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Dependence Between Foreign Direct Investment and Carbon Dioxide Emissions in East Africa: Bivariate Distributional Copula Regression Technique

Twahil Shakiru*

Department of Statistics, University of Dar es Salaam, Tanzania

Jiangxi University of Finance and Economics, China

Abstract

Environmental concerns have become more prominent as the global economy has grown faster, impeding sustained economic growth at high standards. Cross-border foreign direct investment (FDI) has played a pivotal role in economic growth, but it has also significantly contributed to environmental pollution in many host nations. Linear regression models have limitations in capturing the complex bi-directional transmission pathways involved. Various factors, including economic growth, electricity consumption, urban population, labor force, exports, and imports, can influence the relationship between carbon dioxide emissions and foreign direct investments. This research employs distributional copula models to ascertain the conditional relationship between FDI and carbon dioxide emissions. The study analyzes data from six East African countries from 1989 to 2020 to quantify their impacts. The findings indicate that FDI is associated with reduced CO2 emissions. Furthermore, the study investigates how economic growth moderates this relationship, utilizing the feasible generalized least squares (FGLS) method. The findings reveal that carbon emissions in East Africa tend to increase with economic expansion, while FDI shows a negative correlation with CO2 emissions. These results underscore the importance of encouraging and incentivizing investments that prioritize environmental sustainability, such as those in renewable energy and energy-efficient infrastructure.

Keywords: foreign direct investment; carbon dioxide emissions; bivariate distributional copula regression; economic growth

JEL Classification: F21; F64; Q56

*Corresponding Author, Address: P.O Box 35047, Dar es Salaam, Tanzania, Email: hemed.twahil@udsm.ac.tz, hemedtwahil@gmail.com

1. Introduction

Foreign direct investment (FDI) is among the primary forces driving economic development and employment for large and small economies. Since manufacturing investments have grown faster than international trade flows of goods and services, FDI has recently become even more significant than global trade (Chen and Moore, 2010). In response to the rise in trade protection on a global level, FDI offers businesses a way to enter markets that are being protected by doing their production to those nations (Demena & Murshed,2018). In order to encourage FDI, numerous countries are adopting assertive marketing techniques (Narula & Dunning, 2000). Government-controlled investment agencies (IPA) frequently use these marketing techniques, which are widespread in several nations. Several governments have found that these IPAs successfully lure international investment and technical expertise (Harding & Javorcik, 2011).

Investors are considering the nation's environmental restrictions when deciding which investments to make. It is well known that as countries' level of development rises, the measures concerning environmental protection also rise since the rise in income leads to more consumer demand for environmentally friendly goods and increases the pressure on governments to conserve the environment. Additionally, governments in sindustrialised nations intervene on technological, managerial, financial, and legal bases to safeguard the environment and prevent pollution. Government interventions related to the environment may be in the form of restrictions and incentives. Environmental-related government measures may take the form of prohibitions and incentives such as environmental fees, environmental duties, permits, approvals, licenses, financial assistance, environmental research support fund, and tax motivations. These government environmental measures to protect the environment increase the production cost and consequently lower the firm profits.

In numerous developing countries, the lack of substantial attention to environmental regulations is a common occurrence, owing to factors such as the high capacity to absorb pollution, the necessity to engage in industrial activities due to elevated poverty levels, insufficient environmental awareness, and inadequate protection of property rights (Gökalp & Yıldırım, 2004).. Moreover, low environmental standards may also cause their failure to create these measures to promote foreign direct investment in their nations. Therefore, multinational firms seek competitive advantage by choosing countries with undetermined environmental regulations to gain high profits. Multinational firms are disregarding the adverse effects of their investments in the environment. The pollution haven theory is the famous name given to this phenomenon in environmental studies. This theory supports the claim that moving polluting activities to develop nations has reduced emissions in many wealthy countries (Kearsley and Riddel, 2010). Circumstantial evidence supports the theory because developing nations are responsible for the most significant proportion of FDI inflow and global emissions. Foreign direct investment inflows to developing countries have increased from 34% in 2018 to 45% in 2019, although the International Monetary Fund (IMF) reports that they have been on a downward trend globally.

The current debate and significant problem with foreign direct investment are its possible adverse environmental effects (Zhu et al., 2016). Due to the possibility that increasing FDI may also result in higher environmental emissions, the economic benefits of this development could likely be offset by environmental costs (Cole et al., 2011). For example, Pao and Tsai (2011) suggest that due to FDI's propensity to promote economic growth, environmental emissions related to FDI could be conveniently disregarded. Many nations are now selective about the type of FDI that enters their country due to an awareness of the potential environmental costs associated with foreign direct investment. Currently, several nations are promoting green foreign direct investment, which emphasizes FDI capable of facilitating economic development while simultaneously internalizing the negative environmental externalities associated with industrial production (Golub et al., 2011).

Even if this negative view of FDI's impact on the environment predominates the literature, it's also possible that FDI can help make the world cleaner. Particularly if foreign investments are associated with clean technology, it is also proved that international businesses in emerging nations take environmental protection more seriously than domestic ones (Eskeland and Harrison, 2003). This study demonstrates that United States of America-owned facilities in developing countries use less and more environmentally friendly energy. Studies like Zarsky (1999) and Zhu et al. (2016) provide additional evidence that FDI may lessen pollutant volume. Zhu et al. (2016) claim that international businesses are more environmentally conscious than internal businesses because they employ better management techniques and cutting-edge technologies.

Numerous researchers have undertaken empirical evaluations on how FDI affects environmental emissions to address the theoretical uncertainty surrounding the Relationship between FDI and the environment. Several researchers have used FDI and trade openness to investigate their relationship with carbon emissions. For example, Seker et al. (2015) investigated the effects of Turkey's FDI and other variables on carbon dioxide emissions from 1975 to 2010. Khan and Ozturk (2020) examined the causal association between carbon dioxide emissions and FDI and a few other variables using data from 17 Asian nations. Wen et al. (2021) used data from China's provinces to assess the effect of FDI on carbon dioxide emissions, while Jiang and Ma (2019) investigated the relationship between foreign direct investment and carbon dioxide emissions in 155 nations. The conclusions reached have been inconsistent because of the disparate factors, data, and methodologies used in these studies.

Some researchers use different nations or sets of nations to assess heterogeneity. For example, Zhu et al. (2016) studied five Asian countries and discovered that FDI is the decreasing function of carbon dioxide emissions. The study by Cole et al. (2011), conducted in 113 towns in China, found that FDI increases pollution. Similarly, the study by He and Richard (2010), addressing twenty-nine provinces in Canada, found a positive relationship between FDI and carbon emissions. Moreover, Eskeland and Harrison's (2003) study focused on US-specific foreign investment in 4 African developing nations and discovered that FDI is significantly more energy efficient and cleaner type of energy. Further studies include those by Sapkota and Bastola (2017), which focus on fourteen Latin American nations and found the validity of both PHH and EKC hypotheses, along with Pao and Tsai (2011), who investigated the association between foreign direct investment and CO_2 emissions for the Gulf Collaboration Council nations discovered that there exists strong bidirectional causality between

FDI and emissions. The inconsistencies in the findings from these studies arise from the fact that these nations vary in terms of their levels of economic development, environmental laws, and approaches to attracting foreign investment. According to Copeland and Taylor (2003), industrialized and developing nations have different environmental policies. Therefore, the effect of foreign direct investment (FDI) on the environment can depend on the seriousness of the national environmental policies.

This work contributes to the body of the available literature by investigating the effect of FDI on CO_2 emissions in East Africa, employing the data from 1989 to 2020. Additionally, this study differs from earlier studies as follows. Firstly, in contrast to prior studies, the objective of the current study is to examine the effects of FDI inflows on CO_2 emissions through innovative routes with the moderator of economic growth. This is because there is limited research about the indirect impact of FDI on the environment, particularly in determining the channels of influence. Secondly, using the bivariate distributional copula model, this work examined conditional dependence structures between foreign direct investment and CO2 emissions. The mean regression model considers the normality assumptions and the covariates' steady impacts and looks into the transmission channels in one direction relationship. Therefore, the current study analyses the association by integrating CO_2 emissions and FDI inflows into a bivariate response vector. The copula captures the conditional dependence structure inside the vector of carbon emissions and foreign direct investment. Furthermore, it is possible to examine the nonlinear impacts of influencing factors on the connection using the distributional regression models built into the copula model.

2. Carbon dioxide Emissions and Foreign Direct Investment Relationship

Numerous studies have empirically explored the relationship between carbon dioxide emissions and FDI. However, the findings of these studies differed from those of many others due to varied objectives, data sets, and covariates. For example, Tang et al. (2022) examined the variance in the effect of FDI on carbon production under several entrance routes from 2007 to 2019 by using geographical econometric models to sand analyze a panel of data containing 25 Chinese provinces. Their study found that when foreign investment enters China through joint enterprises, there is potential for a favorable geographical spillover effect, which might increase China's carbon dioxide production. However, when FDI enters China through entirely foreign-owned firms, a negative geographical spillover impact will prevent China from increasing carbon production. Using data from 57 developing countries from 1980 to 2013, Kim (2019) employed VECM to investigate the causative relationships between carbon dioxide emissions, FDI, and other covariates and found that, in the short run, FDI did not directly affect carbon dioxide emissions. Abban et al. (2020) established a bidirectional causal relationship between Foreign direct investment and carbon dioxide emissions in BRI countries using a data set of twenty years. Moreover, Islam et al. (2021) examined the effect of FDI on carbon dioxide emissions in Bangladesh during the period of institutional quality, and they found that FDI negatively affects carbon dioxide emissions.

Other numerous research has been conducted based on the two famous hypotheses. The first is known as the "pollution haven" hypothesis, which contends that as a result of economic globalization, wealthy economic nations allocate polluting businesses to low-economic countries, promoting economic growth in those nations while increasing the use of fossil fuels, which results in significant carbon dioxide gas emissions (Nadeem et al. 2022; Omari et al. 2014; Bakhshet et al. 2017). Cil (2023) examined the relationship between foreign direct investment and environmental degradation in Turkey. This study used Fourier approximation for covariates. The findings indicated a positive link between FDI and environmental pollution. This demonstrated the validity of the pollution haven hypothesis (PHH). Thus, it is essential to promote FDI that uses cutting-edge, environmentally friendly technology to boost energy efficiency and minimize pollution.

Similarly, Malik et al. (2020) discovered that economic development and FDI had long- and short-term environmental effects. In addition to confirming the results above, this study showed a feedback relationship between economic expansion and environmental pollution. Furthermore, this study suggested that when foreign direct investment declines, policymakers should implement carbon pricing and energy diversification policies to prevent environmental degradation.

The second hypothesis, called "pollution halo," contends that FDI can improve manufacturing structures and energy structures by spilling over green technologies and allocating resources more efficiently in the host country, hence lowering the production of carbon dioxide gas. Ahmad et al. (2021) examined how foreign direct investment affects carbon dioxide emissions using data from individual cities. They discovered that FDI was generally favorable to environmental sustainability, supporting the "pollution halo" argument. Thei findings confirmed the "pollution halo" idea, which showed that FDI was beneficial to environmental protection. The effects were heterogeneous at the city level. The results revealed that foreign direct investment had a favorable influence on carbon dioxide emissions in 7 cities but an unfavorable impact in 15 cities. The results further demonstrate the validity of two hypotheses in fragile economies. According to Liu et al. (2017), when developed nations make foreign investments in the host country, their modern environmental management technology and environmental degradation measure system flow over, potentially raising the host nation's environmental quality level to flexible degrees.

Along with these two assumptions, some scholars have revealed that foreign direct investment has no effects or an unclear impact on carbon dioxide emissions. For example, Gao et al. (2022) employed data from 1973 to 2019 to examine the association of carbon dioxide emissions, foreign direct investment, and terrorism in 10 fragile countries. The study discovered the un-existence of asymmetric effects among these covariates. Similarly, the investigation of Chen and Yang (2013) to examine the impact of FDI on carbon dioxide emissions by utilizing the STIRPAT technique discovered that FDI has no effect on CO_2 emissions in Taiwan. Furthermore, utilizing the data from the Gulf Collaboration Council nations, Al-Mulali and Tang, (2013) investigated the effects of FDI on CO_2 emissions. It discovered an insignificant Relationship between FDI and environmental pollution.

2.1 Summary of the Literature Review

The previous section addressed theoretical and empirical research on the Relationship between FDI and carbon dioxide emissions. Table 1 lists the most current works on this subject. The theoretical and empirical reviews mentioned earlier present contradictory findings. These reviews indicate a lack of consensus on the impact of FDI on CO2 emissions. From the existing literature, it is evident that opportunities for enhancements still exist. Based on the available literature, it is clear that there is still a chance for improvements. Therefore, this study aimed to examine the effects of FDI inflows on CO2 emissions through innovative routes with the moderator of economic growth in East African countries. This can be attributed to the constraints of research concerning the indirect effects of FDI on the environment, especially in terms of identifying the channels of influence.

Furthermore, the bivariate distributional copula model examined dependence structures between foreign direct investment and CO2 emissions. The mean regression model, which considers the normality assumptions and steady impacts of the covariates, looks into the transmission channels in one direction relationship. Finally, this study is significant because the effect of FDI on CO_2 emissions in East African countries has not been examined using the most accurate estimation methods.

Table 1: Summary of the literature review

Author(s)	Countries/Region	Study Period	Methods	Findings
Tang et al. (2022)	China	2007-2019	Spatial econometric models	Positive Relationship
Kim, (2019)	Fifty-seven wealthily economies	1980-2013	Vector-Error Correction Model (VECM)	Long-run Relationship
Abban et al. (2020)	Belt-Road Initiative	1995-2015	Granger Causality Test	Bidirectional causal relationship
Islam et al. (2021)	Bangladesh	1972-2016	Dynamic ARDL Simulation Technique	Negative Relationship
Cil, (2023)	Turkey	1970-2020	Fourier Approximation for Covariates	Positive Relationship
Malik et al. (2020)	Pakistan	1971-2015	Nonlinear ARDL Technique	Positive Relationship

Ahmad et al. (2021)	China	1998-2016	Dynamic Common Correlated Effects-mean group model	Positive and Negative Relationships
Liu et al. (2017)	China	2002-2015	Spatial Models	Negative Relationship
Gao et al. (2022)	10-Fragile Countries	1973-2019	NADRL and ARDL	Positive Relationship
Chen and Yang, (2013)	Taiwan	1992-2005	STIRPAT technique	Insignificant Results
Al-Mulali and Tang (2013)	Gulf Cooperation Council nations	1980-2009	Granger Causality Test	Insignificant Results

2.2 Conceptual Framework

A conceptual framework is a graphical image of the connection between the primary components, covariates, or concepts chosen for the investigation. For this research topic, FDI is employed as the explanatory variable, economic growth measured by GDP per capita is used as the mediator variable, and carbon dioxide emissions are used as the response variable. The conceptual framework employed in this study is displayed in Figure 1 below. This figure shows the direct impact of FDI inflow on CO_2 emissions, especially investigating the influence channels. In contrast to previous research, this study also examines the effects of FDI inflows on carbon emissions through innovative channels, considering economic growth as a moderating factor influencing the indirect impacts on carbon emissions.

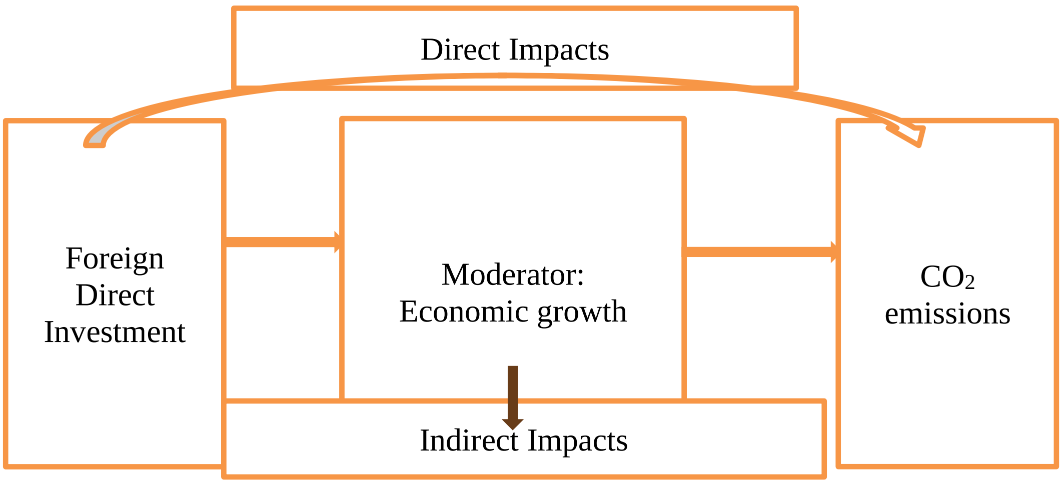


Figure 1: Conceptual framework

Source: Author's compilation based on the reviewed literature.

3 Methodology

3.1 Data

The data used in the study is balanced panel data set with six East African nations from 1989 to 2020 that was gathered from World Bank and International Monetary Fund (IMF) publications. This study focused on the association between CO_2 emissions and foreign direct investment with a moderating influence on economic growth, making up the bivariate result vector for our distributional copula model. The study condition that the association between FDI and carbon emissions on the control variables such as electricity consumption, urban population, labor force, exports, and imports following both theoretical and empirical literature on the current subject (Islam et al., 2021; Abban et al., 2020; Cil, 2023). In detail the data of all variables comes from World Bank Indicators, except imports and exports data collected from IMF. Furthermore, the details of the units and descriptions for the mentioned variables are presented in Table 2.

Table 2: Variable measurements

Variable (s)	Measurements (Unit)
GDP per capita	US$
CO_2 emissions	Megatons (Mt)
Foreign Direct Investment	US$
Electricity Consumption	Giga watt-hour (GWh)
Urban population	Count
Exports	US$
Imports	US$

3.2 The Overview of Copulas

Copula is the mathematical probability model that simulates a multivariate uniform distribution, looking at the correlation or dependence between two or more covariates. In other words, a copula assists in separating the joint or marginal probabilities of two covariates that are intertwined in a more complex multivariate system. In that case, the copula is the unique index or set of guidelines for specifying how those pairs fit together in the more complicated structure. This technique is advantageous since it can assist in finding counterfeit relationships in the data. Sklar, (1959) introduced the copula as a function for joining several univariate marginal distributions of random covariates into a joint distribution. Let's assume that there is a d-dimensional random vector $Y = (y_1, y_{2,\dots,}y_n)^T$ possessing the marginal cumulative distribution functions $F_1(y_1), F_2(y_2), \dots, F_n(y_n)$ and probability density function of this form $f_1(y_1), \dots, f_n(y_n)$. Hence, the joint cumulative density function and joint probability density function are defined in equations (1) and (2) respectively.

$$F(y_1, y_2, \dots, y_n) = C[F_1(y_1), F_2(y_2), \dots, F_n(y_n)] = C(u_1, u_2, \dots, u_n) \quad \text{.............................} (1)$$

$f(y_1, y_2, \dots, y_n) = \{\prod_{i=1}^{n} f_i(y_i)\} C(u_1, u_2, \dots, u_n)$ .... (2)

The capital letter C represents the copula function expressed as $C = \frac{\partial^n C}{\partial F_1, \partial F_2, \dots, \partial F_n}$ of the related copula density function. For the case of the continuous marginal distribution, copula function (C) tends to be unique. In contrast, if one of the distributions is discrete, C is expressed by the support of joint distribution (Sklar 1959). The copula can be seen as "independent" of the margins in continuous distributions, where it is possible to separate the multivariate dependence structure from the marginal distributions (Joe, 1997). Thus, the copula enables the combination of any two or more continuous marginal distributions and specifies the dependence structure of those distributions.

Theorem

In every bivariate cumulative density function $F_{S,Z}$ on R^2 having the marginal cumulative density function F of S and G of Z there is the existence of some function $C: [0,1]^2 \rightarrow [0,1]$ known as the called the dependency or copula function, like

$F_{S,Z}(s, z) = C[F(s), F(Z)], \quad -\infty \leq s, z \leq \infty$ .... (3)

As explained in section 3.2, equation (3) tends to be unique if both F and G are continuous. The copula is a uniformly distributed cumulative distribution function on the interval $[0,1]^2$. This theorem represents the bivariate CDF as a function of each univariate CDF. In other words, regardless of the marginal distribution, the copula captures the dependence structure in the pair (S, Z) . It enables disjointedly dealing with the unpredictability of the dependent structure and margins. Copulas are naturally linked with the quantile transform as formula (2) entails that. The quantile transformation and copula are inextricably related because of the presentation described in equation (2) that $C(u, v) = F_{S,Z}[F^{-1}(u), G^{-}(v)]$. Therefore, this study will suppose that the copula function $C(u, v)$ has a density function $C(u, v) = \frac{\partial^2}{\partial u \partial v} \times C(u, v)$. Pertaining to the Lebesgue measure on the interval $[0,1]^2$ and that F and G are increasing differentiable functions with densities f and g. $C(u, v)$ and $c(u, v)$ are then the cumulative density functions and density of the transformed covariates $(U, V) = [F(S), G(Z)]$. The joint density is obtained by differentiating two sides of the equation (3) such that

$f_{SZ}(s, z) = \frac{\partial^2}{\partial s \partial z} F_{SZ}(s, z) = f(s) g(z) \times C[F(s), G(z)]$, which gives the following condition density function

$f_{Z|S}(s, z) = \frac{F_{SZ}(s,z)}{f(s)} = g(z) \times C[F(s), G(Z)]$ .... (4)

Figure 1 below depicts the graphical representation of bivariate copula density.

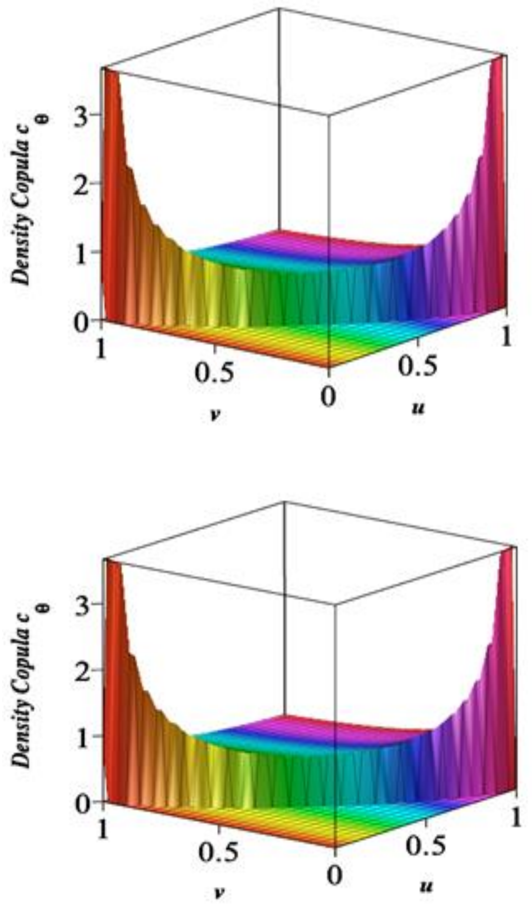


Figure 2: Graphical illustration of the Copula density

This study uses bivariate distribution copula techniques to capture varying dependence structures among the variables, which the mean regression model cannot determine under the ordinary least square estimation technique.

3.3 Bivariate Distributional Copula Regression Technique

The analysis of the dependence structure is the primary emphasis of the bivariate distributional copula regression method, which also permits a variety of effects across the range of variables. The copula is a statistical technique that uses a bivariate cumulative distribution function (CDF) to connect the marginal distributions of the two variables, FDI and CO2 emissions, to examine their joint properties. This approach uses generalized additive models for location size and shape (GAMLSS) as the fundamental units for the marginal probability distributions of foreign direct investment and CO2 emissions. Contrary, commonly and frequently employed univariate regression techniques assess only mean impacts and neglect to consider the variable dependence structure. Moreover, as discussed in Sections 1 and 2, current evidence indicates a connection between FDI and CO_2 emissions. Since there is no apparent direct link between FDI and CO_2 emissions, it is important to understand the degree and variety of the association. Thus, this study employed bivariate distributional copula regression techniques to capture the dependence structure in the study variables.

3.3.1 Bivariate Copula Regression Model

Distributional copula regression for foreign direct investment and CO_2 emissions combines the following two important characteristics: Firstly, this model stipulates the two marginal distributions individually, and then it describes the relationship between FDI and CO_2 emissions, with the ability to model regression impacts on all relevant bivariate distributional factors. Secondly, this model enables the separation of the dependence and the marginal distribution specification. It includes the capability of modelling the effects of regression on all potential parameters of the subsequent bivariate distribution. The parameters of both the marginals and the copula are now connected to regression predictors through copula regression. Consider that $\emptyset = (\emptyset'_1, \emptyset'_2, \emptyset'_c)$ to be the K-dimensional vector of parameters illustrating the margin $(\emptyset_1 \& \emptyset_2)$ and copula $(\emptyset_C)$. This study assumes that each of the parameters varies as a function of the covariates y that, $\emptyset_{ik} = \emptyset_k(y_i), \quad k = 1,2, \dots, K$ for the sample $i = 1,2, \dots, n$. Then, using copula regression, it can easily to modify any bivariate distribution response variable feature. Additionally, it is possible to express the marginal distribution flexibly with various dependencies, especially those that do not reflect a linear relationship. In order to introduce flexibility into the regression model, this study sutilizes a semi-parametric specification that goes beyond solely linear regression predictors, incorporating a partially-linear predictor;

$$\pi_i^{\emptyset_k} = y'_i \beta^{\emptyset_k} + \sum_{j=1}^{J} f_k^{\emptyset_k}(z_{ij}) \quad \dots\dots (5)$$

which is linked to the distributional parameter $\emptyset_k$ via a strictly monotonically increasing response function s_h such that;

$$\emptyset_k(y_i) = s_k\left(\pi_i^{\emptyset_k}\right) \quad \dots\dots (6)$$

The explanatory variable combines linear impacts $y'_i \beta^{\emptyset_k}$ based on the variable y_i and regression coefficients $\beta^{\emptyset_k}$ with nonlinear impacts $f_k^{\emptyset_k}(z_{ij})$ of continuous variables z_{ij}. This study uses spenalized splines, or cubic B-splines of modest size coupled with a second-order difference penalty, to attain a data-driven level of non-linearity in the effect estimations. The following section outlines the model specification calculating the bivariate distribution specified in equation (1).

3.4 Specification of the Analytical Model

The model is specified following the two essential processes outlined in part 3.3.1. Initially, the marginal distribution of FDI and CO_2 emissions are identified to create a GAMLSS model for each covariate. Next, the study established the copula and the marginals to develop the joint distribution of FDI and CO_2 emissions. Decisions for selecting distribution are established by comparing the results of the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) choosing criterion with QQ graphs of the model residuals for various distribution options. The copula and distributions with the lowest values of AIC and BIC are chosen. The models which did not converge were not considered because this typically means that the dependency shown in the data does not follow the structure postulated by the specified copula.

Several parameters $\emptyset_k, \ k = 1,2, \dots, K,$ as described in 5 and 6, are used to describe the particular marginals and copulas. The predictor $\pi^{\emptyset_k}$ of parameter $\emptyset_k$ depends on the variables presented in section 3.1. Therefore, the model is specified as follows;

$$\pi_i^{\emptyset_k} = \beta_{0i}^{\emptyset_k} + s_i(GDPP)^{\emptyset_k} + \beta_{3i}^{\emptyset_k} EC + \beta_{4i}^{\emptyset_k} EXP + \beta_{5i}^{\emptyset_k} IMP + \beta_{6i}^{\emptyset_k} UP + \beta_{7i}^{\emptyset_k} LF + s_i(year)^{\emptyset_k} \quad (7)$$

To control the nonlinear and economic growth variation in time among East African counties, we employed a nonlinear effect (as a generalized spline model) for the years. The study builds ten inner knot splines s_i with the panel data set for the year affecting the year. Similarly, to account for nonlinear impacts, the study modelled GDP by utilizing a generalized spline with 10 inner knots. Splines help smooth the effects between knots, which increases flexibility compared to a conventional quadratic connection (Dorn et al., 2021).

This study further investigates the moderating effects of economic growth to a closer look at the direct impacts of FDI on CO_2 emissions. Adopting the same methodologies of Zheng et al. (2021) and Ehigiamusoe et al. (2020), the regression model with moderation effect is described in equation (8):

$$CO2_{it} = \beta_0 + \beta_1 FDI_{it} + \gamma GDP_{it} + \alpha GDP_{it} * FDI_{it} + \sum_{k=1}^{K} \delta_k CV_{k,it} + \tau_i + \sigma_t + \epsilon_{it} \ \ldots\ldots \ (8)$$

In equation (8) $CO2_{it}$ denotes the response covariate of CO_2 emissions. The explanatory covariate of foreign direct investment is represented as FDI, measured by net inflows. β_0 and β_1 represents the regression coefficients of intercept and foreign direct investment, respectively. GDP denotes economic growth measured by gross domestic product per capita. Similarly, α denotes the regression coefficient of economic growth. The interacting term defines the moderating effects $(GDP_{it} * FDI_{it})$ of economic growth and foreign direct investment, and α denotes the coefficient of interacting terms. δ_k denotes the coefficients of the control variables (CV_k), and K represents the total number of control variables included in the study. In order to obtain better estimates, this study includes both country dummies (τ_i) and year dummies (σ_t). Moreover, the error term is denoted as (ϵ_{it}), which considers the influence of the other variables not included in the model. The control variables (CV_k) Included in this study are electricity consumption (EC), urban population (UP), the labor force (LF), export (EXP), and import (IMP).

4. Results

4.1 Summary Statistics

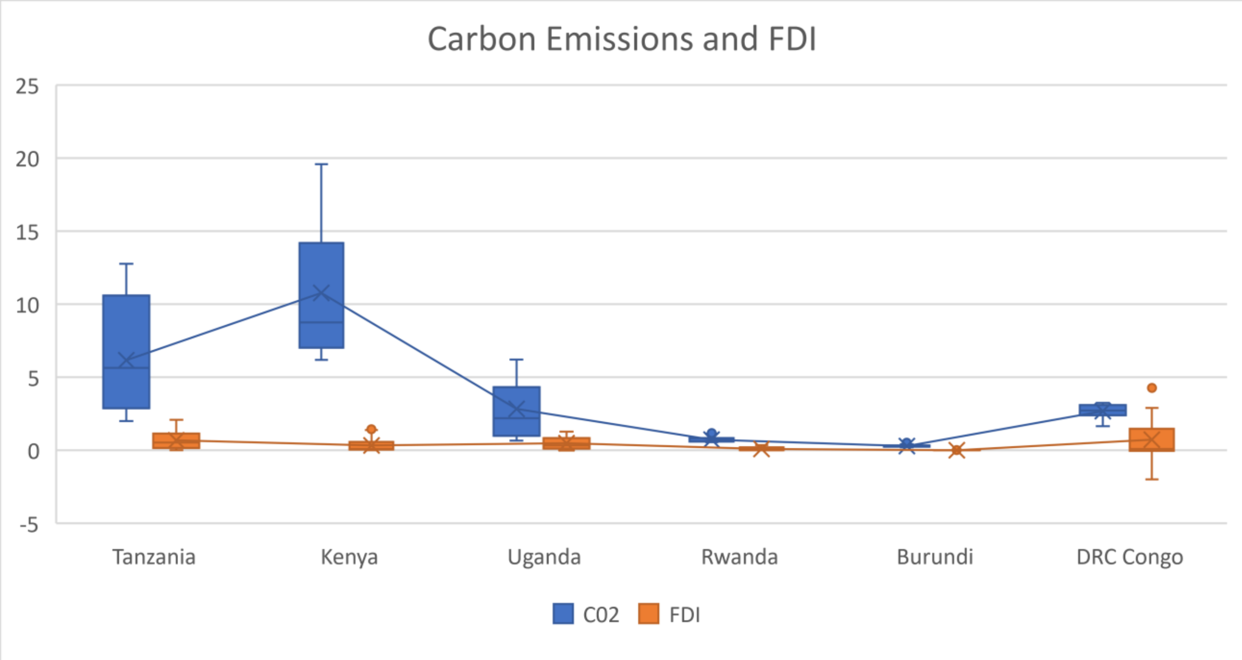
Table 3 shows the average Gross Domestic Product per capita of the selected East African countries at a value of 501 US$. The dependent variables in the table show that the average CO2 emissions for the selected East African countries are about four megatons, and the average electricity consumption is about 2645 GWh. The average foreign direct investment is about 0.4 US dollars, implying that foreign investment is very low in East African countries. The control variables show that the average urban population of the selected East African countries is about 21 million people, and the average labor force is 12,391,712 people. The average import is about 4.1 billion US dollars.

In comparison, the average export is about 3 billion US dollars, which suggests that the East African communities engage more in importation than exportation, contributing to poor economic growth. Besides, the skewness for each variable does not approach zero, and the corresponding kurtosis of the variables is not equal to 3. This is against the normality concept for data to be normally distributed. The skewness needs to approach zero, and kurtosis needs to be 3. The results of the Jarque-Bera test in Table 2 lead to the rejection of the null hypothesis at 1%. This implies that the variables are not normally distributed. Thus, it is essential to undertake a natural log transformation of the data so that it is normally distributed.

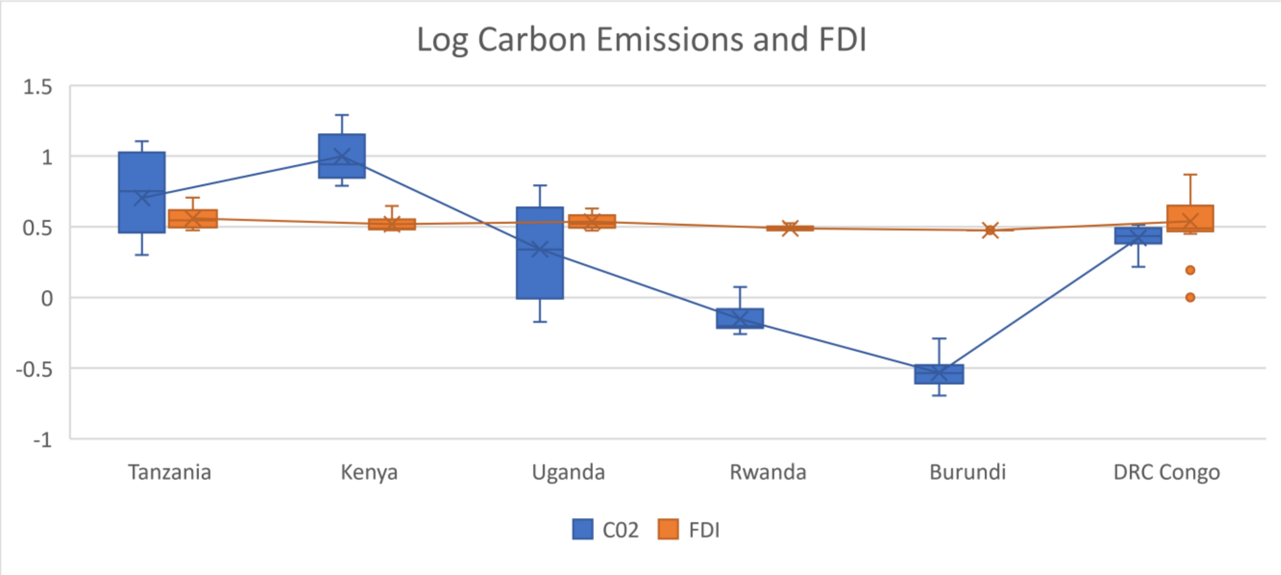
Figure 3 (a) and (b) shows a box plot with the variables FDI, carbon dioxide emissions, and logarithmic carbon dioxide emissions and FDI respectively, demonstrating the significant variation amongst the six East African countries. Due to scale issues, the carbon dioxide emissions and FDI variables are shown as their logarithm in Figure 3(b) plot. There are differences in the levels of FDI and carbon emissions among the six countries. The number of emissions rise as FDI within the countries declines while some of the countries like Rwanda, Burundi, and the DRC Congo CO_2 emissions is associated with an increase in FDI. Figure 3 shows that some nations follow a trajectory of increasing emissions with relatively stable FDI. Additionally, it implies that depending on the quantity of emissions in each country, the strength of the dependence may vary.

Table 3: Summary statistics

Variables	Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera P-value
GDP Per Capita	500.61	352.44	1.391	2.835	0.0000
CO_2 emissions	3.91	4.40	1.655	5.319	0.0000
FDI	0.393	0.751	-0.678	2.316	0.0001
Electricity Consumption	2644.71	2508.43	0.775	4.480	0.0000
Urban population	20.92	9.91	0.601	2.632	0.0018
Labor force	12391712	7826500	0.417	2.070	0.0024
Export	3.011	3.373	0.371	4.103	0.0091
Import	4.109	4.763	-0.431	2.058	0.0000



(a)



(b)

Figure 3: Box plots of the carbon dioxide emissions and FDI pooled over all years in East African countries

4.2 Marginal Distributions and Copula Specifications

As indicated in section 3.4, the marginal distributions of the variables concerning foreign direct investment and carbon dioxide emissions were initially established. Secondly, the copula and marginal distributions determine how FDI and carbon dioxide emissions are jointly distributed. The AIC and BIC selection criterion values and QQ plots of the model residuals for various distribution choices are compared to make all distribution decisions of a particular type. Choosing the copulas and distributions with the lowest AIC and BIC values were decided. The specifications with non-convergent models were not taken into account. This typically means the data's observed dependence does not follow the copula's assumed structure. Table 4 shows the chosen marginal distributions and copula specifications based on the predictor's specification and associated parameters. The results in Table 4 show that both FDI and carbon emissions have a log-normal distribution. Two parameters govern all chosen distributions. The copula specification is determined to be a Frank copula under the assumption that these selections for the marginal distributions are accurate. The Frank copula captures the joint behaviour or dependence structure between FDI and carbon emissions. It provides a way to model their relationship, considering the correlation or association between the two variables. The Frank copula's parameters, particularly the dependence parameter (θ), can help determine the strength and nature of the dependence between FDI and carbon emissions.

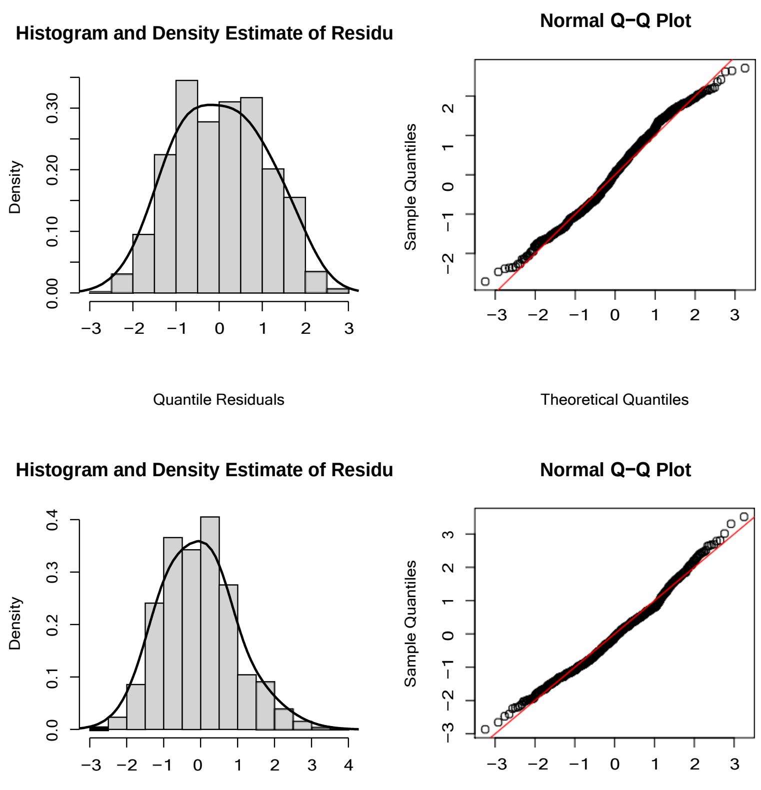


Figure 4: Histogram and Q-Q plots for model residual of CO_2 emissions and FDI in East Africa

Figure 4 illustrates a relatively limited number of data points, with normally distributed data falling in the few highest and few lowest quantiles. The top figure represents the histogram and Q-Q plot of carbon dioxide emissions, while the bottom figure represents the histogram on the left and Q-Q plot on the right of the FDI. Both the FDI and CO2 Q-Q plots in Figure 4 indicate that at extremes, there is a higher likelihood of observing random fluctuations. Clearly, FDI and CO2 emissions do not precisely follow a normal distribution, but they are not significantly deviating from it.

Table 4: Selected Marginal distributions and Copula of the FDI and CO_2 emissions

Variable	Marginal Distribution	Copula
FDI	Log-normal distribution	Frank
CO_2 emissions	Log-normal distribution	

All resultant bivariate distributions $D = F_{1,2}$ depend on five parameters $\emptyset_k, k = 1,2,3, \dots ,5$ with two parameters for each of the two marginal distributions and one parameter for the copula. The following five parameters define the bivariate distribution:

$$\begin{Bmatrix} FDI \\ CO2\ emissions \end{Bmatrix} \sim D(\emptyset_1, \emptyset_2, \emptyset_3, \emptyset_4, \emptyset_5) \tag{9}$$

The main goal of this study is to model how the factors affect dependence. In light of this, the analysis concentrates on the estimation result of equation (7) for the copula parameter. The estimates for the copula parameter $\emptyset_5$ are shown in Table 5. The estimates cannot be considered as mean effects due to the emphasis on distribution, but they provide insight into the direction and significance of the impact.

Table 5: Estimation of the Copula parameter $\emptyset_5$

Variable	Coefficients	Std Error	Z-value	P-value
EC	0.045	0.020	4.861	0.000
UP	0.021	0.010	6.987	0.000
LF	0.028	0.010	5.871	0.010
Import	0.081	0.024	3.972	0.010
export	-0.032	0.018	-4.765	0.000
Intercept	0.671	0.578	1.657	0.345
Smooth	Components Edf	Approximate Ref. df	Significance Chi-square	
S(GDP)	7.342	7.887	408.28	$< 2e-13$
S(Year)	6.892	7.504	22.67	0.00531

The results in Table 5 of the estimated copula equation show that electricity consumption, urban population, labor force, and import significantly impact the copula parameter. In contrast, export negatively affects the dependence between FDI and CO2 emissions. In other words, if the predictor for a given country is initially negative, an increase in export leads to an even stronger negative relationship. In contrast, if the predictor is initially positive, an increase in export leads to a weaker positive relation and can produce a negative or decoupling scenario. Positive and negative effects must be positioned about the initial predictor and might simultaneously reflect strengthening and weakening effects.

It is evident that the degree of reliance/dependence varies across different GDP level. A spline assesses the nonparametric effects of the GDP and year's effects on the connection between carbon emissions and foreign direct investment. According to the results in Table 5, the spline shows a statistically significant nonlinear relationship between dependency and GDP per capita. In contrast, the year effect's spline does not significantly change during the period, indicating that year effects are not changing the dependence.

4.3 Relationship between FDI and CO_2 Emissions Results

The contour plots in Figure 5 show how FDI and carbon dioxide emissions in East Africa relate to one another. The Figure 5 contour plot illustrates the distribution of data points in a two-dimensional space, with the x-axis standing for foreign direct investment and the y-axis for carbon emissions. The image reveals that the lower left corner of the plot has a relatively large density of data points, showing that there are numerous nations with low levels of both FDI and carbon emissions. The number of data points drops in the upper right quadrant of the plot, showing fewer nations with high levels of FDI and carbon emissions. This indicates a cluster of observations where countries may have low carbon emissions and attract higher levels of foreign direct investment. On the other hand, the drop in the number of data points in the upper right quadrant of the plot suggests a sparser concentration of observations. This suggests that there are fewer cases in which countries simultaneously exhibit both high carbon emissions and high levels of FDI. Considering all these observations collectively, they align with the negative association between carbon emissions and FDI.. The contour plot provides evidence that, generally, as carbon emissions increase, the level of FDI tends to decrease, and areas of high carbon emissions and high FDI are less common. In other words, countries with high foreign direct investment are less likely to have high carbon emission levels. Figure 5 demonstrates a correlation, not a cause-and-effect relationship. Thus, this interpretation should be used with caution. To establish causation, additional investigation is required.

Figure 5 shows a weak negative association between carbon emissions and foreign direct investment (FDI), with Kendall's tau value of -0.09. If the value were 1, it would mean that the Relationship between FDI and carbon emissions was perfectly negative, meaning that as FDI rises, emissions fall and vice versa. The association between FDI and carbon emissions is weak, with Kendall's tau value of -0.09, although a tiny trend exists for emissions to fall as FDI rises. The contour plot reveals a concentration of observations at low carbon emission levels and high FDI levels, supporting the weak negative connection Kendall's tau value suggested.

Higher levels of FDI and carbon emissions have also been observed, which raises the possibility that there may be more complexity in the link between these two factors. Generally, the contour plot and Kendall's tau value collectively indicate that there may be an association between carbon emissions and FDI; however, it is not very strong and may be influenced by other variables not considered in the analysis.

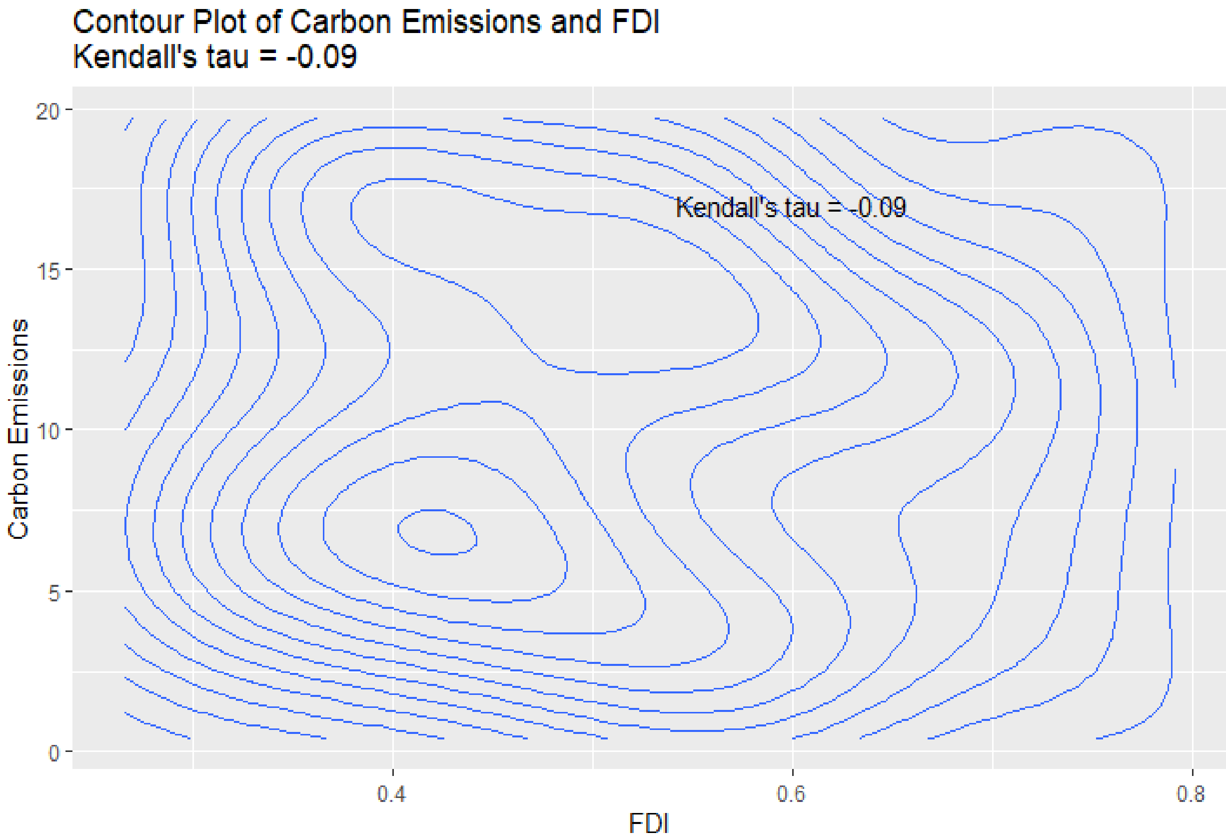


Figure 5: Contour Plot for FDI and CO_2 emissions in East Africa

4.4 Further Analysis and Discussion

The findings in Figure 5 demonstrate a correlation, not a cause-and-effect relationship. Thus, further analysis was conducted to examine the influence channels of FDI inflows on carbon dioxide emissions by investigating the moderating effect of economic growth. To achieve this objective, the study utilized the feasible generalized least square (FGLS) method. The economic growth moderated regression findings are shown in models one to three of Table 6. The results in all three models indicate that coefficients of FDI inflows are negative and statistically significant at a 1% significance level. This means that increased FDI inflows reduce carbon emissions in East Africa. This is because when developed nations make foreign investments into the host country, their modern environmental management technology and environmental degradation measure system flow over, potentially raising the host nation's environmental quality level to flexible degrees. The results confirm the "Pollution halo" hypothesis, which states that FDI benefits environmental protection.

Furthermore, this finding is consistent with the results of Ahmad et al. (2021) and Liu et al. (2017), who also discovered that FDI was the decreasing function of CO2 emissions in China. Similarly, sociologist Mejia, (2022) findings from fixed effects panel regression models indicate that inward FDI stocks in all economic sectors exert a beneficial influence on carbon dioxide emissions per capita in analyses of developed countries, developing countries, and in a global sample of countries. These results are inconsistent with the results of Jorgenson et al. (2007) and Huang et al. (2022) in the group of the 20 countries (G20). Overall analyses of Jorgenson et al. (2007) support the Eco structural theory of foreign investment dependence and underscore the sociological relevance in considering the environmental impacts of the transnational organization of production and the overall scale of production. The GDP (economic growth) variable is included in Model 2. The findings demonstrate that Esat Africa's carbon emissions increase with economic expansion. The results do not support the Environmental Kuznets Curve (EKC) hypothesis. The interacting term of economic growth and FDI inflows (GDP*FDI) is included in the model (3) in addition to the model's specification (2). The findings imply that the interaction term's coefficient is markedly negative, which suggests that economic expansion lessens the effects of FDI inflows on carbon emissions. The results show an inverted U-shaped relationship between income and environmental pollution, which differs from the relationship between economic growth and carbon dioxide emissions. This implies that if a nation achieves strong economic growth, it will focus more on sustainable and green development, bringing in green FDI and reducing carbon dioxide emissions.

In models (1), (2), and (3) of Table 6, all control variables are incorporated. The country dummies are included in all estimations because the East African nations differ significantly. Models (1) and (3) do not include the year dummies. This study uses year dummies to remove estimation bias in the model (2) estimations. The estimation findings show that the coefficients of the exports of commodities and services are notably negative, which suggests that a nation's carbon dioxide emissions decrease as it increases its exports. Melitz, (2003) argues that countries with higher productivity and technology levels can export more commodities and compete globally. The findings show a statistically significant positive association between carbon dioxide emissions and imports, which aligns with the study of Ali et al. (2021). It is important to note that the net effect on emissions will depend on various factors, such as the types of imported goods, the distance travelled, and the energy sources used in production and transportation.

Furthermore, the findings show that the coefficient of electricity consumption is positive to increase CO2 emissions. This conclusion is backed up by the fact that most of the electricity utilized in these countries is generated from non-renewable resources like natural gas, coal, and oil. Previous research has demonstrated that using non-renewable energy causes air pollution and contributes to environmental degradation because of the significant CO2 emissions.

Similar to the impact of electricity consumption on carbon dioxide emissions, the results indicate a statistically significant positive nexus labor force and urban population specific to carbon dioxide emissions.

This finding aligns with Chen et al. (2021), who proposed that an increase in population results in higher energy consumption, consequently leading to increased carbon dioxide emissions.

Table 6: Results of the moderating effects of the economic growth

Variable (s)	Model (1)	Model (2)	Model (3)
FDI	-0.0028	-0.00021	-0.0031
	(0.0000)	(0.0000)	(0.0000)
GDP		0.0270	0.0451
		(0.0201)	(0.0310)
GDP*FDI			-0.0342
			(0.0281)
Electricity consumption	0.0018	0.0017	0.00161
	(0.0000)	(0.0000)	(0.0000)
Urban Population	0.0231	0.0253	0.0321
	(0.0321)	(0.0201)	(0.0234)
Labor Force	0.0671	0.0719	0.0623
	(0.0000)	(0.0000)	(0.0000)
Export	-0.0067	-0.0073	-0.0070
	(0.0401)	(0.0201)	(0.0202)
Import	0.0491	0.0432	0.0462
	(0.0341)	(0.0320)	(0.0201)
Country Dummy	*YES*	*YES*	*YES*
Year Dummy	*NO*	*YES*	*NO*
Adjusted R-square	0.7531	0.792	0.8621
Probability chi-square	0.000	0.000	0.000

Note: The values in brackets () indicate the probability

4.5 Robustness Check

A comprehensive robustness assessment is conducted to enhance the reliability and objectivity of the estimation results. The first approach involves the use of the least squares dummy variable (LSDV) as an alternative to traditional regression. The second approach re-estimates the model using samples of countries with above-average GDP per capita. This study employs the panel data with the fixed effects (FE) regression method because the feasible generalized least squares (FGLS) technique is applicable only for balanced panel data. The findings of these initial two approaches, which aim to assess the robustness of the estimates, are presented in Columns (1) and (2) of Table 7, respectively. The results reveal statistically negative coefficients for FDI inflows, and most control variables align with anticipated outcomes.

The dynamic generalized method of moments (GMM) estimation method is also employed in this work to reduce estimation bias brought on by the endogeneity of FDI inflows and carbon emissions. For this analysis, the dependent variable of FDI inflows' first- and second-order lag terms are entered in Column (3). The Arellano-Bond test determines whether the GMM estimator is reliable, and the null hypothesis is that the error term does not exhibit second-order autocorrelation. The findings indicate a Z-statistic of 1.871 and a p-value of 0.3091, implying that the null hypothesis cannot be statistically rejected. Hence, the GMM estimator used in this study is considered reliable.

Additionally, a Sargan test is performed in this study to determine if there are too many instrumental variables. The null hypothesis of the Sargan test is that the instrumental variables are suitable. The findings show that the null hypothesis cannot be rejected because the Chi-square is 932.1002 and the p-value is 0.2100. Moreover, the difference in GMM is used in this study, and the results are reported in Column 3 of Table 7. The findings demonstrate that FDI inflows continue to have a negative impact on carbon emissions, and the majority of the control variables continue to have their initial indications. Thus, the robustness check's results continue to support the study findings.

Table 7: Results of the robustness check

Variable (s)	(1)	(2)	(3)
L.CO_2 emissions			0.0732
			(0.0002)
L2.CO_2 emissions			0.2302
			(0.7102)
FDI	-0.0531	-0.0421	-0.0348
	(0.0032)	(0.0030)	(0.0031)
GDP	0.2380	0.2201	0.5630
	(0.0291)	(0.0201)	(0.0301)
E. Consumption	0.0353	0.0182	0.2891
	(0.0000)	(0.0001)	(0.0000)
Urban population	0.0071	0.2301	0.9045
	(0.0120)	(0.0145)	(0.0301)
Labor force	0.2017	0.4201	0.0482
	(0.0000)	(0.0002)	(0.8211)
Export	-0.1067	-0.4081	-0.4981
	(0.0301)	(0.0321)	(0.0409)

Import	0.0023	0.0381	0.8921
	(0.0291)	(0.0100)	(0.6801)
Country dummy	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Adjusted R-square	0.8710	0.7920	
Probability chi-square			0.0000

Notes; The values in brackets () indicate the probability. The panel data techniques using the FE and LSDV regression are used in Columns (1) and (2), respectively. The dynamic GMM estimation is applied in Column (3).

5. Conclusion and Policy Recommendations

5.1 Conclusion

The study examined the dependence between foreign direct investment (FDI) and carbon dioxide (CO2) emissions in East Africa. In this study, panel data of the six East African countries from 1989 to 2020 are utilized to investigate the dependence of FDI inflows on carbon emissions. This study uses the bivariate distributional copula regression technique to provide more reliable and precise estimates and discovers a negative dependence between the two variables. The findings indicate that a rise in FDI is linked to a reduction in CO2 emissions, suggesting that FDI can promote cleaner and more effective technologies to support sustainable development in the region. The moderating channels of economic growth are simultaneously investigated using the practicable sgeneralized least square (FGLS) approach. The result suggested that Esat Africa's carbon emissions increase with economic expansion. The interacting term of economic growth and FDI inflows (GDP*FDI) suggests that economic expansion lessens the effects of FDI inflows on carbon emissions. The findings highlight the value of promoting and offering incentives for investments sprioritising environmental sustainability, such as renewable energy and energy-efficient infrastructure. Decision-makers can use these results to create policies and actions that support sustainable FDI in East Africa and improve the economic and environmental performance of the region. Additional studies are required to comprehend the underlying causes of this negative dependency and to evaluate the efficacy of policy initiatives in fostering sustainable FDI and lowering CO2 emissions in the region.

Enhancing the model's precision can also involve accounting for dependencies along development trajectories, such as through the use of cointegrating relations. In order to achieve this, the current copula modelling paradigm needs to be theoretically expanded. An intriguing variation of the economic model involves evaluating alternative techniques for controlling environmental pollution. Due to the more immediate impact of the outcomes, countries might find it easier to be persuaded to prioritize the reduction of emission factors like methane (CH4), nitrous oxide (N2O), and industrial gases. This study predicts similar dependence patterns for these alternative measures. To facilitate the transition towards a sustainable future, it becomes imperative to simultaneously address both the social and environmental dimensions while considering their intricate interrelationship.

5.2 Policy Recommendations

Based on the analysis's finding that there is a negative correlation between FDI and carbon emissions, a policy recommendation might emphasize the promotion of environmentally friendly and sustainable business practices to increase FDI. The Green Investment Incentives (GII) rules, which provide rewards and incentives to businesses using sustainable practices, should be implemented. This could include tax breaks, grants, or subsidies for investments in renewable energy, energy efficiency, or carbon-neutral technologies. Countries can entice environmentally conscientious overseas investors by promoting and rewarding green investments. Additionally, countries should tighten environmental regulations to guarantee adherence to global norms and advance sustainable development. A nation can attract ethical foreign investment by demonstrating its commitment to decreasing carbon emissions and environmental damage through stringent laws and monitoring mechanisms.

East African nations should also create policies that promote active involvement in global initiatives and climate change agreements like the Paris Agreement. Countries can improve their reputation as environmentally responsible investment destinations and potentially draw additional FDI by showcasing a commitment to global climate action. Making policy recommendations requires considering each nation's unique circumstances and objectives. Therefore, conducting cost-benefit evaluations, consulting with pertinent stakeholders, and taking into account any potential unintended repercussions of policies are crucial elements in the formulation of policies.

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