFDI_t	1.60(0.22)	1.30(0.30)	–	2.83(0.06)*	2.86(0.06)*	–
	ΔY_t	1.48(0.25)	0.31(0.81)	1.83(0.17)	–	1.40(0.27)	–
	ΔY_t^2	1.52(0.24)	0.30(0.81)	1.85(0.17)	1.27(0.31)	–	–

Notes: 1) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively. 2) The numbers in parentheses are probability values.

For Kenya, the bounds testing procedures revealed two cointegration relationships with energy consumption and CO_2 emissions as the dependent variables. According to the short-term results presented in Table 8, there is unidirectional Granger causality running (1) from energy consumption to CO_2 emissions, (2) from FDI to CO_2 emissions, (3) from GDP to CO_2 emissions, and (4) from GDP to FDI. There is no evidence of any bidirectional causality relationships between the variables. In the long run, the results imply that energy consumption, FDI, and GDP have a statistically significant influence on CO_2 emissions. This is revealed by the coefficient of the error correction term, which is statistically significant at the 1% level. Because changes in energy consumption, FDI, and GDP appear to precede changes in CO_2 emissions and not the other way round, it could be possible to reduce CO_2 emissions in Kenya without adverse effects on economic development in the short run. However, strict environmental regulations need to be enforced in order to mitigate the negative effects of FDI predicted by the pollution haven hypothesis (see also Table 6). The results also imply that the level of economic development is crucial in attracting foreign investors and FDI to Kenya, indicating that the country should pay attention to improved institutional quality and other factors that have been found to affect the level of economic development positively.

In the case of South Africa, we have one cointegration relationship with FDI as the dependent variable. Hence we incorporate the error correction term in the corresponding equation. In the short run, we find three unidirectional Granger causality relationships: (1) from energy consumption to CO_2 emissions, (2) from FDI to CO_2 emissions, and (3) from GDP to FDI. In addition, the statistically significant coefficient of the error correction term indicates that there is a long-term relationship running from all the other variables to FDI. This result is in line with the bounds testing results. Because growing energy consumption causes more emissions in South Africa (see Table 6), the country should encourage the use of renewable sources of energy and invest more in energy efficiency projects. The country is very rich in coal, but increasing use of greener energy will reduce the consumption of coal in energy production and hence reduce CO_2 emissions.

As to Zambia, bounds testing results revealed three cointegration relationships, and the error correction term was thus incorporated in these three equations. The short-term results imply that GDP Granger-causes energy consumption, but that there is no bidirectional causality. We do not find any evidence for causality relationships in the long run. The finding of one-way causality running from economic development to energy consumption implies that policies designed to reduce energy consumption may have little or no adverse impact on the level of economic development. Lotfalipour et al. [55] reach the same conclusion in the case of Iran. However, the results are somehow beyond our expectations because many developing countries are somewhat dependent on energy consumption in some stages of economic development. Numerous economic activities need an abundant amount of energy to be viable. Furthermore, Zambia is one of the leading copper and cobalt producers in Sub-Saharan Africa, and has been ranked the seventh-largest producer of copper worldwide [83], meaning that the country needs a substantial amount of energy for its economic operations. Therefore, we would expect to observe also the reverse causality from energy consumption to economic development.

In the case of Zimbabwe, we found one cointegration relationship as reported in the bounds testing results. This is found when energy consumption is a dependent variable, hence, as we pointed out earlier, the error correction term is included only in this equation. The results for the Granger causality analysis indicate a one-way causality running from GDP to FDI. This means that changes in GDP precede changes in FDI in this particular country. Hence the country should put more pressure on other deep determinants of economic development, such as institutional quality, good infrastructure, expansion of the exports base, inter alia, in order to be able to attract more FDI. Furthermore, the results reveal the neutrality hypothesis between energy consumption, CO_2 emissions, and GDP, because the variables do not affect each other either in the short run or in the long run. However, we did not find a long-term relationship between any pair of variables as supported by the coefficient of the error correction term.

To summarise, the most common short-term Granger causality relationships can be found from the other variables to CO_2 emissions (DRC, Kenya, and South Africa, with different variables Granger-causing CO_2 emissions in different countries) and from GDP and GDP squared to FDI (Kenya, South Africa, and Zimbabwe). It thus appears to be the case that Granger causality running from the other variables to CO_2 emissions is more common in the countries where the EKC theory also seems to hold (DRC and Kenya in our sample). In addition, there is unidirectional Granger causality from GDP to FDI in both countries, with evidence for the pollution haven hypothesis (Kenya and Zimbabwe); and from FDI to CO_2 emissions in both countries, with evidence for the halo effect (DRC and South Africa). Otherwise, the causality relationships vary greatly between the countries, indicating that it is impossible to give universal policy recommendations and that the country characteristics with regard to causality relationships have to be assessed individually.

5. Conclusions

This study investigates the causal links among energy consumption, CO_2 emissions, economic development, and FDI by employing time series data for six Sub-Saharan African countries. The countries under investigation are the Republic of the Congo, the DRC (Democratic Republic of the Congo), Kenya, South Africa, Zambia, and Zimbabwe. Therefore, the sample consists of countries that are at different levels of economic development. Stationarity tests show that all the series are integrated to the order of 0 or 1, which means that the ARDL bounds cointegration test can be used to test for cointegration between the variables. The results indicate that there is a long-term relationship between the variables. The results also support the EKC hypothesis for DRC, Kenya, and Zimbabwe, implying that there could be an inverted-U-shaped relationship between the level of economic development and environmental damage in these countries. Interestingly, these are the countries with the lowest GDP per capita figures in our sample (apart from Zambia). This suggests that the EKC hypothesis is more likely to hold at low levels of economic development. In addition, FDI appears to increase CO_2 emissions in Kenya and Zimbabwe (which supports the so-called pollution haven hypothesis), while the opposite effect can be observed in DRC and South Africa (which supports the halo effect hypothesis).

The Granger causality analysis found several unidirectional Granger causality relationships between the variables of interest. The most common short-term causality relationships appear to run from the other variables to CO_2 emissions (with different variables Granger-causing CO_2 emissions in different countries), and from GDP to FDI. Interestingly, in our sample Granger causality running from the other variables to CO_2 emissions appears more probable in the countries where the evidence also supports the EKC hypothesis. In addition, the pollution haven hypothesis seems to be associated with causality from GDP to FDI, and the halo effect with causality from FDI to CO_2 emissions. The latter relationship implies that particularly DRC and South Africa should try to attract more FDI in order to benefit from the resulting transfers of cleaner technology, while the other countries in the sample should be more cautious and focus more on updating their environmental legislation. We did not find any evidence of bidirectional causality relationships between the variables. In general, the causality relationships vary greatly between the countries, indicating that it is impossible to give universal policy recommendations.

The differences in the country results might be attributed to the economic structures of each economy. For instance, in the least developed country of our sample, DRC, the economy is propelled by the primary sector, particularly agriculture, forestry, fishing, and hunting, which are not that energy intensive. Therefore, the country's energy consumption is not that strongly related to the other variables of interest even if the country's secondary sector is mainly composed of extractive industries and construction [84]. Together with Granger causality from GDP to CO_2 emissions, the support for the EKC hypothesis implies that advances in DRC's level of economic development are likely to be associated with environmental degradation at the beginning but that the situation should improve over time if the economy continues to develop further. The same conclusion holds for Kenya, where the most important sectors comprise agriculture, tourism and manufacturing. Agriculture contributed almost 21% of the country's GDP in 2013, followed by the industrial sector which contributed nearly 16% of GDP [85]. Granger causality from energy consumption to CO_2 emissions is likely to reflect the larger (in comparison to DRC) role of the manufacturing sector in the country's economy. This effect is also visible in South Africa, the country with the highest level of economic development in our sample. It is one of the emerging economies whose economic structure is highly dependent on the secondary sector. The country is one of the top ten producers of base metals and coal worldwide, while agriculture, forestry and fishing contributed only 2.2% of GDP in 2013 [86]. Thus, the larger the role of energy intensive sectors is in an economy, the more likely energy consumption is to Granger-cause CO_2 emissions. Interestingly, this effect is not visible in Zambia, where industrial sector and particularly copper industry play large roles. The latter contributed 31.3% of GDP in 2013, although agriculture employed 85% of the whole population in the same year [87]. In Zambia, Granger causality from GDP to energy consumption implies that changes in the level of economic development precede changes in energy consumption, presumably because economic development is associated with the economic structure of the country. The economy of the Republic of the Congo is dominated by the oil sector, which accounted for almost 67.3% of the country's GDP in 2013. The rest of GDP is accounted for by such sectors as forestry, agriculture, mining, industry and services [88]. The significance of the oil sector shows as the second-highest GDP per capita in our sample. The large role played by the sector is also visible in Granger causality from energy consumption and CO_2 emissions to GDP. The most important sectors in Zimbabwe are agriculture, mining and manufacturing. The manufacturing industries contributed 23.9% of GDP, followed by the agricultural sector which contributed 19.1% of GDP in 2013 [89]. Our results for Zimbabwe support the so-called neutrality hypothesis between energy consumption, CO_2 emissions and GDP: there are no causality relationships between the three variables. This result might be associated with the general turmoil in the country's economy during the observation period.

The results pose some policy implications for the policy-makers in the countries investigated. For instance, the causality running from FDI to CO_2 emissions might support the pollution haven hypothesis or the halo hypothesis. This means that the presence of multinationals in the host countries could either increase or decrease the level of emissions, implying that the host countries must try to assess the environmental impact of FDI before welcoming foreign investors into the country. Another crucial result is the Granger causality running from energy consumption to GDP. If energy consumption is one of the determinants of economic development, attempts to curb energy consumption may have an adverse effect on the economic development of the country in question. On the other hand, if GDP Granger-causes energy consumption in Zambia and not the other way round, it might be the case that energy-saving policies could be implemented in the country with little or no adverse effect on the level of economic development. Moreover, the results showing that energy consumption and GDP Granger-cause CO_2 emissions are associated with the fact that, as a country develops, it tends to consume more energy than before. As a result, its emissions increase as well. Such countries should encourage the use of renewable sources of energy in order to minimise the adverse effects of emissions. In addition, we would like to recommend that the countries should invest more in energy efficiency projects in order to continue protecting the environment. Furthermore, the results showing that FDI Granger-causes GDP indicate that FDI is one of the determinants of economic development. Hence the potential host countries should continue with strategies of attracting more FDI. For other countries, the reverse causality from GDP to FDI seems to hold. In such cases, the level of economic development of the host country is one of the determinants of FDI. This has been the case especially in the market seeking FDI. The potential host countries should encourage other determinants of economic development, such as institutional quality, expansion of the export base, persistent improvements in domestic investments, and improvement in infrastructure, in order to attract more foreign investors.

The results are subject to a number of limitations. First, the period used in this study is relatively short, particularly for time series analysis. Second, it is also possible that the causality relationships have changed over time, indicating that it could be enlightening to evaluate the possible changes. This might be particularly relevant in the case of Zimbabwe. Hence, further analysis is needed in future research.

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Carbon dioxide emissions, energy consumption and economic development in Sub-Saharan Africa: Panel cointegration and causality analysis

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Abstract

This study examines the causal links among carbon dioxide (CO_2) emissions, energy consumption and economic development using panel econometrics in 13 countries from Sub-Saharan Africa. The countries are analysed as one region. In order to examine whether the relationships between the variables have changed over time, the data is divided into two periods: 1971-1990 and 1991-2010. The results show that there is a long-term relationship between the variables. The results also support the Environmental Kuznets Curve hypothesis in the latter period, but not in the first period. The Granger causality tests reveal some differences between the two periods, indicating that causality relationships change over time. Moreover, the results imply that reducing CO_2 emissions and conserving energy should not hamper economic growth in Sub-Saharan Africa (on average), meaning that these tools could help the region to achieve sustainable development. More specifically, energy efficiency should be increased and the adverse impacts of electricity generation should be reduced, but without decreasing electricity supply to the end-users. In addition, Sub-Saharan African countries should invest in energy infrastructure and initiate energy conservation policies to reduce CO_2 emissions. According to the results, energy-efficiency projects can also mitigate the impact of economic growth on environmental quality.

Keywords: Carbon dioxide emissions, energy consumption, economic development, cointegration, Granger causality, Sub-Saharan Africa

Introduction

The threat of global warming has motivated an enormous amount of research on the causes of this phenomenon during the past two decades. The prevailing view is that greenhouse gas emissions resulting from human activities are the main cause of global warming e.g., [1]. Various initiatives have been put in place to restrict the adverse impacts of global warming. These include, among others, capacity building in mitigation and adaptation to climate change, enforcement of different environmental and energy conservation policies, and the use of renewable sources of energy. In addition to these measures, international treaties have been concluded in order to reduce the level of greenhouse gas emissions in the atmosphere. Most notably, the Kyoto Protocol of 1997 required the developed countries to reduce their greenhouse gas emissions by at least 5.2% against 1990 levels [2]. The first commitment period of the protocol (2008-2012) has already ended, while the second phase (2013-2020) has been put in place but has not entered into legal force.

Sub-Saharan Africa contributes to global environmental degradation to a lesser extent than other regions. However, land degradation and water pollution, two of the three main aspects of environmental degradation besides air pollution, are pervasive in the region due to factors such as poverty, population growth, poor technology, deforestation, overgrazing, urbanization, and poor farming and mining practices. The major sources of energy in Sub-Saharan Africa include wood fuel, biofuel, hydroelectric power, natural gas and coal reserves. Wood fuel accounts for 70% of the total energy consumption in the region because the majority of citizens live in rural areas where wood fuel can be accessed more easily than in urban areas, and it is cheap [3]. In general, other sources of energy, although abundant, have not been fully tapped due to poor technology. This is relevant because energy consumption affects the quality of the environment, including the level of greenhouse gases in the atmosphere, most specifically if the energy efficiency policies are flouted.

Carbon dioxide (CO_2) has been singled out as an important greenhouse gas and, as a result, the extant literature has devoted much attention to exploring the determinants of CO_2 emissions globally. As a consequence, energy consumption and the level of economic development have been singled out to be the major determinants of CO_2 emissions. Other variables that could affect the level of CO_2 emissions include, among others, trade openness, urbanisation, labour force, industrial structure, foreign direct investment, capital stock, and the level of financial development see, e.g., [1,4,5]. In comparison to other regions, the level of CO_2 emissions per capita has been very low in Sub-Saharan Africa. However, the area's energy consumption rose by 6% and CO_2 emissions by almost 20% between 2000 and 2008 [5]. The simultaneous increase in GDP per capita was 2.5%, which indicates that CO_2 emissions, energy consumption and economic development are positively correlated in the region. Therefore, Sub-Saharan African CO_2 emissions are likely to increase significantly in the future if the economies of the region's countries grow and nothing is done to curb the level of emissions.

Some of the earlier studies examining the links between CO_2 emissions, energy consumption and economic development employ one-way causality analysis without taking into consideration reverse causality or the fact that CO_2 emissions, energy consumption and the level of economic development can be determined simultaneously. Other studies account for reverse causality e.g. by applying Granger causality analysis but make too strong conclusions based on the empirical results: Granger causality cannot be used to deduce whether changes in a variable have a positive or negative impact on another variable. In addition, most of the existing studies focus on other geographic areas than Sub-Saharan Africa, although understanding the causal relationships between CO_2 emissions, energy consumption and the level of economic development would be particularly important for developing economies that would need to catch-up richer countries in terms of GDP per capita but preferably without severe environmental degradation.

In this study, we aim to complement the existing literature by examining the causal links between CO_2 emissions, energy consumption and economic growth in 13 Sub-Saharan African countries. We use panel data, meaning that the countries included in the study are analysed as one region. This is something that the previous literature has rarely done even if panel data estimation methods will result in more reliable results when time-series length is short. Among the notable exceptions of e.g., Al-mulali and Binti Che Sab [5], Apergis and Payne [6], and Sharma [1], the study by Al-Mulali and Binti Che

Sab is the only one that focuses on Sub-Saharan Africa. Moreover, we divide our data into two periods to examine whether the causal relationships between the variables have changed over time. To the best of our knowledge, this is the first study trying to analyse whether the causal links between the three variables of interest have changed over time in Sub-Saharan Africa. Thus, the results of this study may be of interest to both policy makers and academics. In particular, they could help policy makers construct the appropriate policies.

The next section reviews the results from the previous literature. Section 3 discusses the theoretical model employed, the data used and the methodologies employed in this study. Section 4 presents the empirical results and, finally, Section 5 concludes with the policy implications.

1. Literature review

The previous literature has examined the causal links between CO_2 emissions, energy consumption, and economic development based on different approaches and methodologies. The results are also varied. The previous studies can be arranged into three strands. The first strand focuses on the causal links between environmental pollution captured by CO_2 emissions and economic development measured by GDP per capita, the second strand on the causal links between energy consumption and economic development, and the last strand on the causal links among all the three variables using multivariate framework. Al-mulali and Binti Che Sab [5], Bashiri Behmiri and Pires Manso [7] and Saidi and Hammami [8] present excellent overviews of the existing literature, while Kivyiro and Arminen [9] discuss the strands of literature that are particularly relevant from the point of view of developing countries.

The first strand can be termed the environmental pollution – economic growth nexus and has been a subject of debate for the past two decades. This nexus is closely related to the testing of the Environmental Kuznets Curve (EKC) hypothesis, which was first proposed by Grossman and Krueger [10,11]. According to the hypothesis, the relationship between environmental degradation and the level of economic development resembles an inverted U-shape. This means that environmental degradation increases with an increase in income up to a certain turning point, after which the pollution level decreases with an increase in income. There have been numerous studies that have tested the validity of the EKC hypothesis using different environmental indicators (see e.g., [12-15] for surveys). Although some of the studies support the EKC, the results of others indicate that the level of environmental pollution increases monotonically with the income level. A study by Kijima et al. [14] posits that the model specification and methodologies employed by the various studies have been singled out to be major causes of such controversies. To give two examples of the studies conducted for developing countries, Narayan and Narayan [16] test the EKC hypothesis for 43 developing countries. Their results are in line with the EKC hypothesis. In contrast, the results of Fodha and Zaghdoud [17] for Tunisia support the EKC hypothesis with SO_2 emissions but not with CO_2 emissions.

Also the energy consumption – economic growth nexus has drawn the attention of numerous researchers since the seminal study of Kraft and Kraft [18] (see [19] for an extensive literature review). Some of the studies, e.g., [19-24], focus on Africa. For example, the study of Odhiambo [21] implies that there is a long-term relationship between the two variables in Tanzania. In addition, there seems to be a one-way causality running from energy consumption to economic growth. In a related study, Odhiambo [19] finds that there is a one-way Granger causality running from energy consumption to economic growth also in Kenya and South Africa, while a reverse causality seems to exist in the Democratic Republic of the Congo. According to Akinlo [20], energy consumption has a significant positive long-term effect on economic growth in Ghana, Kenya, Senegal and Sudan. The results from Granger causality analysis reveal a bidirectional causality between the variables in Gambia, Ghana and Senegal, and a unidirectional causality running from economic growth to energy consumption in Sudan and Zimbabwe. Neutrality hypothesis of no causal relationships between the pair of the variables also gets support in some countries. Bashiri Behmiri and Pires Manso [7] examine how crude oil consumption affects economic growth of Sub-Saharan African countries. The results reveal a bidirectional Granger causality between the variables in the oil-importing region while there seems to be a one-way causality running from crude oil consumption to economic growth in the oil-exporting region. In the long-run, the results indicate bidirectional causality between the two variables in both regions.

The third strand incorporates the two nexus in a single multivariate model. Only few studies have examined the causal links between the variables in Sub-Saharan Africa. The first line in this strand of literature comprises of individual country studies. The results from these studies, discussed in e.g. [9], are mixed. The second and more recent line employs a panel data approach e.g., [4,5,25-29]. Panel data techniques enhance the reliability of the results especially when the time span of the data is very short [7,30]. This is relevant from our point of view because in some countries particularly in Sub-Saharan African region, the time span of many macroeconomic variables is short and using simple time series data might lead to spurious results. In a rare study conducted with panel data for Sub-Saharan Africa, Al-mulali and Binti Che Sab [5] investigate the impacts of energy consumption and CO_2 emissions on economic growth and financial development in the region. They find causality running from both directions in the case of total primary energy consumption and CO_2 emissions; and also between GDP per capita and investment. The authors are not interested in the validity of the EKC hypothesis in their sample. Moreover, we find some of the conclusions made in this study problematic, since despite the claims made by Al-mulali and Binti Che Sab, Granger causality only indicates that changes in one variable precedes changes in another variable, not whether the variables are positively or negatively related.

2. Model, data and econometric methodogy

2.1 Structure of the model

In this study, we employ the technique suggested by Ang [31] but in a panel framework. The same approach has been used previously by Apergis and Payne [6], Pao and Tsai [25] and Wang et al. [32]. The long-term relationship between CO_2 emissions, energy consumption and economic growth is captured by the following equation:

$$CO_{it} = \alpha + \beta_1 EN_{it} + \beta_2 Y_{it} + \beta_3 Y_{it}^2 + \varepsilon_{it} \qquad (1)$$

where $i = 1,2,\dots,N$ represents the countries, $t = 1,2,\dots,T$ represents the time periods, *CO* stands for CO_2 emissions per capita (measured in metric tons), *EN* stands for energy use per capita (measured in kg of oil equivalent), *Y* stands for GDP per capita (measured in constant 2000 US dollars) and Y^2 is the square of GDP per capita. The parameters β_1, β_2, and β_3 stand for the long-term elasticity estimates of CO_2 emissions with respect to energy use, GDP per capita and GDP per capita squared, respectively. In accordance with the discussion above, β_1 is expected to be positive since an increase in energy consumption can be expected to increase CO_2 emissions. The inverted-U-shaped relationship between environmental pollution and the level of economic development implied by the EKC hypothesis can be captured mathematically by including the squared value of GDP per capita in the set of regressors. We thus expect β_2 to be positive and β_3 to be negative.

2.2 Data

The data used in this study are annual data extracted from World Bank Development Indicators [33]. CO_2 emissions per capita are measured in metric tons per capita, energy consumption per capita in kg of oil equivalent per capita, and, GDP per capita in constant 2000 USD per capita. In order to examine whether the causal relationships between the variables have changed over time, we consider two time periods separately: Panel One covers the period between 1971 and 1990, while Panel Two covers the period between 1991 and 2010. The panels have thus been formed by splitting the data into two data sets of the same size. This makes comparisons between the samples easier and more reliable. The sample, which was dictated by data availability, consists of 13 countries from the Sub-Saharan African region: Benin, Cameroon, the Democratic Republic of the Congo, the Republic of the Congo, Ivory Coast, Gabon, Ghana, Kenya, Nigeria, Senegal, Togo, Zambia, and Zimbabwe. South Africa is not included in the sample because its economic situation is quite different from the other countries in the region. The variables used in the analysis are expressed in natural logarithmic form. We report the summary statistics in Table 1 for both panels.

Table 1. Descriptive statistics (before data transformation)

Statistic	CO_2 emissions		Energy		GDP per capita	
	Panel One	Panel Two	Panel One	Panel Two	Panel One	Panel Two
Mean	0.49	1.01	515.14	577.09	1152.98	1314.67
Standard error	0.03	0.12	16.79	26.52	102.39	119.83
Standard deviation	0.53	1.96	270.73	427.67	1651.03	1932.19
Range	3.54	10.84	1136.37	2250.51	7426.99	12130.9
Minimum	0.03	0.08	207.76	224.43	201.73	320.77
Maximum	3.57	10.92	1344.13	2474.94	7628.72	12451.7
Count	260	260	260	260	260	260

The summary statistics reported in Table 1 show that the mean values of all variables are smaller in Panel One (1971-1990) than in Panel Two (1991-2010). The remaining statistics imply that the differences between the countries (as well as within-country variation) were larger in 1991-2010 than in 1971-1990.

2.3 Methodologies

The objectives of this study are (1) to test whether the variables of interest move together in the long run and (2) to examine whether there are Granger causality relationships between the variables. In addition, we estimate the long-term elasticity estimates of CO_2 emissions with respect to the other variables for the purpose of testing the validity of the EKC hypothesis. The steps of the process are summarised in Figure 1.

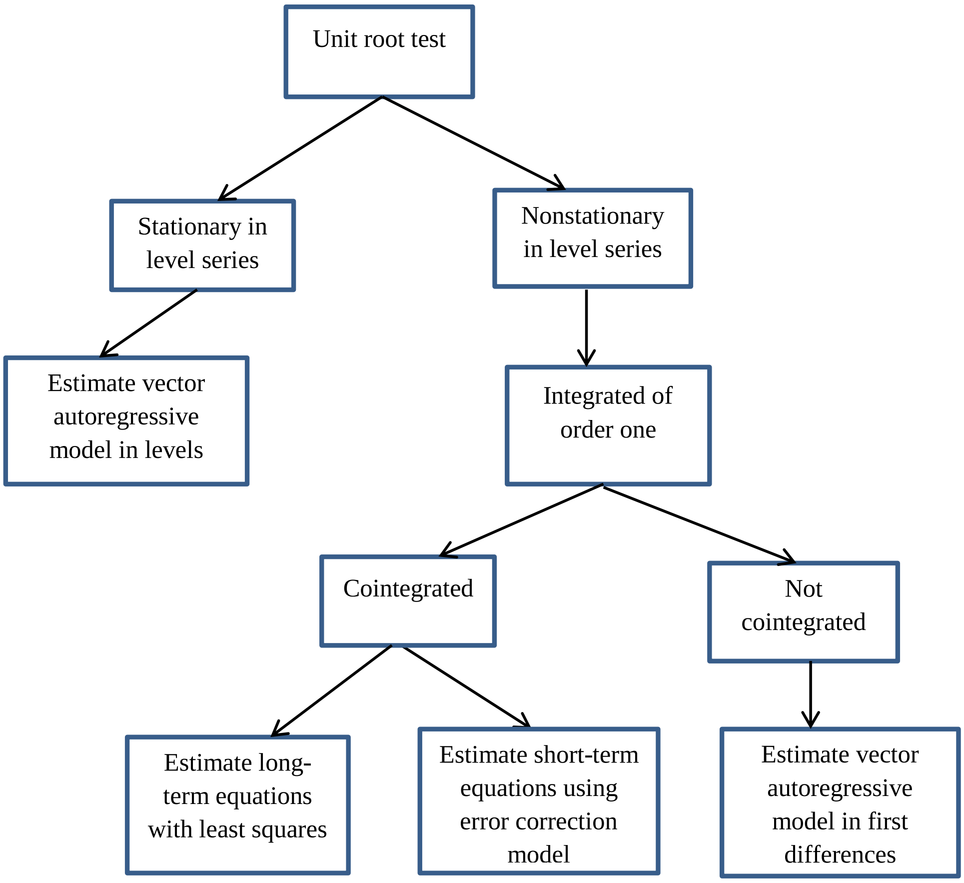

Figure 1. Regression analysis with nonstationary variables

2.3.1 Panel unit root tests

The methods that have been used to test for stationarity in a panel data framework comprise, among others, the Breitung test [34], the Levin-Lin-Chu (LLC) test [35], the Im-Pesaran-Shin (IPS) test [36], the ADF-Fisher test [37], and the Hadri test [38]. We employ the LLC, Breitung and IPS tests in order to enhance the robustness of the results. The tests are discussed in more detail in Appendix A.

2.3.2 Panel cointegration tests and estimation of cointegration equations

If all the time series seem to be integrated of order one (i.e. are nonstationary but become stationary when differenced once), we need to find out whether there is a long-term relationship between the variables. We thus test for cointegration among the variables. Several methods have recently been developed for testing for cointegration with panel data e.g., [39-42]. In this study, we employ the residual-based procedures proposed by Pedroni, since they have been used frequently in recent studies see e.g., [5,26]. We also use Johansen-type panel cointegration tests procedures developed by Maddala and Wu [40] in order to check for the robustness of the results.

Next, we estimate the cointegration equations with CO_2 as the dependent variable. The methods commonly used in estimating cointegration relationships in panel data framework include, among others, the residual-based panel Fully Modified OLS (FMOLS) and Dynamic OLS estimators, both of which produce asymptotically unbiased, normally distributed coefficient estimates [43-46]. In this study, we follow Pedroni's [41,42] suggestion and employ the FMOLS.

2.3.3 Granger causality analysis

We use the Granger causality test developed by Granger [47] and Wiener [48] to analyse the relationships among CO_2 emissions, energy consumption, and the level of economic development. A variable *x* is said to Granger cause another variable *y*, if the variable *y* can be better predicted by the past or lagged values of both *x* and *y* than by the lagged values of *y* alone. Granger causality cannot be used to deduce whether changes in a variable have a positive or negative impact on another variable and it does not indicate directly that the movement of one variable causes the movement of another variable. Instead, it shows the chronological ordering of movements [49].

The history of Granger causality testing with panel data is relatively brief. We follow the strand of the literature initiated by Holtz-Eakin et al. [50,51] by assuming that the coefficients of the explanatory variables are identical across all countries and that there is no causal variation across the countries. To make this assumption more likely to hold, we have dropped South Africa from our sample of Sub-Saharan African countries.

The Granger causality test can be carried out by either a vector autoregressive (VAR) or a vector error correction model (VECM) framework. The VAR model was popularised by Sims [52]. In a VAR system of equations, all of the variables are treated as endogenous and independent; although sometimes exogenous variables can also be included see, e.g., [53]. If the variables are cointegrated, VAR produces spurious and misleading results [54]. Therefore, this study employs the VECM to examine Granger causality. The VECM incorporates the first difference terms and an error correction term that captures the speed of adjustment to long-term equilibrium values after a short-term shock. The existence of cointegration shows also that there is at least one long-term equilibrium relationship between the variables [55].

We follow the two-step procedure proposed by Engle-Granger [55] with the application of VECM. Thus, we begin by estimating the form of equation (1) by using FMOLS in order to get the residuals (i.e., error correction terms). First, CO_2 emissions per capita will be used as the dependent variable, then energy consumption and, lastly, GDP per capita and GDP per capita squared. The residuals obtained will be incorporated in estimating the VECM as specified in equations (2) to (5):

$$\Delta CO_{it} = \alpha_1 + \sum_{k=1}^{p} \delta_{1k} \Delta CO_{it-k} + \sum_{k=1}^{p} \lambda_{1k} \Delta EN_{it-k} + \sum_{k=1}^{p} \theta_{1k} \Delta Y_{it-k} + \sum_{k=1}^{p} \gamma_{1k} \Delta Y^2_{it-k} + \sigma_1 ECT_{it-1} + \varepsilon_{1it} \tag{2}$$

$$\Delta EN_{it} = \alpha_2 + \sum_{k=1}^{p} \delta_{2k} \Delta CO_{it-k} + \sum_{k=1}^{p} \lambda_{2k} \Delta EN_{it-k} + \sum_{k=1}^{p} \theta_{2k} \Delta Y_{it-k} + \sum_{k=1}^{p} \gamma_{2k} \Delta Y^2_{it-k} + \sigma_2 ECT_{it-1} + \varepsilon_{2it} \tag{3}$$

$$\Delta Y_{it} = \alpha_3 + \sum_{k=1}^{p} \delta_{3k} \Delta CO_{it-k} + \sum_{k=1}^{p} \lambda_{3k} \Delta EN_{it-k} + \sum_{k=1}^{p} \theta_{3k} \Delta Y_{it-k} + \sum_{k=1}^{p} \gamma_{3k} \Delta Y^2_{it-k} + \sigma_3 ECT_{it-1} + \varepsilon_{3it} \tag{4}$$

$$\Delta Y^2_{it} = \alpha_4 + \sum_{k=1}^{p} \delta_{4k} \Delta CO_{it-k} + \sum_{k=1}^{p} \lambda_{4k} \Delta EN_{it-k} + \sum_{k=1}^{p} \theta_{4k} \Delta Y_{it-k} + \sum_{k=1}^{p} \gamma_{4k} \Delta Y^2_{it-k} + \sigma_4 ECT_{it-1} + \varepsilon_{4it} \tag{5}$$

Here, *CO* stands again for CO_2 emissions per capita, *EN* for energy use per capita, *Y* for GDP per capita, and Y^2 for the square of GDP per capita. Δ is the first difference operator,

$i = 1, \ldots, N$ represents the individual countries, $t = 1, \ldots, T$ denotes the time period, and k represents the lag length. *ECT* is the error correction term capturing the speed of adjustment to the long-term equilibrium after a short-term shock, $\sigma_1, \sigma_2, \sigma_3, \sigma_4$ are autoregressive long-term regression coefficients, and ε_{it} is the error term that is assumed to be independent and identically distributed with a mean of zero and a constant variance. The regression coefficients of the first difference terms (δ, λ , θ, γ) capture the short-term Granger causality between the variables. An explanatory variable Granger causes the dependent variable if the estimated coefficients of the lagged values of the explanatory variable are statistically significantly different from zero as a group. The Wald test statistic is used to test the joint null hypothesis of the coefficients. We use the fixed effects estimator to estimate the VECM specified in equations (2) to (5).

3. Results

3.1 Panel unit root tests

Table 2 reports the results of the unit root tests for the level and first difference series of Panel One and Table 3 for Panel Two. For both Panels, the test equations in the level series incorporate individual effects and a linear trend as exogenous variables, while in the first difference series only individual effects are included. However, for those level series (e.g., CO_2 emissions) where individual effects and trend are statistically insignificant, we do not include them in the corresponding test equations. Furthermore, because Breitung test requires individual effects and linear trend to be included in both level and difference series, we include them in this case. According to the results, all the variables are integrated of order 1, i.e. I(1), in both panels, indicating that cointegration tests can be performed in the next step.

Table 2. Balanced panel unit root test results: Panel One (1971-1990)

	LLC		Breitung		IPS	
	Level series	First difference	Level series	First difference	Level series	First difference
CO_2	1.556	-13.408***	-1.846	-5.161***	-0.761	-12.848***
EN	-0.758	-12.367***	1.332	-8.066***	1.356	-9.335***
Y	0.004	-9.260***	-0.348	-4.961***	0.312	-8.677***
Y^2	-0.074	-9.367***	-0.389	-5.047***	0.270	-8.730***

Notes: 1) LLC represents the Levin et al. (2002) unit root test. 2) IPS represents the Im et al. (2003) unit root test. 3) The optimal number of lags was selected automatically using the Schwarz Information Criterion. 4) *** denotes statistical significance at the 1% level of significance.

Table 3. Balanced panel unit root test results: Panel Two (1991-2010)

	LLC		Breitung		IPS	
	Level series	First difference	Level series	First difference	Level series	First difference
CO_2	-2.160	-11.266***	-1.009	-4.743***	-1.531	-12.935***
EN	-0.341	-10.074***	0.868	-8.409***	0.2731	-11.013***
Y	2.096	-6.943***	5.270	-3.158***	4.191	-7.675***
Y^2	2.115	-6.885***	5.310	-3.076***	4.275	-5.165***

Notes: 1) LLC represents the Levin et al. (2002) unit root test. 2) IPS represents the Im et al. (2003) unit root test. 3) The optimal number of lags was selected automatically using the Schwarz Information Criterion. 4) *** denotes statistical significance at the 1% level of significance.

3.2 Cointegration tests, cointegration equations and the Environmental Kuznets Curve

Table 4 depicts the results of the cointegration tests for Panel One and Panel Two. The test equation for Panel One includes the individual intercept and deterministic trend, while the test equation for Panel Two includes neither.

Table 4. Balanced panel cointegration test results

Pedroni test	Panel One (1971-1990)		Panel Two (1991-2010)	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	1.557**	0.0597	0.728	0.2332
Panel rho-Statistic	-0.376	0.3536	-2.785***	0.0027

Panel PP-Statistic	-1.951**	0.0256	-5.964***	0.0000
Panel ADF-Statistic	-1.907**	0.0282	-6.219***	0.0000
Group rho-Statistic	-0.283	0.3886	0.832	0.7973
Group PP-Statistic	-4.328***	0.0000	-2.565***	0.0051
Group ADF-Statistic	-4.279***	0.0000	-5.892***	0.0000
Johansen Fisher test				
	Trace_statistics	Prob	Trace_statistics	Prob
None	511.6	0.0000	304.5	0.0000
At most 1	221.6	0.0000	137.2	0.0000
At most 2	81.47	0.0000	67.99	0.0000
At most 3	48.28	0.0050	34.65	0.1193

Notes: 1) The optimal lag lengths were selected automatically using the Schwarz Information Criterion in Pedroni test. 2) The optimal lag length was set to 1 in the Johansen Fisher test. 3) *** and ** denote the rejection of the null hypothesis of no cointegration at the 1% and 5% levels, respectively.

For Panel Two, we do not include exogenous variables in the test equation. The results based on the different statistics are mixed: with panel PP and ADF statistics, the null hypothesis of no cointegration is rejected at the 5% level in both panels while the results based on the remaining two panel statisistics (rho and v) are more conflicting. Moreover, two out of the three group statistics depicted in Table 4 imply that the null hypothesis of no cointegration should be rejected at the 1% level in both panels. According to Pedroni [42], the main difference between the panel statistics (i.e. within-dimension based statistics) and the group statistics (i.e. between-dimension based statistics) is that the former are based on estimators that effectively pool the autoregressive coefficients across different members for the unit root tests on the estimated residual, whereas the latter are based on estimators that simply average the individually estimated coefficients for each member. The Pedroni test results are complemented by the Johansen Fisher test, which rejects the null hypothesis of no cointegration at the 1% level for both panels and shows that there are at most two cointegration equations in both panels. Since the majority of the tests statistics indicates that the null hypothesis should be rejected, we can conclude that the variables are cointegrated, which means there is a long-term relationship between the variables. This implies also that there will be at least one direction of causality between the variables [54].

Next, we proceed with the analysis by estimating the cointegration equations with CO_2 as the dependent variable. The objective is to estimate the long-term elasticity estimates of CO_2 with respect to the other variables. We follow Pedroni's [41,42] suggestion and employ the FMOLS estimator. The results based on equation (1) are reported in Table 5.

Table 5. The long-term elasticity estimates of CO_2 with respect to the other variables

	Panel One (1971-1990)		Panel Two (1991-2010)	
Variable	Coefficient	Prob	Coefficient	Prob
EN	1.388***	0.0000	0.271***	0.0000
Y	2.756***	0.0000	3.657***	0.0000
Y^2	-0.117	0.1743	-0.345***	0.0000

Notes: 1) *** denotes the rejection of the null hypothesis at the 1% level of significance.

According to the results for Panel One, the long-term elasticity of CO_2 emissions per capita with respect to energy consumption per capita is 1.388, which indicates that CO_2 emissions per capita increase by 1.388% if energy consumption per capita increases by 1%. The result indicates in addition that CO_2 and energy consumption have a positive long-term relationship with each other. The results also show that the long-term elasticity estimate of CO_2 emissions per capita with respect to GDP per capita is 2.756–0.234Y. All the coefficients have the expected signs, but because the coefficient of GDP per capita squared is statistically insignificant, the results do not support the EKC hypothesis. Instead, the results indicate that there was a linear relationship between CO_2 emissions and the level of economic development between 1971 and 1990: the higher the level of economic development, the higher the level of CO_2 emissions. One possible explanation for this is that the countries in this sample had not reached high enough economic development for the decreasing part of the inverted U of the EKC at that time.

In the case of Panel Two, the long-term elasticity of CO_2 emissions per capita with respect to energy consumption is 0.271. Therefore, as in Panel One, CO_2 and energy consumption seem to have a positive long-term relationship with each other. The results also show that the long-term elasticity estimate of CO_2 emissions per capita with respect to GDP per capita is 3.657–0.690Y. All the coefficients have the expected sign, and because the coefficient of GDP per capita squared is also statistically significant, the results for Panel Two support the EKC hypothesis. This implies, on average, that if a Sub-Saharan African country attains a high enough level of economic development, the state of the environment should start to improve instead of deteriorating with further economic growth. The turning point can however be expected to vary between the countries. It is also quite likely that not all of the countries in the sample have surpassed their turning points already. Therefore, in some of the countries, economic growth is likely to result in more serious environmental pollution until these countries have reached their turning points.

3.3 Granger causality results

The Granger causality results for Panel One are reported in Table 6 and the results for Panel Two in Table 7. The implied short-run and long-run Granger causality relationships are summarised in Figures 2 and 3, respectively.

Table 6. Granger causality test results: Panel One (1971-1990)

	Dependent Variable			
	ΔCO_2	ΔEN	ΔY	ΔY^2
ΔCO_2	-	0.2137 (0.8078)	6.4389*** (0.0020)	6.483 (0.0019)
ΔEN	0.277 (0.7582)	-	5.225*** (0.0062)	7.165 (0.0010)
ΔY	0.070 (0.9323)	3.8923** (0.0221)	-	2.1309 (0.1309)
ΔY^2	0.111 (0.894)	4.853*** (0.0088)	2.323* (0.1008)	-
ECT	-0.154*** (0.0012)	-0.006 (0.393)	-0.0649*** (0.0000)	-1.044**** (0.0000)

Notes: 1) ***, ** and * denote rejection of the null hypothesis of no Granger causality at the 1%, 5% and 10% levels, respectively. 2) The numbers in parentheses are the P-values.

Table 7. Granger causality test results: Panel Two (1991-2010)

	Dependent Variable			
	ΔCO_2	ΔEN	ΔY	ΔY^2
ΔCO_2	-	2.739* (0.0672)	0.7544 (0.4717)	0.7941 (0.4535)
ΔEN	1.157 (0.3167)	-	0.337 (0.7143)	0.516 (0.5975)
ΔY	10.010*** (0.0001)	2.516* (0.0836)	-	0.3759 (0.6872)
ΔY^2	10.049*** (0.0001)	1.447 (0.2378)	0.189 (0.827)	-
ECT	-0.186** (0.0134)	-0.0325*** (0.0066)	-1.010 (0.330)	-0.152 (0.2581)

Notes: 1) ***, ** and * denote rejection of the null hypothesis of no Granger causality at the 1%, 5% and 10% levels, respectively. 2) The numbers in parentheses are the P-values.

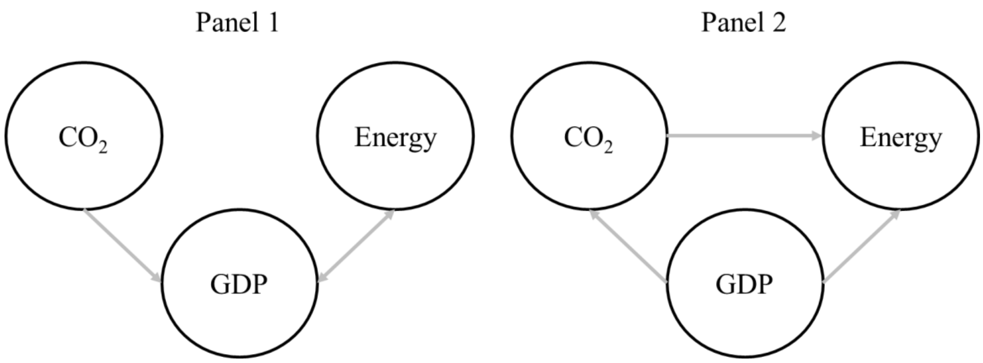

Figure 2. Short-run Granger causality results

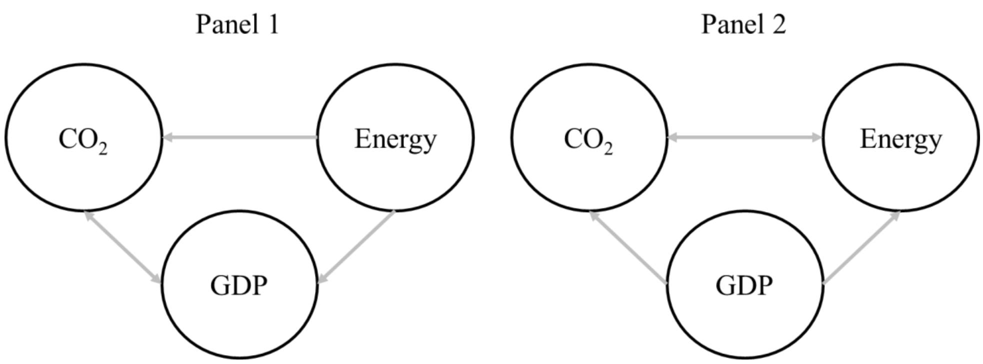

Figure 3. Long-run Granger causality results

According to Table 6 for Panel One, there is a one-way Granger causality running from CO_2 emissions per capita to GDP per capita at the 1% level of significance. We also find two-way Granger causality between GDP per capita and energy consumption per capita at the 5% level of significance. For the long-run, the *P*-values of the ECTs show that there is causality running from energy consumption and GDP to CO_2 emissions at the 1% level of significance. The coefficient of the ECT is -0.154, which implies that the speed of adjustment towards the long-term equilibrium is 15.4% per year after a short-term shock. The coefficients of ECTs with GDP per capita and GDP per capita squared as the dependent variables are also statistically significant at the 1% level, implying that there is a long-run causality running from CO_2 emissions and energy consumption to GDP.

Table 7 shows the results of the Granger causality analysis for Panel Two. In the short-run, the *F*-statistics of the Wald test suggest a one-way causality from GDP per capita to CO_2 emissions per capita and to energy consumption per capita. In addition, there is a one-way Granger causality running from CO_2 emissions per capita to energy consumption per capita, indicating that GDP may affect energy consumption both directly and indirectly through CO_2 emissions. In the long-run, the *P*-values of the ECTs suggest a causality relationship running from energy consumption and GDP to CO_2 emissions at the 5% level of significance and from CO_2 emissions and GDP to energy consumption at the 1% level of significance. Therefore, the results suggest that all three variables interact together to restore the long-run equilibrium after a short-term shock that has caused a devition from it.

The results for Panels One and Two are thus somewhat different. The difference in the results indicates that there have been changes in the causality relationships over time. This is natural, because it is quite possible that the relationship between the level of economic development and CO_2 emissions per capita changes, as the level of economic development changes (see, Table 1). There are also some similarities between the results for the two panels: in both cases we find GDP per capita to Granger cause energy consumption. However, the causality relationship between the two variables is bidirectional in Panel One and unidirectional from GDP per capita to energy consumption per capita in Panel Two. Our results are thus only partly in line with the previous results for Sub-Saharan African countries: Bashiri Behmiri and Pires Manso [7] find evidence for a bidirectional causality between crude oil consumption (which is a proxy for energy consumption) and GDP per capita in the short-run, and Al-mulali and Binti Che Sab [5] also find bidirectional causality between energy consumption and GDP per capita. One potential explanation for the different results is that we divided the data sample into two panels.

4. Conclusions and policy implications

The first objective of this study was to test whether there is a long-term relationship between energy consumption, CO_2 emissions and the level of economic development in a panel of 13 Sub-Saharan African countries. The second objective was to test the validity of the Environmental Kuznets Curve (EKC) hypothesis in the region, and the third objective was to examine Granger causality relationships between the variables. In order to analyse whether the causal links between the variables have changed over time, we divided our sample into two periods: 1971-1990 and 1991-2010. To the best of our knowledge, this is the first study addressing these topics using panel data econometrics for such a large Sub-Saharan African sample although questions related to economic development, energy use and availability, and environmental degradation are particularly acute in the region.

According to the results, there is a long-term relationship between CO_2 emissions, energy consumption and economic development. This highlights the role of economic development and energy consumption in defining the level of CO_2 emissions. In Panel One (1971-1990), the relationship between the level of economic development and CO_2 emissions seems to follow a linear monotonic function, which does not support the EKC hypothesis. Some previous studies have reported a similar result but not with the panel data approach (see, e.g., [56,57]). In contrast, the results from Panel Two (1991-2010) support the EKC hypothesis. Our results indicate thus that the earlier contradictory results on the validity of the EKC may be partly explained by the changes in the relationship between the level of emissions and the level of economic development over time. They imply also that, on average, environmental quality should start to improve with further economic growth in a Sub-Saharan African country when (and if) that country attains a high enough level of economic development. However, because it is unlikely that all Sub-Saharan African countries have already surpassed their turning points, further economic growth is likely to result in more severe environmental degradation in some of the countries until they have reached their turning points.

The Granger causality results for Panel One show that there was a unidirectional short-term causality running from CO_2 emissions per capita to GDP per capita and a bidirectional causality between energy consumption per capita and GDP per capita. This indicates that attempts to curb CO_2 emissions might have affected the level of economic development between 1971-1990. Instead, and more interestingly from the point of view of current policy implications, in Panel Two Granger causality runs from economic development to CO_2 emissions per capita both in the short-run and long-run, indicating that changes in GDP per capita now precede changes in CO_2 emissions per capita. This implies that investing in pollution abatement technologies and emissions reduction policies should not hurt economic growth in Sub-Saharan Africa (on average), meaning that these tools could help the region to achieve sustainable development. Because GDP seems to Granger cause energy consumption as well (in accordance with the so-called conservation hypothesis, see [7]), the results imply also that, on average, energy conservation policies could be followed without impeding economic growth in Sub-Saharan Africa during 1991-2010. However, as Wolde-Rufael [24] points out, in many Sub-Saharan African countries the state of the energy infrastructure is such that some energy conservation policies are not an option because economic growth, which is necessary for raising the living standards of the people, requires energy. It is nevertheless possible to reduce electric power transmission and distribution losses in countries like Nigeria and Senegal. All in all, the objective should be to improve energy efficiency while reducing the adverse impacts of electricity generation, without reducing electricity supply to the end-users [24]. In the long-run, energy consumption and GDP per capita appear to influence CO_2 emissions per capita in both samples. Hence, energy-efficiency projects can mitigate the impact of economic growth on environmental quality. Furthermore, the bidirectional long-run Granger causality between CO_2 emissions and energy consumption in Panel 2 indicates that improving energy efficiency of e.g. energy equipment and reducing the losses in power transmission and distribution could be useful instruments in controlling the level of CO_2 emissions. Therefore, Sub-Saharan African countries should invest in energy infrastructure and step up energy conservation policies in order to reduce CO_2 emissions.

Although Sub-Saharan Africa is the region least responsible for global climate change, it is acutely vulnerable to its adverse effects on economic growth and sustainable development, poverty reduction, human security, and the prospects for achieving the Millennium Development Goals [58]. Hence, the countries in this region need to find coherent ways to tackle environmental degradation. The means to offset the effects of environmental degradation should include capacity building in mitigation and adaptation to climate change. They should include, among others, the use of renewable sources of energy, afforestation and reforestation activities, empowering small-scale miners by giving them more advanced extractive tools, and educating people about legitimate methods of environmental management [59,60]. Moreover, the sources of energy should be examined critically. For example, fossil fuels, most specifically coal, are a major source of CO_2 emissions. Therefore, the use of fossil fuels should be reduced in order to decrease CO_2 intensity. To do this, the countries with extensive hydro-electric capacity (such as the Democratic Republic of the Congo) should improve their institutional quality and reduce political uncertainty to attract investors to the country [19]. Furthermore, since Sub-Saharan African civilians rely heavily on wood fuel, which causes deforestation and health problems, expansion of electricity supply through a more efficient electricity sector that is made available to a larger part of the population is necessary to enable them to use alternative sources of energy [23,24]. The Sub-Saharan African countries could also try to attract Clean Development Mechanism projects, as these should try to assist developing countries in achieving sustainable development.

As discussed above, Granger causality is limited in the sense that it does not indicate whether the impact of a factor on another factor is positive or negative. This limits the usefulness of Granger causality tests for policy implications. Future research should therefore utilise other techniques such as impulse response functions and variance decompositions that make it possible to analyse the relationships between different factors in more detail. These require, however, that longer time series of data would be available. Moreover, our results apply to Sub-Saharan African countries on average, while some previous studies have shown that the differences between countries even with respect to the direction of Granger causality can be significant. Therefore, although panel data analysis is in principle more reliable when the time dimension of the data is short, the analysis of this paper should be complemented with country-level studies. To complete the picture, future research should also consider other measures of energy consumption and environmental pollutants.

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Appendix A. Panel unit root tests

This study employs the Breitung [34], the Levin-Lin-Chu (LLC) [35], and the Im-Pesaran-Shin (IPS) [36] tests to test for stationarity. Each of the three tests has some advantages over the others. First, the LLC test takes into account the heterogeneity of various cross-sections, but has low power in a small sample, implying that serial correlation can not be eliminated entirely. Also the IPS test takes into account the heterogeneity of various cross-sections, in addition to which it can eliminate serial correlation and is viable in small samples [32]. The LLC and Breitung tests assume a common unit root process and, hence, homogeneity across all the cross-sections, while the IPS test assumes individual unit root processes and thus permits heterogeneity across the cross-sections. The null hypothesis of all three tests is that there is a unit root (i.e., nonstationarity) while the alternative hypothesis is that there is no unit root (i.e., stationarity). Theoretically, all three tests are based on the Augmented Dickey-Fuller (ADF) specification of equation (A.1):

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=1}^{pi} \beta_{ij} \Delta y_{it-j} + X'_{it} \delta + \varepsilon_{it} \qquad \text{(A.1)}$$

Tests by Breitung and LLC consider the conventional ADF specification (A.1) and assume a common intercept $\alpha = \rho - 1$ but permit a different lag order (pi) across the cross-sections. The null hypothesis is that $\alpha = 0$ against the alternative hypothesis that $\alpha < 0$. Im et al. [36] consider a separate conventional ADF regression for each cross-section, and allow for different orders of serial correlation. The null hypothesis is that $\alpha_i = 0$ for all cross-sections i, and the alternative hypothesis is that $\alpha_i = 0$ for $i = 1, 2, \ldots, N$ and that $\alpha_i < 0$ for $i = N+1, N+2, \ldots, N$.

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Exploring the Factors Affecting the Clean Development Mechanism in the Developing Countries

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***Abstract*— The primary goal of the Clean Development Mechanism (CDM) of the Kyoto Protocol is to reduce the costs of greenhouse gas emission abatement for Annex I countries (developed countries). Furthermore, the mechanism aims at sustainable development in the developing economies. However, there has been an uneven distribution of CDM projects among the developing countries, and a major share has gone to only a few developing economies such as India, China, Brazil and Mexico. In this paper, we explore the factors that have affected the number and scope of CDM activities in the developing countries. We use the Poisson and censored regressions as our estimation methods. Our results suggest that the quality of institutions and the size of the potential host country have been particularly important determinants of the number of CDM projects hosted so far in the developing countries. The main policy implications include the importance of increasing the pace for fulfilling the institutional requirements of the CDM, improving the government structure to become free from corruption and engaging more in capacity building in order to attract more CDM projects. But improvements also in the infrastructure, most specifically in electricity capacity, are crucial in order to make the CDM activities viable in the developing countries.**

***Index Terms*-- Clean Development Mechanism, Developing countries, Greenhouse gas emissions, and Kyoto Protocol**

I. Introduction

In addition to the primary goal of reducing the costs of greenhouse gas emission abatement for Annex I countries or the developed countries, the Clean Development Mechanism (CDM) aims at sustainable development in the developing economies (non-Annex I countries). UNEP [1] states that the CDM can achieve this through the transfer of technology and financial resources, sustainable ways of energy production, increasing energy efficiency and conservation, poverty alleviation via income and employment generation, as well as local environmental side benefits. Although it is not clear that the CDM has been successful in promoting sustainable development so far [2], [3], the goal makes it worthwhile to investigate the requirements for CDM investments. In addition, there has been an uneven distribution of CDM projects and the predicament has adversely affected the developing countries in one way or another. Although the debate is intense concerning the sustainable development objective, it is clear that the developing countries need more investment from abroad (e.g., CDM projects) in order to achieve the highest level of economic development required.

Moreover, due to the rapid economic growth in the developing economies, the countries' greenhouse gas emissions are also increasing [4], indicating that it is necessary to curb their emissions as well. For example, Schneider, Holzer and Hoffmann [4] find that the CDM or a modified version of the CDM is likely to be part of the solution also in the future. However, following the ending of the first phase of the Kyoto Protocol commitment period (as from 2008 until December 31, 2012), the future of CDM projects cannot be stated with certainty and a number of questions have been raised regarding whether the mechanism will continue to thrive [5].

Hitherto, the CDM has been widely discussed in the academic literature during the recent years, but it has been claimed that the existing research mainly focuses on fine-tuning the mechanism [3]. To the best of our knowledge, there are hardly any studies that analyze the prerequisites for CDM projects using up-to-date statistical methods. Our aim is to contribute to the literature by filling this gap. We are particularly interested in the role of institutions in successful CDM project registrations. In addition, other factors that might affect CDM development activities, e.g. the level of previous emissions, human capital and economic development will be incorporated in the regression model.

Our analysis differs from the previous few studies employing statistical methods to analyze CDM investment with respect to the explanatory variables included in the model e.g.[6]; [7]; [8]: the study of Winkelman and Moore [8] places great emphasis on the level of past greenhouse gas emissions but neglects to control for the size of the country with any other explanatory variable. To our understanding, the exclusion of the size of a country biases the conclusions drawn based on the other explanatory variables.

This paper is organized as follows: Section 2 reviews both theoretical and empirical literature related to the distribution of CDM projects in the developing countries. Section 3 presents the methodology, which we start by deep explanations of the explanatory variables used in the analysis and the hypotheses to be tested. Section 4 reports the estimation method used in the analysis as well as the regression results. Section 5 discusses the results and Section 6 provides the conclusions these components, incorporating the applicable criteria that follow.

II. Literature Review

The CDM is one of the market mechanisms designed in the Kyoto Protocol signed in Japan on December 11, 1997. It was designed to meet two objectives: first to assist Annex 1 (developed) countries to achieve their emission limitations and reduction in cost-efficient ways and, second, to assist the developing countries in their strategies of achieving sustainable development via numerous benefits related to economic, social and environmental development [9]. However, due to the absence of an acceptable definition of sustainable development, the host country is responsible for determining whether a CDM project contributes to national sustainable development. The assessment is done by the nominated Designated National Authority (DNA) of the host country which is responsible for approving a particular CDM project proposed [10]

A. Theoretical Review

The literature has identified various factors as necessary for successful CDM project registrations. Issues to consider include e.g. property rights, the quality of other institutions, political stability and predictability, transaction costs and the date of Kyoto Protocol ratification see, e.g. [11]; [6]; [8]. Essentially, the CDM host countries can be seen as competing with one another in attracting foreign capital or foreign direct investment (FDI). In addition, as highlighted by Niederberger and Saner [11] and Jung [12], CDM investors base their decisions on the business environment, potential volume of economical emission reductions and local institutional capacity to organize CDM projects. We include variables representing each of these aspects in our model.

First, Byigero, Clancy and Skutsch [13] pointed out that the general business environment is closely associated with the investment climate, which is one of the most important factors in initiating CDM projects. Therefore, factors that have been found to impact on FDI also affect the number of successfully registered CDM projects. There is vast literature assessing such factors. In recent years, it has been recognized that institutional quality is one of the most important determinants of the general investment climate. The role of long-lasting institutions, such as property rights and the rule of law, is particularly important [14]; [15]. Also political stability matters. These general-level measures of institutional quality are important because even if well-functioning and efficient CDM institutions are a key element in attracting CDM projects, they have a very limited impact on the general investment climate [12]; [4]. For example, it is virtually impossible to impact on political stability through CDM institutions [3].

In particular, the level of corruption may play a role: e.g. Shleifer and Vishny [16] and Bardhan [17] find that corruption inhibits productive investment. More generally, corruption lowers investment relative to GDP by increasing risks (for example, by lowering the security of property rights) and by increasing costs. Mauro [18] and [19] was the first one to verify empirically in a cross-section of countries that corruption lowers investment, a result which has later gained further support e.g. from [20]. The detrimental effects of corruption do not depend solely on the level of overall corruption, but also on its predictability: countries with more predictable corruption tend to have higher investment rates (see [21] and [22] for foreign direct investment). If domestic investors are sensitive to the level of corruption, it should not come as a surprise that foreign investors are equally or even more sensitive.

Second, the supply of cheap and feasible emission reduction projects is also important. It is at least partly dictated by the level of economic development in the host country. Therefore, GDP per capita, urbanization and industrialization can be used to measure the range of opportunities for CDM. Of course the size of the country also plays a role: large countries tend to offer more opportunities. It might thus be necessary to control for population. Moreover, the level of greenhouse gas emissions reflects the CDM potential of a country and may thus be used as an indicator for the emission reduction potential of CDM host countries [12].

Third, local institutional capability to organize CDM projects plays a significant role. This requires that the CDM host country has invested in its domestic CDM capacity by increasing its CDM awareness, offering training programs and facilitating project identification [11]. Jung [12] uses the following indicators to measure CDM capacity: ratification of the Kyoto Protocol, participation in the Activities Implemented Jointly pilot phase, a timely establishment of a Designated National Authority and completion of the National Strategy Study (NSS). The NSS is a program designed by the host country to build its capacity towards the flexible mechanisms of the Kyoto Protocol (including the CDM). Another aspect is that the size of the CDM is likely to depend on the transaction costs in the host countries to a significant degree [23]. The magnitude of transaction costs impacts on which projects are economically viable. Because the multiple stages of the CDM require careful monitoring, transaction costs are unavoidable, but may decline when more experience is gained [24]. Therefore, the more efficient the local CDM institutions are, the lower the transaction costs are. The level of transaction costs also depends on the country's institutional quality: the more inefficient the regulatory framework, the higher the transaction costs [23].

It has been shown that a lack of human capital is associated with an increase of transaction costs that could be avoided if the level of human capital could be sufficient enough within a particular country hosting CDM projects [8]. However, different factors may be important for different CDM projects.

B. *Empirical Review*

Many researchers have investigated the determinants of CDM projects theoretically without testing the hypotheses by empirical data e.g. [25]; [26]; [27]. In addition, some researchers have focused on the case studies of projects registered in some specific countries, which hinders the generalization of the results e.g. [28]; [29].

Winkelman and Moore [8] empirically investigated the differential distribution of CDM projects among the host countries and found that factors such as human capital, greenhouse gas emission levels, and the quality of the host countries' institutions influenced which countries hosted projects. They used two regression models: the probit model in which the dependent variable was the binary for a country that hosts one or more projects and the truncated regression model with the number of CERs created acting as a dependent variable.

Jung [12] conducted a cluster analysis to investigate host country attractiveness for CDM non-sink projects and found that very few potential host countries are able to attract CDM activities due to their credibility and general investment climate. The variables used in the analysis are grouped in three different factors, and these include mitigation potential, institutional CDM capacity and the general investment climate. The mitigation potential of the host county was measured by absolute greenhouse gas emissions, which differed from the work investigated by [30]. The institutional CDM capacity of the host country is a proxy for Kyoto ratification and the establishment of a Designated National Authority (DNA) and whether the country has participated in capacity building programms. The quality of institutions was captured by government indicators for political stability, the rule of law and regulatory quality.

Dinar, Rahman, Larson and Ambros [6] investigated factors affecting the levels of international co-operation in carbon abatement projects and found out that factors such as economic development, institutional development, the energy structure of the economies, the level of country vulnerability to various climate changes and the state of international relations between the host country and investor countries are the most prominent predictors of the level of co-operation in CDM projects.

III. METHODOLOGY AND DATA ANALYSIS

The aim of the statistical analysis is to use the regression analysis to identify the statistically significant explanatory variables for CDM project registrations. Because it is difficult to deduce the lags with which explanatory variables impact on CDM registrations, we use cross-sectional data and let the explanatory variables represent the initial conditions in each of the host countries of our sample. The dependent variable, which is the total number of CDM projects in June 2012, has been taken from the CDM Pipeline. The explanatory variables come from the year 2004, which is a year before the CDM projects could be registered by the United Nations Framework Convention on Climate Change (UNFCCC).

A. *Data Description*

Our analysis is restricted to 159 non-Annex 1 countries that have ratified the Kyoto Protocol and established a Designated National Authority (DNA). Data used in this study has been collected from different sources. For the purpose of the empirical analysis some of the data extracted has been transformed before being used in the analysis. Data on the number of CDM projects comes from the CDM/JI Pipeline (http://www.cdmpipeline.org/) which was last modified by the United Nations Environment Programme (UNEP) on June 1, 2012. All the data has been taken from the UNFCCC, CDM and Project Design Documents (PDD), and it includes CDM projects from the validation stages, through registration until the issue of Certified Emission Reductions (CERs). So far the pipeline consists of 8,584 CDM projects of which 4,279 are at the validation stage, 135 in the process of registration and 4,170 are already registered projects. The emission level consists of all greenhouse gases (GHG) emissions and the data was taken from the World Resource Institute, 2012 [31].

Institutional quality is measured by six dimensions of good governance as proposed by [32]. According to Kaufmann, Kraay and Mastruzzi [32] the six dimensions of good governance are i) voice and accountability, ii) political stability and absence of violence, iii) government effectiveness, iv) regulatory quality, v) the rule of law and vi) control of corruption. The dimensions were estimated based on different sources ranging from individuals, the governance of public sectors and private sectors to non-governmental organization experts in 212 countries. Kaufmann, Kraay and Mastruzziet [32] used an unobserved component model to aggregate the above individual measure. We also used measures from the International Country Risk Guide, and these include the level of corruption, law and order, bureaucracy quality and ethnic tensions.

The level of economic development was captured by GDP per capita the data on which came from the Word Bank [32]. Human capital has also been reported in various studies to influence the number of CDM projects in the developing countries e.g. [8]. In this study we used the average years of total schooling as the proxy for human capital. The data is from the Barro-Lee Education Attainment Dataset (http://barrolee.com/) see [34]

The level of the infrastructure was measured by the electricity capacity of the host country. The literature has pointed out that countries that offer a growing market for CDM co-products, such as electricity, are more attractive to CDM activities [8].

We used the ease of doing business indicator (*EDB*) to capture the effect of transaction costs associated with the implementation of the CDM project. The indicator was also used by Dinar [6] when they were investigating the factors affecting the level of international co-operation in carbon abatement projects. According to the World Bank [33] the EDB index ranks economies from 1 to 185. For each economy the index is calculated as the ranking on the simple average of its percentile rankings on each of the 10 stages of a business's life. The stages include i) starting a business, ii) dealing with licenses, ii) employing workers, iv) registering property, v) getting credit, vi) protecting investors, vii) paying taxes, viii) trading across borders, xi) enforcing contracts and x) closing a business. The high ranking, which is a low numerical rank e.g. 1, indicates that the regulatory environment is conducive to business operation.

B. *Hypotheses to Be Tested*

The regression analysis includes a particular set of explanatory variables that may have an effect on the number of CDM projects registered in the developing countries. The variables chosen represent the categories discussed earlier. We hypothesized that the level of economic development may influence the projects to be implemented because investors may be reluctant to invest in countries the level of economic development of which is low. Moreover, the scope of feasible emission reduction projects is also at least partly dictated by the level of economic development in the potential host country.

Other variables that may have an effect on the number of CDM projects are the institutional quality (*institutional quality*) captured by the level of corruption in this study, emissions of greenhouse gases (GHG) (*log_emission*), human capital (*Education_Index*), infrastructure (log_*Electricity*) and the level of transaction costs captured by the measure of ease of doing business (*EDB*). First, we hypothesized that CDM occurrence will increase with an improvement in institutional quality. Second, the higher the level of human capital, the more CDM projects there should be. We also expect that the level of the infrastructure in the host country has a significant positive effect on the number of CDM projects, and we have used the electricity capacity of a host country to capture the level of infrastructural development. We expect that CDM activities will spur in areas where the level of infrastructure is well developed. As mentioned, we use the ease of doing business indicator (*EDB*) to capture the effect of transaction costs associated with the implementation of the CDM project.

Mathematically we estimate the following regression equation:

$$\begin{aligned} &\log\_CDMprojects_i = \beta_0 + \beta_1 \log\_Emission_i + \\ &\beta_2 \log\_GDPpercapita_i + \beta_3 insitutional\,quality_i + \\ &\beta_4 Education\_Index_i + \beta_5 \log\_population + \beta_6 \log\_Electricity + \\ &\beta_7 EDB_i + \mu_i \end{aligned} \tag{1}$$

The expected signs of the coefficients are the following:

$\beta_1, \ldots, \beta_6 > 0$ and $\beta_7 < 0$

IV. EMPIRICAL RESULTS

The following subsection reports the results of the regression analysis. We used both the Poisson and Tobit regression models. In the Poisson regression model, our dependent variable was the number of CDM projects. This is an appropriate model because our dependent variable is a non-negative integer and before incorporating the Poisson regression model we tested whether the conditional mean for our dependent variable was equal to the conditional variance of the dependent variable. In other words, we tested for the effect of overdispersion in our dependent variable using the regression test as proposed by [35]. We fail to reject the null hypothesis (the results are available from the authors upon request); hence there is no overdispersion in the dependent variable. We then proceeded to using the Tobit regression analysis. In the Tobit model our dependent variable was transformed into a logarithm, as can be seen from the above equation. We used the Tobit model because our dependent variable has a limiting value which is zero. The results for the Poisson and Tobit regression analysis are reported in Table I.

A. *Poisson Regression Results*

We first employed the Poisson regression technique to explore the factors that affect the number of registered CDM projects in the developing countries. The results are reported in Table I below. We employed two models in our analysis as can be observed in Table I. The first equation consists of five explanatory variables: the emission level which was transformed into a logarithm, institutional quality measured by the level of corruption, GDP per capita which captures the level of economic development of a particular country, education index and, finally, population which captures the size of the country. In the second equation we added the infrastructure which is captured by the level of the electric capacity of the host country. The ease of doing business indicator was used to capture the level of transaction costs in the host country.

The results show that the level of emissions is not statistically significant although it has got the expected (positive) sign. However, in contrast to Winkelman and Moore [8], we also included population in our model to capture the size of the country. As our results indicate, putting a large emphasis on the level of past greenhouse gas emissions while neglecting to control for the size of the country with any other explanatory variable may lead to wrong conclusions. After all, the total level of emissions is highly correlated with the size of population. In the second equation, which adds the measures of infrastructure and transaction costs to the list of explanatory variables, the level of emissions was still not significant. Therefore, our results indicate that the size of the country is more important than the mere level of past emissions.

Institutional quality, captured by the level of corruption, is another variable suggested to affect the potential of CDM projects. The variable has the anticipated sign and is also statistically significant at the one percent level in both equations. GDP per capita, which captures the level of economic development, is not statistically significant even at the ten percent level. Instead, the education index, which is captured by the average years of total schooling, has the anticipated sign and is also significant in the first equation. Population, which captures the size of the country, is statistically significant at the one percent level in both equations: there thus are more opportunities for CDM investment in large countries (e.g. China and India).

Table I: Poisson and Tobit estimation results

Variable	Poisson1	Poisson 2	Tobit1	Tobit2
Constant	-16.32512*** (0.0004)	-20.59501*** (0.0002)	-18.83488*** (0.0000)	-22.27483*** (0.0000)
Log of Emission	0.224122 (0.2588)	-0.144864 (0.6124)	-0.144456 (0.5153)	-0.264177 (0.2923)
Institutional quality	0.58557*** (0.0007)	0.606745*** (0.0004)	0.345106* (0.0696)	0.451993* (0.0516)
Log of GDP per capita	0.066096 (0.6883)	-0.221831 (0.3341)	0.36482** (0.0334)	0.171408 (0.5446)
Education index	0.094398* (0.0596)	0.037673 (0.4966)	0.17693*** (0.0017)	0.147642** (0.0404)
Log of Population	0.96196*** (0.0001)	1.295442*** (0.0000)	1.05396*** (0.0000)	1.205552*** (0.0000)
Log of Electricity	-	0.474222** (0.0453)	-	0.391575* (0.0713)
Ease of doing business	-	-0.005014* (0.0837)	-	0.001662 (0.6976)
R-squared	0.992937	0.993848	0.681775	0.677372
Included observations	71	63	71	63

Notes: 1) ***, **, *Denotes significance at 1%, 5% and 10% levels respectively. 2) The numbers in parenthesis denote the P-values

The ease of doing business indicator was included in Equation 2. The variable is used to capture transaction costs that are related to CDM activities within a host country. The variable has the anticipated sign and is statistically significant at the ten percent level. The infrastructure, which is captured by electricity capacity, was incorporated in Equation 2, and is significant at the five percent level: the better the infrastructure, the better the ability to attract CDM investments.

B. Tobit Regression Results

Since our dependent variable was censored and had a limiting value, we also employed the Tobit regression model in our analysis see [36]. The model was estimated to explain the log of CDM projects as the dependent variable, the results of which have been reported in Table I as well. Equation 1 consists of the basic variables used in the study and Equation 2 incorporates two more indicators, the infrastructure and ease of doing business. We can observe that the estimated coefficients of institutional quality, GDP per capita, education index and population are statistically significant in the first equation. The signs are the same as in the context of the Poisson model presented above. The level of emissions is again statistically insignificant. As discussed above, the main reason behind this can be the fact that both emissions and population measure essentially the same thing, the size of the country. In the second equation, GDP per capita, ease of doing business and the emission level are not significant. The other explanatory variables are statistically significant at least at the ten percent level.

C. Robustness Checks I

In order to check for the robustness of the model, we estimated several regressions. For the case of the Poisson model, we used the number of Certified Emission Reductions (CERs) generated by the CDM projects as the dependent variable. We estimated both the Poisson and Tobit regressions, and the results are reported in Table II. Ideally, the results would be almost similar to the main results. Results show that the emission level is a significant determinant of CERs which contradicts the main results reported in Table I. Institutional quality is still significant in both Equations at the ten percent and five percent levels respectively. The log of population is significant in Equation 2 and has the same sign as in Table I. Electricity capacity is not a significant determinant of CDM activities. In any case, the results concerning the positive roles of the institutional quality and the size of the country (which is now captured by the level of emissions as well as the population size in Equation 1) seem very robust.

The results of the Tobit model with the level of emission credits, i.e. CERs as the dependent variable are somehow different from the main results. We can observe that some of the variables that were expected to be significant for robustness are now insignificant (e.g. institutional quality, education index). The coefficient of emission level is significant in both equations but negative, which contradicts the earlier expectations. However, GDP per capita and population are significant in both equations.

Table II: Robustness check I: Certified Emission Reductions as the dependent variable

Variable	Poisson1	Poisson2	Tobit1	Tobit2
Constant	-9.570293 (0.1667)	-12.70838 (0.1290)	-17.229*** (0.0000)	-20.17005*** (0.0000)
Log of Emission	0.70418** (0.0411)	0.487094 (0.30419	-0.38861* (0.1170)	-0.514635** (0.0432)
Institutional quality	0.50367*** (0.0008)	0.503224*** (0.0016)	-0.106647 (0.6729)	0.022173 (0.9351)
Log of GDP per capita	0.287140* (0.0995)	0.162787 (0.4199)	0.85518*** (0.0000)	0.679839** (0.0501)
Education index	0.121183 (0.2649)	0.087441 (0.4489)	0.104688 (0.2389)	0.040952 (0.6971)
Log of Population	0.634609* (0.1161)	0.835239* (0.0996)	1.19114*** (0.0000)	1.310491*** (0.0000)
Log of Electricity	-	0.293945 (0.3650)	-	0.411056* (0.1014)
Ease of doing business	-	-0.001593 (0.6198)	-	0.000988 (0.8419)
R-squared	0.997416	0.997735	0.687859	0.695501
Included observations	58	52	58	52

Note: 1) ***, **, *Denotes significance at 1%, 5% and 10% levels respectively. 2) The numbers in parenthesis denote the P-values

D. Robustness II: Extreme Bound Analysis

The Extreme Bound Analysis (EBA) is another technique for testing the robustness of explanatory variables. The technique was initially proposed by [37]; [38] then, later was modified by [39]. Basically, the EBA relies on the linear regression model as specified in the following equation:

$$CDM_j = \beta_0 + \sum_{i=1}^{n}\phi_i Y_{ij} + \beta_m M_i + \sum_{i=1}^{m}\varphi_i Z_{ij} + \mu_j \quad (2)$$

Where Y denotes basic free variable(s) that has been pointed out from previous studies to be robust determinants of the dependent variable, M includes the variable(s) of interest whose robustness needs to be tested, and Z are randomly selected control variables taken from the variables available for the specific study. The free variables are included in every regression. In this study, GDP per capita is the only free variable. According to previous studies, the variable is a significant and robust determinant of CDM projects [6];[7]. Furthermore, we have employed seven explanatory variables including the free variables as pointed out above. Our other independent variables are institutional quality, emission level, population size, human capital, infrastructure and ease of doing business indicator. Hence, the variables of interest were selected from the remaining six variables. The technique embarked was that, for a given choice of variables of interest *M*, two *Z* variables were selected from the remaining five variables. This gave altogether ten combinations of different regression models for each variable of interest. The previous literature has pointed out that the maximum number of control variables used in EBA should be three e.g. see [39]. For our case we used two control variables at a time, hence the total number of regressions carried out was 60. According to Levin and Renelt [39], extreme upper bound is defined as the highest value of the parameter estimate plus two standard deviations whereas the extreme lower bound is defined as the lowest value of the parameter estimate minus two standard deviations. We have employed the same technique here.

Table III present the results of the extreme bound analysis.

Table III: Robustness check 2: Extreme Bound Analysis

Variable	Count	Lower Extreme Bound	Upper Extreme Bound	Significant count	Percentage of significance	Remarks
GDP per capita	60	-2.318237	0.656838	38	63.33	Not Robust
Emission Level	30	-0.500116	3.745789	18	60	Not Robust
Institutional quality	30	-2.728159	2.212788	24	80	Not Robust
Human capital	30	-0.359333	0.797297	6	20	Not Robust
Population size	30	0.985243	1.490074	30	100	Robust
Infrastructure capacity	30	-0.073464	2.760133	30	100	Not Robust
Ease of doing Business	30	-0.01608	0.015361	5	16.66	Not Robust

We have the determinants of CDM projects in the first column. In the second column, we show how many times a particular variable is included in the 60 regression models. In columns three and four we report the lower and higher extreme bounds, respectively. Column five depicts how many times a variable has been found statistically significant in all specifications, followed by the corresponding percentage of significance in the sixth column.

Table III indicates that six variables out of seven have a negative lower extreme bound and a positive higher extreme bound. In the EBA, a variable is said to be robust if its lower and upper extreme bounds have the same sign. Hence, based on our results, only population size is robust. To our surprise, the free variable GDP per capita is not robust either.

V. DISCUSSION

In this study we used Probit and Tobit estimation to explore the factors that affect CDM projects in the developing countries. The literature has shown that factors that affect the CDM projects can be either directly related to the projects or the result of the structure and quality of the government of the host country. Factors related to the host country include a governmental policy to facilitate the implementation of the projects and significant resources allocated to promote CDM activities.

According to our results, the institutional framework of a country is an important factor in facilitating the CDM activities within a particular country. It has previously been pointed out that the role of long-lasting institutions, such as property rights, the rule of law and control of corruption, is particularly important [14];[15]. The findings are in line with previous studies that have investigated the effect of corruption on the level of economic development, and posit that corruption has an adverse effect on the GDP of the county e.g., [40]; [41]. This shows that corruption is a sign of a poor institutional framework, which can make a country unattractive to CDM projects. It has also an adverse effect on the general investment climate of a host country. Earlier results on the CDM indicate that countries the institutional framework of which is stable will be more likely to host CDM activities. For instance, administrative practices within a country are often viewed by investors as a proxy for the commitment and capability of the government as a whole, and investment from abroad may be impeded in a country where obtaining permits to implement particular projects involves complications [42].

The level of past greenhouse gas emissions is an important factor in determining which country will host CDM activities. Countries with a higher level of emissions are more likely to offer more opportunities for CDM activities than countries with lower levels of emissions [8]. However, the level of emissions is closely associated with the size of the potential host country because large countries also have more CDM investment opportunities. Our results confirm that the population size of the county is a very significant determinant of CDM projects: large countries tend to offer more opportunities. In fact, the omission of the size of the country from the list of explanatory variables seems to explain some of the previous results on the significance of previous GHG emissions as a determinant of CDM.

The National Designated Authority (DNA) of a particular host county is also an important factor in establishing CDM activities. This is one of the required bodies needed to approve particular projects before being implemented, and in order for a country to be eligible to participate in CDM activities, it needs to establish a DNA. However, it is widely known that some DNAs in some of the developing countries particularly in Africa are so poorly equipped that they lack not only the means to print out the letter of approval but also a regulatory framework through which they can function more successfully [43].

VI. CONCLUSION

The Clean Development Mechanism, which is one of the mechanisms established under the Kyoto Protocol, has been one of the tools that enable the developing countries to achieve sustainable development. The mechanism has two objectives: One of them is to assist the developing country to achieve sustainable development as already stated. The second objective is to assist the developed Annex 1 countries to mitigate GHG emissions by using cost-effective means. However, since 2004, when the first project was launched, CDM activities have been unevenly distributed among the developing countries. For instance, the projects have largely concentrated in a few Asian and Latin American countries such as India, China, Mexico and Brazil.

This study investigated factors that have impeded the development of CDM activities in the developing countries. We were particularly interested in the role of institutions in successful CDM project registrations and other barriers that can hinder the development of CDM activities. Our results suggest that particularly institutional quality and the size of the potential host country have had an impact on the number of CDM projects hosted so far in the developing countries. The level of economic development and human capital seem to play a role, too. Our analysis differs from the previous studies employing statistical methods to analyze CDM investment with respect to the explanatory variables included in the model. The study of Winkelman and Moore [8] puts a large emphasis on the level of past greenhouse gas emissions but neglects to control for the size of the country with any other explanatory variable. According to our results, the exclusion of the size of a country biases the conclusions drawn based on the other explanatory variables (particularly emissions).

It has been shown that most of the stakeholders are not equipped well enough regarding the issues related to the CDM activities, and the local Designated National Authorities (DNAs) of the host countries, which are responsible for the validation of CDM projects, are very poor especially in the African countries. Hence, the governments of the developing countries need to devote time and resources to establish and strengthen various authorities responsible for making CDM activities viable, e.g. the DNAs. Policies that contribute to the improvement of human capital and infrastructure should be encouraged in order to make the countries more attractive to CDM activities. The level of economic development, as we have pointed out earlier, is crucial in making the activities viable; hence, the governments should enhance strategies that can improve the level of economic development.

However, the institutional framework is the main vehicle that carries all other factors. This means that if the institutional framework is strong enough, the level of economic development will be high, human capital will be abundant, CDM capacity building activities will be strengthened and hence more CDM activities will be encouraged. This is because there have been many barriers that are directly linked to the institutional framework of various countries and that have discouraged the private sector to be involved in the development activities. Moreover, in some countries the level of corruption is so high that, in order to get things done, firms have to pay bribes first. Hence, the developing countries must make significant improvements in their institutional framework in order to enjoy the stake of CDM activities in their countries.

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GDP, FDI, and Exports in East and Central African Countries: a Causality Analysis

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Abstract

This study examines Granger causality among gross domestic product (GDP), foreign direct investment (FDI), and exports in seven East and Central African countries using time series and panel data from 1989 to 2011. We employ a Vector Error Correction model to examine the interrelationship among the variables for Tanzania, while we employ a Vector Autoregressive model for the other countries. The findings suggest unidirectional causality from exports to GDP in Burundi, Tanzania and Uganda. The results also indicate causality from FDI to GDP in Rwanda, Tanzania and Uganda, while GDP appears to Granger-cause

FDI in Rwanda and Tanzania. Furthermore, FDI Granger-causes exports in Uganda, while exports Granger-cause FDI in Rwanda. The results also show that GDP Granger-causes exports in the Democratic Republic of the Congo. Bidirectional causality is only observed between FDI and GDP in Rwanda and Tanzania. The results from the panel data analysis indicate that there is bidirectional causality between FDI and exports and unidirectional causality from exports and FDI to GDP.

Keywords: GDP, FDI, exports, Granger causality, East and Central African Community.

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1. Introduction

Previous studies have devoted substantial time and resources to investigating the link between gross domestic product (GDP), foreign direct investment (FDI), and exports. For the past three decades, FDI has been regarded as a key means of fostering economic development in many developing countries. A higher investment rate is believed to signal the pace of country's economic development. Moreover, investments from abroad, such as FDI, are believed to foster more rapid economic growth than domestic investments. This is because FDI increases the degree to which developing economies are integrated with global financial markets, thereby expanding employment and enhancing the export base, particularly through technical and knowledge transfers (e.g., Borensztein et al., 1999; Bwalya, 2006; Elmawazini and Nwankwo, 2012; Gohou and Soumare, 2012).

East African countries (e.g., Tanzania, Kenya, Uganda, Rwanda, and Burundi) and Central African countries (e.g., the Republic of the Congo and the Democratic Republic of the Congo) have also attempted to attract FDI. However, the majority of FDI on the continent has flowed into other African countries, such as Angola, Egypt, Nigeria, and Libya (see Figure 1). Only two Central African countries appeared on the list of the top 10 African FDI recipients in 2009 and 2010. These countries are the Republic of the Congo and the Democratic Republic of the Congo. However, no East African country has ever been included on this list. Recently, East and Central African countries have reformed their trade policies to increase the level of FDI in their economies. A number of reforms have been implemented, such as improving the countries' investment climates, providing investors with tax holidays, and liberalizing trade policies.

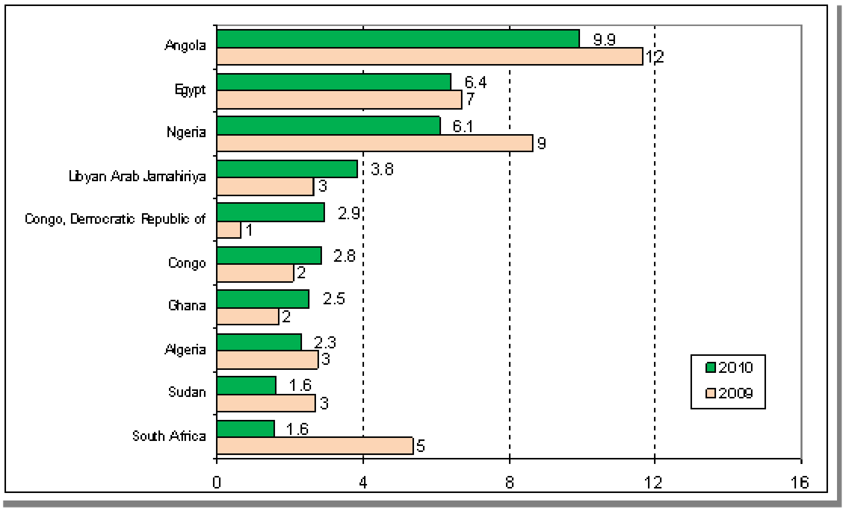

Figure 1. Africa: top 10 recipients of FDI inflows in 2009 and 2010 (billions of dollars).
Source: UNCTAD, World Investment Report 2011

In this study, we investigate the causal relationships among GDP, FDI, and exports. In particular, we focus on the "FDI-led growth" (FLG) and "export-led growth" (ELG) hypotheses (Basu et al., 2003; Chen, 2007; Chow, 1987; Kunst and Marin, 1989; Marin, 1992; Sadorsky and Henriques, 1996; Xu, 1996). Numerous studies have investigated the FDI-growth nexus (e.g., Adam, 2009; De Mello, 1999; Hansen and Rand, 2006; Li and Liu, 2005; Mencinger, 2003). According to Hansen and Rand, FDI has a positive and significant long run effect on economic growth. In contrast, the export-led growth hypothesis considers exports the primary determinant of overall economic growth. This indicates that exports are highly significant in enhancing a given country's level of economic development. Various studies have focused on developing countries and tested the ELG hypothesis, with mixed results. In particular, most time series studies (e.g., Hsiao and Hsiao, 2006) fail to support the hypothesis, while most cross-sectional studies report a significant relationship between exports and growth (see e.g., Kunst and Marin, 1989). As the literature suggests that causal links between FDI and economic growth and between exports and economic growth exist, we add a third hypothesis to determine whether there is also a causal relationship between FDI and exports.

To the best of our knowledge, this is the first study to examine the causal relationships among GDP, FDI and exports in several East and Central African countries. We follow the concepts and methodology suggested by Hsiao and Hsiao (2006) in the context of eight East and Southeast Asian countries, but we instead focus on seven countries in East and Central Africa. Thus, we use both time series and panel data techniques to examine Granger causality among the three variables. According to Granger causality analysis, *x* is said to Granger-cause *y* if its past values can help to predict the future value of *y* rather than predicting *y* using its past values alone (see Granger, 1969).

The paper is divided into 7 sections. Section 2 presents a review of the extant literature. Section 3 reports the trends in GDP, FDI and exports in the region. Section 4 reports the methodology and data employed in this study, while section 5 reports the empirical results. Section 6 presents a discussion of the results, and section 7 concludes the study.

2. Literature Review

Numerous studies have investigated the link between exports and economic growth by employing different methodologies and techniques (see, e.g., Babatunde, 2011; Chen, 2007; Dollar and Kraay, 2003; Frankel and Romer, 1999; Sachs and Warner, 1995). The intuition behind this strand of the literature is that a particular country's level of economic development does not simply depend on the accumulation of physical and human capital but also on the (trade) openness of the economy. The so-called "export-led growth" (ELG) hypothesis was pioneered by the classical economists Adam Smith and David Ricardo, who emphasized the importance of international trade as an engine for economic development (Ricardo, 1817; Smith, 1776).

Several empirical studies have attempted to test the ELG hypothesis but with mixed results (e.g., Ahamad and Harnhirun, 1996; Chen, 2007; Dreger and Herzer, 2013; Furuoka, 2007; Huang and Wang, 2007; Siliverstovs and Hertzer, 2006; Tangavelu and Rajaguru, 2004). For example, Chen (2007) employs the Granger causality test to examine the relationship between exports and growth in Taiwan and concludes that there is a long-run causal relationship between exports and growth. The relationship appears to only run in one direction: from exports to growth and not vice versa. Furuoka (2007) examines the relationship between exports and economic development in Malaysia and finds a unidirectional, short-run causal relationship running from GDP to exports. Dreger and Herzer (2013) examine empirically the ELG hypothesis for 45 developing countries using panel data and find bidirectional causality between exports and GDP in the short run. In the long run, exports affect GDP negatively on average. Overall, the direction of causality between exports and GDP remains unresolved.

Moreover, the link between FDI and economic growth has interested researchers for over three decades. Some previous studies (e.g., Hsiao and Hsiao, 2006; Nair-Reichert and Weinhold, 2001; Zhang, 2001) reported a unidirectional causal relationship between the two variables, while others observed a bidirectional causal relationship (Basu et al., 2003; Chowdhury and Mavrotas, 2006; Hansen and Rand, 2006; Mencinger, 2003). Moreover, the literature disagrees on the sign of the effect of FDI on economic growth. Some studies claim that there is a positive link between FDI and economic growth, while others have been more skeptical, claiming that FDI tends to crowd out domestic investment. Borensztein et al. (1998) investigate the effect of FDI on economic growth using a cross-country regression framework. According to their results, the absorptive capability of the host country is a crucial factor affecting the impact of FDI, indicating that FDI only increases productivity and hence fosters economic development when the host country has reached a minimum threshold stock of human capital. Moreover, Alfaro (2003) finds that FDI has an ambiguous impact on economic growth: FDI in the primary sector appears to have a negative effect on growth, while FDI in the manufacturing sector seems to have a positive impact. Furthermore, other studies indicate that FDI has a significant effect on economic growth when interacted with a financial market variable (Alfaro et al., 2004; Adjasi et al., 2012; Carkovic and Levine, 2005). Moreover, FDI has a positive impact on economic growth via its influence on private domestic investment (Ali-Sadik, 2013; Dash and Parida, 2013; Xu and Ruifang, 2007).

Prior studies have also examined the relationship between FDI and exports. For example, Hsiao and Hsiao (2006) state that exports may boost FDI by providing information on the host country, which helps to reduce investors' transaction costs. They also note that FDI may reduce exports by serving the foreign market through the establishment of production facilities in the host country. However, FDI has been regarded as both a complement to and a substitute for international trade. For example, Liu et al. (2001) emphasize that trade can substitute for the international movement of production factors, including FDI.

As discussed above, the previous literature has examined bivariate causality between the following pairs of factors: exports and GDP, GDP and FDI, and exports and GDP. However, few published works have examined the relationships among all three variables. Liu et al. (2002) examine the relationships among economic growth, FDI, and exports in China and report bidirectional causality between each pairing of real GDP, real exports, and real FDI using seasonally adjusted quarterly data from January 1981 to December 1997. Kohpaiboon (2003) examines the relationship among the three economic variables and finds unidirectional causality from FDI to GDP for Thailand. He uses annual data from 1970 to 1999. According to Hsiao and Hsiao (2006), FDI has a unidirectional effect on GDP directly and indirectly through exports in East and Southeast Asian economies. Their results also support bidirectional causality between exports and GDP for East and Southeast Asian economies. They use time series and panel data from 1986 to 2004 in their analysis. Miankhel et al. (2009) examine the relationships among FDI, exports, and economic growth in South Asia and other emerging economies. According to their results, there is evidence in support of the export-led growth hypothesis. In the long run, they find that GDP has an influence on other variables such as exports in Pakistan and FDI in India. For Mexico and Chile, they found that exports affect FDI and growth in the long run. They also observed bidirectional causality between GDP and FDI in Thailand. In Malaysia, there was no evidence for a relationship among the three variables.

Causal links among FDI, exports, and economic growth in Africa have been examined in previous studies (e.g., Ahmadi and Ghanbarzadeh, 2011; Akoto, 2012; Hansen and Rand, 2006). The results in Ahmadi and Ghanbarzadeh (2011) support the bidirectional causality among all three variables for the underlying sample used in their study (Middle-East and North African countries). Hansen and Rand (2006) conclude that FDI has a significant long-run impact on economic growth. Akoto (2012) examines the nature of relationship among FDI, exports, and GDP in South Africa; the results show that FDI has a significant impact on exports. The author also identifies bidirectional causality between GDP and exports.

To summarize, the previous literature indicates that there are important interlinkages between GDP, FDI, and exports. The issue is thus important from the point of view of developing economies attempting to improve their socio-economic conditions. Therefore, we focus on the causal relationships among the three variables in a region that has been analyzed less by the previous literature: East and Central Africa.

3. Trends in GDP, FDI, and Exports in the Region

3.1 Trends in FDI in East and Central Africa

As FDI has been regarded as a driver of economic development, East and Central African countries have redesigned their investment policies to attract more FDI into the region.

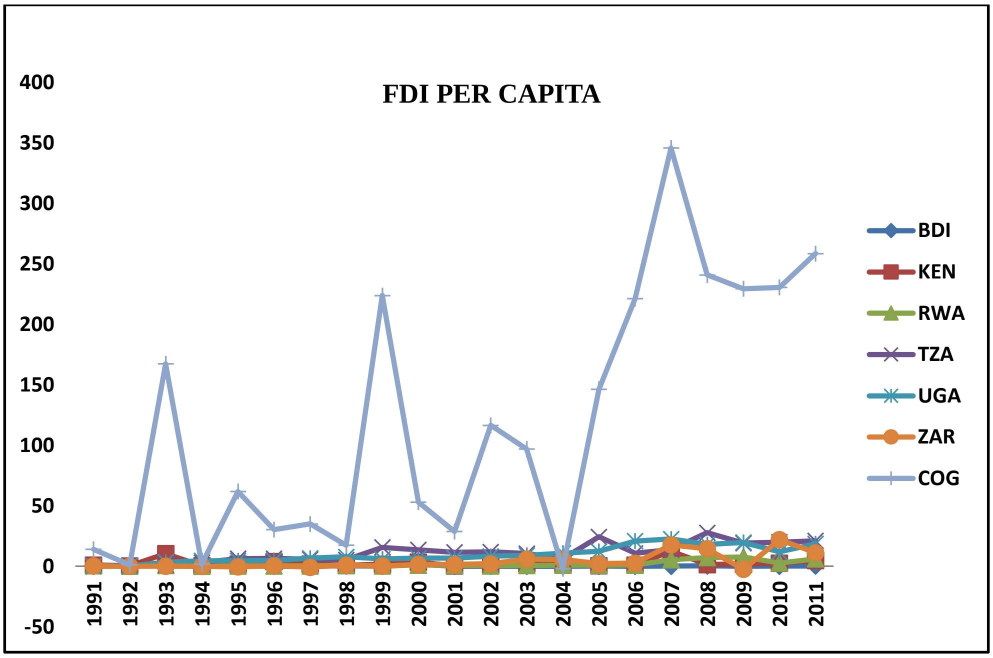

Figure 2. Largest and smallest recipients of FDI among East and Central African countries, millions of USD, 1991-2010. **Source: Authors, using data from UNCTAD (2012)**

Figure 2 depicts the trends in FDI in the region from 1991 to 2010. The figure shows the largest and the smallest recipients of FDI. The figure demonstrates that, when accounting for differences in economic size, the Republic of the Congo is by far the largest recipient of FDI in the region. We observe that for the period between 1991 and 2010, the country attracted an average of 119.91 million US dollars of FDI per capita. Tanzania ranks second in the region with an annual average of 11.18 million US dollars of FDI per capita, followed by Uganda with an average of 9.70 and the Democratic Republic of the Congo with an average per capita FDI of 4.03. Kenya ranks fifth with an average of 2.60 million US dollars of FDI per capita, followed by Rwanda with 1.82, and Burundi ranks last in the region with an annual average of 0.17 million US dollars of FDI per capita.

Some countries in the region have not managed to attract substantial FDI inflows due to factors such as war and political instability. For example, Rwanda and Burundi experienced civil wars in the early 1990s, and hence few investors were willing to invest in these countries. In certain years, e.g., 1999, 2001 and 2003, Burundi experienced net FDI outflows instead of net inflows, although these circumstances recently changed. The recent trend from 2004 to 2010 shows that conditions improved in the case of Rwanda, as the country has managed to increase the pace at which it attracts FDI (see UNCTAD, 2012).

Despite the region's wealth of natural resources, attractive national parks, and in numerous other respects, its countries have received little FDI compared to other emerging economies. This situation has been explained by factors such as lack of skilled labor, smaller market size, poor infrastructure, poor institutional frameworks that enable corruption, and numerous other issues (Fedderke and Rom, 2006; Dupasquier and Osakwe, 2006; Gohou and Soumare, 2012).

3.2 Trends in Exports in East and Central Africa

Figure 3 depicts the trends in exports per capita in East and Central African countries and presents the values of exports in millions of US dollars from 1990 to 2010. The figure shows that the Republic of the Congo has performed well in terms of exports relative to the other countries in the region. The Republic of the Congo generated per capita export revenues of 794.10 million US dollars, followed by Kenya with total per capita exports of 115.01 million US dollars. The third-ranked country is Tanzania, which reports total exports per capita of 67.8 million US dollars, followed by Uganda with average annual exports per capita of 41.3 million US dollars. The fifth-ranked country in terms of exports per capita is the Democratic Republic of the Congo, with an average of 34.9 million US dollars, followed by Rwanda with an average of 23.10 million US dollars of exports per capita. The smallest exporter in the region is Burundi, with an average of 11.08 million UD dollars of exports per capita. Again, as was the case for FDI, Burundi has not performed well in terms of exports. The factors identified above that hamper FDI can also impede trade with other countries. Due to civil war, productivity in Burundi declined substantially. Rwanda also experienced a civil war, but the crisis there was not as prolonged as in the case of Burundi.

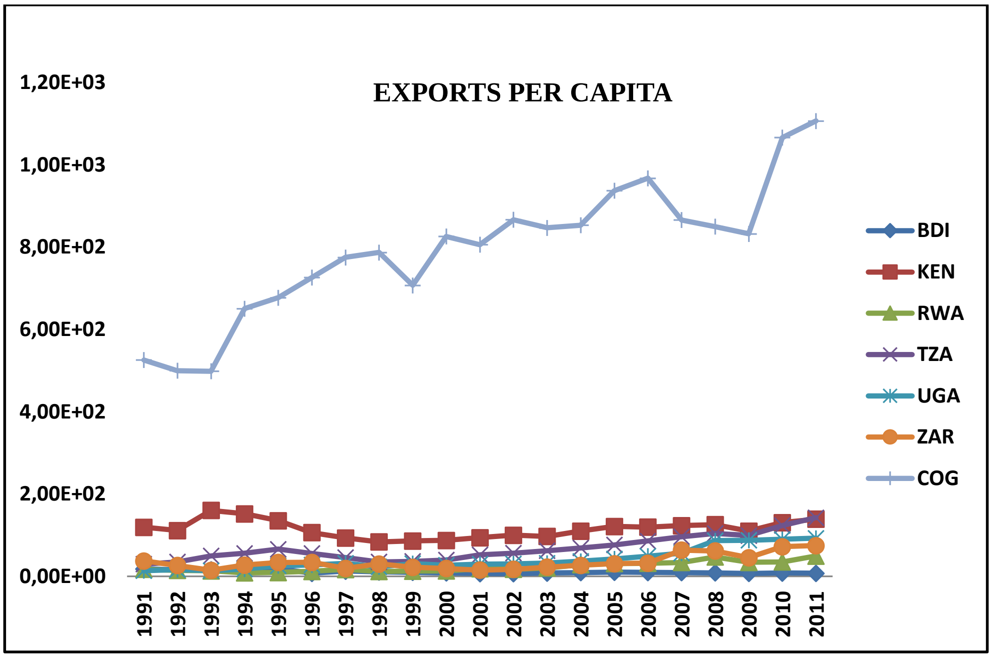

Figure 3. Largest and smallest exporters in East and Central Africa, millions of USD, 1991-2010. **Source: Authors, using data from UNCTAD (2012)**

3.3 Trends in GDP in East and Central Africa

The level of economic development as measured in terms of GDP per capita of each country has been reported in Figure 4. The figure shows that GDP per capita is the highest in the Republic of the Congo, and this indicates that the country's economic development performance is superior to that of the other countries in the region. The Republic of the Congo's average GDP per capita is 1098.32 million US dollars followed by Kenya, which has a GDP per capita of 428.53 million USD.

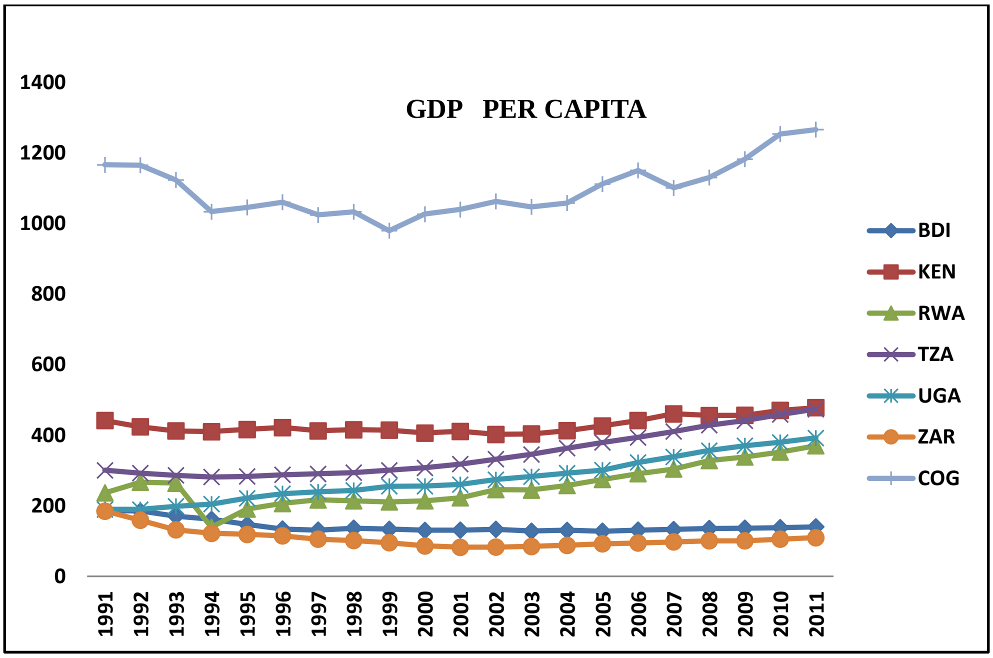

Figure 4: Comparison of the level of economic development in East and Central Africa, 1991-2010. **Source: Authors, using data from UNCTAD (2012)**

Tanzania ranks third with an average GDP per capita of 346.44 million USD, followed by Uganda with an average GDP per capita of 276.66 million. The fifth-ranked country is Rwanda, with an average GDP per capita of 256.98 million USD, followed by Burundi with a GDP per capita of 142.34 million. The country with the lowest GDP per capita is the Democratic Republic of the Congo, with an average of 107.87 million USD. The previous literature implies that a country's level of economic development has a significant impact on FDI (e.g., Zhang, 2001; Nunnenkamp, 2002). It is noteworthy that Kenya, which has a higher GDP per capita than Tanzania and Uganda, has not managed to attract as much FDI as Tanzania and Uganda.

4 Methodology and Data

In this subsection, we explain the methodology employed in this study. We begin by describing the data used in this study. We use time series data extracted from the World Development Indicators database (World Bank, 2013) covering the period between 1989 and 2010. All of the series are measured in constant USD, and we employ real GDP in our analysis.

We use the Granger causality test developed by Granger (1969) and Wiener (1956) to analyze the relationships among GDP, FDI, and exports. By applying the Granger causality test in the framework used here, we avoid the complicated and difficult issue of endogeneity of explanatory variables, which would arise in many other econometric approaches due to the interlinkages among the three variables. A variable *X* can be said to Granger-cause another variable *Y* if the past values of *X* help to explain *Y*, even after the impact of past values of *Y* is taken into account. The test for bilateral causality can be performed by estimating the following equations:

$$Y_t = \alpha_0 + \sum_{j=1}^{n} \alpha_j Y_{t-j} + \sum_{k=1}^{n} \beta_k X_{t-k} + e_{1t} \qquad (1)$$

$$X_t = \gamma_0 + \sum_{j=1}^{n} \gamma_j Y_{t-j} + \sum_{k=1}^{n} \delta_k X_{t-k} + e_{2t} \qquad (2)$$

Where e_{1t} and e_{2t} are assumed to be uncorrelated.

X is said to Granger-cause *Y* if the estimated coefficients of the lagged values of *X* in the first equation are statistically significantly different from zero as a group, and *Y* is said to Granger-cause *X* if the estimated coefficients of the lagged values of *Y* in the second equation are statistically significantly different from zero as a group. Granger causality is not causality in the traditional sense, and the concept cannot be used to deduce whether changes in a variable have a positive or negative impact on another variable. It is straightforward to generalize the Granger causality test to cover a system of three endogenous variables.

The history of Granger causality testing using panel is relatively brief. Here, we follow the strand of the literature initiated by Holtz-Eakin et al. (1988; 1989) by assuming that the coefficients of the explanatory variables are identical across all countries and that there is no causal variation across the countries.

As in Hsiao and Hsiao (2006), we employ time series and panel data techniques to assess the Granger causality among the variables. We begin by examining the time series data to determine whether the series are stationary. It is important to explore the properties of time series data to avoid spurious results. Moreover, the Granger causality test requires the series to be stationary. Thus, we examine the stationarity of the series and identify the order of integration before proceeding with further analysis.

The literature has concluded that most macroeconomic time series data follow a random walk (see Brooks, 2008). In other words, most macroeconomic data are non-stationary. However, even non-stationary series can exhibit a long-run relationship (e.g., Brooks, 2008; Ericsson and MacKinnon, 2002). Such a long-run relationship between time series variables has been termed cointegration. According to Brooks (2008), cointegration has been defined as the long-run relationship between non-stationary time series, the linear combination of which is stationary. Thus, if the series are non-stationary in levels but stationary in first differences, we proceed to test for the presence of cointegration. However, if the above conditions are not met, there will be no need to test for cointegration among the variables.

There are numerous techniques available to test for the presence of a unit root in time series variables. The most commonly employed techniques are the Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests (see Dickey and Fuller, 1979; 1981; Said and Dickey, 1984; Phillips and Perron, 1988). In this study, we employ the ADF and PP approaches for comparison purposes. We base our analysis on an ADF test that incorporates the trend component, as indicated in equations (3) to (5) below:

$$\Delta FDI_t = \delta_0 + \delta_1 T + \theta_1 FDI_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta FDI_{t-i} + \mu_t \tag{3}$$

$$\Delta EXPORTS_t = \alpha_0 + \alpha_1 T + \theta_2 EXPORTS_{t-1} + \sum_{i=1}^{p} \beta_i \Delta EXPORTS_{t-i} + \mu_t \tag{4}$$

$$\Delta GDP_t = a_0 + a_1 T + \theta_3 GDP_{t-1} + \sum_{i=1}^{p} \lambda_i \Delta GDP_{t-i} + \mu_t \qquad (5)$$

Where Δ is the first-difference operator such that $\Delta FDI_t = FDI_t - FDI_{t-1}$, $\Delta EXPORT_t = EXPORT_t - EXPORT_{t-1}$ and $\Delta GDP_t = GDP_t - GDP_{t-1}$

$\delta_1, \alpha_1, a_1, \theta_1, \theta_2, \theta_3, \gamma_i, \beta_i, \lambda_i$ are the regression coefficients to be estimated, δ_0, α_0, a_0 are the intercepts and T denotes the trend component.

5 Causality Analysis for Individual Countries

We use the Inverse Hyperbolic Sine (IHS) to transform our level series, as some of the series, e.g., FDI, include non-positive observations. This transformation was also employed by Busse and Hefeker (2007). The IHS equation is presented in equation (6) below:

$$y = \ln\left(x + \sqrt{(x^2 + 1)}\right) \qquad (6)$$

Where x denotes the variable to be transformed, i.e., FDI, exports, or GDP in this study. The series are denoted by lower-case letters after the transformation, as indicated in Tables 1 and 2.

5.1 Unit Root Test Results

Tables 1 and 2 present the results of the ADF and PP unit root tests for the level series and the first-difference series for each of the seven East and Central African economies: Burundi, Kenya, Rwanda, Tanzania, Uganda, the Republic of the Congo (Congo, Rep), and the Democratic Republic of the Congo (DRC). For the PP test, the Newey and West (1994) method is applied to select the optimal lag length, which was found to be 3 for all variables, as indicated in the notes below Tables 1 and 2. In the case of the ADF test, Schwarz's Information Criterion (SIC) is used with the maximum lag length set at 4. We also employ MacKinnon's p-value criteria when testing for the presence of a unit root (MacKinnon, 1996). All estimations have been conducted with Eviews version six.

Table 1. ADF and PP unit root tests on level series: individual East and Central African economies

		lag	ADF test statistic	PP test statistic	Bandwidth
1	Burundi				
	export	0	-2.93 (0.1723)	-2.95 (0.1661)	2
	fdi	3	-3.45 (0.0703)*	-3.40 (0.0768)*	2
	gdp	0	-0.05 (0.9925)	-0.42 (0.9800)	2
2	Congo, Rep				
	export	0	-2.66 (0.2593)	-2.66 (0.2593)	0
	fdi	0	-6.05 (0.0003)***	-6.20 (0.0003)***	2
	gdp	4	-2.68 (0.2547)	-0.07 (0.9920)	12
3	DRC				
	export	0	-1.97 (0.5869)	-1.75 (0.6917)	3
	fdi	0	-6.14 (0.0004)***	-6.07 (0.0004)***	2
	gdp	2	-1.75 (0.6932)	-1.05 (0.9151)	0
4	Kenya				
	export	1	-1.66 (0.7335)	-1.69 (0.7208)	1
	fdi	0	-5.44 (0.0013)***	-6.25 (0.0002)***	11
	gdp	0	-0.77 (0.9536)	-0.81 (0.9489)	2
5	Rwanda				
	export	1	-2.11 (0.5121)	-2.11 (0.5103)	4
	fdi	4	-9.17 (0.0000)***	-4.47 (0.0093)**	1
	gdp	4	-35.2 (0.0000)***	-2.10 (0.5153)	4
6	Tanzania				
	export	3	-1.41 (0.8208)	-1.69 (0.7191)	1
	fdi	0	-2.53 (0.3118)	-2.70 (0.2435)	1
	gdp	0	-0.87 (0.9407)	-0.90 (0.9376)	1
7	Uganda				
	export	0	-2.39 (0.3710)	-2.46 (0.3401)	2
	fdi	0	-3.34 (0.0853)*	-6.66 (0.0001)***	11
	gdp	0	-1.93 (0.6039)	-2.04 (0.5435)	1

Notes: (1) The test equations include an intercept and a linear trend. The null hypothesis is that the series has a unit root. (2) The lag length for the ADF test is automatically selected using the SIC with a maximum lag = 4, and the lag length for the PP test is selected using the Newey and West method with an optimal lag length of 3. (3). *, **, and *** denote rejection of the null hypothesis at the 10%, 5%, and 1% levels, respectively. 4) The numbers in parentheses are p-values.

The results for the level series are reported in Table 1 above. According to our results, the GDP and export series in levels appear to be non-stationary for all seven countries at the 10% significance level. However, the null hypothesis of non-stationarity for the level FDI series is rejected at the 10% level for six countries: Burundi, the Republic of the Congo, the Democratic Republic of the Congo, Kenya, Rwanda, and Uganda. Only Tanzania's level FDI series seems to be non-stationary.

Table 2. ADF and PP unit root tests on the first-difference series: individual East and Central African economies

		lag	ADF test statistic	PP test statistic	Bandwidth
1	Burundi				
	dexport	0	-7.46 (0.0000)***	-7.71 (0.0000)***	2
	dfdi	0	-5.94 (0.0001)***	-8.69 (0.0000)***	10
	dgdp	4	-4.59 (0.0104)**	-2.94 (0.1709)¤	4
2	Congo, Rep				
	dexport	0	-4.88 (0.0000)***	-4.88 (0.0009)***	1
	dfdi	0	-7.69 (0.0000)***	-20.67 (0.0000)***	20
	dgdp	3	-5.49 (0.0018)***	-12.09 (0.0000)***	19
3	DRC				
	dexport	0	-4.69 (0.0014)***	-4.69 (0.0014)***	1
	dfdi	1	-7.05 (0.0000)***	-14.43 (0.0000)***	4
	dgdp	1	-3.32(0.0918)*	-2.83 (0.2013)¤	2
4	Kenya				
	dexport	0	-4.07(0.0054)***	-4.07 (0.0055)***	1
	dfdi	2	-7.24 (0.0000)***	-13.10 (0.0000)***	8
	dgdp	0	-3.93 (0.0290)**	-3.92 (0.0294)**	2
5	Rwanda				
	dexport	0	-4.51(0.0021)***	-4.51 (0.0021)***	1
	dfdi	3	-2.63 (0.1057)¤¤	-11.45 (0.0000)***	8
	dgdp	3	-2.93 (0.17531)¤	-5.29 (0.0020)***	4
6	Tanzania				
	dexport	2	-3.57 (0.0177)**	-3.42 (0.0223)**	2
	dfdi	2	-4.37 (0.0033)***	-5.86 (0.0001)***	0
	dgdp	0	-4.48 (0.0098)***	-4.21 (0.0166)**	2

7	Uganda				
	dexport	0	-5.74 (0.0001)***	-5.74 (0.0001)***	0
	dfdi	0	-4.70 (0.0014)***	-4.70 (0.0014)***	1
	dgdp	0	-3.93 (0.0073)***	-3.93 (0.0073)***	1

Notes: (1) The test equations include an intercept and a constant. The null hypothesis is that the series has a unit root. (2) The lag length for the ADF test is automatically selected using the SIC with maximum lag = 4, and the lag length for the PP test is selected using the Newey and West method with an optimal lag length = 3. (3). *, **, and *** denote rejection of the null hypothesis at the 10%, 5%, and 1% levels, respectively. 4) ¤ and ¤¤ denote rejection of the null hypothesis at the 20% and 15% levels, respectively. 5) The numbers in parentheses are p-values.

Table 2 shows the results of the first-difference series. Both the ADF and PP tests indicate that nearly all first-difference series are stationary. The test equations included a constant but no trend with the exception of the GDP series; because we found that the GDP first-difference series exhibits a trend in all countries, we included the trend component in the unit root test equation for GDP. In the case of Burundi, all of the series are stationary at the 5% level of significance with the exception of the GDP series using the PP test. The PP test statistic indicates that Burundi's first-differenced GDP series is stationary at the 20% level of significance. In the case of the Republic of the Congo, the unit root test shows that all series are stationary at the 1% level of significance. The unit root tests also indicate that the first-differenced export and FDI series are stationary at the 1% level of significance in the case of the Democratic Republic of the Congo, while the GDP series only appears stationary at the 10% (ADF test) or 20% (PP test) level. With respect to Kenya, all of the series are stationary at the 5% level. Furthermore, both the ADF and PP test statistics indicate that Rwanda's export series is stationary at the 1% level of significance. The FDI series is stationary at the 15% level (ADF test) or the 1% level (PP test). The GDP series is stationary at the 20% level (ADF test) or the 1% level (PP test). In the case of Tanzania, all of the first-differenced series are stationary at least at the 5% level. Furthermore, all of the series are stationary at the 1% level of significance in the case of Uganda.

However, when testing for the presence of a unit root, significance levels of up to 20% are acceptable (see Maddala and Kim, 1998). Employing this threshold, we reject the null hypothesis of non-stationarity for values up to the 20% level of significance.

To summarize, all of the series seem stationary in first differences. In other words, the series exhibit integration of order one, i.e., $I(1)$, with the exception of FDI, which was stationary in levels. Cointegration tests can be conducted for series that are non-stationary in levels but stationary in first differences (Brooks, 2008). Table 1 demonstrated that the FDI level series is stationary for six countries; hence a linear combination of all series that includes FDI will not be cointegrated. However, this is not the case for Tanzania, where the FDI series is non-stationary in levels. This is a special case where a cointegration test can be conducted (see Johansen, 1991). The results of the cointegration test (Table 3) for Tanzania show that there are at most 2 cointegrating vectors; hence we used a Vector Error Correction model (VECM) to examine the Granger causality among the variables. This was only feasible in Tanzania; we employed a Vector Autoregressive (VAR) model for the other countries.

Table 3. Cointegration test results

Country	Hypothesized No. of CE(s)	Eigen value	Trace Statistic	Critical Value (5%)	Prob.**	No of CE(s) at 5% level
TANZANIA	None *	0.975665	97.30684	29.79707	0.0000	3
	At most 1 *	0.786206	37.85369	15.49471	0.0000	
	At most 2 *	0.560938	13.16984	3.841466	0.0003	

Note: CE(s) is an abbreviation for cointegration equations.

5.2 Vector Autoregressive Model, Vector Error Correction Model, and Granger Causality Test

The VAR model is one of the multivariate time series models popularized by Sims (1980) as an extension of the univariate autoregressive model and simultaneous regression models. In a VAR system of equations, all of the variables are treated as endogenous and independent; although exogenous variables can also be included in certain instances (see, e.g., Ramey and Shapiro, 1998). Furthermore, all variables included when estimating a VAR must be stationary (see Brooks, 2008).

In this study, we examine Granger causality among GDP, FDI, and exports using a VAR framework in six countries which are Burundi, Republic of the Congo, Democratic Republic of the Congo, Kenya, Rwanda, and Uganda. Because the unit root tests imply that all of the series are stationary in first differences, we use the first-difference series to estimate the VAR model. Our approach is somewhat similar to that adopted by Ahmadi and Ghanbarzadel (2011), who employed first-differenced series in their Granger causality analysis of FDI, exports, and economic growth in the Middle-East and North Africa (MENA) region.

The VAR (p) model involves the estimation of a system of equations as indicated in equation (7):

$$y_t = \beta + \Gamma_1 y_{t-1} + \Gamma_2 y_{t-2} + \ldots + \Gamma_p y_{t-p} + \mu_t \qquad (7)$$

Where y_t is a (3×1) column vector of the three endogenous first-differenced variables ($dfdi_t$, $dexports_t$, $dgdp_t$), p is the number of lags in each equation, β is a (3×1) constant vector, μ_t is a (3×1) vector of random error terms in the system, and Γ_i for $i = 1, 2, \cdots, k$ are (3×3) matrices of regression coefficients.

According to Granger (1988), the VAR framework is only valid when the variables under consideration are not cointegrated. VAR captures only short-run effects among the variables, while VECM takes into account short-run and long-run causal relationships. VECM of lag 2 is specified by equation (8):

$$\Delta y_t = \Pi ECT_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \mu_t \qquad (8)$$

Where y_t is a column vector of the endogenous variables, Π is the long-run coefficient matrix, ΠECT_{t-1} is the long-run error correction term, and Γ_i for $i = 1, 2$ are the short-run regression coefficients. The VECM indicates thus that the differenced dependent variables (in our case: GDP, exports, and FDI) are affected by the long-run error correction term and the short-run first-differenced lagged variables ($\Delta y_{t-1}, \Delta y_{t-2}$).

Table 4. Individual country Granger causality tests

Country	EXP →GDP	GDP →EXP	FDI →GDP	GDP →FDI	FDI →EXP	EXP →FDI
Burundi	7.5369** (0.0254)	1.4148 (0.4929)	2.2361 (0.3269)	2.0816 (0.3532)	3.0437 (0.2183)	1.6996 (0.4275)
Congo,Rep	0.6630 (0.7178)	0.8606 (0.6503)	2.6730 (0.2628)	0.8329 (0.6594)	3.1956 (0.2023)	0.0936 (0.9543)
DRC	1.8247 (0.6096)	6.3830* (0.0944)	1.0545 (0.7880)	0.3036 (0.9593)	4.3458 (0.2023)	0.7128 (0.8702)
Kenya	1.4963 (0.8273)	5.4483 (0.2443)	0.4488 (0.9783)	7.0840 (0.1315)	1.2075 (0.8769)	7.1544 (0.1280)
Rwanda	5.7654 (0.2174)	5.7932 (0.2151)	8.2732* (0.0821)	9.3972* (0.0519)	5.5400 (0.2362)	8.6210* (0.0713)
Tanzania	10.3680*** (0.0056)	1.8900 (0.3887)	17.0796*** (0.0002)	21.0927*** (0.0000)	1.6126 (0.4465)	4.2428 (0.1199)
Uganda	86.5897*** (0.0000)	0.5921 (0.9639)	160.669*** (0.0000)	0.6730 (0.9546)	31.3542*** (0.0000)	1.9264 (0.7493)

Notes: 1) *, **, and *** denote significance at the 10%, 5%, and 1% significance levels, respectively. 2) The numbers in parentheses are p-values. 3) The test statistics follow an asymptotic Chi-square distribution. 4) The test results are based on a VAR for all other countries except Tanzania, for which VECM is used.

5.3 Discussion of Individual Country Results

Table 4 presents the results of the Granger causality test based on the estimated VAR(p) and VECM models. The corresponding parameter estimates of the VAR models are available upon request. The lag length p was selected using the minimum value of Akaike's Information Criterion (AIC) with the maximum lag length set at 4. The optimal lag length for Kenya, Rwanda, and Uganda was 4; the optimal lag length for Burundi, the Republic of the Congo, and Tanzania was 2, and the optimal lag length for the Democratic Republic of the Congo was 3.

The results imply that there is no bidirectional causality between any pair of variables in Burundi. However, there is evidence of a unidirectional Granger causality from exports to GDP at the 5% level of significance. This implies that changes in exports precede changes in GDP. However, contrary to our expectations, FDI does not seem to Granger-cause GDP in

Burundi. A potential explanation is that Burundi has not attracted substantial FDI inflows due to a lack of good policy and political stability. According to the Burundi Investor's Guide (2012), the country has attempted to improve the regulatory environment, and its GDP is expected to grow by 4.8% in 2013. The agriculture sector accounts 27.1% of Burundi's GDP, and this sector is also one of the country's major exporters.

We failed to observe any Granger causality relationships among the variables for the Republic of the Congo. Therefore, further study is required to investigate the causal relationships in this country.

In the case of the Democratic Republic of the Congo, there is evidence of unidirectional Granger causality from GDP to exports at the 10% significance level. The country is suffering from a civil war, making foreign investors reluctant to invest in the country, which might appear in the Granger causality results concerning FDI (Kalala and Cassimon, 2010).

In Kenya, there is no evidence of causal relationships among the underlying variables. Hence further investigation needs to be done in this country.

In the case of Rwanda, there is bidirectional Granger causality between FDI and GDP at the 10% level of significance. Thus, FDI and GDP appear to be interdependent in this country. It is interesting that this bidirectional causality seems to apply to Rwanda but not the countries discussed above. This indicates that foreign investors are now willing to invest in Rwanda due to the conclusion of its civil war. The test results also reveal unidirectional causality from exports to FDI at the 10% level of significance.

The test results for Tanzania are based on the VECM. The results show that there is bidirectional Granger causality between FDI and GDP at the 1% level of significance, indicating that FDI and GDP are interdependent in this country. In this sense, Tanzania appears similar to Rwanda. In addition, exports Granger-cause GDP at the 1% level of significance, and also exports also Granger-cause FDI indirectly through GDP. Thus, the export-led growth hypothesis receives support in the Tanzanian data.

The Granger causality test for Uganda is again based on the VAR model. There is evidence of unidirectional causality from exports to GDP, from FDI to GDP and from FDI to exports at the 1% level of significance. Therefore, the results suggest that both exports and FDI are sources of economic growth in Uganda. Furthermore, changes in FDI seem to precede changes in exports, implying that the country should continue to attempt to attract FDI and enforce export policies to achieve sustainable development.

To summarize, the situation in each country seems to differ from that in the others. The export-led growth hypothesis receives some support in Burundi, Tanzania, and Uganda. Changes in GDP seem to precede changes in exports in only one country, i.e., the Democratic Republic of the Congo. The FDI-led growth hypothesis receives some support in Rwanda, Tanzania, and Uganda, while there is also evidence of Granger causality from GDP to FDI in Rwanda and Tanzania. FDI seems to Granger-cause exports in Uganda alone, while exports seem to Granger-cause FDI only in Rwanda.

6 PANEL DATA CAUSALITY TEST

In addition to the individual time series analysis, we also employed panel data analysis. The panel data techniques have an advantage over individual time series analysis because they take unobserved, country-specific effects into account during the analysis. Moreover, time specific effects can be taken into consideration. Two possible estimation methods for panel data are the fixed effects (FE) model and the random effects (RE) model. In the FE model, the country-specific effects are represented by intercepts and are assumed to be fixed. In contrast, the variations across countries are assumed to be random in the RE model. For the RE estimator to be consistent, the explanatory variables must be independent of both the random individual error and the usual random error of the regression as a whole. For further information see, for example, Baltagi (2005). A Hausman (1978) test can be used to choose between the two estimation methods. The null hypothesis is that the error terms are uncorrelated with the explanatory variables, meaning that the RE model is also consistent. If the null hypothesis is rejected, the FE model must be used.

6.1 Unit Root Tests for Panel Data

There are numerous means of testing for the presence of a unit root with panel data (see, e.g., Breitung and Meyer, 1991; Im et al., 2003; Hadri, 2000; Levin et al., 2002; Maddala, 1999) We use the two methods proposed by Maddala and Wu (1999). These methods are ADF-Fisher Chi-square and PP-Fisher-Chi-square tests. The results of the unit root test for both levels and first differences are reported in Table 5. The lag length was specified by the authors and was set to 4. The results show that exports and GDP are non-stationary but the FDI series is stationary in levels. All three variables are stationary in first-differences.

Table 5. Panel data unit root test results

Panel level series			Panel first-difference series		
	ADF-Fisher Chi-square	**PP**-Fisher Chi-square		**ADF**-Fisher Chi-square	**PP**-Fisher Chi-square
Exports	14.462 (0.4159)	11.908 (0.6137)	dexports	45.9389*** (0.0000)	104.038*** (0.0000)
FDI	34.077*** (0.0020)	74.855*** (0.0000)	dfdi	54.898*** (0.0000)	336.766*** (0.0000)
GDP	24.417 (0.1742)	2.964 (0.9991)	dgdp	273.599*** (0.0000)	45.369*** (0.0000)

Notes: 1) In the level series, the test equations include individual effects and a linear trend. 2) In the first-difference series, the test equations include individual effects but no trend. 3) The numbers in parentheses denote p-values. 4) ***, **, and * denote rejection of the null hypothesis that the 'panel series has a unit root', at the 1%, 5%, and 10% significance levels, respectively.

6.2 Panel Data Granger Causality Test

We also employ a VAR model to test for Granger causality using the panel data. The specification of our VAR model is:

$$y_{it} = \Gamma_1 y_{it-1} + \Gamma_2 y_{it-2} + \ldots + \Gamma_p y_{it-p} + \mu_i + \varepsilon_{it} \tag{9}$$

Where the subscript i indexes the country ($i = 1, \ldots, N$) and t indexes time ($t = 1, \ldots, T$), Γ_{ji} are (3×3) matrices of the parameters to be estimated, μ_i are country-specific intercepts and

ε_{it} is a (3×1) idiosyncratic error component. The lag length p in the VAR model was selected using the minimum AIC, and the optimal lag length was 3. However, because RE estimation requires the number of cross-sections to be greater than the number of coefficients, we used 2 lags. Furthermore, the panel data analysis requires using the Hausman test to choose between the FE and RE estimators. The results are reported in Table 6. The results indicate that the null hypothesis cannot be rejected; hence, RE estimation is appropriate in all three regressions. Therefore, we employ RE estimation procedures in all three equations.

Table 6. Hausman test results

Dep.var	Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
dfdi	Cross-section random	2.082709	6	0.9119
dexports	Cross-section random	6.994302	6	0.3214
dgdp	Cross-section random	8.307424	6	0.2164

Note: The null hypothesis is that the RE estimator is consistent

The results in Table 7 report the direction of Granger causality in a panel data framework. There seems to be unidirectional causality running from exports to GDP at the 5% level of significance. Furthermore, the results reveal unidirectional causality from FDI to GDP at the 1% level of significance. This implies that both exports and FDI are significant in fostering GDP of the countries under this study. We also observe bidirectional causality between FDI and exports, both at the 1% level. This indicates that when our series are pooled in a panel, there is evidence of interdependence among the variables, which is not the case for individual countries as reported in section 4.

Table 7. Panel data Granger causality test results

	EXP →GDP	GDP →EXP	FDI →GDP	GDP →FDI	FDI →EXP	EXP →FDI
Wald test statistics	7.0576** (0.0293)	4.5316 (0.1037)	13.7331*** (0.0010)	0.8015 (0.6698)	12.4804*** (0.0019)	10.8798*** (0.0043)

Notes: 1) ***, **, and * denote rejection of the null hypothesis at the 1%, 5%, and 10% levels, respectively. 2) The Hausman test was used to choose between the FE and RE models. As a result, RE estimation is used in all cases.

7 Conclusions

FDI has been welcomed in many countries due to its perceived impact on social-economic development. It is believed that FDI can contribute to technological progress and capital flow formulation and can enhance domestic investment. Moreover, FDI has also been identified as the only funding source that internalizes foreign savings by investing in host countries. Therefore, due to the importance of FDI, many countries have formulated policies enabling them to attract this type of investment. East and Central African counties are no exception; they have devoted their best efforts to attract FDI. Nonetheless, FDI is unevenly distributed across the region.

This paper employed time series and panel data frameworks to identify the causal relationships among GDP, FDI, and exports in selected countries from East and Central Africa. These countries are Burundi, the Republic of the Congo, the Democratic Republic of the Congo, Kenya, Rwanda, Tanzania, and Uganda. To our knowledge, this is the first study to examine the causal links among the three variables in the region. Furthermore, the study employs both individual time series and panel data analysis, which has not been done before for East and Central African countries.

All of the individual time series are found to be stationary in first differences; hence, we use first-differenced series to estimate the VAR model. In the case of Tanzania, VECM is used. We find that the situation in each country differs from that in the others. There is evidence for the export-led growth hypothesis in Burundi, Tanzania, and Uganda. There is also evidence of growth-led exports in the Democratic Republic of the Congo. The results also demonstrate that FDI Granger-causes GDP in Rwanda, Tanzania, and Uganda and that GDP Granger-causes FDI in Rwanda and Tanzania. The FDI-led export hypothesis is supported by the data on Uganda, whereas the export-led FDI hypothesis is supported by the data on Rwanda. Therefore, based on our results, the policies that should be pursued to attract FDI should differ across the countries considered.

However, the panel data analysis appears superior to the individual time series analysis. The results demonstrate that there is bidirectional causality between FDI and exports. Furthermore, the panel results reveal unidirectional causality from exports and FDI to GDP. The evidence for these effects was not found in all of the individual countries.

Generally, the results have policy implications for the countries under study. The countries should place greater emphasis on other determinants of economic development, as a well-developed country is more likely to attract additional foreign investors. However, as we observed from the results, FDI and exports are interdependent. Thus, we expect that if the countries attract more FDI, the share of exports will also increase. In addition, recent studies have advised developing countries to place greater emphasis on innovation management and to embrace a knowledge-based economy to catch up with developed countries (Jayech and Zina, 2013; White et al., 2013; Tipu, 2012).

Based on the existing literature, the results regarding the causal links between GDP and other macroeconomic variables have been mixed. The factors that have been identified as contributing to such differences include: the methodology employed, sample selection and the analytical tools used in the analysis.

Our results and conclusions are also subject to a number of limitations. First, the period used in this study is relatively short especially for time series analysis. This might affect the reliability of the results. Second, variance decompositions and impulse responses could provide more insight into the causal relationships between our variables. These features should be used in future research. Third, our sample included countries only from East and Central Africa, meaning that the conclusions might not be generalized to other countries located elsewhere. In order to overcome this shortcoming, the future research should also incorporate developing countries in other regions. These constraints might have contributed to the results we obtained. Further studies are thus necessary to obtain more reliable results.

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Foreign Direct Investment, Exports, Imports and Economic growth of South Africa: Granger causality analysis

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Abstract

The study examines Granger causality among GDP, foreign direct investment (FDI), exports and imports in South Africa by employing the vector autoregressive (VAR) methodologies. Moreover, we examine the responsiveness of one of the variables with respect to one standard deviation positive shock given to other variables using impulse response functions (IRFs). We also investigate the proportions of movement in one variable with respect to the shocks given to other variables by employing variance decomposition techniques. The findings indicate that, GDP, exports and imports Granger cause FDI. The results are strengthened by IRFs which show that the FDI responds positively to the shocks given to GDP and exports, and negatively with respect to the shock given to imports. Furthermore, variance decomposition analysis shows that, the variations in FDI are mainly explained by GDP than other two variables. The results also show unidirectional causality running from imports to exports, and IRFs show that exports respond negatively to imports shocks. We also find that GDP Granger causes imports.

Key words: FDI, GDP, exports, imports, South Africa, Granger causality analysis

1. Introduction

South Africa is one of the emerging economies with deliberate policies to attract foreign direct investment (FDI). Historically, FDI inflows started picking up the pace in the country since early 1990, whereby before that there were a contraction of foreign investment due to apartheid that the country was enduring. The country's trade and investments were affected by the persistence of sanctions and boycotts of other countries which were against apartheid. It has been pointed out by the World Bank (2013a) that, between 1985 and 1994, the average FDI inflows were -0.38 per cent, which indicates that the country had attracted a low level of FDI. However, since 1990 South Africa has attracted a substantial amount of FDI and currently is one of the top 10 recipients of FDI. Likewise, due to the realization of benefits embedded in the FDI, the majority of developing countries have been devoting time and resources to attract FDI in their investment agenda.

FDI has been reported to contribute to economic growth in many ways. It has been revealed that, FDI contributes to economic growth by providing access to new markets, crowding in domestic investment, enhancing the total factor productivity, promoting domestic competition, creating employment and through technological spill over. However, there are mixed results regarding the relationship between FDI and economic growth (see, e.g., Adams, 2009; Alfaro et al., 2004; Dash and Parida, 2013; Hansen and Rand, 2006; Herzer et al., 2008; Li and Liu, 2005; Nair-Reichert and Weinhold, 2001; Vu and Noy, 2009). Differences in the methodologies employed have been singled out to be one of the major factors to such mixed results. Some of the studies that employed Granger causality approaches have found bidirectional causality between FDI and GDP. Whereas, others have found unidirectional causality, running from FDI to GDP or from GDP to FDI. We are testing the validity of such hypotheses in the case of South Africa.

Furthermore, exports are investigated to be an engine of economic growth of South Africa. The country believes in export led growth hypothesis. The major sources of exports in the country are gold, coal, diamond, metal, minerals and farming products such as corn, fruits, sugar and wool (Bahmani-Oskooee and Shabsigh, 1991;

Hausmann and Klinger, 2008). The country is the second largest gold producer and also the largest producer of manganese, platinum, vanadium and vermiculite. In this study, we expect to test the Granger causality between exports and economic growth. However, it has been pointed out that FDI can also act as a conduit in facilitating trade in developing countries; hence we also test the causal relationship between exports and FDI in South Africa

The link between imports and economic growth has also been a subject of debate in previous studies. However, the studies in this category are very scant as compared to those examining the exports-growth nexus and the results are mixed (see, e.g., Islam et al. 2012; Kim et al. 2007; Rahman and Shahbaz, 2013; Rodrik, 2008; Uğur, 2008). Among the few studies that focus on developing countries, Rodrik (2008) and Islam et al. (2012) investigate the effect of imports in the case of South Africa. Rodrik (2008) indicates that the import penetration level in South Africa has increased to some extent within the manufacturing sector from around 20% before 1990 to 28% in 2000. This shows that both import substitution and export-oriented firms in South Africa are facing much greater competitive castigation. The major source of imports in the country are; fuel, motor vehicle, medicines, food, capital and other intermediate goods.

Generally, this study aims at investigating the relationships between GDP, FDI, exports and imports in South Africa. We employ the methodology suggested by Granger (1969) to identify the causal links among the four mentioned variables. Furthermore, we use the variance decomposition and impulse response functions (IRFs) to identify the responsiveness of each of the variable to the innovations or shocks of itself and other variables. This is because the Granger causality analysis does not show whether, the changes in one of the variables has a significant positive or negative influence to changes in another variable. It is somehow a misnomer process and only indicates the chronological ordering of movement among the variables of interest, and not how the movement of one variable real cause the movement of another variable (Tang, 2008). Moreover, it does not also identify the contribution of each variable to the variation of the dependent variables. Hence our study is different from previous studies in the sense that it employs both Granger causality analysis and other vector autoregressive (VAR) dynamic analysis such as variance decomposition and impulse response to examine the links between the variables under the study.

1.1 Distribution of GDP, FDI, Exports and Imports in South Africa.

Figure 1 reports the distribution of GDP, FDI, exports and imports in South Africa from 1985 to 2010. We can see from the Figure that the GDP of the country has been increasing dramatically. Exports and imports have increased but at small rates as compared to GDP. The volume of FDI has been fluctuating with some few years showing significant increase (e.g. 2001, 2008).

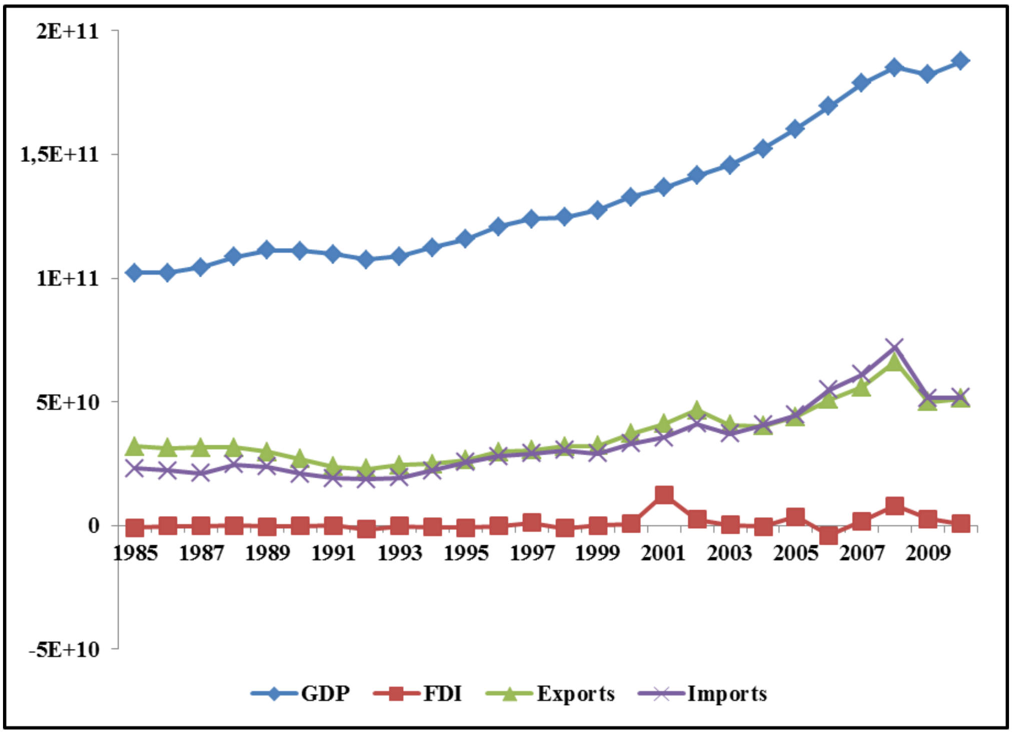

Figure 1: Distribution of GDP, FDI, exports and imports in South Africa from1985 to 2010: Source: World Bank (2013b)

The next section presents a detailed literature review of the previous studies. Section 3 presents the methodology and descriptive statistics of the data used in this study. In section 4 we present empirical results and findings followed by conclusion in section 5.

2. Literature Review

Previous literature has identified the causal link between GDP, FDI, exports and imports and the finding are mixed (see, e.g., Khan and Nawaz, 2010; Marwah and Tavakoli, 2004). The inconclusive results are however, due to numerous factors such as the sample used in the study, the time period employed, the econometric method used and treatment of the variables used in the analysis. Since the macroeconomic data are far from being stationary, data transformation is sometimes very imperative before embarking in the normal analysis. Some have transformed the data in logarithmic form, others into inverse hyperbolic function, and also in percentage change. The treatment of the data can be another factor that has contributed to variations of the results.

Akoto (2012) examines the causal link between GDP, FDI and exports using quarterly data covering the period between 1960 and 2009 in South Africa and concludes that, FDI granger causes exports in the long run, and in the short run the study found one bidirectional causality between GDP and exports. Furthermore, the author shows that FDI granger causes GDP and exports are not very responsive to changes in FDI.

The relationship between FDI and economic growth has been a subject of debate since the last three decades. The results are mixed, with most prominent researchers revealing that there is a positive link between FDI and the level of economic growth (see, e.g., Adam, 2009; Adjas et al., 2012; Alfaro et al., 2004; Borenstein et al., 1998; Carkovic and Levin, 2003; Chakrabarti, 2001; Chowdhury and Mavrotas, 2006; Kottaridi and Stengos, 2010). However, some other studies have been skeptical with respect to the contribution of FDI in developing countries most specifically in Africa (see, e.g., Gohou and Soumaré, 2012; Olayiwola and Okodua, 2009). Other studies posit that, FDI has a negative effect of domestic investment by tending to crowd out the domestic investment (see, e.g., Adam, 2009; Carkovic and Levin, 2003; Fedderke and Romm, 2006; Herzer et al., 2008; Kholdy and Sohrabian, 2005).

Fedderke and Romm (2006) investigate the growth impact and determinants of FDI into South Africa using time series data covering the period between 1960 and 2002. He found out that FDI tends to crowd out the domestic investment in the short run. However, in the long run, the positive impact of FDI can be realized. Herzer et al. (2008) do not find any significant impact of FDI on economic growth using the time series data covering the period between 1970 and 2003 employing a sample of 28 developing countries.

The impact of FDI on exports has been examined in the literature as well. The results are, however mixed and inconclusive. Some have found substitutional effect whereby others have observed the complementary effect or both. Helpman (1984) and Horst (1972) say that FDI tends to reduce exports from the home countries whereas others have said that FDI tends to boost exports from the home countries (see, e.g., Camarero and Tamarit, 2004; Ekholm et al., 2004; Head and Ries, 2001; Markusen and Maskus, 2002).

The links between exports and economic growth has been examined critically in the previous literature following the hypothesis that exports led growth. A number of studies have pointed out that exports are significant for a well functioning economy via its positive impact on the improvement of productivity in the host country (Helpman and Krugman, 1985; Krugman, 1997). Furthermore, export expansion has been viewed as the means for removing foreign exchange constraints and also acts as a conduit to access international markets (see, e.g., De Gregorio, 1992; Holden, 1996; Kormend and Meguire, 1985; Mbaku, 1989; Nidugala, 2001).

The causal links between imports and the level of economic growth has also been a subject of debate among eminent researchers for the past three decades. However, there has been few studies in this category as compared to the other nexus described in the above paragraph and the results are, however mixed (see.e.g., Islam et al. 2012; Kim et al. 2007; Rahaman and Shahbaz, 2011; Uğur, 2008). Islam et al. (2012) investigate the link between imports and economic growth for 62 countries, and the results reveal that, the level of income dictates the direction of causality between the two macroeconomic variables. They find that in high income countries, which also include South Africa, import-led growth hypothesis are vindicated and no feedback is found. In the case of low income countries they find bidirectional causality between the two variables. Rahman and Shahbaz (2013) employ autoregressive distributed lag model (ARDL) bounds testing procedures and vector error correction model (VECM) to investigate the causal links between imports, foreign capital inflows and economic growth in the case of Pakistan. Their results show the bidirectional causality between imports and economic growth. Uğur (2008) posits that the direction of causality between imports and economic growth is subjected to the type of goods imported. The results indicate bidirectional causality between real GDP and investment goods and raw materials.

However, as we have pointed out earlier. Previous studies have come up with mixed results with respect to the causality among the variables, due to different econometric methodologies used, sample selected, and sometimes due to the span of the data used. Some have come up with one way causality whereby causality either runs from GDP to FDI or from FDI to GDP. The studies that have investigated the determinants of FDI have used single equation whereby GDP and other control variables such as the measures of macroeconomic stability, trade openness, physical infrastructure, human capital infrastructure and exchange rates are used as exogenous variables (see, e.g., Blonigen, 2005; Charkrabarti, 2001; Globerman and Shapiro, 2002; Moosa and Cardak, 2006).

Furthermore, previous studies have employed simultaneous equation technique to examine the causal link between the variables. This is because some of the macroeconomic variables have been identified to be simultaneous with each other, rather than one way causality as it is in a single equation analysis (see, e.g., Agbloyor et al., 2011; Basu et al., 2003; Li and Liu, 2005; Mencinger, 2003; Zhang, 2001). Li and Liu (2005) treated both FDI and GDP as endogenous variables and examined the direction of causality between the two variables using panel data for 84 countries over the period between 1970 and 1999. The results show that there is an endogenous relationship between FDI and GDP. According to Basu et al. (2003) there is a bidirectional causality between FDI and GDP whereby the results were supported by the study of Mencinger (2003)

In order to examine causality relations between the variables, previous literature has employed the methodology suggested by Granger (1969). According to Granger causality analysis, x is said to granger cause y if its past values can help to predict the future value of y rather than predicting y using its past values only. Studies have employed Granger methodology and have come up with mixed results (see, e.g., Basu et al., 2003, Choe, 2003; Cuadros et al., 2004; Dritsaki, 2004; Hsiao and Hsiao, 2006; Kholdy and Sohrabian, 2005; Mencinger, 2003; Makki and Somwaru, 2004; Nidugala, 2001)

In this study we employ Granger causality test in VAR framework to examine the direction of causality between four variables; GDP, FDI, exports and imports in the case study of South Africa. Furthermore, we estimate variance decomposition and Impulse response function to examine the shocks to variables and examine their effects on variation of other variables. The study by Akoto (2012) uses similar technique and the same case study, but employs only three variables which are GDP, FDI and exports and concludes that FDI has a significant impact on boosting exports in the long run. Moreover, the author indicates that there is bidirectional causality between GDP and exports and unidirectional causality from FDI to exports in the short run. The author also finds unidirectional causality from FDI to GDP in the short run.

3. Methodology and Data

3.1 Descriptive Statistics of the Data

The data used in this study are taken from the World Bank Development Indicator. We used the time series data covering the period between 1985 and 2010. All the four time series are adjusted for inflation, and hence we used the real variables instead of nominal variables. In this subsection, we describe the methodology employed in our study. The description begins with a summary of the data used in the study as indicated in Table 1.

Table 1: Descriptive Statistics

	GDP	FDI	Exports	Imports
Mean	1.33E+11	8.81E+08	3.67E+10	3.39E+10
Maximum	1.88E+11	1.24E+10	6.63E+10	7.19E+10
Minimum	1.02E+11	-3.97E+09	2.29E+10	1.86E+10
Std. Dev.	2.83E+10	3.17E+09	1.12E+10	1.45E+10
Skewness	0.736	2.261	0.889	1.032
Kurtosis	2.167	8.682	3.045	3.179
Jarque-Bera	3.100	57.145	3.431	4.657
Observations	26	26	26	26

3.2 Granger Causality Analysis

As in Akoto (2012), we employ time series data techniques in examining the causality between the variables. We start by testing the features of time series data such as unit root tests, cointegration tests, inter alia, in order to avoid spurious results. Also the Granger causality test requires the series to be stationary. Hence we examine the stationarity of the series and identify the order of integration before implementing further analysis.

Previous literature conclude that most macroeconomic time series data are far from stationary. In other words, most macroeconomic data are non-stationary, and this might have a greater impact on the results.

3.3 Unit Root Testing

There are numerous techniques used to test the unit root in the time series variables. The most commonly used techniques are Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) (see, e.g., Dickey and Fuller, 1979, 1981; Said and Dickey 1984; Phillip and Perron, 1988). In this study we employ ADF and PP approaches for the purpose of checking the robustness of the results. The ADF test equations used are as indicated in equation (1) to (4):

$$\Delta FDI_t = \delta_0 + \delta_1 T + \theta_1 FDI_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta FDI_{t-i} + \mu_t \quad (1)$$

$$\Delta EXPORT_t = \alpha_0 + \alpha_1 T + \theta_2 EXPORT_{t-1} + \sum_{i=1}^{p} \beta_i \Delta EXPORT_{t-i} + \mu_t \quad (2)$$

$$\Delta GDP_t = a_0 + a_1 T + \theta_3 GDP_{t-1} + \sum_{i=1}^{p} \lambda_i \Delta GDP_{t-i} + \mu_t \quad (3)$$

$$\Delta IMPORTS_t = \beta_0 + \beta_1 T + \theta_4 IMPORTS_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta IMPORTS_{t-i} + \mu_t \quad (4)$$

3.4 Vector Autoregressive (VAR) and Granger Causality

VAR model is one of the multivariate time series models which was embraced and popularized by Sims (1980) as the extension of the univariate autoregressive model and simultaneous regression models. In the VAR system of equations all the variables are treated as endogenous and independent, although sometimes the exogenous variables could also be included (see, e.g., Ramey and Shapiro, 1998). Furthermore, all variables to be included in estimating VAR need to be stationary (see, Brook, 2008). In this study, we examine Granger causality between the variables by employing a VAR framework. Our method is somehow similar to a recent study by Ahmadi and Ghanbarzadel (2011) who use VAR model, in the first difference series to examine the causal links between FDI, exports, and economic growth in the MENA region.

The VAR(p) model involves estimation of the systems of equations as indicated in equation (5):

$$y_t = \beta + \Gamma_1 y_{t-1} + \Gamma_2 y_{t-2} + \ldots + \Gamma_p y_{t-p} + \mu_t \quad (5)$$

Where y_t is a (4×1) column vector of the four endogenous first difference variables (*dfdi*$_t$, *dexports*$_t$, *dgdp*$_t$, *dimports*$_t$), p is the number of lag in each equation, β is a (4×1) constant vector, μ_t is a (4×1) vector of random error terms in the system, and Γ_i for $i = 1, 2, \cdots, k$ are (4×4) matrices of regression coefficients. The discussion of the results are reported in the next section.

4 Emprical Analysis and Findings

4.1. Results for Unit Root Test

The results of the unit root test are reported in Table 2. The Table provides the evidence that, three series out of four are not stationary at the level when ADF and PP techniques are employed. The series are real exports, real GDP, and real imports. The real FDI is stationary at the level in both ADF and PP techniques. Furthermore, we test the existence of a unit root in the first difference series. We see that all the four time series are stationary after the first difference when PP technique is employed. But also three series are stationary when ADF is employed with the exception of exports series. Generally, we can conclude that all first difference series are stationary. In other words we say that the series are said to be integrated of order one, .i.e. I(1)

Furthermore, since real FDI level series is stationary we fail to embark on testing cointegration among the series due to cointegration technique that we were planning to employ. Moreover, cointegration is the long run relationships between non-stationary level series which are all integrated of same order, e.g. I(1) (Engle and Granger, 1987). In fact, many financial and economic variables are said to have one unit root and are thus integrated of order one, i.e. I(1) hence we would expect the stationarity of many series to be induced after the first order of integration. However, there are some extreme cases where the series are found to have more than one order of integration as well. But in this study we find that the order of integration among the series are mixed. Hence, since Johansen cointegration test (Johansen, 1988) require all the series to be integrated of order one, we fail to continue with cointegration test in this study. This is because, our plan was to employ this technique to test whether the variables move together in the long-run.

Table 2: The unit root test both in the level series and the first difference

Level series			First-difference series		
	ADF-t-Statistics	**PP**-adj.t-Statistcs		**ADF**-t-Statistics	**PP**-adj.t-Statistics
exports	-2.356 (0.3910)	-2.350 (0.3942)	dexports	-1.163 (0.6673)	-5.160*** (0.0004)
fdi	-4.679*** (0.0051)	-5.108*** (0.0020)	dfdi	-5.054*** (0.0006)	-16.541*** (0.0001)
gdp	-1.034 (0.9205)	-1.126 (0.9039)	dgdp	-2.744* (0.0814)	-2.744* (0.0814)
imports	-1.666 (0.7316)	-2.443 (0.3503)	dimports	-3.757** (0.0103)	-5.100*** (0.0004)

Note: 1) In level series the test equations include constant and linear trends. 2). In the first difference series, the test equations include constant 3) The numbers in parentheses denote the P-values. 3) ***, **,* denote rejection of null hypotheses, at 1%, 5%, and 10%

4.2. Results for VAR Estimation

We constructed VAR systems of equation with our four time series variables (real GDP, real FDI, real exports, and real imports. Following the results from unit root test we decided to use first difference series in the estimation of VAR model. This is because Granger causality test requires stationary variables (Brook, 2008), and the results show that all the series are stationary after being differenced once hence we used the first difference series. Table 3 below indicates the results of lag selection criteria used in this study.

Table 3: VAR lag length selection criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2086.830	NA	4.16e+77	190.0754	190.2738	190.1222
1	-2015.390	110.406*	2.78e+75	185.0355	186.0274	185.2691
2	-1993.377	26.015	1.91e+75	184.4888	186.2742	184.9094
3	-1972.237	17.296	1.98e+75	184.0215	186.6003	184.6290
4	-1923.612	22.101	3.85e+74*	181.0557*	184.4280*	181.8501*

Notes:
** indicates lag order selected by the criterion*
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion

SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

From Table 3 we see that, sequential modified LR test statistics suggest using lag 1 as an optimal lag length. Final Prediction Error (FPE) suggests lag 4, Akaike Information Criterion (AIC) suggests lag 4, Schwarz and Hannan- Quinn information criterion both suggest lag 4. Therefore, we base our lag selection criterion on AIC where the maximum lag length is 4. The results for estimated VAR estimates are reported in Table 4.

Table 4: VAR Model estimates with lag of four

	ΔGDP	ΔFDI	ΔEXPORTS	ΔIMPORTS
ΔGDP(-1)	0.329	1.748	1.368	1.954
	(0.909)	(0.664)	(1.325)	(1.320)
ΔGDP(-2)	-0.922	1.140	-0.579	-1.112
	(0.888)	(0.649)	(1.295)	(1.290)
ΔGDP(-3)	1.686	-2.156	1.858	2.195
	(0.923)	(0.674)	(1.346)	(1.342)
ΔGDP(-4)	-0.610	1.282	-0.920	-0.981
	(0.742)	(0.542)	(1.082)	(1.079)
ΔFDI(-1)	-0.804	-0.311	-0.546	-0.367
	(0.555)	(0.405)	(0.809)	(0.806)
ΔFDI(-2)	-1.528	-0.048	-1.591	-1.366
	(0.805)	(0.588)	(1.174)	(1.170)
ΔFDI(-3)	-1.846	0.668	-1.431	-1.087
	(0.934)	(0.682)	(1.361)	(1.356)
ΔFDI(-4)	-1.082	-0.212	-1.041	-1.0155
	(0.701)	(0.512)	(1.022)	(1.019)
ΔEXPORTS(-1)	-0.269	2.929	1.233	0.279
	(0.912)	(0.666)	(1.330)	(1.326)
ΔEXPORTS(-2)	2.455	-2.778	1.633	1.815
	(1.446)	(1.056)	(2.108)	(2.101)
ΔEXPORTS(-3)	1.251	1.585	1.650	1.149
	(0.933)	(0.682)	(1.361)	(1.356)
ΔEXPORTS(-4)	0.806	-2.786	-1.522	-1.093
	(0.714)	(0.521)	(1.041)	(1.037)
ΔIMPORTS(-1)	0.145	-3.437	-1.798	-1.122
	(0.849)	(0.620)	(1.238)	(1.234)
ΔIMPORTS(-2)	-1.191	0.266	-1.791	-1.930
	(0.759)	(0.555)	(1.107)	(1.104)
ΔIMPORTS(-3)	-1.697	0.687	-2.087	-1.961

	(0.780)	(0.569)	(1.137)	(1.133)
ΔIMPORTS(-4)	-1.071	1.077	0.680	0.304
	(0.860)	(0.628)	(1.254)	(1.250)
C	3.98E+09	-3.24E+09	3.94E+08	65800630
	(2.2E+09)	(1.6E+09)	(3.2E+09)	(3.2E+09)

Note: 1) Standard errors in parenthesis 2) Δ stands for the first difference operator

4.3 Results for Granger Causality Test/Block Exogeneity Test

We used the methodology suggested by Granger (1969) to examine causality between the four variables under this study. The results are reported in Table 5. The results in the Table consist of four main components. The first part reports the results of testing whether we should exclude FDI, exports and imports from GDP equation. Furthermore, the next part reports the results of testing whether we should exclude GDP, exports and imports from FDI equation. Similarly, the next part requires testing whether we should exclude GDP, FDI and imports from exports equation. Then, the other part requires testing whether we should exclude GDP, FDI and exports from imports equation. There are four columns in each component. The first column as indicated in Table 5. The first column lists the variables that need to be excluded from the equation. The next column stands for the values of Chi-squares, followed by the degrees of freedom and then the P-values. The last row in each part denotes the joint statistics of the three variables excluded from the corresponding equation.

The results denote that all the variables, GDP, FDI, exports and imports are not exogenous since the corresponding P-values of the joint test for each equation are 0.1075, 0.000, 0.0142 and 0.0074 respectively. The null hypothesis of excluding all the variables is rejected in most cases with the following exceptions. We fail to reject the null hypothesis of excluding FDI, exports and imports from GDP equation. We also fail to reject the null hypothesis of excluding FDI from exports and then we also fail to reject the null hypothesis of excluding FDI and exports from imports.

In examining the Granger causality analysis, we see that there is almost five unidirectional causality between the variables. First GDP granger causes FDI, exports granger causes FDI and imports also granger causes FDI at the 1% level of significance. This indicates that, the changes in all the three variables; GDP, exports and imports precede changes in FDI in the case of South Africa. Furthermore, there is unidirectional causality running from GDP to imports at the 5% level, and also from imports to exports at 10% level of significance. This shows that changes in GDP precede changes in exports indirectly through imports. However, we do not observe any feedback relationship between and pairs of the variables. The results imply that, there is neither export-led growth hypothesis nor FDI-led growth hypothesis in the case of South Africa which contradicts the results of Akoto (2012).

Table 5: Granger Causality/Block Exogeneity Wald Test

Dependent variable: ΔGDP			
Excluded	Chi-sq	df	Prob.
ΔFDI	5.381	4	0.2504
ΔEXPORTS	5.350	4	0.2532
ΔIMPORTS	5.397	4	0.2489
All	18.278	12	0.1075
Dependent variable: ΔFDI			
Excluded	Chi-sq	df	Prob.
ΔGDP	15.869***	4	0.0032
ΔEXPORTS	47.212***	4	0.0000
ΔIMPORTS	31.589***	4	0.0000
All	57.933***	12	0.0000
Dependent variable: ΔEXPORTS			
Excluded	Chi-sq	df	Prob.
ΔGDP	7.276	4	0.1220
ΔFDI	3.460	4	0.4839
ΔIMPORTS	7.618*	4	0.1066
All	25.131**	12	0.0142
Dependent variable: ΔIMPORTS			
Excluded	Chi-sq	df	Prob.
ΔGDP	10.849**	4	0.0283
ΔFDI	3.716	4	0.4458
ΔEXPORTS	6.738	4	0.1504
All	27.121***	12	0.0074

Note: 1)***, **, * denote significance at 1%, 5%, and 10% level respectively 2) Δ Stands for the first difference operator

However the Granger causality analysis in VAR framework is limited in the sense that, the Chi-square or the block F-tests from Wald tests do not provide information about the sign of the relationship or how long these effects require to take place (Brook, 2008). Furthermore, it does not indicate the relative importance between variables that simultaneously affect each other. For example, we have pointed out from above that, changes in GDP, exports and imports have an influence on changes in FDI; however, we cannot tell based on the results whether changes in the variables have a positive or negative effect on the FDI. But also we cannot tell whether the impact of GDP, is stronger than that of exports and imports. To respond to these questions, we analyze the VAR's impulse response function and variance decomposition.

4.4 Results for Impulse Response Function

The impulse response identifies the responsiveness of the dependent variables (endogenous variables) in VAR model to shocks given to each of the other variables in the study. According to Brook (2008), for each variable from each equation, a unit shock is applied to the error term separately. The significance of the impulse response function is that, they are used to show whether there exists a positive or negative relationship between the variables in VAR framework. The results of the impulse response function are reported in Figure 2:

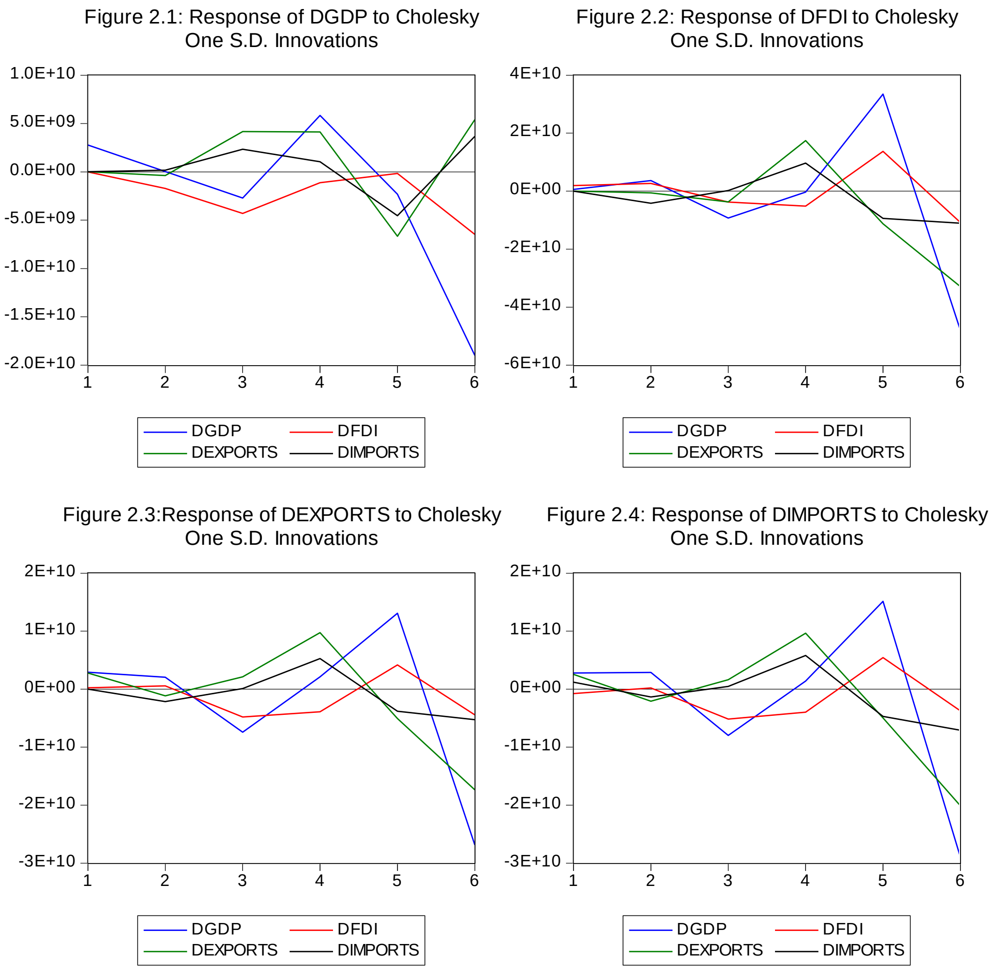

Figure 2: Impulse Response Function of each target variable (GDP, FDI, exports and imports)

Figure 2 denotes the generalized impulse response function. There are four small figures whereby each one illustrates the dynamic response of each endogenous variable (i.e. GDP, FDI, exports, imports) to one standard deviation shock (innovation) on itself and other variables. The horizontal axis in each figure denote the six periods following the shock, whereas the vertical axis measures the yearly impact of the shock on each endogenous variable

Figure 2.1 illustrates the response of GDP to one standard deviation positive shocks given to GDP, FDI, exports and imports variables. The results show that a one standard deviation positive shock given to FDI will have a negative impact to GDP up to three periods. After that, the reaction gradually increases up to period five, then decreases thereafter. The shock given to exports, will have a negative effect to GDP up to period two, and a positive impact up to period three then constant by period four. From period four to five the GDP will decrease and becomes negative, and then will increase again. The results also show that one standard deviation shock given to imports will have a positive impact on GDP up to three periods, thereafter the effect is negative. However, the results somehow contradict that of the Granger causality test.

Figure 2.2 illustrates the response of FDI to one standard deviation positive shock given to GDP, FDI, exports and imports. The results show that a shock to GDP will have a positive impact to FDI up to period two, then negative up to period three. Furthermore, the reaction will increase again up to period four, then will become positive through period five. Then, a shock given to exports, will have a marginal positive impact to FDI up to period two and then negative to period three then positive again through period four, then decreases thereafter. Furthermore a shock given to imports will have a negative impact to FDI until period two, then will increase the FDI up to period four. Furthermore, will become negative up to period five and then stabilize thereafter.

Figure 2.3 illustrates the response of exports to one standard deviation positive shocks given to GDP, FDI, exports and imports. We observe that, a shock given to GDP has a positive impact to exports up to the next two periods, and then negative up to the third period. We further observe a positive impact up to period five, then eventually decreases and becomes negative in subsequent periods. The results also show that, a shock given to FDI has a positive impact to exports up to two periods, and then has a negative effect until period three then positive thereafter until period five. Furthermore, the shock given to imports has a negative impact to exports up to two periods, then gradually increases up to period three and becomes positive in period four. In period five the same very shock makes exports to decrease, and eventually becomes negative in subsequent periods.

Figure 2.4 illustrates the response of imports to one standard deviation positive shocks given to GDP, FDI, exports and imports. The results show that, a shock given to GDP has a positive impact to imports up to next two periods. Then, the impact of shock is negative up to period three and thereafter there is a positive effect until period five. The results also show that, the shock given to FDI has a positive impact to imports up to two periods, then negative through period three then positive thereafter. Furthermore the shock given to exports has a negative impact to imports up to period two then positive thereafter. Generally results from Impulse Response Functions contradict that of Granger causality test with the exception of a few observations.

4.5. Results for Variance Decompositions

Variance decompositions on the other hand provide the proportion of the movements or fluctuations in one variable that are subject to their own shocks (innovations) as well as shocks from other variables (Brook, 2008). We use a 6-year time horizon in this analysis and the results for variance decomposition of each of the variables are reported in Tables 6-9.

Table 6: Variance Decomposition of GDP

Period	S.E.	ΔGDP	ΔFDI	ΔEXPORTS	ΔIMPORTS
1	2.78E+09	100.0000	0.000000	0.000000	0.000000
2	3.30E+09	71.00542	27.39829	1.313434	0.282856
3	7.72E+09	25.31518	36.09326	29.36265	9.228907
4	1.06E+10	43.41718	20.15478	30.59179	5.836250
5	1.36E+10	29.66342	12.43230	43.08032	14.82395
6	2.51E+10	66.04596	10.29284	17.20393	6.457267

Table 7: Variance Decomposition of FDI

Period	S.E.	ΔGDP	ΔFDI	ΔEXPORTS	ΔIMPORTS
1	2.03E+09	9.615113	90.38489	0.000000	0.000000
2	6.49E+09	32.71899	25.72183	0.878866	40.68032
3	1.25E+10	63.67658	16.11105	9.181937	11.03044
4	2.41E+10	17.11207	8.873238	54.94924	19.06545
5	4.59E+10	57.96021	11.39605	21.18118	9.462560
6	7.57E+10	61.48194	6.228420	26.67845	5.611187

Table 8: Variance Decomposition of Exports

Period	S.E.	ΔGDP	ΔFDI	ΔEXPORTS	ΔIMPORTS
1	4.05E+09	52.41985	0.363974	47.21618	0.000000
2	5.19E+09	47.52428	1.480617	33.59986	17.39524
3	1.05E+10	62.03869	21.29474	12.37739	4.289172
4	1.59E+10	28.80448	15.32166	43.01725	12.85661
5	2.19E+10	50.77576	11.64381	27.84440	9.736024
6	3.94E+10	62.26383	4.876861	28.04555	4.813762

Table 9: Variance Decomposition of Imports

Period	S.E.	ΔGDP	ΔFDI	ΔEXPORTS	ΔIMPORTS
1	4.03E+09	47.81254	3.389886	39.88601	8.911558
2	5.55E+09	52.26135	1.914495	35.17327	10.65089
3	1.11E+10	64.25732	22.01730	10.91158	2.813804
4	1.64E+10	30.37981	16.04180	39.77739	13.80100
5	2.40E+10	54.19138	12.62595	22.87862	10.30405
6	4.34E+10	61.14321	4.601482	28.44879	5.806522

Tables 6-9 report the results of variance decomposition of each endogenous variable; GDP, FDI, exports and imports. Each Table has six columns. The first column list the period used. The second column reports the standard error. The remaining columns report the variance proportions of the shock to each variable in each period. In Table 6, we observe that, the fluctuations of GDP are mainly explained by the shock of GDP in the first period. The GDP shocks account 100% in the first period and decreases in the second period to 71%, and then in the third and fifth period is mainly explained by shock to FDI and exports.

Table 7 reports the variance decomposition of FDI. We observe that, fluctuations of FDI are mainly explained by FDI shock which accounts for 90.38% in the first period. It continues to decrease in the subsequent period and reaches 6.22% in the 6th period. In period two the fluctuation of FDI is explained by imports shocks whereas in period 3 it is explained by GDP shock, the GDP shocks dominate in periods 3, 5 and 6, and it accounts for 63.67%, 57.96%, 61.48% of fluctuation if FDI with respect to these particular periods. However, we observe that in the 6th period almost 61.5% of fluctuations in FDI is explained by GDP followed by the exports which explains the fluctuations in FDI by 26.7%

Table 8 reports the variance decomposition of exports. We see from the Table that, fluctuations in exports are mainly explained by GDP and exports shocks in period one. The GDP shock accounts for 52.41% whereby exports shocks account for 47.21%. The GDP proportion in variance of exports fluctuates over time and reaches 62.26% in the sixth year. Furthermore, the proportion of export shock in variation of exports fluctuates over time and it reaches 26.67% is the sixth period. Table 9 reports the variance decomposition of imports. We observe that the fluctuations of imports are mainly explained by GDP and exports shocks. The proportion of GDP shock is 47.81% whereas that of exports is 39.88% in the first period. During the second year, the GDP shock accounts for 52.26% of the variation of imports whereby exports account for 35.17%. The proportion of GDP shock reaches 61.14% in the sixth period and export shock reaches 28.44.

Generally the results indicate that export shock is a significant source of shock to imports. GDP shock in the most important source of shock to imports, exports and FDI. We also observe that, the shocks to GDP, FDI and exports are the sources of fluctuations for themselves and this self-effect fluctuates over time. Furthermore, we observe that the effect of exports to FDI is much bigger than the influence of FDI to exports. The same results have been reported by Akoto (2012). One possible explanation of this significance influence of exports to FDI is that; an improvement in export base, tends to trigger and improve other factors such as terms of trade, regulatory and tax environment, market condition and hence be able to attract more FDI (Akoto, 2012).

5. Conclusion

This study examined the causal links among GDP, FDI, exports and imports in the case of South Africa using the methodology proposed by Granger (1969). We further investigated the responsiveness as well as the proportion of fluctuations of all the variables used with respect to the shocks of the other variables. We archived this using the impulse response function techniques and variance decomposition. The findings indicate that the three variables, GDP, exports and imports Granger cause FDI in South Africa at 1% level of significance. However, there is no feedback, the causality is one way. Moreover, the results show that, GDP Granger cause exports at 15% level of significance and also GDP Granger causes imports at 5% level of significance. There is also bidirectional causality between exports and imports at 10% and 15% level of significance.

The results from Impulse response function denoted that shocks to GDP, exports and imports have positive impact to FDI in the first two years whereby beyond that the shocks have a negative impact. Furthermore, the results show that imports respond positively to GDP shock in the first two years and respond positively to export shock in one year time. However, exports respond negatively to imports shock during the first two years.

Variance decomposition analysis show that, the variations in the FDI are explained more by the shock to FDI in the first period and thereafter, it is explained by imports and GDP in the second period. The variations in imports are explained more by the shock in GDP than any other variables. Furthermore, variations in exports are explained by GDP shocks. The results are somehow similar to that of Granger causality.

Generally, we did not find any evidence of either export-led growth hypothesis or FDI-leg growth hypothesis in the case of South Africa which is beyond our expectations. However, we suggest that, in the future research, one should employ autoregressive distributed lag model (ARDL) in the analysis. This is because, ARDL approach can be used regardless of whether the variables are stationary in level or integrated of order one, i.e. I(0), or I(1). In this analysis, we found some of the variables to be stationary at their level form, while other variables were found to be stationary in their first difference form, hence we could not test for cointegration. This is because, some of cointegration test methodologies need all the variables to be integrated of order one (see, e.g. Engle and Granger, 1978; Johansen and Juselius, 1990; Johansen, 1988,1991). But ARDL model estimation and cointegration approach proposed by Pesaran and Shin (1999) and later extended by Pesaran et al. (2001), is free from the above requirements.

The results imply that South Africa as a country, should embrace other determinants of economic growth in order to be in a position to attract more FDI. This is because, the level of economic growth has been observed to be one of the significant determinants of FDI, as vindicated in this study. This is not surprising, since for the market seeking FDI, a large market size which is captured by the level of GDP is very imperative. The country also needs to expand the exports and imports base.

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