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## Article

Impact of foreign direct investment on carbon emission in Sub-Saharan Africa: The mediating and moderating roles of industrialization and trade openness

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## ACCOUNTING, CORPORATE GOVERNANCE & BUSINESS ETHICS | RESEARCH ARTICLE

# Impact of foreign direct investment on carbon emission in Sub-Saharan Africa: The mediating and moderating roles of industrialization and trade openness

Joseph Owusu Amoah<sup>1\*</sup>, Imhotep Paul Alagidede<sup>1,2</sup> and Yakubu Awudu Sare<sup>1</sup>

**Abstract:** Over the years, Sub-Saharan Africa (SSA) has become the pollution haven for most industrious companies around the globe due to foreign direct investment (FDI) activities. As a result, policymakers and researchers are striving to implement policies to guide the conduct of FDI since ineffective policies and strategies on FDI will increase carbon emissions in SSA. Also, integrating the mediating and moderating roles of industrialization and trade openness is yet to receive significant research attention in developing economies like SSA. Hence, this current study fills the gap in the literature and provides novel insight into FDI and carbon emissions. Taking into account the mediating and moderating roles of industrialization and trade openness. The study employed panel data comprising 30 countries in SSA from 2000 to 2022, which was used for the empirical investigation. The study utilized the common correlated effects mean group as the primary estimator and the augmented mean group as the robustness estimator. The findings affirm the need for the government in SSA to strengthen policies governing FDI to reduce carbon emission since FDI inflows positively affect carbon emission, while FDI outflows negatively affect carbon emission. Also, the mediating role results affirm the need for government restructuring policies governing industrialization to reduce carbon emissions in SSA. Lastly, the moderating findings demonstrate the need for effective policies on trade openness to reduce carbon emissions.

**Subjects:** Environmental Economics; Finance; Business, Management and Accounting;

**Keywords:** foreign direct investment; carbon emission; Sub-Saharan Africa; industrialization; urbanization and trade openness

### 1. Introduction

Over decades, countries in Sub-Saharan Africa (SSA) remained significantly developing due to growth in foreign direct investment (FDI) and industrialization, which have caused economies of scale in SSA (Nketiah-Amponsah & Sarpong, 2020). Studies claim that a country's economic development is determined by external and internal factors, including FDI, industrialization, and international trade (Ostic et al., 2022). Thus, foreign direct investment and industrialization foster

economic sustainability by accumulating wealth, technical progress, and advancement from aggregating and deploying funds, industrial progress, and stimulating investment. It is claimed that FDI has a significant role in enhancing the macroeconomic situation of the host nation, increasing innovation, and improving the business environment (Agyemang et al., 2023).

According to Nyead (2023), foreign direct investment and industrialization have advanced quickly due to economic integration, expansion, globalization, international commerce, and trade openness. Thus, trade openness has significantly benefited from international investments after the turn of the twenty-first century. Thus, trade openness is essential for economies to become industrialized and aid in transferring technology between advanced and emerging nations (Kongkuah et al., 2021). Notwithstanding the numerous benefits of FDI and industrialization on economies in SSA, it has also increased the aggregation of carbon emissions in SSA.

Foreign direct investment and carbon emissions have been hot study topics in developed and developing economies. This is due to the increase in carbon emissions in most countries due to a rise in FDI. Various research has been conducted on the effects of FDI on carbon emission but their results still need to be clarified due to contradictions in their findings (Agyeman et al., 2022; Amuakwa-Mensah & Adom, 2017; Hishan et al., 2019). Also, studies have not considered the moderating and mediating role of trade openness and industrialization in their empirical model. This calls for further studies taking into account the most recent data. Hence, this study fills the gap in the literature on FDI and carbon emissions by considering the mediating and moderating roles of industrialization and trade openness.

Based on the existing literature gap, the study aims (1) To examine the effects of FDI inflows on carbon emission in SSA. (2) To examine the effect of FDI outflows on carbon emission. (3) To assess the mediating role of industrialization on FDI and carbon emission in SSA. (4) To establish the moderating role of trade openness on FDI and carbon emission in SSA.

In terms of innovation and motivation, this study disparity from prior studies and offers novel insights into FDI, industrialization, and carbon emission in several ways. Firstly, in contrast to prior research that concentrated on the direct impact of FDI and carbon emission, this study provides empirical insight and novelty on the influence of the moderating and mediating roles of trade openness and industrialization. Trade openness shows the tendency of trade liberalization of a country. As such, more open countries are likely to get more FDI inflows. Hence, considering the moderating role of trade openness in this study offers new insight compared to the direct relationship most earlier studies have focused on. Also, industrialization must be included in the empirical models of earlier studies. However, industrialization is vital for foreign stakeholders to capitalize in a country. Hence, in this study, we added industrialization as a mediating variable that has yet to be used in previous studies. Therefore, trade openness and industrialization indicating the fundamentals of a country's development were used as moderating and mediating variables, respectively, to examine the effects on FDI and carbon emission, which provides a novel insight and motivates the applicability of the empirical results in SSA countries as compared to prior studies that concentrated on the direct impact.

Regarding methodological innovation, prior studies used only foreign direct investment inflows as a proxy for FDI, which was one-sided. Using this proxy implies that FDI solely depends on its inflows. Arguably, FDI inflows as a measure of FDI are challenging and one-sided, raising much doubt about the applicability of their results in SSA countries. Consequently, this research employed two proxies to measure FDI: foreign direct investment inflows and outflows.

Additionally, the studies employed a relatively large sample size and comprehensive control variable for FDI, industrialization, and carbon emission nexus. The study employed a large sample size of 30 countries in SSA for an extended period of 22 years, which was used in the empirical analysis compared to earlier studies that used relatively small sizes and very few years in their

research. The study also employed seven (7) comprehensive control variables, making innovation and motivating the applicability of the empirical results.

Lastly, contrary to prior studies, this study employed more reliability and robustness tests to guarantee that the results are reliable and can be relied on for policy implications. Some of the earlier studies should have considered issues like cross-sectional dependency in their data and the stationarity of the data. The studies used some estimators without considering the challenges of these estimators. To ensure the validity of the findings, this study performed several reliability and robustness tests. This makes the existing research innovative and different from most prior research. Hence, this study examines the effects of FDI on carbon emission in SSA, considering the mediating and moderating role of industrialization and carbon emission.

To achieve the research aims, secondary data was extracted from the World Development Indicators (WDI) database from 2000 to 2021 for the empirical examination. Thirty countries with complete and available data were chosen out of the 50 countries in SSA. The study employed CCEMG and AMG for the empirical investigation. Stata version 17 was used for the empirical examination. The findings call for strengthening, restructuring, and enforcing FDI policies, industrialization regulations, and trade openness policies to decrease carbon emissions in SSA countries.

The current study seeks to contribute to the literature in several ways: First, the study will enable policymakers to initiate laws, regulations, and policies to decrease carbon emissions in SSA countries. Second, the study will enable countries to make accurate decisions to guide trade openness to control FDI. Thirdly, since SSA is a developing region, the study will provide empirical evidence to support policymakers and authorities in improving FDI to control carbon emissions. The study contributes significantly to the academic debate on foreign direct investment and carbon emissions.

The remaining part of the paper is divided as follows. The second part reviews the literature, the third is devoted to methodologies, the fourth section analyzes and discusses the data, and the last is devoted to the conclusion, recommendation, and policy implications.

## 2. Background

Carbon emissions and FDI substantially affect Africa's ability to manage its environment and promote sustainable development. FDI is the term used to describe investments made by foreign entities in domestic businesses or projects to acquire a long-term interest and level of ownership. Conversely, carbon emissions release greenhouse gases into the air, chiefly carbon dioxide (CO<sub>2</sub>) (Agyemang et al., 2023; Jijian et al., 2021). Therefore, a study must investigate the impact of foreign direct investment and carbon emissions in Africa. On the plus side, FDI may provide money, technology, and knowledge that support economic development and growth (Haque & Ntim, 2022). Increased energy consumption, higher living standards, and decreased poverty may all result from this economic expansion. However, owing to increasing industrialization and energy consumption, this expansion may also result in more carbon emissions if it is not effectively controlled (Haque & Ntim, 2020). The energy industry is one of the key industries where FDI significantly affects carbon emissions in Africa. For power production, many African nations, including SSA, significantly depend on fossil fuels, which are a substantial origin of carbon emissions (Nketiah-Amponsah & Sarpong, 2020). Diversifying the energy mix and reducing dependence on carbon-intensive energy sources may be accomplished with foreign investment in renewable energy projects like solar, wind, and hydropower in Africa. Foreign direct investment may help reduce carbon emissions in Africa by encouraging the transfer of clean energy technology and aiding the development of renewable energy infrastructure (Wiredu et al., 2023).

Additionally, Foreign direct investment effects on industrialization and manufacturing may influence carbon emissions (Jijian et al., 2021). Foreign investors in these industries could bring antiquated or ineffective technology that raises emissions (Zhou et al., 2022). Adopting cleaner

technology, increased energy efficiency, and better waste management techniques may all help cut emissions (Agudze & Ibhagui, 2021). Foreign direct investment focused on environmentally friendly sectors and sustainable production methods (Ayamba et al., 2019). This may be accomplished by enforcing and encouraging environmentally responsible behavior among foreign investors through laws and policies.

In conclusion, there are several facets to the association between FDI and African carbon emissions. While foreign direct investment may help with economic development and progress, if improperly handled, it may also result in a rise in carbon emissions. African nations may profit from FDI while reducing its adverse effects on carbon emissions by supporting sustainable investment practices, luring capital to renewable energy projects, and enforcing environmental laws. For Africa to have long-term sustainable growth, economic development, and environmental sustainability must be balanced (Ayamba et al., 2019). Therefore, a study must investigate the relationship between FDI and carbon emissions in the SSA region towards achieving sustainable development.

### 3. Theoretical review

#### 3.1. Theory of political economy

Political economic theory examines the interplay between political and economic factors and their influence on decision-making processes by governments of a country. It recognizes the impact of political factors on economic decisions and analyzes how different economic systems are shaped by political ideologies and institutions. The theory of political economy aims to provide insights into the complex relationship between politics and economics and its societal implications (Zhang et al., 2021).

This theory contends that political variables may significantly affect the course and results of industrialization and FDI, including their potential effects on carbon emissions (Leykun Fisseha, 2023). The direction and level of FDI and industrialization in a nation or area are significantly shaped by political factors such as government policies, restrictions, and incentives. Politics may sometimes prioritize economic development above environmental sustainability, favoring resource-intensive businesses or prioritizing immediate financial rewards (Cheng et al., 2020; Ihsan et al., 2022). Governments may prioritize economic development for various reasons, including job creation, higher tax income, and luring foreign investment. However, focusing on economic growth without proper environmental safeguards may result in more significant carbon emissions (Haque & Ntim, 2020).

The analysis of the effects of FDI and industrialization on carbon emissions is made possible by the political economy theory linkage, which provides a comprehensive framework. A complex interaction of economic variables, political institutions, and policy decisions shapes the link between FDI, industrialization, and environmental effects. Political institutions primarily develop and implement environmental rules and regulations that control industrial operations and carbon emissions (Ayamba et al., 2020). The degree to which FDI and industrialization are managed responsibly and reduced carbon emissions are greatly influenced by the performance of these institutions, such as environmental ministries, regulatory agencies, and enforcement mechanisms (Edziah et al., 2022).

#### 3.2. Theory of environmental sociology

The theory of environmental sociology investigates the social implications of environmental challenges and the relationship between society and the natural environment. The theory asserts that social, economic, and political systems impact the environment (Orazalin et al., 2023). The theory examines the social causes of environmental deterioration and examines the social repercussions of environmental problems, such as social injustice and environmental justice (Jijian et al.,

2021). The theory of environmental sociology seeks to explain how society and the environment interact, directing efforts toward environmentally sound and fairly distributed activities.

Environmental sociology theory investigates the social aspects of environmental issues and how they affect carbon emissions. Modernization and FDI inflows may impact countries' carbon emissions. They suggested that changes in consumer behavior and environmental awareness are the primary causes of these effects. Consumption habits and lifestyles often change when nations undergo economic expansion and modernization aided by FDI. Foreign direct investment may affect introducing new goods and technology, shifting consumer preferences for carbon-intensive items, or increasing energy consumption (Jijian et al., 2021). This can result in increased carbon emissions.

#### 4. Empirical literature review and hypothesis development

Political, economic, and environmental sociology theories offer valuable insights into understanding the effects of FDI and industrialization on carbon emissions. According to Kong et al. (2019), political and economic theory highlights the significance of power dynamics, interests, and institutions in determining economic activity and its environmental effects. Increased carbon emissions are often a result of industrialization and foreign direct investment, which are motivated by economic development and growth objectives. Political and economic theory, on the other hand, stresses that the balance of power and interests among different parties, such as governments, global businesses, and local populations, may influence how industrialization and foreign direct investment will damage the environment (Ayamba et al., 2020; Cheng et al., 2020; Haibo et al., 2020). By looking at political and economic dynamics surrounding FDI and industrialization, researchers and policymakers may better understand the variables causing carbon emissions and create policies that balance economic growth with environmental sustainability.

Also, Environmental sociology theory, which focuses on the social and cultural aspects of environmental issues, supplements this research. It looks at the effect of social elements on environmental practices and results, including norms, values, and behaviors. Environmental sociology theory looks at how social and cultural variables affect carbon emissions in SSA in the context of FDI and industrialization. For instance, adopting environmentally friendly technology and practices in industrial operations may be influenced by cultural attitudes, social conventions, and local community engagement (Haque & Ntim, 2022). Policymakers and academics may create methods that support sustainable industrialization and lower carbon emissions by integrating social and cultural components into environmental policies and considering these social variables.

Ostic et al. (2022) discovered a favorable link between FDI inflows and China's carbon emissions. This was explained by the fact that FDI often entails the formation or growth of industrial operations, which results in higher energy consumption and carbon emissions. Similar findings were made by Odugbesan and Adebayo (2020), who discovered a good link between carbon emissions in Nigeria and FDI inflows. This might be attributed to the fact that FDI inflows often encourage the growth of companies that produce large amounts of carbon dioxide, such as mining and manufacturing. Khan and Ahmad (2021) discovered that long-term FDI inflows lower carbon dioxide emissions.

Similarly, Twum et al. (2022) study showed that FDI inflows in SSA lower carbon emissions. This was further shown by Chen et al. (2023), who argued that FDI inflows had an unfavorable effect on carbon emissions. This was supported by (Nhuong & Quang, 2022), who discovered that FDI inflows positively impacted carbon emissions in Vietnam. The pollution haven theory, which contends that FDI flows to nations with laxer environmental rules, increasing pollution and carbon emissions, is supported by this.

Contrasted (Ssali et al., 2019), could not discover any connection between foreign direct investment inflows and carbon emissions in African nations. This could be because FDI less impacts

environmental laws and policies in these nations or because other variables affect carbon emissions more. Similar findings were made by (Nihayah et al., 2022), which found a negative connection between FDI inflows and CO<sub>2</sub> emissions in Central and Eastern European countries. This might result from these nations having excellent environmental laws and policies to reduce the negative impact of FDI operations on the ecology. Musah et al. (2021) discovered a favorable association between FDI inflows and CO<sub>2</sub> emissions in China supported this further. This might be attributed to China's strict environmental rules and active promotion of cleaner industrial techniques, which may mitigate any possible environmental harm from FDI activity. Ren et al. (2021) discovered that higher carbon emissions result from FDI inflows, leading to environmental deterioration in the area. This was corroborated by (Boamah et al., 2023), who discovered that FDI inflows had a short-term beneficial effect on CO<sub>2</sub> emissions. Similarly (Mujtaba & Jena, 2021), used time series data from 1980 to 2011 to examine the effect of foreign direct investment inflows on carbon emissions in Nigeria. According to the report, Nigeria's carbon emissions rise due to foreign direct investment inflows.

A study by Pan et al. (2023) revealed a link between carbon emissions and FDI outflows. The fundamental reason is that FDI outflows could entail investments in energy production or businesses that emit high carbon emissions in the host nations. The results are similar to that of Joshua et al. (2020), who discovered a favorable correlation between FDI outflows and carbon emissions. It implies that Chinese businesses may invest abroad in sectors with high carbon intensity, which would raise carbon emissions. Additionally, Musah et al. (2021) found a favorable association. Since the host nations' environmental policies are less strict, FDI inflows from developed countries to SSA may include investments in businesses with greater carbon intensity.

In their study by (Pan et al., 2023), they found no evidence of a connection between FDI outflows and carbon emissions. Other variables, such as the country's energy mix and environmental restrictions, may contribute more to carbon emissions than FDI outflows. This was consistent with Hou et al. (2021) results that no meaningful link existed. It implies that FDI outflows lack significant direct influence on regional CO<sub>2</sub> emissions and that FDI's influence on environmental outcomes may depend on the context. Additionally (Nhuong & Quang, 2022), discovered that FDI outflows positively impact carbon emissions in West Africa. According to (Bakhsh et al., 2021), higher carbon emissions are one detrimental effect of FDI outflows from industrialized nations on the environment in SSA. Jan et al. (2023) also find no statistically significant connection. It implies that other variables, like host nation characteristics and environmental legislation, may affect how FDI affects the environment and that FDI outflows may not substantially drive carbon emissions in the area.

Industrialization and carbon emissions were shown to be positively correlated, according to a study by (Jijian et al., 2021). It suggests that more industrialization is associated with higher carbon emissions (Haque & Ntim, 2022). Likewise, the results were made by (Boamah et al., 2023) in their study, which found that industry growth, as determined by industrial value-added, had a substantial favorable effect on carbon dioxide emissions. Bulus and Koc (2021) discovered that economic expansion, often linked to industrialization, was positively connected with carbon emissions in China and provided more support for this.

In contrast, a study by (Chen et al., 2023) revealed that other variables, such as population growth, were more significant than industrialization regarding increasing CO<sub>2</sub> emissions in SSA. Ma et al. (2023) discovered that industrialization in Sub-Saharan Africa did not impact carbon emissions in another study they conducted. They discovered that energy usage and population expansion were the primary causes of CO<sub>2</sub> emissions. According to a study by (Liu et al., 2023), although industrialization reduced CO<sub>2</sub> emissions in certain SSA nations, it increased them in others. It demonstrates how intricately linked regional industrialization and carbon emissions are.

In contrast to the aforementioned discouraging results (Khan & Ahmad, 2021), prove that industrial output and CO2 emissions in SSA have a favorable connection. It implies that more industrialization results in greater energy use and, as a result, more significant CO2 emissions. Li et al. (2020) study confirm that industrialization and CO2 emissions are positively correlated in eastern Africa. It implies that increased energy consumption by industrialization, especially in industries with significant carbon emissions, is a factor.

Jan et al. (2023) assert that trade openness can play a crucial moderating role in shaping the link between FDI and carbon emissions in SSA. Jan et al. (2023) said that increased trade openness could lead to the allocation of cleaner technologies and better environmental practices, allowing SSA countries to attract FDI while reducing their carbon footprint. Additionally, trade openness can help to alleviate potential adverse environmental impacts of FDI by promoting greater accountability and transparency (Chen et al., 2023). Contextual elements, including the degree of institutional quality, technological capabilities, and market structures in SSA countries, might impact these outcomes.

By encouraging the use of green technology and lowering carbon-intensive Industries, trade openness in SSA moderates' industrialization and carbon emissions. With the inclusion of SSA nations in international commerce, there has been a rise in foreign direct investment and economic development, which has sparked industrialization and increased energy consumption. In contrast to other areas, SSA has comparatively low levels of carbon emissions since its industrial sector is undeveloped. SSA nations may acquire more environmentally friendly technology, tools, and inputs via trade openness regulations, which lowers their carbon footprint. A more sustainable and environmentally friendly industrialization process results from SSA industries adopting cleaner production methods and reducing their carbon emissions due to increased competitiveness in global markets (Panait et al., 2022). In order to encourage green industrialization in SSA, trade openness is crucial. As a result of the majority of findings, the study hypotheses predict that;

**H1:** FDI inflows and CO2 emissions in SSA nations are positively correlated.

**H2:** FDI outflows and CO2 emissions in SSA nations are negatively correlated.

**H3:** Industry mediates a favorable link with FDI and CO2 emissions in SSA countries.

**H4:** Urbanization mediates a favorable association with FDI and CO2 emissions in SSA countries.

**H5:** The connection between FDI and CO2 emissions is adversely moderated by trade openness.

**H6:** The link between industrialization and CO2 emissions in SSA nations is favorably moderated by trade openness.

## 5. Research design

The development and growth of industrialization and FDI in both developing and developed economies have caused a surge in CO2 emissions, especially in countries in SSA. As a result, a study must investigate the linkage between industrialization, trade openness, FDI, and carbon emission in SSA countries. Therefore, the study selected countries in SSA for the empirical analysis. The study extracted panel data from 30 SSA nations from 2000 to 2022 from the World Development Indicator database. The study selected these years because of the unavailability of data on some variables employed in the empirical investigation. The data for the study parameters like gross fixed capital formation, energy consumption per capita, and political stability needed to

**Table 1. Population and sampling**

Regions in Sub-Saharan Africa	Countries	Countries Excluded
Southern Africa	South Africa, Lesotho, Botswana, and Namibia	No country was excluded in this region
East Africa	Malawi, Seychelles, United Republic of Tanzania, Burundi, Comoros, Mauritius, Djibouti, Eritrea, Madagascar, Ethiopia, Uganda, Kenya, Mozambique, Rwanda, Zambia, and Zimbabwe, Somalia and Mayotte.	Seychelles, Burundi, Comoros, Mauritius, Djibouti, Eritrea, Somalia, and Mayotte
Central Africa	Democratic Republic Congo, Angola, Chad, Equatorial Guinea, Central African Republic, Gabon, and Cameroon	Democratic Republic Congo, Chad, Equatorial Guinea, and Central African Republic
West Africa	Benin, Ghana, Cabo Verde, Liberia, Mauritania, Gambia, Niger, Guinea, Guinea-Bissau, Mali, Sierra Leone, Cote d'Ivoire, Nigeria, Senegal, Burkina Faso and Togo	Cabo Verde, Mauritania, Guinea-Bissau, and Mali
Total	46	16

be included in some countries in SSA with their years. Due to this, the study considered countries with available and reliable data for the empirical investigation. In effect, out of the 50 countries in SSA, the study selected only 30 of these countries due to data unavailability of some variables employed in the study. Table 1 presents the countries selected and excluded for the study.

### 5.1. Model specification

To examine the effect of FDI on carbon emission in SSA, considering the moderating and mediating roles of trade openness and industrialization, the following multiple linear regression model is formulated:

$$CEM_{it} = \beta_0 + \beta_1 FDII_{it} + \beta_2 FDIO_{it} + \beta_3 IND_{it} + \beta_4 POS_{it} + \beta_5 EXCH_{it} + \beta_6 LFP_{it} + \beta_7 UPOP_{it} + \beta_8 EUSE_{it} + \beta_9 GFCF_{it} + \varepsilon_{it} \quad (1)$$

$$CEM_{it} = \beta_0 + \beta_1 FDII_{it} + \beta_2 FDIO_{it} + \beta_3 URB_{it} + \beta_4 POS_{it} + \beta_5 EXCH_{it} + \beta_6 LFP_{it} + \beta_7 UPOP_{it} + \beta_8 EUSE_{it} + \beta_9 GFCF_{it} + \varepsilon_{it} \quad (2)$$

$$CEM_{it} = \beta_0 + \beta_1 FDII_{it} + \beta_2 FDIO_{it} + \beta_3 IND_{it} + \beta_4 URB_{it} + \beta_5 POS_{it} + \beta_6 EXCH_{it} + \beta_7 LFP_{it} + \beta_8 UPOP_{it} + \beta_9 EUSE_{it} + \beta_{10} GFCF_{it} + \varepsilon_{it} \quad (3)$$

$$CEM_{it} = \beta_0 + \beta_1 (FDII_{it} \times TO_{it}) + \beta_2 (FDIO_{it} \times TO_{it}) + \beta_3 (IND_{it} \times TO_{it}) + \beta_4 POS_{it} + \beta_5 EXCH_{it} + \beta_6 LFP_{it} + \beta_7 UPOP_{it} + \beta_8 EUSE_{it} + \beta_9 GFCF_{it} + \varepsilon_{it} \quad (4)$$

$$CEM_{it} = \beta_0 + \beta_1 (FDII_{it} \times TO_{it}) + \beta_2 (FDIO_{it} \times TO_{it}) + \beta_3 (URB_{it} \times TO_{it}) + \beta_4 POS_{it} + \beta_5 EXCH_{it} + \beta_6 LFP_{it} + \beta_7 UPOP_{it} + \beta_8 EUSE_{it} + \beta_9 GFCF_{it} + \varepsilon_{it} \quad (5)$$

$$CEM_{it} = \beta_0 + \beta_1 (FDII_{it} \times TO_{it}) + \beta_2 (FDIO_{it} \times TO_{it}) + \beta_3 (IND_{it} \times TO_{it}) + \beta_4 (URB_{it} \times TO_{it}) + \beta_5 POS_{it} + \beta_6 EXCH_{it} + \beta_7 LFP_{it} + \beta_8 UPOP_{it} + \beta_9 EUSE_{it} + \beta_{10} GFCF_{it} + \varepsilon_{it} \quad (6)$$

where CEM represents Carbon emission (metrics tons per capita), IND represents industry (such as construction, value-added) (% GDP), URB represents Urbanization (% of urban growth population), FDII represents Foreign Direct Investment Inflow, FDIO represents Foreign Direct Investment Outflow, TO represent Trade openness, POS represent Political stability, EXCH represents Exchange rate, LFP represents Labor force participation, UPOP represents Urban population

growth, EUSE represents Energy consumption per capita, GFCF represents Gross Fixed Capital Formation,  $\varepsilon$  Error term,  $t$  Year, and  $i$  Country.

## 5.2. Study variables

The study used carbon emission as the dependent variable, FDI as the independent variable, industrialization as the mediating variable, trade openness as the moderating variable, and political stability, exchange rate, labor force participation rate, urban population growth, energy consumption per capita, and gross fixed capital formulation as the control variables. The measurement of the variables is presented in Table 2.

## 6. Empirical results and discussion

### 6.1. Cross-sectional dependency test analysis

Panel data may be prone to ubiquitous cross-sectional dependency, in which all the variables in a cross-section are associated. The degree and kind of cross-sectional correlations, among other factors, determine how well cross-sectional dependence may be assessed (Kong et al., 2023; Sare et al., 2023). Neglecting cross-sectional dependence might reduce estimates' precision significantly (Osei et al., 2023). Table 3 presents the results of the Pesaran Cross-Sectional Dependency test for the study.

**Table 2. Summary of variables**

Type of variables	Variables Name	Sign	Description	Expected sign
Dependent	Carbon Emission	CEM	CO2 emissions (metrics tons per capita)	
Independent	Foreign direct investment inflows	FDII	Foreign direct investment, net inflow (% of GDP)	+
	Foreign direct investment outflows	FDIO	Foreign direct investment, net outflows (% of GDP)	-
Mediating	Industrialisation	IND	The ratio of industry (including construction, value added) to percentage of GDP	+
	Urbanization	URB	The percentage of people living in cities beyond a certain minimal limit	+
Moderating	Trade openness	TO	Ratio of exports to imports as a percentage share of GDP	+
Controls	Political stability	POS	Political stability and a lack of terrorism or acts of violence; estimations	-
	Exchange Rate	EXCH	Official exchange rate (LCU per US dollar)	+
	Labor force participation	LFP	Total rate of labour force participation (percentage of persons aged 15 to 64) (ILO model projections)	+
	Urban population growth	UPOP	(% annually) Urban population increase	+
	Energy Consumption	EUSE	Energy use per capita (in kilograms of oil equivalent for each capita)	+
	Gross Fixed Capital Formation	GFCF	Gross Fixed Capital Formation (annual % growth)	-

The results from Table 3 review significant statistical values for all the variables employed in the study, both the dependent, independent, control, and moderating variables. The significance of all the study parameters shows the presence of cross-sectional dependency. As a result, we support the alternative hypothesis of cross-sectional reliance and reject the null hypothesis that there is no cross-sectional dependency in the study variables, which implies that any absolute shockwave of the sampled SSA countries can impact the other countries in SSA.

### 6.2. Stationarity test

Panel data is considered stationary if its statistical characteristics or, more precisely, the process that produces it remains constant throughout levels. Due to the dependence on several practical analytical methods, statistical tests and modeling on stationarity are crucial in determining the level of data before selecting the appropriate estimation techniques needed for the analysis (Agyemang et al., 2023; Wen et al., 2023). Stationarity tests allow the levels of the data for the study. Table 4 presents the CIPS Unit Root stationarity test for the study.

The CIPS Unit Root Test in Table 4 posits that all the parameters are stationary at the level because they recorded values more significant than the critical values of  $-2.3$  for constant and  $-2.81$  for constant and trend excluding EXCH and GFCF, which revealed values less than the critical values at the trend and constant with the trend. Therefore, it was necessary to conduct the first difference to validate if all the parameters would be stationary before selecting the best estimator for the analysis. Due to this, the first difference was conducted, and all the variables were stationary after the test. Hence, we disapprove of the null hypothesis that all the study parameters were stationary at the level and support the alternative hypothesis that the first difference was conducted to make all the variables stationary. It implies that the study parameters were stationary at first difference.

### 6.3. Cointegration test

The cointegration test is run to confirm that the study variables have an ongoing interaction. Without a cointegration test, it is possible to conclude that there is no long-term link among the parameters under study (Osei et al., 2019). In light of this, it is essential to perform the cointegration test to assess the long-term connection among the study parameters. Table 5 presents the Pedroni cointegration test analysis for the study.

The results from Table 5 indicate the Pedroni cointegration test findings for the study, demonstrating the long-term link among the study parameters. The findings affirm probability values less

**Table 3. Pesaran cross-sectional dependency test analysis**

Variables	Pesaran CD Test
CO2	71.99***
FDII	17.90***
FDIO	5.47***
IND	66.73***
URB	63.89***
TO	3.76***
POS	43.96***
EXCH	39.58***
LFP	56.68***
UPOP	44.03***
EUSE	26.00***
GFCF	21.54***

\*\*\*=1%, \*\*=5%, \*=10%.

**Table 4. CIPS Unit Root stationarity test**

Variables	Level		First Difference	
CO2	<b>-6.111</b>	<b>-6.234</b>	<b>-5.561</b>	<b>-5.469</b>
FDII	-4.776	-4.774	-6.101	-6.243
FDIO	-5.312	-5.375	-5.956	-6.110
IND	-5.143	-5.119	-6.055	-6.146
URB	-5.530	-5.777	-6.128	-6.248
TO	-4.469	-4.591	-6.090	-6.236
POS	-4.216	-4.246	-5.852	-5.840
EXCH	-2.044	-2.515	-4.105	-5.322
LFP	-5.266	-5.315	-6.190	-6.417
UPOP	-4.810	-5.026	-5.949	-5.975
EUSE	-3.864	-4.231	-5.583	-5.536
GFCF	-1.191	-2.211	-4.876	-5.950

than 1%, which is a 1% significant level to the statistics values for all the tests performed. Since the statistical values were significant at all the tests performed, it implies a long-term link exists between the parameters under consideration. Consequently, we support the alternative hypothesis of cointegration and disapprove of the null hypothesis of cointegration. It affirms a continuous relationship between the factors considered in the integrated assessment.

#### 6.4. Estimation techniques

To avoid the discrepancies in the regression results brought on by using a lousy estimate approach, the author used the CCEMG and AMG estimators. The examination is carried out by the CCEMG and AMG estimators, who closely examine the parameters' cointegration and susceptibility to contingent stationarity (Zhou et al., 2022). A further benefit is that the CCEMG estimator using panels accommodates heterogeneous slant coefficients (Osei et al., 2023). These estimators have the advantage of evaluating least-squares logical advantageous reversion when empirically plausible regressors are added, in addition to accounting for the clear implications of the cross-segment for the econometric approach and the valuable regressors that act as spares for the variables. All potential endogeneity issues were considered using the estimators (Osei et al., 2023). The AMG estimator is nonetheless used to evaluate the robustness of the study parameters in the different models. The study employed Equation 1 to 3 from Model 1 to 3 for the direct and mediating relationship between the variables. Table 6 presents the estimation techniques.

The AMG estimator is nonetheless used to evaluate the robustness of the study parameters in the different models. The study employed Eq. 1 to 3 from Model 1 to 3 for the direct and mediating relationship between the variables. Table 6 presents the estimation techniques.

The findings in the estimation techniques in Table 6 for the link between FDI, industrialization, and CO2 emission show Wald Chi2 values of 584.52, 645.32, and 1452.74 for models 1, 2, and 3, indicating that the variables and methods are statistically appropriate for the empirical analysis. It implies that the estimators employed to examine the relationship concerning the two types of

**Table 5. Cointegration Pedroni cointegration test**

Test	Statistics	P-value
Modifies Phillips-Perron t	8.4821	.0000
Phillips-Perron t	-20.3827	.0000
Augmented Dickey-Fuller t	-10.6939	.0000

**Table 6. Estimation techniques**

Variables	MODEL 1		MODEL 2		MODEL 3	
	R1	R2	R1	R2	R1	R2
LNFDII	0.0443***	0.2557**	0.1202***	0.1178***	0.2199***	0.1533***
LNFDIO	−0.0103**	−0.0978**	−0.0395***	−0.0437**	−0.0123**	−0.0197**
LNIND	0.5930***	0.7421***			0.8758***	0.3933***
LNURB			1.0801**	1.1230**	1.0620**	1.2560***
LNPOS	0.0962***	−0.1522**	−0.0782**	0.3092**	0.1714***	0.6381**
LNEXCH	0.0471	0.0744	0.0433**	0.2414**	0.2605*	0.2595**
LNLFP	1.6640*	3.4020*	3.1150	3.1291	0.3959**	2.8710**
LNUIPOP	−0.6772***	−0.3920***	−0.2996**	−0.4077**	−0.4145***	−0.3428***
LNEUSE	−0.0818***	−0.0621***	−0.0560**	−0.0523*	−0.0271***	−0.1253***
LNGFCF	0.0062***	0.0478**	0.0308	0.0629	0.0452**	0.0155***
Sargent Test/ Wald chi2	45.21	584.52	30.21	645.32	78.64	1452.74
AR (2) Test/ Prob > chi2	0.542	0.0000	0.651	0.0000	0.784	0.0000
Obs.	660	660	660	660	660	660

\*\*\*=1%, \*\*=5%, \*=10%.

variables in the study are reliable for the applicability of the result. Moreover, the high AR (2) values of 0.651, 0.542, and 0.784 for models 1, 2, and 3 affirm the occurrence of a significant variation in how the dependent and independent parameters relate to the study. Furthermore, the findings of the Sargent test and the p-values show the reliability, accuracy, and effectiveness of the results for the empirical analysis, which can apply to the countries in SSA, governments, and investors. As a result, the approach appropriately captures a more significant share of the variety of impacts that the different independent parameters exert on the dependent variable. Therefore, the estimators employed for the empirical analysis adequately represent examining the link between the dependent and independent parameters and their impacts.

Regarding the link between FDI inflows and CO2 emission with the mediating role of industrialization (Industry and Urbanization), FDII revealed a positive and statistically significant association with CO2 emission in all the models. The results affirm that a percentage upsurge in FDI inflows will exert an upsurge in CO2 emissions of SSA countries. Also, including the mediating variable of industrialization has increased the FDII and CO2 emission coefficient. It affirms that an upsurge in industries in SSA will increase FDII and carbon emissions of the sampled countries in SSA. Therefore, the hypothesis is accepted since it matches the theoretical underpinning. The results suggested that governments in SSA countries should implement policies to control and monitor industries and FDII to reduce carbon emissions. These government regulations and policies on FDII will help control the operations of foreign investors and companies in SSA, which will reduce CO2 emissions and control the economy in the long term.

However, FDI outflows revealed a negative and statistically significant link with CO2 emission by 0.0103, 0.0395, and 0.0123 percentage points when it was mediated by industrialization (industry and Urbanization). It implies that if the investors in SSA increase their investment in foreign nations, carbon emissions will decrease in SSA countries and contribute to economic growth and development; also, with the inclusion of the mediating role of industrialization, FDIO, and CO2 emission increases. It affirms that industrialization affects FDIO and CO2 emissions. Additionally, employing the models at various levels reveals a negative relation, implying that CO2 emission will decrease if FDIO increases in SSA. Therefore, the hypothesis is accepted since the theoretical assumption was negative. It

suggested that investors in SSA should promote their investment in foreign nations to decrease carbon emissions in SSA countries and boost economic growth and development.

Moreover, the industry as the mediating role posits a positive and statistically significant link with CO<sub>2</sub> emission by 0.5930 and 0.8758 for models 1 and 3. The findings imply that an upsurge in industries in SSA will increase carbon emissions. The increase was statistically significant at 1% for models 1 and 3. The results also imply that a surge in industries will correspond to a percentage increase in FDI and CO<sub>2</sub> emission in SSA since industries positively affect CO<sub>2</sub> emission and FDI. In light of this, the hypothesis is accepted. Hence, it is recommended that strict policies and regulations govern industries in SSA to control FDI inflows, outflows, and carbon emissions in SSA countries, which will boost economic sustainability.

In addition, urbanization as the second mediating role posits a positive and statistically significant link with carbon emissions. It implies that an increase in Urbanization in SSA countries will cause a significant increase in carbon emissions of the sampled companies in SSA. The findings also show that an upsurge in urbanization will increase carbon emissions and FDI since Urbanization mediates CO<sub>2</sub> emission and FDI positively. Therefore, the hypothesis is rejected. Therefore, it is recommended that the government along the scope of SSA should implement and strengthen policies concerning refuse dumping and industrial activities in the urban centers to control SSA countries' carbon emissions.

In regards to the robustness results at (R2) in each model, FDII recorded a positive and statistically significant association with carbon emission by .2557, 0.1178, and 0.1533 for models 1, 2, and 3, respectively, with the mediating role of industrialization. It implies that a percentage upsurge in FDII will result in an upsurge in CO<sub>2</sub> emission of the sampled countries in SSA. Also, an increase in the mediating role of industrialization increases the coefficient of FDII and CO<sub>2</sub> emission of the sample countries in SSA, resulting in a rise in carbon emission. The AMG robustness results agree with the primary estimator's (CCEMG) findings. However, FDIO reveals an adverse and statistically significant link with CO<sub>2</sub> emission, the mediating role of industrialization. It affirms that an upsurge in FDIO will cause a significant reduction in carbon emissions. Therefore, the AMG robustness estimator results follow the CCEMG results. Contrarily, the Industry recorded a positive and significant relationship with carbon emission by 0.7421 and 0.3933 for models 1 and 3. It implies that a percentage upsurge in industries will increase CO<sub>2</sub> emission in the sampled nation in SSA. Also, the results from the CCEMG correspond with that of the robustness results. The mediating role of urbanization reveals a favorable and statistically significant association with CO<sub>2</sub> emission. It affirms that an upsurge in urbanization will increase the SSA's sampled countries' carbon emissions. The results affirm that of the primary estimator CCEMG.

#### **6.5. The moderating role of trade openness on FDI, industrialization, and carbon emission**

The studies introduced a moderating role of trade openness to access the influence on FDI, Industrialization, and CO<sub>2</sub> emission of sampled nations in SSA. The findings of the moderating role determine whether the influence is much stronger than that of the mediating and the direct link among the dependent and independent parameters in this study. In testing the moderating role of trade openness on FDI, Industrialization, and carbon emission, the studies employ CCEMG as the primary estimator at (R1) and AMG as the robustness estimator at (R2). These estimators take into consideration any possible endogeneity problems for the empirical analysis. To access the link between the moderating role of trade openness on FDI, industrialization, and carbon emission. Table 7 presents the moderating role of trade openness on FDI, Industrialization, and carbon emission for Eq. 4 to 6 and for Model 4 to 6.

The findings from the moderating role in Table 7 show that the coefficient of the variables has increased due to the introduction of the moderating role of trade openness in the research. The results reveal that the coefficient of FDII has increased more than that of the direct relationship and is positively affecting carbon emission, which is statistically significant at 1% in all the models.

The results from the moderating role in terms of FDII imply that if trade openness increases, the coefficient of FDII and carbon emission will increase. Also, regarding FDIO, the findings reveal a favorable but statistically insignificant link with CO<sub>2</sub> emission. Hence, the hypothesis is rejected. The link is insignificant because of the total transfer of the resources and assets of SSA countries to other foreign nations, which will not affect CO<sub>2</sub> emissions in the home country. The direct and the mediating links posit a native and statistically significant relationship, but the results of the moderating role demonstrate a positive and insignificant link. The results indicate that trade openness positively influences carbon emissions and increases the FDI and Industrialization coefficient. Therefore, the findings of the moderating role demonstrate that an upsurge in trade openness will raise CO<sub>2</sub> emissions.

Moreover, by introducing the moderating role of trade openness, industry reveals a positive and statistically significant association with CO<sub>2</sub> emission. The result was similar to the direct and mediating role, except that the coefficient of the moderating role is much higher than that of the direct link. It implies that an upsurge in trade openness will cause an immediate increase in industries' coefficient, which will increase CO<sub>2</sub> emission. Additionally, urbanization reveals a positive and statistically significant association with CO<sub>2</sub> emission when moderated with trade openness. Therefore, the hypothesis is accepted based on the assumption. The direct and mediating role reveals a positive relationship, and the moderating role of trade openness also reveals a favorable and statistically significant relationship with CO<sub>2</sub> emissions. It demonstrates that an upsurge in trade openness will increase the coefficient of urbanization, which will increase carbon emissions in SSA. Therefore, if SSA countries open up their trade with other foreign countries and companies, it will cause an upsurge in urbanization, increasing carbon emissions as many people will be employed to work in industries. The results further imply that if Urbanization in SSA countries increases, carbon emissions will also increase when the countries open up their trade to other foreigners or foreign companies through export and import. Therefore, the governments around SSA should implement policies to govern imports and exports as Africa has become the haven of pollution in recent years.

**Tables 7. Moderating role analysis**

Variables	MODEL 4		MODEL 5		MODEL 6	
	CCEMG	AMG	CCEMG	AMG	CCEMG	AMG
	R1	R2	R1	R2	R1	R2
LNFDII	0.6245***	0.5141***	0.7561***	0.6854**	0.7851***	0.6542***
LNFDIO	-0.5812	-0.4875	-0.6321	-0.5481	-0.6845	-0.5214
LNIND	0.4365***	0.3512***			0.5231**	0.5124***
LNURB			0.6751***	0.5462**	0.6482**	0.5942***
LNPOS	0.7515***	0.6845**	0.4512***	0.3542*	0.4512**	0.4321**
LNEXCH	0.8542	0.8321	0.3845	0.3215	0.5846	0.5413
LNLFP	2.3150**	2.6521***	3.5120***	2.3651**	3.6354***	0.3642***
LNUPOP	0.7845***	0.6852**	0.5421	0.5124	0.6854**	0.6215**
LNEUSE	0.6821**	0.6142**	0.7512**	0.6542***	0.7452*	0.6921**
LNGFCF	0.7542**	0.6521**	0.6542	0.5423	0.6211**	0.5941*
Sargent Test/ Wald chi2	58.54	530.42	64.12	751.81	81.52	1871.65
AR (2) Test/ Prob > chi2	0.6242	0.0000	0.5481	0.0000	0.7240	0.0000
Obs.	660	660	660	660	660	660

\*\*\*=1%, \*\*=5%, \*=10%.

The robustness results of the moderating role also present that FDII reveals a positive and statistically significant association with CO<sub>2</sub> emission. The positive increase was influenced by the moderating role of trade openness, which increases the coefficient of FDII and, as a result, increases CO<sub>2</sub> emission. The moderating robustness result differs from the direct link, and the mediation role robustness results in that the moderating role has increased the coefficient of FDII and influenced carbon emission to increase. Conversely, FDIO reveals a negative and insignificant link with carbon emission. The negative and insignificant link is due to the outflows of resources in SSA to the outside world. The results differ from the mediating role and the direct link as they recorded a negative but significant relationship.

Regarding industry, the robust results for the moderating role reveal a favorable and statistically significant association with CO<sub>2</sub> emission. The coefficient of the industry has increased than the direct link, which implies that the moderating role has caused a more significant effect on the industry than the direct effect. Also, Urbanization reveals a favorable and statistically significant relationship with CO<sub>2</sub> emissions. The robust results for the moderating role reveal a positive and significant link, while the results from the direct relationship and the mediating role review an adverse and significant link with CO<sub>2</sub> emission. It affirms that trade openness has moderate Urbanization and CO<sub>2</sub> emission positively in the robustness results compared to the direct relation robustness results.

#### **6.6. Granger causality test**

In order to examine the causality among the parameters under consideration, the study utilized the Pairwise Granger Causality Test analysis. The results from Table 8 show bi-direction, uni-directional, and no causality between the study variables. Table 8 demonstrates the Granger causality test analysis findings between the study parameters.

The findings from Table 8 show a combination of bi-directional causality of CEM and FDII, IND and CEM, URB and CEM, IND and FDIO, URB and IND, TO and CEM, TO and FDII, TO and FDIO, TO and IND, and TO and URB. It implies that CEM causes FDII and the reverse, IND causes CEM and the reverse, URB causes CEM and the reverse, IND causes FDIO and the reverse, URB causes IND and the reverse, TO causes CEM and the reverse, TO causes FDII and the reverse, TO causes FDIO and the reverse, TO causes IND and the reverse, TO causes URB and the reverse. The results imply that an upsurge in one parameter will cause a change in the other parameter and the reverse. As a result, the null hypothesis that there is an absence of causality is rejected, and the alternative hypothesis that there is causality is accepted. Moreover, the results for the bi-directional causality show that there is a protracted link between the variables. Accordingly, the results also affirm no causality between FDIO and FDII and FDIO and CEM. It implies that FDIO does not cause FDII and the reverse, and FDIO does not cause CEM and the reverse. The findings affirm that there exists no protracted link between the study parameters.

Finally, uni-directional causality was identified in IND and FDII, URB and FDII, and URB and FDIO. It affirms that IND causes FDII, but FDII does not cause IND, and URB causes FDII, but FDII does not cause URB. Likewise, URB cause FDIO, but FDIO does not cause URB. The opposite is not possible since the causality moves in only one direction.

#### **7. Discussion**

The increase in FDI and industrialization in the world today have caused a corresponding increase in carbon emissions in many countries, including developing and developing economies. Due to this, environmental agencies in nations have stated policies and regulations to govern the conduct and activities of industries, import, export, and FDI to reduce carbon emissions. Furthermore, increased carbon emission results from trade openness brought up by increased international trade in both developing and developed economies. Trade openness has paved the way for businesses and companies to extend their ideas and generations to many countries, which has increased FDI, industrialization, and carbon emission. In effect, countries in SSA have benefited from industrialization and FDI in developing the macroeconomic fundamentals of their states.

**Table 8. Granger causality test**

Null hypothesis	F-Statistics
CEM ≠ FDII	3.5421***
FDII ≠ CEM	24.5134***
FDIO ≠ FDII	31.5423
FDII ≠ FDIO	6.6542
IND ≠ FDII	8.4563***
FDII ≠ IND	21.5423
URB ≠ FDII	32.5124***
FDII ≠ URB	21.5324
FDIO ≠ CEM	34.2651
CEM ≠ FDIO	6.5423
IND ≠ CEM	8.4523***
CEM ≠ IND	34.6521***
URB ≠ CEM	4.5462***
CEM ≠ URB	8.6425***
IND ≠ FDIO	24.5423***
FDIO ≠ IND	31.2431***
URB ≠ FDIO	18.6482***
FDIO ≠ URB	6.5432
URB ≠ IND	8.5642**
IND ≠ URB	4.5642***
TO ≠ CEM	32.5423***
CEM ≠ TO	15.3542***
TO ≠ FDII	28.4752***
FDII ≠ TO	18.6542***
TO ≠ FDIO	25.4523***
FDIO ≠ TO	6.5124***
TO ≠ IND	7.5462***
IND ≠ TO	31.4562***
TO ≠ URB	15.4826***
URB ≠ TO	5.6452***

\*\*\*=1%, \*\*=5%, \*=10%.

Developing countries are aligned with less carbon emission; contrary, due to international trade that has increased industrialization and FDI, developing countries are now striving to reduce their states' carbon emissions. Today most countries in SSA have strengthened their environmental agencies to reduce carbon emissions due to industrialization and trade openness. In order to control carbon emissions in SSA countries, government all around SSA should strengthen their policies on trade openness, industrialization, and FDI.

According to political economy theory, institutional frameworks, domestic political and economic considerations, and domestic and international investors' behavior influence decisions. Higher carbon emissions may result from FDI inflows that prioritize short-term economic gains in nations with lax environmental laws and systems. On the other hand, nations with sound environmental governance and institutions can encourage FDI inflows that are benign to the environment, which will reduce carbon emissions. This emphasizes how crucial domestic policies, institutional strength, and governance frameworks are in determining how FDII affects carbon emissions (Acheampong et al., 2019). Foreign direct investment inflows significantly contribute to higher

carbon emission (Musah et al., 2021). Foreign direct investment inflows consider all foreign investors who invest in other countries for returns. It involves many individuals and companies investing their capital and resources in foreign countries to gain higher returns. A country's development is based on factors that promote and enhance its international trade and significantly constitute gross domestic product (GDP) growth. Foreign direct investment inflows constitute one of the essential contributors to a country's economic growth and development.

The findings affirm that FDII has a favorable and statistically significant link with carbon emission in the sampled countries in SSA. It affirms that a rise in FDII will cause a significant increase in carbon emissions in SSA countries. It further affirms that any increase in the FDII of the sampled countries in SSA will direct a positive increase in carbon emission. Therefore, the hypothesis is accepted. The findings recommend that the government in SSA should strengthen FDII policies to decrease CO<sub>2</sub> emissions in SSA. Based on the estimation techniques results, the hypothesis predicted based on the theoretical underpinning is supported. Our findings are similar to those of (Musah et al., 2021), who found that FDII positively affects CO<sub>2</sub> emissions, underscoring the role of industrial activities and energy consumption.

Similarly, Dong et al. (2019), reveal a favorable and statistically significant link between FDI inflows and CO<sub>2</sub> emission, highlighting the carbon-intensive nature of foreign investment in manufacturing industries. Furthermore, a cross-country analysis by (Edziah et al., 2022) involving a global sample of countries corroborated the positive association between FDI inflows and carbon emissions, particularly in developing economies. Studies such as (Klafke et al., 2018) also support the notion that FDI inflows contribute to increased carbon emissions, reinforcing the importance of addressing the environmental consequences and adopting sustainable practices and technologies.

Secondly, ecological modernization and environmental justice shed light on the social and institutional factors that shape environmental outcomes. The behaviors of multinational firms and the institutional framework of the host country are essential factors in the environmental impact of FDI (Wiredu et al., 2023). Cleaner technology and lower carbon emissions are more likely to be adopted by businesses with better environmental standards and corporate social responsibility policies (Edziah et al., 2022). The degree to which FDI outflows contribute to environmental degradation or sustainable development is also influenced by host nation rules, governance systems, and socioeconomic inequality (Gyamfi, 2022). By emphasizing the significance of environmentally sound practices and equitable, sustainable development pathways, the integration of environmental sociology theory improves our comprehension of the social and institutional dynamics that mediate the effect of FDI outflows on CO<sub>2</sub> emissions (Nyeadi et al., 2020). Foreign direct investment outflows involve all local citizens of a country investing in other foreign countries to gain returns. It contributes significantly to the growth and well-being of the host nations. Many nations worldwide invest in other nations to exploit their natural resources and gain more insight into the trade due to foreign direct investment outflows. From our findings, FDI outflows negatively affect carbon emissions in SSA countries, revealing that an increase in FDI outflows decreases carbon emissions. The hypothesis suggests that FDI outflows have a negative association with carbon emissions, and the findings support this claim, revealing a significant negative association between the two variables. It affirms that countries with higher FDI outflows tend to have lower carbon emissions, presenting an opportunity to leverage FDI as a catalyst for environmentally sustainable practices. Our results are similar to the findings of (Jijian et al., 2021), who identify a negative link between FDIO and CO<sub>2</sub> emission. Similarly, Gyamfi (2022) also discovered a negative association between FDIO and carbon emission.

Higher levels of FDI inflows tend to be associated with technological breakthroughs, knowledge spillovers, and access to international markets as countries participate in economic integration and draw FDI (Acheampong et al., 2019). Lower carbon emissions are produced due to the creation of more sophisticated and effective production processes (Haque & Ntim, 2020). The mediating role of industry emphasizes the significance of sector-specific considerations and policies in achieving

sustainable development goals and exploiting the environmental benefits of FDI. The industry as a measure of industrialization emphasizes how a country grows through enhanced development of its industrial sector and enhanced national economic growth. The growth of a nation's FDI depends on the degree of industries and the contribution the industries make towards the growth and development of the economy. The findings affirm that industry has a favorable relationship with FDI inflows, outflows, and carbon emissions of countries in SSA. It implies that including industry as the mediating variable will positively increase the FDI and carbon emission coefficient. The results further suggest that to decrease carbon emissions and promote industrialization, governments around SSA countries should strengthen and formulate policies and programs governing industries to reduce carbon emissions. It implies that industrialization performs a strong economic impact on shaping the environmental needs of FDI and carbon emissions. Countries experiencing higher levels of industrialization tend to exhibit a more favorable association between FDI and a rise in CO<sub>2</sub> emissions. Based on the findings, the theoretical underpinning is accepted.

Neoclassical Theory holds that FDI input into the industrial sector generates job possibilities, increasing economic activity and production. As a result, if firms adopt more efficient technology and procedures, this could reduce the intensity of carbon emissions per unit of output. By creating jobs, FDI can boost economic expansion, causing a structural shift toward greener industries and reducing CO<sub>2</sub> emissions. The capacity of FDI to support sustainable development by fostering economic growth and lowering CO<sub>2</sub> emissions in the industrial sector is highlighted by employment's mediating function in this process. Urbanization determines the volume of FDI and the level of carbon emission that will be generated. The findings reveal an intriguing association between FDI, industrialization, and CO<sub>2</sub> emissions. Based on the study results, the theoretical assumptions are rejected. Specifically, Urbanization positively mediates the association between FDI and carbon emissions. It implies that increasing Urbanization in SSA countries while stimulating FDI, industrialization, and economic growth will contribute to a significant upsurge in CO<sub>2</sub> emissions of the sampled SSA countries. The findings further claim that Urbanization mediates the coefficient of FDI and carbon emission to increase. Therefore, the theoretical underpinning is rejected.

Also, drawing on the philosophy of environmental governance, good environmental governance can influence the results of FDI and trade activities, resulting in more sustainable development outcomes. This includes strict rules, institutional capacity, and stakeholder involvement. Trade openness serves as a stimulus for transferring environmentally beneficial technologies, adopting cleaner manufacturing methods, and cross-border cooperation on environmental norms in the context of FDI and carbon emissions. Governments can use trade openness to temper the environmental implications of FDI, promoting sustainable economic growth and lowering CO<sub>2</sub> emissions by embedding environmental governance concepts into policy frameworks. Based on the above theoretical underpinning, we hypothesized that trade openness positively moderates the linkage between FDI, industrialization, and CO<sub>2</sub> emissions. The findings of this study demonstrate that trade openness plays a favorable moderating role in the association between FDI and carbon emissions. This implies that SSA nations with a higher degree of trade openness experience a more extraordinarily pronounced upsurge in CO<sub>2</sub> emissions due to FDI inflows. The association between FDI and trade openness creates a synergistic impact that facilitates the adoption of cleaner technologies, knowledge transfer, and more sustainable production processes. The favorable moderating role of trade openness suggests that countries embracing international trade and investment integration are better positioned to harness the environmental benefits of FDI. Therefore, our hypothesis is accepted since it aligns with our findings. Thus, foreign multinational companies were more likely to adopt cleaner and more efficient technology in countries with open trade policies. Similarly, a study by (Voumik et al., 2023) found that trade openness positively moderated the link between FDII and environmental performance.

## 8. Summary and conclusion

In recent decades, there has been a growth in worldwide awareness regarding environmental concerns such as climate change and the pollution caused by carbon emissions. To keep up with the speed of the contemporary world, FDI and industrialization have become essential aspects of

economic growth and development. However, this trend would only be ecologically sustainable if the growing demand for industrialization and FDI could be satisfied without harming the environment. Hence, this study examines the effect of FDI on CO<sub>2</sub> emission, considering the moderating and mediating role of industrialization and trade openness in SSA.

Secondary data was extracted from the World Development Indicator database for the countries in SSA, which was used for the empirical investigation. Due to data unavailability, the authors considered the years from 2000 to 2022 for the empirical examination. The study also utilized stepwise regression using CCEMG and AMG estimators for the analysis. According to the FDI and carbon emission results, FDI reveals a positive link with CO<sub>2</sub> emission, while FDI outflows reveal an adverse link with carbon emission.

In addition, the mediating role of industrialization measured by Urbanization and Industry reveals a favorable and statistically significant association with FDI and CO<sub>2</sub> emission of countries in SSA. Thus, the advancement of industrialization in SSA will influence FDI and carbon emissions to rise. The results indicate that the development of industrialization in SSA countries will cause FDI and CO<sub>2</sub> emissions to increase. Similarly, the moderating role of trade openness revealed a positive association between FDI and CO<sub>2</sub> emissions, affirming that increased trade openness will increase FDI and carbon emissions in SSA countries.

According to the findings, it is recommended that governments in SSA countries should strengthen and restructure policies and programs governing FDI, industrialization, and trade openness systems in order to reduce carbon emissions. Moreover, policies must govern the exploitation of resources to control FDI inflow and carbon emissions. Additionally, industries in SSA must have uniform rules and regulations governing their conduct and activities to control carbon emissions. Lastly, it is suggested that although trade openness promotes economic growth, strict control measures must govern the importing and exporting of goods and services to control FDI and carbon emissions.

### 8.1. Policy implications

A sustainable economic agenda must be considered when nations improve their economic growth, which may be done by conserving the environment. Consequently, this statement has sparked academic discussion on how FDI affects carbon emissions. The results include several pragmatic framework recommendations. To guarantee economic development and ecological security for countries in SSA, enhancing and implementing carbon emission regulations is necessary. This could be done through moving toward environmentally friendly technologies that reduce CO<sub>2</sub> emissions while preserving reasonable economic growth.

Also, governments all around SSA countries should embrace the sustainability agenda by protecting the environment and human life in terms of industrial action and carbon emissions. Industry in SSA countries should impose measures and regulations to control industrial actions to reduce carbon emissions in SSA countries.

Furthermore, rules and regulations governing FDI should be strengthened to control SSA countries' carbon emissions. Governments in SSA countries should implement policies governing FDI inflows, outflows, and carbon emissions. Lastly, policymakers should strengthen trade openness policies in order to control FDI and carbon emissions.

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