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Effectiveness of Climate Related Development Finance in Reducing Greenhouse Gas Emissions of Selected African Countries: The Role of Source and Recipient Country Income Levels

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ABSTRACT

Despite CRDF allocation opportunities since the Kyoto Protocol in 1997, greenhouse gas emissions in developing countries remain high. Existing evidence on the CRDF-GHG emissions nexus is based on aggregate climate finance without also considering the impact of recipient income levels. This study examined the effectiveness of climate-related development finance in reducing GHG emissions, examine the role of CRDF sources in emissions reduction, and assess the influence of recipient country's income level. The study used panel data from selected African countries (Botswana, Burkina Faso, Cameron, Ethiopia, Ghana, Kenya, Tanzania, Zambia, and Zimbabwe). Pooled OSL, Random Effects and Fixed Effects were used to analyse the relationship between GHGs emissions as the dependent variable and CRDF, CRDF sources, and recipient income levels as independent variables. The results revealed a significant negative relationship between aggregated CRDF and GHGs emissions. An increase in CRDF leads to investment in mitigatory measures that subsequently decrease GHGs emissions. Furthermore, the study found that CRDF sources have significant heterogeneous effects on developing countries' GHGs emissions where CRDF from Asia result in significant reductions in GHG emissions, while CRDF from Europe increases emissions. The interaction between CRDF and recipient incomes was also found to significantly increase emissions. The study highlights the critical role of CRDF in reducing GHG emissions in the selected African countries. The study recommends a continuous flow of CRDF to developing countries, prioritizing funding sources from Asia complemented by measures to decouple economic growth from emissions thereby further enhancing the effectiveness of CRDF in reducing GHG emissions.

Keywords: CRDF, GHG emissions, panel data
JEL Classifications: H60, Q53, Q56

1. INTRODUCTION

Climate change has become one of the most pressing global challenges of our time, affecting every aspect of human life and the natural environment. Carbon dioxide (CO_2) pollutants dominate global greenhouse gases (GHGs) (United Nations Framework Convention on Climate Change, 2015) and CO_2 emissions are now considered the highest in history (National Aeronautics and Space Administration, 2020). According to the National Aeronautics and Space Administration (NASA) estimates, human activities have raised atmospheric concentrations of CO_2 by 47% since 1850, and this increase is more than what had happened naturally in 20,000 years (NASA, 2020). The accumulation of CO_2 in the atmosphere beyond certain limits can lead to irreversible impacts, which will be challenging to tackle at later stages (Intergovernmental Panel on Climate Change, 2018). The increasing trend in CO_2 emissions across developing countries including Africa is re-echoing the need to focus on climate change mitigation and adaptation (World Bank, 2019). Also, CO_2 emissions are linking up with business cycles (Espoir et al., 2024) hence the need to be considered carefully at national, regional and global climate change policy frameworks.

The United Nations (UN), through the Sustainable Development Goals (SDGs), places climate change mitigation and adaptation under Goal 13 (SDG 13) as efforts for the attainment of the 2030 Agenda for Sustainable Development (UNFCCC, 2015). SDG 13 envisages reduction of GHGs and management of climate change effects in all forms by 2030 (UNFCCC, 2015). Anthropogenic actions, such as industrialization, burning of fossil fuels, deforestation, and other human activities have been linked to the increase in greenhouse gases (GHGs) concentration in the atmosphere, leading to global warming, sea level rise, extreme weather conditions, and other adverse effects of climate change (Intergovernmental Panel on Climate Change [IPCC], 2018). The United Nations Development Programme (UNDP) estimates that climate change could push more than 200 million people into extreme poverty by 2030 (UNDP, 2019).

World Bank (2019) revealed that climate change is dwindling economic growth and causing instability of financial systems especially in developing and least developed worlds. This is mainly because the developing and least developed worlds' economies have poor adaptive capacity and they depend on climate sensitive sectors, including agriculture, forestry, energy, infrastructure, and tourism, among others. The most profound socio-economic impact caused by climate change is the rise in temperatures, resulting in severe weather events such as floods, drought, heatwaves, and storms, disrupting agricultural productivity resulting in food scarcity in a world where there is already a significant food deficit (Organisation for Economic Cooperation and Development [OECD], 2016). A study conducted by the International Food Policy Research Institute reveals that climate-induced crop yield losses could cause a doubling of food prices leading to severe hunger and malnutrition in developing regions such as Asia and Africa.

In areas where water resources are already scarce, climate-induced drought conditions will increase the cost of irrigation and crop production (OECD, 2016). The impact of climate change on water resources is increasingly critical in the context of food security. Socially, climate change has a significant impact on livelihoods, including health effects, displacement, and social conflict, particularly in low-income countries. Climate-induced food scarcity, for example, leads to malnutrition and increased susceptibility to diseases in young children (UNICEF, 2022). Additionally, severe weather events can lead to the displacement of populations and local communities, with adverse effects on the social fabric of societies. A report by the United Nations indicates that by 2050, up to 200 million people could be displaced due to the impact of climate change on food, water and land resources (OECD, 2016).

In view of the above complex global environmental problems, climate change requires comprehensive and urgent action to mitigate the accompanying catastrophic effects. An analysis of climate change shows that its impacts cut across various sectors, including the economy, society, and the environment. The increasing frequency and severity of climate-induced events such as floods, droughts, and forest fires demonstrate the urgency of mitigating climate change through a wide range of policy measures, including greenhouse gas emissions reduction, adoption of renewable energy, and conservation of natural resources.

The need to reduce GHG emissions and achieve sustainable development has, therefore, become a top priority for policymakers, development agencies, and other stakeholders. The Intergovernmental Panel on Climate Change (IPCC, 2021) has warned that global emissions must decline by about 45% by 2030 to limit global warming to 1.5°C compared to preindustrial levels. Achieving this target requires massive investments in clean energy, efficient transport, sustainable agriculture, and other low-carbon technologies. The cost of achieving this target is estimated to be between $1.6 and $5 trillion per year until 2050. Climate-related development finance (CRDF) has emerged as a key mechanism to support developing countries in their efforts to reduce greenhouse gas emissions and adapt to the impacts of climate change (UNFCCC, 2015; Chung et al., 2018; Carfora and Scandurra, 2019). Understanding the role being played by Climate Related Development Finance is key especially within the context of African developing countries, which are still at an early stage of industrialization and growth but are expected to significantly contribute to reducing GHG emissions (World Bank, 2019).

The overall purpose of this study aims to evaluate the effectiveness of CRDF in reducing GHG emissions. To analyse the effectiveness of climate-related development finance in reducing GHGs emissions. Specifically, the study seeks to examine the role of CRDF source in greenhouse gas emissions reduction, to assess the influence of the recipient's income level on greenhouse gas emissions reduction so that evidence-based recommendations will be provided on how to increase the effectiveness of climate-related development finance in reducing GHGs emissions.

1.1. Background

Climate Related Development Finance (CRDF) refers to financial resources mobilized and disbursed to support climate change mitigation and adaptation initiatives that improve the wellbeing of vulnerable populations in developing countries (OECD, 2022). These resources include grants, concessional loans, and technical assistance provided by multilateral and bilateral development finance institutions, as well as private sector investors (OECD, 2016). CRDF represents a significant opportunity for developing countries to transition to low-carbon development pathways, build resilience against climate change, and achieve the Sustainable Development Goals (SDGs).

Efforts to address climate change through CRDF can be traced back to 1997. Climate change response finance, especially for carbon emission efficiency, has long been the cornerstone of climate policy initiatives, most recent of which are under the auspices of the Kyoto Protocol of 1997 and the Paris Agreement of 2015 (UNFCCC, 2015). World Bank (2019) estimated that climate related development finance flows need to increase to USD 5 trillion per year by 2030 to limit global warming to the more ambitious target of below 2°C, preventing temperatures from increasing beyond 1.5°C and reaching zero emissions by 2050. Relatedly, adaptation to climate change will also require huge climate related development financial flows, especially to developing countries, which are most vulnerable to rising temperatures and sea-level rises. According to estimates by UNEP (2020), adaptation costs for developing countries are expected to rise to USD 140-300 billion annually in 2030, up from USD 70 billion per year in 2020. The Paris Agreement recognizes the need for additional financial resources and climate related technologies to support the implementation of climate-related actions in developing countries.

The allocation of CRDF from development finance institutions and donor countries to developing countries has increased in the past decade due to provisions of the Paris Agreement and the Kyoto Protocol. For example, in 2017 according to OECD (2019) the global CRDF reached $681 billion, which is a significant increase from $75 billion in 2010. For the past 2 decades the global efforts have been mainly on mobilizing additional climate related funds for developing countries to manage climate change causes and effects with little attention rendered towards analysing the progress realised in achieving reduced GHGs emissions. Whether climate-related development finance could effectively reduce the carbon emissions level of developing countries receiving assistance is the focus of this dissertation.

Understanding the role being played by Climate Related Development Finance is key especially within the context of developing countries, which are still at an early stage of industrialization and growth but are expected to significantly contribute in reducing GHG emissions (World Bank, 2019). In this direction, most studies have however concentrated on general effects of climate change on the economic growth and development (World Bank, 2019). Katsuya (2017) and Espoir and Sunge (2021) studied the linkage between economic growth and environmental degradation using concentration of GHG emissions as a proxy for environmental degradation. This area of study received much attention from the early 1990s in the discipline of environmental economics (Abid, 2016). The link is attributed to Kuznets' famous Environmental Kuznets Curve (EKC) theory (1955). According to Abid (2016) EKC implies that environmental degradation and per-capita income have an inverted-U connection (Grossman and Krueger, 1991). Environmental degradation would increase during the early stages of economic expansion, but after a particular threshold of per capita income is reached, economic growth would result in better environmental outcomes.

More closely to this study, some studies looked at the effects of climate related development finance on the rates of adoption and reduction of renewable energy and non-renewable sources of energy respectively (Carfora and Scandurra, 2019; Li et al., 2017). Li et al. (2022) analysed these links and showed that climate-related development finance significantly increased production of renewable energy and renewable energies production led to a reduction in non-renewable energy production over time. Carfora and Scandurra (2019) assessed the impact of climate related development finance on economic growth and their role in substituting fossil energy sources. The study reveals that climate funds contributed to the decreasing of greenhouse gas (GHG) emissions and promoted the change in generation energy systems supporting the replacement of fossil sources with renewable sources.

It is important to note that the link between CRDF and GHG emissions has received little attention in empirical literature, but this body of knowledge is growing and findings are mixed. Some scholars (Chung et al., 2018; Aquilas and Artemnkeng, 2022) contend that climate-related development finance does not significantly reduce GHG emissions. Other studies (Li et al., 2017; Lee et al., 2022; Carfora et al., 2017) posit that climate related development finance significantly reduces GHG emissions. The conclusions from these studies are premature because of insufficient empirical evidence, to which this study tries to contribute and also due to the inconclusiveness of previous findings. Nonetheless, existing studies on impacts of CRDF base their conclusions on aggregate CRDF. Disintegrating CRDF is logical given the reality that CRDF from different sources maybe heterogeneous. In addition, these studies have been mixed and inconclusive mainly because they did not consider that recipient developing countries are not homogenous hence this may have contributed to inconclusiveness of previous findings.

However, some of the areas of study that have not received much attention are whether and how results on the effects of CRDF on GHG emissions vary according to sources and level of incomes of the recipient developing countries. Hence with the case of CRDF source of funding may result in different effects across developing countries. Additionally, the effectiveness of CRDF may depend on the income levels of the recipients. Like FDI, it can be argued that developing countries with higher income levels may be more effective in implementing mitigation and adaptation projects since they have better institutional capacity (Hussein, 2019).

In addition, whether climate related development finance has been appropriately managed and delivered is worth discussing. At the same time, the questions of what factors contribute to the effectiveness of CRDF have become key issues. For example, in recent years, the various financial programs supporting climate action and sustainable development in African developing countries such as Botswana, Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Tanzania, Zambia and Zimbabwe have been expanding through sources, such as the America, Asia and European regions (World Bank, 2019). The effect of these sources has been excluded in the existing literature hence worthy analysing.

Based on this, CRDF is a well-accepted tool for promoting reduction of GHG emissions and promoting sustainable development in developing countries, its effectiveness in achieving these goals may depend on several factors, including the source and recipient income levels. The dissertation aims to assess the effectiveness of CRDF in reducing GHG emissions, using these factors as the basis for analysis. The findings of the study will provide insights into how to improve the effectiveness of CRDF in reducing GHG emissions and enhancing sustainable development.

1.2. Research Problem

Climate change has emerged as a critical global environmental issue, posing adverse impacts on social, economic, and environmental systems worldwide. Recognizing the urgency to address this pressing challenge, international agreements like the Paris Agreement and Kyoto Protocol, operating under the United Nations Framework Convention on Climate Change (UNFCCC), have aimed to combat climate change and ensure sustainable development. A significant outcome of these agreements has been the substantial increase in Climate-related Development Finance (CRDF) flow to developing countries, rising from $75 billion in 2010 to approximately $900 billion in 2021 (OECD, 2022). Despite this exponential growth in CRDF, many developing countries have struggled to achieve their intended goals in reducing greenhouse gas (GHG) emissions. The sustainable development goals (directly Goal 13 and indirectly 1, 2, 3, 6, 7, 8, 11 and 12) achievement is still an uphill task for the developing economies. This raises concerns about the effectiveness of CRDF in curbing GHG emissions across developing regions. The problem intensifies when considering the interconnectedness of emissions with other pressing issues, such as food and water security, in Africa. These issues continue to escalate in Africa despite the availability of climate related development finance. Climate change continues to exert detrimental effects on agriculture in Africa, including changing weather patterns, declining crop yields, and increased occurrence of pests and diseases. Consequently, agricultural production becomes vulnerable, exacerbating food and nutritional insecurity in Africa and posing significant challenges to achieve sustainable and inclusive development.

1.3. Research Contribution and Significance

The study contributes by adding to few previous studies on climate related development finance, focusing particularly on its contribution to climate change mitigation actions meant to reduce GHG Emissions in developing countries. Many studies have analysed the link between environmental degradation and economic growth as well as renewable energy with most concluding that the economic growth leads to accumulation of financial savings later used for adoption of renewable energies to reduce GHG emissions (Khan et al., 2018; 2019; Lima et al., 2020; Chung et al., 2018). While this study adds to this literature, it significantly contributes by analysing the effect of climate related development finance by disaggregating CRDF by source of funding and analysing the contribution of income levels of recipient developing countries on the emission of GHGs, aspects which are still scant in the literature. This interaction is particularly important as it helps in understanding whether these factors contribute to the relationship between climate related development finance and GHG emissions reduction. The contributions of this study to previous literature are worth highlighting. First, the body of knowledge focusing on the combined effect of climate finance and funding sources on GHG emissions reduction is very limited. After close to two decades of serious advocacy for climate protection, more empirical studies are needed to ensure that climate policies undertaken at national or global levels are informed by empirical evidence.

Second, the few studies conducted to ascertain the impacts of CRDF in reducing GHGs concluded mixed results. The conclusions on the relationship between CRDF and GHG emissions reduction, from the existing studies are mixed. Some scholars (Chung et al., 2018; Aquilas and Artemnkeng, 2022) contend that climate-related development finance does not significantly reduce GHG emissions. Other studies (Li et al., 2022; and Carfora et al., 2017) posit that climate related development finance significantly reduces GHG emissions. Hence other factors may be responsible for the mixed conclusions. Factors responsible for shaping the effectiveness of CRDF both at source and recipient are not known. Hence it became imperative for this study to ascertain the conditions necessary for CRDF to be effective in developing countries. This is a key issue lacking in literature on how to encourage developed countries to provide adequate assistance by observing necessary conditions to effectively address climate change challenges.

Third, this study is one of the few to consider the non-linear effects of climate-related development finance on GHG emissions. Studies such as Chung et al. (2018); Aquilas and Artemnkeng, (2022), Li et al. (2022); Lee et al. (2022); Carfora et al. (2017) did not use non-linear effects. Since the GHG emission levels of the Parties under the climate agreements are expected first to peak before falling, the idea of introducing a quadratic term of climate finance is to determine at what level of climate financial support this peak should occur. This would guide climate policy by matching CRDF to the evolution of GHG emissions. This is particularly relevant in the context of developing countries since their GHG emission levels should take longer to peak relative to developed countries.

Fourth, Chung et al. (2018) evaluated the effects of CRDF on GHGs focusing on country specific effects whilst some were treating CRDF sources as the same (Chung et al., 2018; Aquilas and Artemnkeng, 2022; Li et al., 2022; Lee et al., 2022; Carfora et al., 2017), hence this study will use 9 developing countries with different income levels for analysis. This study accounts for this limitation by interacting climate related development finance, recipient income levels and source of funding. This interaction is important because it highlights the place of source of funding and recipient income levels in the climate financing policy framework.

1.4. Assumptions of the Study

This study assumes that climate-related development finance can play a significant role in reducing GHGs emissions. The study also assumes that GHGs emissions reduction is a global public good that requires collective action. However, this study recognizes that some countries may lack the political will and capacity to implement policies and programs that promote GHGs emissions reduction. The subsequent sections literature review, research methodology, data analysis, Results presentation and discussion; and lastly, conclusions and policy recommendations.

2. THEORETICAL LITERATURE REVIEW

2.1. Environmental Kuznets Curve

The most extensive theory is the Environmental Kuznets Curve (EKC) theory developed by Simon Kuznets (1955) which has theoretical roots in classical economics (income elasticity, trade and competitive markets). Environmental economists have traditionally relied on the Environmental Kuznets Curve (EKC) hypothesis to assess the environmental impacts of economic development parameters. Economic growth has been claimed to be of benefit to environmental quality. In this view, environmental quality is a luxury good, and consumers are said to be willing to spend a larger share of their incomes on environmental goods as they become richer. Pollution will therefore diminish as the result of economic growth. This claim was first hypothesized by Beckerman (1972), as long ago as the 1970s. However, the claim could for a long time not be supported empirically because adequate data on the release of pollutants to the environment were not available. Empirical data on various pollutants became available in the 1990s with the aid of NASA, Eurostat and the environmental data compendia by the OECD (OECD, 2016). These data sets have facilitated testing the relationship between environmental pressure and income among other variables.

The EKC hypothesis, proposed by Grossman and Krueger in 1991, initially suggested a relationship between environmental degradation indicators and gross domestic product (GDP) per capita that follows an inverted U-shape. Several scholars, including Panayotou (1993), Grossman and Krueger (1995), and Stern et al. (1996), have further expanded on this hypothesis their findings were in tandem with Kuznets's findings (an inverted U-shaped relationship between environmental pollution and economic growth was confirmed). The inverted U-shaped curve is mainly because the preliminary stages of production are backed by carbon emissions based natural resources such as fossils. Common proxies used to measure environmental pollution are greenhouse gas emissions, particularly CO_2 emissions, along with the ecological footprint, which provides a broader perspective on environmental pollution. In summary, the inverted U-shaped curve represents pre-industrial (low-income economies) and beyond the turning point, post-industrial (high income economies where more resources will be availed for green technology investments (Abid, 2016). The theory of the EKC is based on the effects of the transition from agricultural production in to industrial production and its intensification result in increased pollution, with time, and income growth, the industrial-heavy production will be phased out for more highly-technological and service-centralized production that will counteract the pollution increase in pollution and eventually result in decreasing pollution levels per unit of output. Confirmation of the EKC is from other theories like which tend to validate its existence. The Green Solow (Brock and Taylor, 2010), Stokey Alternative (Stokey, 1998; Brock and Taylor, 2010), and the Composition Shifts (Stern, 2004; Brock and Taylor, 2010) which further explained how economic growth may reduce environmental degradation.

2.2. Brundtland Curve Hypothesis (BCH)

Contrary to the EKC theory, the WCED report World Commission on Environment and Development Report (WCED) of 1978 named "Our future," commonly known as the Brundtland report, code named the Brundtland Curve Hypothesis (BCH) presents another view of the relationship between GDP and environmental damage. It argued that poor countries, initially cause high levels of environmental degradation, followed by a decrease in environmental degradation as economies grow until a turning point is reached, at which environmental degradation will then increase exhibiting a U-shaped BCH opposite to the inverted U-shaped EKC. Justifications of the BCH curve are that low-income countries cause high damage to the environment due to inability to prioritize environmental wellbeing. As the economy grows, environmental damage decreases (poverty decreases). When the turning point is reached, pollution increases with economic growth and eventually get as high as originally. The positive trend in environmental degradation is caused by increased consumption which leads to increased production. The environmental damage resulting from increased production is as damaging to the environment as the problems caused by poverty according to the theory (Field and Field, 2013). Investing in green and innovative production can counteract the increasing pollution levels (Bratt, 2012).

2.3. The Environmental Daly Curve Hypothesis

The third theory is the Environmental Daly Curve hypothesis (EDCH) of 1973 by an ecological economist called Daly. He described the relationship between economic growths and environmental damage by arguing that today's economy driven by increased production is doomed and a steady-state type of economy could be the alternative. He further argued in 2004 that the impact of human creativity, innovation and green technology development is insufficient to lower pollutions and to offset the usage of scarce natural resources and the overall environmental damage. Incentives for a better, high-quality environment may occur when a country reaches a particular point of wealth but environmental damage will already be too severe. Environmental damage increase with economic growth, no matter the willingness of the citizens and policymakers to counter it (Daly and Farley, 2004). Therefore, the EDCH suggests that an increase in per capita GDP will lead to higher environmental damage (due to increased production). Hence the EDCH does not depict a turning point at any level of wealth, such as the EKC and the Brundtland Curve (Bratt, 2012).

2.4. Pollution Haven Hypothesis

The Pollution Haven Hypothesis (PHH) is a widely debated theory that seeks to explain the relocation of industries from developed countries to developing nations. This theory suggests that companies relocate their operations to countries with weaker environmental regulations, also referred to as "pollution havens," to exploit lax laws and standards in order to minimize costs and maximize profits (Huang et al., 2020). In recent times, this hypothesis has garnered significant attention within the context of greenhouse gas (GHG) emissions. GHG emissions from industrial activities contribute significantly to global climate change, making it crucial to understand the role of the PHH in exacerbating this issue. The hypothesis posits that when environmental regulations are stringent and enforced in developed countries, industries seek refuge in nations where regulations are less rigorous. By doing so, companies can bypass costly pollution control measures and potentially increase their economic competitiveness. Proponents of the PHH argue that if firms relocate to pollution havens, global GHG emissions would simply be shifted geographically rather than being genuinely reduced (Han and Jun, 2022). The channels for shifting pollution to developing countries is achieved and disguised through Foreign Direct Investments and conditional climate financing such as establishing of energy saving automobile production plants in developing countries such as Volkswagen in Rwanda and South Africa may be seen as support for climate mitigation but production of automobiles is heavily associated pollution (World Bank, 2022).

In this sense, the EKC is potentially a reflection of the Pollution Haven Hypothesis, because one of the factors that may drive the increase in environmental degradation seen in pre-industrial economies is an influx of waste from post-industrial economies. This same transfer of polluting firms through trade and foreign investment could lead to the decrease in environmental degradation seen in downward-sloping section of the EKC, which models post-industrial (service) economies. Governments worldwide must collectively strive to implement stringent standards that discourage the relocation of industries purely for regulatory arbitrage, while simultaneously supporting the adoption of sustainable practices both in developed and developing economies.

2.5. Jevon Paradox and Rebound Effect

The Jevon Paradox was proposed by Stanley Jevons in 1865 and is associated with observations that improvements in energy efficiency are often connected with rising not falling of energy consumption (Jevons, 1866). It appears that increase in energy efficiency do not translate directly into reduction in energy demand as expected rather an increase in consumption hence greenhouse gas emissions continue to be a challenge. For example, efficiency gains from improved steam engines in line with climate change mitigatory practices in United Kingdom did not decrease consumption of coal instead coal was used in more industries thereby increasing consumption.

The difference between the theoretical efficiency gains and the actual consumption is called rebound effect. The formula for rebound effect is denoted by (expected-actual)/(actual). Hence the difference between Javon paradox and Rebound Effect is that Jevons paradox only applies when takeback/rebound effect is more than 100% meaning gains in efficiency have resulted in an overall increase in consumption whilst the rebound effect problem is referred as the rebound effect when the takeback effect is <100% (Yu et al., 2022). In the case of greenhouse gas emissions, this implies that while technological advancements might reduce emissions per unit of output, overall emissions may still continue to rise due to increased consumption. For example, if a more fuel-efficient car is developed, it may incentivize people to drive more, offsetting any emissions reductions achieved through efficiency gains.

The Jevons Paradox poses considerable challenges to climate change mitigation efforts. Policymakers must recognize that simple technological improvements alone may not be sufficient to curb greenhouse gas emissions. Relying solely on efficiency gains may inadvertently encourage increased resource consumption, exacerbating rather than mitigating climate change. It is crucial to adopt a holistic approach that encompasses both efficiency improvements and demand-side management strategies.

2.6. Empirical Literature Review

Han and Jun (2022) examined whether international climate finance support for developing countries improves mitigation of greenhouse emissions by employing variables such as economic growth, emissions, population density, renewable energy consumption, urban population, and climate finance using a panel data for 141 countries between 1990 and 2015. The study revisited the environmental Kuznets curve (EKC) hypothesis by focusing specifically on the developing country context and the growth-emissions nexus is explained with three panel regression models which include Pooled OLS, Random and Fixed Effects. The study found an existence of the EKC hypothesis in quadratic specification, while the EKC is largely not found with clustered data and cubic polynomial functions. The effects of mitigation aid vary by dataset, implying that simply increasing mitigation aid may not be enough to reduce emissions in developing countries.

Ngo et al. (2021) examined the impact of green finance that includes green investment and green loan on the economic growth of Vietnam. The data have been obtained from the central bank of Vietnam and World Bank Indicators (WDI) from 1986 to 2019. This study also executed the Autoregressive Distributed Lag (ARDL) approach to examine the links among the explanatory variables such as green loan, green investment, Urban-Rural income ratio and Per capita Expenditures for Economic Growth. The results exposed that green finance along with all control variables have a positive association with economic growth. The study recommended that regulators in Vietnam to increase their focus on green finance that could increase the economic growth in the country.

D'Orazio and Dirks (2022) explored the effects of CRDF on carbon emissions in G20 countries. The focus was particularly on financial policies implemented to scale up green finance and address climate-related financial risks from 2000 to 2017. The study utilised a panel quantile regression approach for analysing CRDF, country population, GDP, short term and long term CRDF policies as explanatory variables on carbon emission proxied by CO_2. The empirical results indicate that the impacts of the different explanatory variables on carbon emission are heterogeneous. Specifically, the effect of the stock of short-term financial policies on carbon emissions is negative, and its effect becomes smaller at higher quantiles. The stock of long-term policies also shows significant negative coefficients, but its impact is stronger for higher quantiles. No significance is reported for the lowest quantile. The study concluded that CRDF contributes to improving environmental quality, and its impact is larger in higher emission countries. Energy consumption increases carbon emissions, with the strongest effects occurring at higher quantiles. The study recommended G20 countries to adopt more international climate change mitigation policies such Kyoto Protocol, Paris Agreement since they result on greenhouse gas emission reduction.

Chung et al. (2018) conducted a study to examine the effectiveness of climate-related development finance (CRDF) in reducing CO_2 emissions in China. By utilizing empirical analysis and panel data techniques, the researchers assessed the impact of CRDF on greenhouse gas reduction, focusing on specific industrial sectors within the recipient country. Secondary data from 2000 to 2015 were obtained from the OECD Creditor Reporting Systems Databases and World Bank WDI Database for CRDF and CO_2 emissions. The study aimed to identify key industrial sectors sensitive to CRDF with regards to greenhouse gas emissions. The findings indicated that while CRDF did not have a significant effect on reducing CO_2 emissions at the country level, a notable reduction was observed when assessing sector-by-sector effects. The researchers concluded that expanding climate-related development finance, with a specific focus on reducing CO_2 emissions within each sector, is necessary to effectively address carbon emissions.

Carfora and Scandura (2019) conducted a comprehensive analysis to assess the effectiveness of policies implementing climate funds in 149 developing countries. The primary objective of their research was to determine whether Climate Related Development Finance (CRDF) leads to a significant reduction in greenhouse gas (GHG) emissions, as previous studies analysing CRDF at the country level did not yield conclusive results in terms of reducing GHGs in developing nations. To accomplish this, the researchers accessed CO_2 a proxy for total GHG emissions from the World Bank Databases, while CRDF data was obtained from the OECD CRS databases. By employing counterfactual analysis and panel data techniques, the findings suggested that CRDF has played a crucial role in reducing GHG emissions and encouraging the transition from fossil fuel-based energy systems to renewable sources. Additionally, it highlights the positive economic impact of climate finance in the selected countries.

Aquilas and Artemnkeng's (2022) examination of climate-related development finance in the Congo Basin offers insights into their impact on greenhouse gas (GHG) emissions. The study specifically aimed to improve the analysis of CRDF by combining it with data of renewable energy consumption. Hence the study aimed at analysing the interaction effect of climate finance and renewable energy consumption on GHG emissions in countries within the Congo Basin. Utilizing the pooled OLS, fixed effects regression estimates, and random effects regression, the study concluded that climate-related development mitigation finance has an increasing effect on GHG emissions not the expected reduction. Remarkably, this effect persists even when accounting for a time lag of one year to accommodate the period in which climate aid is allocated for the production and consumption of emissions-reduction technologies. To address this issue, the study advocates for a continuous flow of climate-related development mitigation finance from donor countries and organizations to developing nations on a more consistent basis so that long run analysis can be made.

Li et al., (2022) conducted a study to explore ways to encourage developed countries to provide sufficient assistance to developing countries and enhance their enthusiasm in tackling climate change challenges. In order to achieve this goal, the researchers evaluated the impact of climate-related development finance funding from developed countries on carbon emission reduction in developing countries, employing a "quasi-natural experiment" approach across various island regions. To assess the environmental impact of developed countries' climate assistance, Li et al. (2022) selected total greenhouse gas emissions of carbon dioxide equivalent and energy consumption emissions of carbon dioxide equivalent as indicators of climate environmental performance from 1990 to 2017. By utilizing the differences-in-differences (DID) method, the researchers were able to identify the causal effect of this quasi-natural experiment.

In the study conducted by Carfora et al. (2017), the authors aimed to analyse the flow of Climate related development funds (CRDF) designated to reduce greenhouse gas emissions. The study sought to identify the preferential channels responsible for the effectiveness of CRDF by examining the allocation of funds among countries and the relationship between climate finance and a composite indicator that ranks greenhouse gas emissions after realising mixed conclusions from the studies conducted to ascertain the effectiveness of CRDF on reducing greenhouse gases emissions. To accomplish this, the authors employed a multi-step procedure, utilizing a substantial dataset of 83 countries. Utilizing a quantile regression model, the authors discovered a strong heterogeneity in the way funds are allocated by donors. They emphasized the importance of analysing political contexts to ensure accurate analysis. Quantile regressions confirmed a link between the environmental index, representing a synthesis of GHG emissions, and climate finance. Their findings highlighted a significant relationship between the amount of funds disbursed and GHG emissions, particularly in the case of funds aimed at biosphere protection. This includes considering the influence of different international funding sources that direct funds towards specific needs and priorities. The analysis of CRDF from different sources in the current proposed study will expose a significant heterogeneity in how funds are allocated by donors.

3. RESEARCH METHODOLOGY

The empirical research design for this study examines the effectiveness of CRDF in reducing GHG emissions in developing countries. The study adopts a quantitative approach using secondary data and econometric techniques to test the hypotheses developed to answer the research questions. This study uses a panel data from 9 countries for the period 2002 to 2021. Baltagi (2005), indicated that panel data can controls for individual heterogeneity which cannot be addressed in time-series or cross-sectional data; provide more informative data, less multicollinearity among the variables compared with time-series studies, more degrees of freedom, more variability and more efficiency; and investigate the dynamics of adjustment better than cross-sectional data. The selection of the 9 African countries was based on their status as developing countries and their continued access to CRDF since year 2000. African continent was targeted because they are still few studies that have managed to analyse the effects of climate related development finance on GHG emissions. The period from 2003 to 2021 was selected for 9 African developing countries because all the 9 countries have received CRDF on yearly basis from the 3 sources including Asia, America, and Europe continents to ensure panels with balanced observations. The three sources were selected based on availability of data on CRDF released to developing countries from 2000 to 2021 form the above mentioned 3 sources. All the 3 selected continents had allocated CRDF to the 9 African countries except for Australia which only started funding developing countries with regards to climate financing since 2010 and funding is not consistent to ensure balanced panels based on OECD data sets. The selection of 2000-2021 was based on the fact that data available for CRDF is always 2 years older during the time of access because Climate related development finance data is certified after 2 years of use (OECD, 2022). However, this study then used 2003-2021 time period because Asia continent started to release CRDF in 2003. According to UNFCCC (2022a) the impacts of climate mitigation practices start to realise significant impacts after 10 years. Realising this many African countries based on CRDF data accessed from OECD website especially across regional blocs like SADC did not meet the least basic criteria of number of years needed to significantly ascertain effectiveness of CRDF on GHG emissions.

The dependent variable is GHG emissions, measured in metric tons of carbon dioxide equivalent ($MtCO_2e$), while the independent variables include CRDF, source of CRDF, and recipient income level as proxy by GDP per capita measured in USD. Since this study uses panel data from 9 countries spanning from 2003 to 2021 panel regression models were selected to assess the relationship between the independent and dependent variables

3.1. Model Specification

In-line with the Environmental Kuznets Curve (EKC), studies, the study follows the EKC standard regression model proposed by Stern (2004): The econometric model is specified as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

$\beta_1=\beta_2=\beta_3=0$, then X and Y have no relationship

- $\beta_1 > 0, \beta_2 = \beta_3 = 0$, then X and Y have a positive monotonic relationship
- $\beta_1 < 0, \beta_2 = \beta_3 = 0$, then X and Y have a negative monotonic relationship
- $\beta_1 > 0, \beta_2 < 0, \beta_3$ ¼ 0, then X and Y have an inverted U-shape relationship
- $\beta_1 < 0, \beta_2 > 0, \beta_3$ ¼ 0, then X and Y have an U-shape relationship
- $\beta_1 > 0, \beta_2 < 0, \beta_3 > 0$, then X and Y have an N-shape relationship
- $\beta_1 < 0, \beta_2 > 0, \beta_3 < 0$, then X and Y have an inverted N-shape relationship

Where Y is the dependent variable measured in $MtCO_2e$, β_0 is the intercept, β_1, β_2, and β_3 are the coefficients for the independent variables (such as GDP, Population etc), X_1, X_2, and X_3 are the independent variables, and ε is the error term.

$$InY = \beta_0 + \beta_1 InX_1 + \beta_2 InX_2 + \beta_3 InX_3 + \varepsilon$$

Where Y represents emission, X_1 denotes population, X_2 denotes gross domestic product, and *ln* indicates the variables are converted into natural logarithms.

This study used EKC model in reduced form, used in the previous study conducted by Renzhi and Baek (2020). The study evaluated the effectiveness of FDI in reducing GHGs emission of 143 developing countries. The interpretation of variables for the Renzhi and Baek (2020) with reference to environment-income are shown below. Specifically, CO_2 refers to carbon emission of pollutants, FDI represents foreign direct investment, GDP is economic growth, URB percentage of urban population and i and t refer to individual entities and time, respectively.

$$InCO_{2i,t} = \alpha + \beta_1 InFDI_{i,t} + \beta_2 InGDP_{i,t} + \beta_3 InURB_{i,t} + \varepsilon_{i,t}$$

Since this study is focusing of effectiveness of climate related development finance in reducing greenhouse gas emissions the study adopts the above equation. However, the URB percentage of urban population employed by Renzhi and Baek (2020) will not be utilized since the variable is unlikely to direct influence the concentration of greenhouse gases in developing countries. CRDF since it shares almost similar characteristics with FDI i.e., moving from developed to developing countries it will replace FDI in the equation and URB will be replaces by CRDF sources as follows

The implicit form of the model used in this study is given by:

$$GHG\ emission = f(CRDF + In\ Source\ of\ CRDF + In\ IncomeLevel + \varepsilon)$$

The data which include CRDF, GHGs emissions, and GDP per capita (incomes) was transformed through log transformation for the purpose of removing outliers. Logarithm transformation is useful in visualization of data as it offsets the overwhelming effect of large values on small values. Furthermore, by converting the data into logarithms, there is a possibility to express the results as percentages.

In explicit form the model can be expressed as;

$$InCO_{2it} = \alpha + \beta_1 InCRDF_{it} + \beta_2 In\ sourceCRDF_{it} + \beta_3 Inincomeit + \varepsilon_{it}$$

Where, *GHG emission* is the level of Greenhouse Gas emissions, *CRDF* is Climate Related Development Funding, *Source CRDF* is the source of Climate Related Development Funding and *Income Level* is the country's Gross Domestic Product.

3.2. Data Sources and Description

The study uses secondary data from OECD and World Bank data sources to measure the variables in the model. The data on incomes of recipient developing countries was proxied by GDP per capita and was accessed from Development Indicators. CRDF data was accessed from the OECD database. The study covers nine African countries, including Ethiopia, Cameroon, Ghana, Kenya, Burkina

Faso, Zimbabwe, Tanzania, Botswana, and Zambia. The data covers a period of 16 years, from 2003 to 2019. The dependent variable, GHG emissions, is measured in $MtCO_2e$, while the independent variables, CRDF, source of CRDF, and recipient income level, are measured in US dollars, dummy variables, and GDP per capita, respectively. The source of CRDF is categorized into sources which include the level continental regions such as America, Europe and Asia.

3.3. Estimation Techniques

3.3.1 Unit root test

The data was be tested for unit roots using three models. The Levin-Lin-Chu, Harris Tsavalis and Hadri LM test were used for unit root tests. Unit root tests are critical in regression analysis as they assist to ascertain the presence of non-stationarity in the time series data. Interpreting the results of unit root tests, researchers primarily focus on the null hypothesis, which typically assumes the presence of a unit root. If the null hypothesis is rejected, implying the absence of a unit root, it suggests the presence of stationarity in the series. Stationary time series, characterized by a constant mean and variance, indicate a stable relationship between variables and facilitate reliable estimation and forecasting. Alternatively, failing to reject the null hypothesis suggests the presence of a unit root and non-stationarity. In such cases, caution is warranted when dealing with the time series. Non-stationary series can exhibit spurious relationships, where apparent associations between variables may arise purely due to coincidental trends. The regression analysis such as random, fixed effects and pooled OLS regression were carried out after correcting the all the variables under examination to be stationary as violations can lead to spurious regression results and unreliable inferences. The study employed panel data analysis to estimate the model. The study used fixed effects and random effects models to estimate the coefficients of the independent variables.

3.3.2. Fixed effects model

The fixed effects model, also known as the within-effects model or individual-specific effects model, is commonly used in panel data analysis to account for time-invariant heterogeneity across individual units in the panel. The fixed effects model can be represented by the following formula:

$$\mathrm{y}_{it} = \alpha + \beta x_{it} + \gamma_{it} + \varepsilon_{it}$$

Where: y represents the dependent variable for individual *i* at time *t*, *α* is the intercept term, *x* represents the independent variable(s) for individual *i* at time *t, β* is the coefficient(s) associated with the independent variable(s), γ_i is the individual-specific effect or fixed effect, capturing the time-invariant heterogeneity for individual I and *ε* represents the error term.

3.3.3 Random effects model

The random effects model takes into account both time-invariant heterogeneity across individuals and random individual-specific effects. The random effects model can be represented by the following formula:

$$y_{it} = \alpha + \beta_{xit} + u_i + \varepsilon_{it}$$

Where, y_{it} represents the dependent variable for individual *i* at time *t*, *α* is the intercept term, *x* represents the independent variable(s) for individual *i* at time *t*, *β* is the coefficient(s) associated with the independent variable(s), u_i is the individual-specific effect or random effect, capturing the time-invariant heterogeneity for individual I and ε represents the error term.

3.3.4. Pooled ordinary least squares model

A pooled ordinary least squares (OLS) regression model represents a powerful statistical framework used to ascertain relationships between one dependent variable and a set of independent variables across multiple datasets. The model serves as a unifying approach to assess the impact of various predictors on the response variable, regardless of potential heterogeneity across the datasets (Megesa et al. 2016).

In its essence, the model equation for pooled OLS regression embodies the following structure:

$$Y_{it} = \beta_0 + \beta_1 X_{\mathrm{it}} + \beta_2 X_{it} + \cdots + \beta_{\mathrm{k}}\, XK_{it} = \varepsilon_{it}$$

Where; Y_{it} represents the observed value of the dependent variable in the i^{th} dataset and for time *t*, X_{i1}, X_{i2}..., Xik denote k independent variables within each dataset for time *t*, β_0, β_1, β_2..., β_k represent the corresponding regression coefficients to be estimated and ε_{it} denotes the error term, representing unobserved factors affecting Y_{it} that are not accounted for by the independent variables.

The aim of a pooled OLS regression model was to identify the most suitable estimate for the *β* coefficients, enabling the quantification of the effect of each independent variable on the dependent variable across all datasets. The process involves determining the set of *β* coefficients that minimizes the sum of squared residuals (SSR), reflecting the overall discrepancy between the observed and predicted values of the dependent variable. As a formal statistical methodology, the pooled OLS regression model requires independence and homoscedasticity of residuals, absence of multicollinearity among independent variables, absence of endogeneity and autocorrelation, as well as normality and zero mean of the error term ε_{it} ensuring a robust evaluation of causal associations across multiple datasets (Megesa et al., 2016). The appropriate model for the panel data analysis was selected by using the Hausman and Breausch Pagan test. The Hausman test is used to choose the best model between the fixed and the random effect models while the Breusch Pagan model was used to determine the best model between the pooled OLS and the random effect model or fixed effects.

3.3.5. Hausman test

The appropriate model for the panel analysis was selected by using the Hausman and Breausch Pagan test. The Hausman test (Hausman, 1978) is used to choose the best model between the fixed and the random effect models while the Breusch Pagan model will be used to determine the best model between the pooled OLS and the random effect model. The implicit form of the model used in this study is given by:

The Hausman test is used to choose between random effects and fixed effects models in panel data analysis. It assesses the presence of correlation between the individual-specific effects (random effects) and the regressors in the model. If there is no correlation, the random effects model is appropriate. However, if there is correlation, indicating that the random effects assumption is violated, the fixed effects model should be used. The Hausman test statistic is expressed as follows:

$$H = (\beta\_FE-\beta\_RE)'(Var(\beta\_FE)-Var(\beta\_RE))^{-1}(\beta\_FE-\beta\_RE)$$

Where; H is the Hausman test statistic, β_FE is the coefficient vector estimated from the fixed effects model, β_RE is the coefficient vector estimated from the random effects model, $Var(\beta\_FE)$ is the variance-covariance matrix of the fixed effects estimators, $Var(\beta\_RE)$ is the variance-covariance matrix of the random effects estimators, and **"^-"** denotes matrix inverse.

3.3.6. Breusch Pagan test

The formula for the Breusch-Pagan test is as follows:

$$BP = n * R\text{-squared from the auxiliary regression}$$

Where:

BP is the Breusch-Pagan test statistic, n is the sample size, R-squared is the coefficient of determination from the auxiliary regression.

The Breusch-Pagan test statistic follows a chi-square distribution with degrees of freedom equal to the number of independent variables in the auxiliary regression. If the test statistic is statistically significant it suggests the presence of heteroscedasticity in the model, indicating that the assumption of constant variance is violated.

4. RESULTS AND DISCUSSION

4.1. Unit Root Tests

The Levin-Lin-Chu, Harris Tzavalis and LM Hadri test revealed that the dependent variable greenhouse gases emissions (GHGs) contained unit roots and was corrected using first difference while the independent variables were stationary did not contain any unit roots except for the GDP per capita (incomes) which was also corrected for unit roots by first differencing (Table 1). The unit roots were removed by differencing and reducing the dimensionality of the data through logs. For a variable to be stationary all the 3 tests should give $P < 0.05$.

4.2. Hausman Test

The Hausman model was used to select the best model of fit for the analysis between random spatial effects model and fixed effects regression model. The Hausman test which was used to choose between the fixed and random revealed that there was a P-value of 0.9747 hence the null hypothesis could not be rejected. The null hypothesis and the result were that the random effect model is appropriate. The Breusch pagan model was used to determine the best model between the random effects and the pooled OLS had a P-value of 1 hence the null hypothesis could not be rejected. The null hypothesis and results indicated that the pooled OLS estimator was the most appropriate model.

4.3. Regression Analysis Results

The regression results show that the model as a whole is statistically significant (Prob > F = 0.0096), indicating that at least one of the independent variables has a significant relationship with the dependent variable in this case, where 4 variables were statistically significant. The model explains a relatively small portion of the total variation in the dependent variable, with an R-squared value of 0.0910 indicating that the independent variables explain 9.1% of greenhouse gas emissions. The model was corrected for heteroscedasticity and the VIF value was 1.22 suggesting the model was stable.

Table 2 summarizes the results of the regression for the greenhouse gas emissions from Pooled OLS regression which was selected as the best model for the study data set after conducting Hausman and Breusch pagan tests to choose the best model among fixed effects, random effects and pooled ordinary least square regression. The results show that the loggdppc, logcrdfasia, logcrdfeurope, logcrdftotal variables are statistically significant variables at P = 0.024; 0.017; 0.037; 0.77; 0.046 respectively whilst logcrdfamerica is not statistically significant variable at P = 0.77. The coefficient value suggests that a 1% increase in GDP per capita is associated with a 0.786 % increase in greenhouse gas emissions. Likewise, a 1% increase in CRDF from Europe is associated with a 0.007% increase in greenhouse gas emissions. Also, 1% increase in CRDF from ASIA is associated with a 0.003 % decrease in greenhouse gas emissions while 1% increase in CRDF from America is associated with a 0.001% decrease in greenhouse gas emissions. Finally, a 1% increase in total CRDF is associated with a 0.06% decrease in greenhouse gas emissions across developing countries.

Since the coefficient of CRDF from Asia and Total CRDF received

Table 1: P-values logged variables and unit root tests at d-1st difference

Variable	Levin-Lin-Chu	Harris Tzavalis	LM Hadri
EMlog	0.4524	0.0655	0.0000
dEMlog	0.0023	0.0000	0.0000
gdppclog	0.0020	0.9802	0.0000
dgdppclog	0.0014	0.0000	0.0000
tortalcrdflog	0.0001	0.0000	0.0000
crdfeurolog	0.0427	0.0000	0.0000
crdfasialog	0.0002	0.0000	0.0000
crdfamericalog	0.0208	0.0000	0.0000

Table 2: Regression results

Variables	Coefficient	P-value
logdgdpc	0.786	0.024**
logcrdfeuro	0.007	0.017**
logcrdfasia	−0.0039	0.037**
logcrdfamerica	−0.0019	0.77
logcrdftotal	−0.06	0.046**

*P<0.01, **P<0.05, ***P<0.1

by developing countries are negative and statistically significant at the 0.05 significance level (P = 0.037 and 0.046) respectively, indicate that there is an inverse or negative relationship between CRDF from Asia as well as total CRDF received by developing countries and greenhouse emissions. In addition, since the coefficients of income of developing countries as proxied by GDP per capita and CRDF from Europe are positive and statistically significant at the 0.05 significant level (P = 0.024 and 0.017) respectively, indicates that there is a positive relationship between GDP per capita as well as CRDF from Europe and greenhouse gas emissions.

The results obtained from the analysis revealed that the CRDF variable holds significant statistical importance, with a P-value of 0.046. Furthermore, the findings indicate that a 1% increase in CRDF is linked to a 0.06% reduction in greenhouse gas emissions across developing nations. These results hold substantial significance as they demonstrate a negative or inverse relationship between the CRDF received by developing countries and greenhouse gas emissions. The negative coefficient observed for CRDF among developing countries, along with its statistical significance at a $P < 0.05$, further strengthens the notion of an inverse relationship. This implies that as the total amount of CRDF received by developing countries increases, the corresponding greenhouse gas emissions decrease. It is important to note that these findings align with previous studies in the field.

Numerous studies have reported similar outcomes, reinforcing the idea of a negative association between CRDF and greenhouse gas emissions. For example, studies conducted by Li et al. (2022); Lee et al. (2022); Carfora et al. (2017) found that an increase in financial assistance for environmental quality assurance led to a decrease in emissions across developing countries. Their findings support the notion that countries receiving more CRDF tend to exhibit lower levels of greenhouse gas emissions emphasizing the significant role financial support plays in promoting sustainable practices and mitigating the adverse effects of climate change. According to World Bank (2019) CRDF triggers investment in renewable energy sources and mitigatory practices such as afforestation and forest landscape restoration practices hence enhancing carbon sinks which ultimately reduce the GHGs emissions in the atmosphere. Conversely, some studies have presented conflicting results, suggesting a positive relationship between CRDF and greenhouse gas emissions. Chung et al. (2018) as well as Aquilas and Artemnkeng, (2022) conducted research studies that revealed an increase in CRDF among developing nations led to an increase in emissions. These contradictory findings highlight the complexities within the field and highlights the need for further research to better understand the relationship between CRDF and greenhouse gas emissions.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

The study findings indicate several key results regarding the relationship between Climate Related Development Finance (CRDF) and greenhouse gas (GHG) emissions across different regions. CRDF from Asia and Europe were found to be statistically significant. The study findings indicate several key results regarding the relationship between Climate Related Development Finance (CRDF) and greenhouse gas (GHG) emissions across different regions. CRDF from Asia and Europe were found to be statistically significant at 5% level of significance level, respectively. However, CRDF from America was not found to be statistically significant. As CRDF from Europe increases, GHG emissions increase and an increase in CRDF from America results in a decrease in GHG emissions.

One noteworthy finding is the negative and statistically significant coefficient of CRDF from Asia (P = 0.037) which suggests an inverse or negative relationship between CRDF from Asia received by developing countries and GHG emissions. This finding indicates that an increase in CRDF from Asia leads to a decrease in GHG emissions in developing countries. This aligns with previous studies that have shown the importance of international financial assistance in mitigating climate change impacts, particularly in developing regions. Moreover, the positive coefficient of CRDF from Europe suggests a significant increase in GHG emissions as a result of CRDF from this region. This finding is consistent with studies that highlight Europe's contribution to global emissions in recipient developing countries, particularly due to its industrial activities and high energy consumption patterns investments.

It can be deduced that the opposing findings between CRDF from Europe and ASIA indicate that effects CRDF is heterogeneous on greenhouse gas emissions. These findings are in line with other studies conducted on FDI by Chinyanganya and Sunge, (2021) which learnt that FDI can be more effective when sourced from African and Asian continents than Europe and America indicating that the source provides heterogeneous effects of FDI.

The source of funding plays a crucial role in determining their sustainability and impact of recipient country programs to reduce GHG emissions. Donors may provide grants or loans with favorable terms and conditions to support climate projects, reduce GHG emissions, and enhance developing countries' abilities to adapt to the impacts of climate change. However, some donors may prioritize their strategic interests over climate change goals, leading to the funding of projects that do not reduce GHG emissions or promote sustainable development. Moreover, inadequate funding may undermine the implementation of climate-related projects, leading to ineffective outcomes. In support increasing GHGs emission in the presence of CRDF, Aquilas and Artemnkeng's (2022) acknowledged that most studies rely on data pertaining to climate-related development mitigation financial commitments. While these commitments are informative, they may differ from actual financial flows, considering the possibility that certain climate related development finance donors may have failed to honor their commitments fully hence reduction in GHGs will be unobserved.

The interaction of CRDF with income levels of recipient countries, represented by the GDP per capita, serve as a proxy for understanding the relationship between economic prosperity and greenhouse gas emissions. This implies that CRDF and increased income levels contribute to higher levels of emissions. Furthermore, the positive and statistically significant coefficients of income for developing countries, affirm the existence of a positive relationship between GDP per capita and greenhouse gas emissions. This result implies that as developing countries experience economic growth despite the presence of CRDF and an increase in income levels, the emissions also rise.

These research findings align with the Jevons Paradox, which postulates that technological advances or efficiency improvements that aim to reduce resource consumption and emissions might paradoxically lead to an increase in their use. The paradox arises from the fact that the efficiency improvements make resource use and emissions cheaper, thus stimulating their demand and further increasing consumption. This counterintuitive effect has been observed in various studies and provides insights into the relationship between economic development and environmental impact. For example, a study by Shahbaz et al. (2018) demonstrated that the implementation of energy-efficient technologies with support of CRDF in industrial sectors resulted in reduced energy consumption. However, the overall energy demand still increased due to the accompanying economic growth and expanding industries. This study also concluded a positive link between GDP per capita and greenhouse gas emissions.

Similarly, a study conducted by Sinha et al. (2019) investigated the development patterns of several Asian countries. Their findings revealed that as these countries experienced economic growth, there was an upward trend in greenhouse gas emissions. This study provides further evidence supporting the positive association between GDP per capita and greenhouse gas emissions.

On the effectiveness of Climate Related Development Finance (GRDF) in reducing Greenhouse Gas (GHG) emissions, the model showed that the total CRDF variable is statistically significant variables at P = 0.046 and 1% increase in total CRDF is associated with a 0.06% decrease in greenhouse gas emissions across developing countries. This means that an increase in CRDF results in reduction of GHGs emissions. This can be attributed to the fact that CRDF triggers investment in renewable energy sources and investment in mitigatory practices such as afforestation and forest landscape restoration practices hence enhancing carbon sinks.

When it comes to the sources of Climate Related Development Finance, the results indicated that the CRDF from Asia and Europe variables were statistically significant at $P < 0.05$ (0.017 and 0.037) respectively whilst CRDF from America is not statistically significant with a P = 0.77. Whilst the coefficient of CRDF from Europe is positive indicating that CRDF from Europe is causing the significant increase in GHGs. It can be deduced that the opposing findings between CRDF from Europe and ASIA indicate that effects CRDF is heterogeneous on greenhouse gas emissions.

The relationship between the recipient income level and the level of Greenhouse Gases emission was seen to be positive. The results show that the income levels of recipient countries as proxied by GDP per capita variable is statistically significant variable at P = 0.024; The coefficient value suggests that a 1% increase in GDP per capita is associated with a 0.786 % increase in greenhouse gas emissions. In addition, since the coefficients of income of developing countries as proxied by GDP per capita is positive and statistically significant at the 0.05 significant level (P = 0.024), it indicates that there is a positive relationship between GDP per capita and greenhouse gas emissions. This can be attributed to Javon paradox theory in which efficiency do not lead to environment quality since with increase income there will be more resources to spend on fossil fuels and energy efficiency in certain industries such as fuel do not lead 100% avoidance of emissions.

Policymakers should consider increasing CRDF such as funding facilities provided under Global Environmental Facility and Green Climate Fund to developing countries, as it has proven to be effective in reducing emissions. Policymakers in the targeted developing countries should prioritize funding sources from Asia, as it has shown to be more effective in reducing emissions. Additionally, policymakers in recipient countries should carefully evaluate funding proposals to ensure that projects are aligned with climate change goals and promote sustainable development. The study also examined the relationship between recipient countries' income levels and GHG emissions. This aligns with the Jevons Paradox, which suggests that efficiency improvements and technological advancements may paradoxically lead to an increase in resource consumption and emissions. Policymakers should implement measures to decouple economic growth from environmental negative externalities such as promoting sustainable development practices, investing in renewable energy sources, and implementing regulations to reduce emissions.

This study focuses on climate-related development finance, and, therefore, other factors that influence GHGs emissions reductions may not be captured hence other factors should also be incorporated in the further studies. The study focused on two factors responsible for heterogeneity that is source of funding and income levels of recipient countries, therefore, additional factors such as delivery channels, separation of CRDF funding into mitigatory and adaption funds, sectorial contribution of CRDF in reducing emissions are factors that should be incorporated by future studies. To better understand this relationship, further research are needed and should employ more countries.

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