The impact of foreign direct investment on carbon emissions:
The interactive role of industrial growth in an international context

تأثير الاستثمار الأجنبي المباشر على انبعاثات الكربون:

الدور التفاعلي للنمو الصناعي في سياق دولي

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Abstract:

This study aimed to analyze the impact of foreign direct investment (FDI) on carbon emissions, with a focus on the interactive role of industrial growth in this relationship. The study relied on panel data covering the period from 2000 to 2023 for a sample of 11 countries: China, Brazil, Egypt, India, South Africa, France, Germany, Indonesia, Mexico, the United Kingdom, and Australia. The econometric analysis was conducted using R, and the Driscoll-Kraay method was applied to correct statistical issues associated with panel data, including heteroskedasticity, autocorrelation, and cross-sectional dependence.

The results showed that FDI positively impacts carbon emissions; however, industrial growth helped mitigate this effect. The study also found that urbanization increased carbon emissions, while trade openness contributed to reducing them. Based on these findings, the study highlights the importance of adopting environmental policies that encourage FDI in sustainable industrial sectors, ensuring a balance between economic development and environmental preservation.

Keywords: Foreign direct investment, carbon emissions, industrial growth, trade openness, urbanization.

ملخص:

هدفت هذه الدراسة إلى تحليل تأثير الاستثمار الأجنبي المباشر (FDI) على انبعاثات الكربون، مع التركيز على الدور التفاعلي للنمو الصناعي في هذه العلاقة. اعتمدت الدراسة على بيانات بانل شملت الفترة من 2000 إلى 2023 لعينة مكونة من 11دولة، وهي الصين، البرازيل، مصر، الهند، جنوب إفريقيا، فرنسا، ألمانيا، إندونيسيا، المكسيك، المملكة المتحدة، وأستراليا. تم إجراء الدراسة القياسية باستخدام برنامج R ، كما تم الاعتماد طريقة Driscoll–Kraay لتصحيح المشاكل الإحصائية المرتبطة ببيانات البانل، وهي عدم تجانس التباين، الارتباط الذاتي، الاعتماد المقطعي.

أظهرت النتائج أن الاستثمار الأجنبي المباشر له تأثير إيجابي على زيادة انبعاثات الكربون، إلا أن النمو الصناعي ساهم في الحد من هذا التأثير، كما توصلت الدراسة إلى أن التحضر زاد من الانبعاثات الكربونية، في حين أن الانفتاح التجاري ساعد في تقليلها، وبالاستناد إلى هذه النتائج تبرز أهمية بتبني سياسات بيئية تشجع الاستثمار الأجنبي المباشر في القطاعات الصناعية المستدامة، بما يحقق التوازن بين التنمية الاقتصادية والحفاظ على البيئة.

الكلمات المفتاحية: الاستثمار الأجنبي المباشر، انبعاثات الكربون، النمو الصناعي، الانفتاح التجاري، التحضر.

JEL Code : F210, Q540, O14, F13, R120.

1. Introduction

In recent decades, foreign direct investment (FDI) flows have increased significantly, driven by economic globalization and financial integration among countries. Many nations, particularly developing ones, seek to attract FDI as a catalyst for economic growth, employment, and technology transfer. However, the environmental impact of these investments remains a subject of debate. Some studies suggest that FDI may lead to environmental degradation by increasing industrial activities and expanding energy-intensive sectors. In contrast, others argue that foreign investments can contribute to environmental improvements by introducing cleaner technologies and fostering innovation in production processes. In this context, it is crucial to examine the relationship between FDI and carbon emissions while considering intermediary factors that may influence this relationship, such as industrialization, trade openness, and urbanization.

Concerns over the environmental impact of industrial activities are growing, as industrialization serves as a key driver of economic growth but may simultaneously contribute to rising carbon emissions. Understanding the role of industrial value-added in shaping the relationship between FDI and carbon emissions can provide deeper insights into whether industrialization amplifies the negative environmental effects of foreign investments or mitigates them through the adoption of more efficient production technologies. Additionally, trade openness and urbanization may have varying impacts on this relationship, necessitating a thorough analysis of these interactions in the context of sustainable development.

1.1. Research Problem

Despite the economic significance of FDI, its environmental impact remains controversial, with empirical findings differing across countries due to structural variations. This study seeks to answer the following key question:

What is the impact of foreign direct investment on carbon emissions, and what role does industrial value-added play in this relationship?

1.2. Research Hypothesis

This study hypothesizes that foreign direct investment leads to an increase in carbon emissions. However, this relationship may be influenced by the level of industrialization. In other words, industrial activities may either exacerbate the negative environmental impact of FDI or mitigate it by adopting more sustainable production technologies.

1.3. Importance of the Study

This study is significant due to the growing need to understand the relationship between FDI and environmental sustainability, especially in light of global commitments to combat climate change. Incorporating industrial value-added into the analysis provides new insights into how economic policies can be optimized to balance foreign investment attraction with environmental protection. Moreover, the findings of this study can help policymakers develop sustainable strategies that promote clean technologies in industrial sectors.

1.4. Research Objectives

This study aims to:

- Analyze the impact of foreign direct investment on carbon emissions in a selected group of countries.

-Examine the mediating role of industrial value-added in the relationship between FDI and carbon emissions.

- Assess the influence of trade openness and urbanization on carbon emissions in the presence of FDI flows.
- Provide policy recommendations based on the findings to promote sustainable development and reduce the negative environmental effects of FDI.

2. Literature Review and Theoretical framework of the study
2.1. Literature Review
2.1.1. Study by Jiang et al. (2025)
Title: The Impact of Small and Medium-Sized Banks on Industrial Enterprises' Pollution Emissions in China During the Period 2000–2014

This study aimed to analyze the impact of small and medium-sized banks on pollution emissions from industrial enterprises in China during the period 2000–2014, using a quasi-natural experiment involving the establishment of urban commercial bank branches in different provinces. The results indicated that the expansion of small and medium-sized banks significantly reduced wastewater and sulfur dioxide emissions from industrial enterprises, with this effect persisting across multiple robustness tests. Further analysis revealed that the impact was more pronounced in small and medium-sized enterprises facing financial constraints and in regions with stricter environmental policies. The study identified the mechanism of impact as increased industrial production, which reduced pollution intensity, and the promotion of green technological innovation, which improved companies' ability to manage pollutants. It also highlighted the role of government intervention in enhancing or modifying this effect. The study recommended supporting small and medium-sized banks in financing environmental innovation and encouraging government policies to promote green growth (Jiang, Wang, Zhao, Li, & Xu, 2025).

2.1.2. Study by Zhao et al. (2025)
Title: The Impact of Inward and Outward Foreign Direct Investment on Carbon Total Factor Productivity in China's Manufacturing Sector (2003–2016)

This study aimed to analyze the impact of both inward (IFDI) and outward (OFDI) foreign direct investment on carbon total factor productivity (CTFP) in China's manufacturing sector, while also examining the role of the science and technology workforce as a moderating factor. The study utilized two-digit sub-industry data from China for the period 2003–2016 and employed a two-way fixed-effects model for econometric analysis. The results showed that bidirectional FDI significantly improved CTFP, with the impact of OFDI being stronger than that of IFDI. Furthermore, the coordination between inward and outward FDI further enhanced the positive effect on CTFP. The study also revealed that the science and technology workforce negatively influenced the relationship between IFDI and CTFP but reinforced the positive impact of OFDI on CTFP. The study recommended strengthening policies that support bidirectional FDI, developing a technologically skilled workforce to drive environmental innovation, and achieving carbon neutrality goals in China (Zhao, Gao, Feng, & Chen, 2024).

2.1.3. Study by Huo et al. (2025)
Title: Analysis of Key Industrial Sectors and Their Evolutionary Trends in China's Embodied Carbon Emissions Network (2010–2020)

This study aimed to analyze the key industrial sectors and their evolutionary trends in China's embodied carbon emissions network between 2010 and 2020. The research employed input-output analysis and social network analysis. The results indicated that the highest emission-intensive sectors were electricity and heating production, petroleum and coal refining, and coal mining and

washing. The study also found that emission flows between industrial sectors required an average of 1.197 intermediary sectors, highlighting strong inter-industry linkages. Additionally, non-ferrous metals, non-metallic mineral products, and metal processing played a crucial role in emissions networks. The patterns of emissions were influenced by technological developments, environmental policies, and market demand changes. The study recommended enhancing technological innovation, improving energy efficiency, and implementing strict policies to achieve China's dual carbon goals (Huo, Yang, Zhou, & Kang, 2025).

2.1.4. Study by Siripi et al. (2024)

Title: The Relationship Between Foreign Direct Investment, Technological Innovation, and Carbon Emissions in Ghana (1980–2021)

This study aimed to analyze the relationship between foreign direct investment (FDI), technological innovation, and carbon emissions in Ghana using the ARDL model for the period 1980–2021. The results showed that while FDI reduced carbon emissions in the short run, it significantly increased them in the long run, supporting the pollution haven hypothesis. The study also found that technological innovation in Ghana led to higher carbon emissions; however, the interaction between FDI and technological innovation contributed to reducing emissions, emphasizing the importance of aligning foreign investments with sustainable technological advancements. Additionally, the study confirmed the Environmental Kuznets Curve (EKC) hypothesis, where emissions increased with economic growth but slowed at higher GDP levels. The study recommended strengthening environmental regulations, expanding the use of clean energy, and supporting sustainable technological innovation to mitigate the environmental impact of economic growth in Ghana (Siripi, Kuuwill, & Tamakloe, 2024).

2.1.5. Study by Shao et al. (2024)

Title: Measuring Carbon Emissions and Responsibility Sharing in Zhejiang's Industrial Sector (2002–2017)

This study aimed to measure carbon emissions and the responsibility for their reduction in the industrial sector of Zhejiang Province, China, during the period 2002–2017, using the input-output method. The results showed an increase in carbon emissions over this period, despite a decline in emission intensity, reflecting improved energy efficiency. The most polluting sectors included electricity and heating production, petroleum and coal processing, and the chemical industry, with the production sector bearing 70% of the responsibility for emission reduction, compared to only 30% for consumption. The study also revealed the phenomenon of "pseudo-low-carbon sectors", which appear environmentally friendly but contribute to emissions transfer through supply chains. It recommended setting clear targets for reducing emissions in major industrial sectors, enhancing technological innovation, improving energy consumption efficiency, and developing strategies to transition heavy industries into green industries. Additionally, it emphasized the need to strengthen cooperation between producers and consumers to ensure a fair distribution of carbon reduction responsibility, supporting China's efforts to achieve carbon neutrality (Shao, Dong, & Huang, 2024)

2.1.6. Study by Kwablah (2023)

Title: The Heterogeneous Impact of Foreign Direct Investment on Carbon Dioxide Emissions in 36 Sub-Saharan African Countries (1990–2016)

This study analyzed the heterogeneous impact of foreign direct investment (FDI) on carbon dioxide emissions in 36 Sub-Saharan African countries during the period 1990–2016, using the

System GMM estimation technique. The results indicated that FDI in the industrial sector increased CO_2 emissions, supporting the pollution haven hypothesis. However, FDI in the agricultural and service sectors reduced emissions. The study also confirmed a U-shaped relationship between agricultural FDI and carbon emissions, whereas the relationship between industrial FDI and emissions followed an inverted U-shaped curve. Meanwhile, FDI in the service sector exhibited a linear negative relationship with emissions. The study recommended assessing the environmental impact of industrial investments before granting licenses and adopting policies that encourage FDI inflows into the agricultural and service sectors to benefit from clean technology transfer (Kwablah, 2023).

2.1.7. Study by Chang et al. (2023)

Title: The Impact of the Digital Economy on Carbon Emission Intensity: The Role of Industrial Structure Upgrading as a Mediating Variable

This study analyzed the impact of the digital economy on carbon emission intensity, focusing on the mediating role of industrial structure upgrading. The research used regional panel data from China covering the period 2010–2019. The results revealed that the digital economy significantly reduces carbon emission intensity, with industrial structure upgrading playing an important mediating role in this relationship. Additionally, the study found that factors such as economic development, market openness, human capital, technological progress, and urbanization contribute to enhancing the positive impact of the digital economy on carbon emission reduction. Moreover, the study identified a spatial spillover effect, meaning that the benefits of the digital economy in reducing emissions extended to neighboring regions. The study recommended strengthening policies that support the digital economy, developing digital infrastructure, encouraging technological innovation, and promoting industrial transformation toward a low-carbon model to achieve sustainable development (Chang, Ding, Zhao, Hou, & Liu, 2023).

2.1.8. Study by Drissi and Dahmani (2022)

Title: The Impact of Green Finance on Carbon Dioxide Emissions Globally During the Period 2007–2019

This study aimed to measure the impact of green finance on global carbon dioxide emissions from 2007 to 2019 using the ARDL model to examine the long-term and short-term relationships between green bond issuance and carbon emissions. The results showed that every $1 billion increase in climate bond issuance led to a 0.005 metric ton reduction in carbon dioxide emissions in the long term. The findings also indicated a significant inverse relationship between green finance and carbon emissions, highlighting its role in mitigating climate change and reducing environmental pollution. The study recommended enhancing green finance policies and increasing investments in environmentally friendly projects to achieve sustainable development (Drissi & Dahmani, 2022).

2.1.9. Study by Rouaba (2021)

Title: Determinants of Carbon Dioxide Emissions in Algeria During the Period 1980–2017: An Application of the ARDL Model

This study aimed to analyze the determinants of carbon dioxide emissions in Algeria from 1980 to 2017 using the ARDL model. The relationship between emissions and economic growth, energy consumption, foreign direct investment, and trade openness was examined. The results showed a long-term relationship between the variables, where economic growth had a weak impact, while energy consumption was the main determinant of emissions. It was also found that foreign direct

investment had a negative impact on emissions, indicating its role in improving environmental quality, whereas trade openness had no significant effect. The study recommended increasing investment in renewable energy, implementing strict policies to control energy consumption, and promoting environmentally friendly investments (Rouaba, 2021).

2.1.10. Study by moustafaui et al. (2021)

Title: The Impact of Foreign Direct Investment on Supporting the Dimensions of Sustainable Development in Algeria During the Period 1995–2019

This study aimed to measure the impact of foreign direct investment (FDI) on supporting the dimensions of sustainable development in Algeria during the period 1995–2019 using the ARDL model. The relationship between FDI and the economic, social, and environmental dimensions was examined. The results indicated no significant long-term relationship between FDI and the economic dimension. However, FDI had a positive impact on the social dimension by reducing the unemployment rate by 0.04% for every 1% increase in FDI.   Additionally, the study found that FDI positively affected the environmental dimension, as a 1% increase in FDI led to a 0.09% reduction in carbon dioxide emissions. The study recommended strengthening investment in non-oil sectors and creating an attractive investment environment to achieve sustainable development (Moustafaui, Tair, & Rimi, 2021).

2.1.11. Study by Saleh and Belfodil (2021)

Title: Testing the Relationship Between Industrial Sector Value-Added Growth and Environmental Degradation in Algeria

This study aimed to test the relationship between the growth of industrial sector value-added and environmental degradation in Algeria, represented by carbon dioxide emissions, using the Vector Autoregressive (VAR) model. The results indicated no long-term cointegration between the two variables, suggesting that the relationship between industrial growth and carbon emissions is unstable. Additionally, causality tests revealed no direct causal relationship between the variables, meaning that industrial sector growth does not necessarily lead to increased emissions, and vice versa. However, the study uncovered a short-term relationship between changes in industrial value-added and environmental degradation, where fluctuations in one variable could temporarily affect the other. The study recommended strengthening environmental policies in the industrial sector by encouraging clean technologies and improving resource use efficiency to ensure sustainable industrial development in Algeria (Saleh & Belfodil, 2021).

2.1.12. Study by Pazienza (2015)

Title: The Relationship Between Foreign Direct Investment in the Agriculture and Fisheries Sectors and Carbon Dioxide Emissions in OECD Countries During the Period 1981–2005

This study aimed to analyze the relationship between foreign direct investment (FDI) in the agriculture and fisheries sectors and carbon dioxide (CO_2) emissions in OECD countries during the period 1981–2005, using panel data analysis. The results revealed a negative relationship between FDI inflows and carbon emissions, where an increase in FDI led to a reduction in emissions. The study also found that the technological effects (-0.0848), scale effects (-0.0036), and cumulative effects (-0.0044) of FDI all had negative impacts on carbon dioxide emissions, indicating a potential positive role of FDI in reducing environmental pollution. However, the study emphasized that this effect remains relatively neutral in magnitude, making it difficult to conclude a strong role for FDI in environmental improvement. The study recommended avoiding restrictive policies on

FDI inflows in this sector, given the absence of significant negative environmental effects (Pazienza, 2015).

2.2. Theoretical framework of the study

2.2.1. Definition of the main variables in the study:

Before defining the main variables in the study, it is essential to identify the variables that will be relied upon in this study based on previous studies. The variables adopted in previous studies can be summarized as shown in Table 1.

Table 1. The variables used in some previous studies

Authors & Year	Dependent Variable	Independent Variables	Control Variables
Jiang et al. (2025)	Industrial pollution emissions (wastewater, sulfur dioxide)	Expansion of small and medium-sized banks	Urban population density, Government intervention, Green technological innovation, Enterprise productivity
Zhao et al. (2025)	Carbon Total Factor Productivity (CTFP)	Inward and outward foreign direct investment (IFDI & OFDI)	Science and technology workforce, Environmental governance, Industrial competition, Energy consumption, National capital participation
Siripi et al. (2024)	Carbon dioxide emissions (CO_2 emissions)	Foreign direct investment (FDI), Technological innovation	GDP per capita, Urbanization, Industrialization
Chang et al. (2023)	Carbon emission intensity	Digital economy, Industrial structure upgrading	Trade openness, Urbanization, Economic growth, Human capital, Technological progress
Saleh & Belfodil (2021)	Environmental degradation (CO_2 emissions)	Industrial value-added	GDP per capita
Tair, Chafi, & Remi (2021)	Sustainable development (economic, social, environmental dimensions)	Foreign direct investment (FDI)	Domestic investment, Unemployment rate, CO_2 emissions
Rouaba (2021)	Carbon dioxide emissions (CO_2 emissions per capita)	Real GDP per capita, Energy consumption, Foreign direct investment (FDI), Trade openness	–

Source: Prepared by the researcher based on some previous studies.

Based on Table 1, the following variables can be used in the current study: Carbon dioxide (CO_2) emissions from industrial processes, Foreign direct investment (FDI), net inflows (% of GDP), Industry (including construction), value added (% of GDP), GDP per capita, Trade (% of GDP), and Urban population (% of total population).

Additionally, Gross Fixed Capital Formation (% of GDP) is incorporated as a key measure of financing productive assets such as factories and infrastructure, which directly impact industrial activities. Consequently, this variable can help explain whether domestic capital investments enhance the positive effects of FDI or mitigate its negative environmental impact.

The following are the definitions of the study variables.

2.2.1.1. Definition of carbon dioxide (CO_2) emissions from Industrial Processes (Mt CO_2e)

This indicator measures the yearly output of carbon dioxide (CO_2), one of the six greenhouse gases recognized by the Kyoto Protocol, that originates from various industrial activities. These activities are categorized under the IPCC 2006 classification, including cement and lime production, glass manufacturing, chemical and metal industries, the non-energy use of fuels and solvents, electronics manufacturing, the use of substitutes for ozone-depleting substances, and other industrial manufacturing processes. Additionally, it accounts for indirect emissions of N_2O resulting from atmospheric nitrogen deposition (NO_x and NH_3). These emissions are converted into CO_2-equivalent (CO_2e) values using Global Warming Potential (GWP) factors outlined in the IPCC's Fifth Assessment Report (AR5) (World bank group, 2025).

2.2.1.2. Definition of foreign Direct Investment (FDI), net inflows (% of GDP)

FDI reflects the net flow of capital invested to acquire a significant managerial stake (10% or more of voting rights) in a company operating in a foreign economy. This includes equity capital, reinvested earnings, and both long-term and short-term capital movements recorded in the balance of payments. The metric represents total investment inflows after deducting any withdrawals or disinvestments, expressed as a percentage of GDP ((World bank group, 2025).

2.2.1.3. Definition of industry (including construction), value added (% of GDP)

This measure encompasses economic activities related to mining, manufacturing (classified under ISIC 10-33), construction, electricity, water, and gas supply, all categorized under ISIC divisions 05-43. It represents the net contribution of these industries to the economy by summing total output and subtracting intermediate consumption, without accounting for asset depreciation or resource depletion. The classification follows ISIC Revision 4, and in some countries, the gross value added at factor cost is used as the base measurement (World bank group, 2025).

2.2.2. The Relationship Between Foreign Direct Investment and Carbon Emissions, and Between Industrial Growth and Carbon Emissions

Understanding the relationship between foreign direct investment (FDI) and carbon emissions, as well as the relationship between industrial growth and carbon emissions, is a fundamental issue in environmental and economic studies, particularly in the context of sustainable development. While FDI is regarded as a driver of economic growth and technology transfer, it can also impact the environment by influencing carbon emissions. Similarly, industrial growth, despite its importance in enhancing productivity and economic progress, can exacerbate environmental issues by increasing emissions resulting from industrial activities. In this context, this study reviews the existing literature on the relationship between FDI and carbon emissions on one hand and between industrial growth and carbon emissions on the other, based on a selection of recent studies.

2.2.2.1. The Relationship Between Foreign Direct Investment and Carbon Emissions

The impact of FDI on carbon emissions varies depending on the economic sector and the environmental policies of the host countries. Some studies suggest that FDI can contribute to reducing carbon emissions through the transfer of clean technology and improvements in energy efficiency. For example, a study on China's manufacturing sector found that outward FDI (OFDI) positively affects total factor carbon productivity (CTFP), leading to a reduction in emissions, while inward FDI (IFDI) may increase emissions in certain cases if not accompanied by clean technologies (Zhao, Gao, Feng, & Chen, 2024).

On the other hand, some studies support the "pollution haven" hypothesis, where FDI is used in some developing countries to promote polluting industries, thereby increasing carbon emissions. A study on Sub-Saharan African countries found that FDI in the industrial sector leads to higher

carbon emissions, whereas FDI in the agricultural and services sectors has a positive effect in reducing emissions (Kwablah, 2023). In the case of Ghana, research findings indicated that FDI reduces carbon emissions in the short term but leads to an increase in the long term, highlighting the need for strict regulatory policies to ensure that foreign investments contribute to environmental sustainability (Siripi, Kuuwill, & Tamakloe, 2024).

Overall, the impact of FDI on carbon emissions depends on several factors, including the nature of the sector receiving the investment, the extent of environmental regulations, and the commitment of multinational corporations to clean production practices.

2.2.2.2. The Relationship Between Industrial Growth and Carbon Emissions

The industrial sector is one of the largest contributors to global carbon emissions, as many industries rely on fossil fuel sources for production processes. Studies have shown that the relationship between industrial growth and carbon emissions varies depending on a country's level of economic development. In China, a study conducted on the industrial sector in Zhejiang Province found that carbon emissions increased significantly between 2002 and 2017, with varying effects across different sectors. Heavy industries, such as electricity production and chemical refining, were among the largest contributors to emissions, while service-based industries had a lower environmental impact (Shao, Dong, & Huang, 2024).

Additionally, the literature suggests an inverted U-shaped relationship between industrial growth and carbon emissions, where the early stages of industrialization lead to increased emissions, but as economies advance and the use of clean technology increases, emissions begin to decline. This is supported by an analysis of the relationship between industrial innovation and carbon emissions in Ghana, where it was found that technological advancement does not automatically reduce emissions but requires integration with strict environmental policies (Siripi, Kuuwill, & Tamakloe, 2024).

Moreover, another study found that industries relying on foreign investments can benefit from technology transfer to reduce emissions. In China, for example, investment in industrial innovation had a positive effect on carbon efficiency in the industrial sector, contributing to emission reductions (Zhao, Gao, Feng, & Chen, 2024). However, challenges remain in reducing carbon emissions from heavy industries, necessitating continuous efforts to improve energy efficiency, enforce stricter environmental standards, and encourage the transition to renewable energy sources (Shao, Dong, & Huang, 2024).

The previous studies indicate that the relationship between foreign direct investment and carbon emissions is not linear but depends on several factors, including the nature of the investment, environmental policies, and the level of technological advancement in the host country. While FDI in certain sectors may lead to higher emissions, it can also serve as an effective means to adopt more sustainable production practices if properly directed.

Regarding the relationship between industrial growth and carbon emissions, manufacturing is a major driver of rising emissions, particularly in developing countries that rely on energy-intensive industries. However, transitioning toward industrial innovation and adopting clean technologies can reduce these emissions in the long run, emphasizing the need for integrated policies that promote economic growth without harming the environment.

Based on the above, studies recommend adopting strict environmental policies alongside foreign direct investment inflows, as well as encouraging research and development in manufacturing industries to enhance environmental sustainability. Additionally, governments should strive to

balance industrial development with environmental protection by improving resource efficiency, adopting renewable energy sources, and developing green policies to promote environmentally responsible investments.

2.2.3. The role of foreign direct investment and industrial growth in influencing carbon emissions

2.2.3.1. Foreign direct investment as a catalyst for industrial growth and its impact on emissions

Some studies suggest that foreign direct investment (FDI) can promote industrial growth through technology transfer, improved productivity, and increased environmental efficiency, potentially reducing carbon emissions. For example, (Zhao, Gao, Feng, & Chen, 2024) found that the relationship between FDI and overall carbon productivity in China's manufacturing sector is influenced by the level of industrial development. When industrial growth is high and accompanied by clean technology, FDI enhances carbon efficiency and reduces emissions.

2.2.3.2. The interactive relationship Between foreign direct investment and industrial growth and its environmental impact

Some studies indicate that FDI can increase emissions when it supports polluting heavy industries, whereas it can reduce emissions when directed toward advanced manufacturing industries. For instance, (Kwablah, 2023) found that FDI in the industrial sector of Sub-Saharan African countries increased carbon emissions, whereas investment in agriculture and services contributed to emission reductions. This suggests that the impact depends on the types of industries supported by FDI.

2.2.3.3. The interaction between foreign direct investment and industrial innovation in reducing emissions

In a study on Ghana, (Siripi, Kuuwill, & Tamakloe, 2024) found that the interaction between FDI and technological innovation in manufacturing led to lower carbon emissions. When FDI was directed toward industries investing in research and development, it helped improve environmental efficiency, reflecting a positive interactive effect between FDI and industrial growth.

Based on previous studies, the interaction between FDI and industrial growth in influencing carbon emissions depends on several factors. One key factor is the type of industry targeted by FDI—investment in polluting industries leads to higher emissions, whereas investment in industrial innovation helps reduce them. Another crucial aspect is the level of technology accompanying FDI; when foreign investment is coupled with clean technology transfer, it fosters environmentally sustainable industrial growth. Additionally, the regulatory framework and environmental policies play a significant role. Countries with strict environmental regulations can channel foreign investment into more sustainable sectors, thereby mitigating the environmental impact of industrial expansion.

2.2.4. Definition of other study variables

2.2.4.1. GDP per capita, PPP (constant 2021 international $)

GDP per capita, adjusted for purchasing power parity (PPP), indicates the average economic output per person, converted into international dollars to standardize purchasing power across different nations. It accounts for the total value generated by all domestic producers, inclusive of product-related taxes minus subsidies, without adjusting for asset depreciation or environmental degradation. The values are presented in constant 2021 international dollars to maintain comparability over time (World bank group, 2025).

2.2.4.2. Gross fixed capital formation (% of GDP)

Previously known as gross domestic fixed investment, this indicator measures capital expenditures on land development (e.g., fencing, drainage systems), infrastructure construction (e.g., roads, railways, and buildings), and purchases of machinery and equipment. It also includes investments in industrial, commercial, and residential buildings, along with healthcare and educational facilities. Under the 1993 System of National Accounts (SNA), acquisitions of valuable assets are also considered part of capital formation (World bank group, 2025).

2.2.4.3. Trade (% of GDP)

This indicator captures the total value of a country's exports and imports of goods and services as a percentage of its GDP, offering insight into the degree of its economic openness and global trade integration (World bank group, 2025).

2.2.4.4. Urban population (% of total population)

The urban population refers to individuals living in cities and towns as defined by national statistical agencies. The United Nations Population Division compiles, processes, and harmonizes these figures to ensure consistency across countries (World bank group, 2025).

3. Methodology

3.1. Study Methodology

The study adopted a descriptive, analytical, and quantitative approach.

3.2. Study Sample

The sample included 11 countries: China, Brazil, Egypt, India, South Africa, France, Germany, Indonesia, Mexico, the United Kingdom, and Australia, covering the period from 2000 to 2023.

3.3. Study Data

The data was collected from the World Bank and structured in a panel data format, which is appropriate for this type of study as it includes cross-sections (countries) and time series (from 2000 to 2023 for each country).

3.4. Statistical Methods and Tests Used

The R software was used to perform all stages of the econometric analysis, where several descriptive statistics and econometric tests were conducted as follows.

3.4.1. Descriptive Statistics

Descriptive statistics were presented using minimum, first quarter, median, mean, third quarter, and maximum to analyze the study variables. This analysis provided an initial understanding of the data distribution before conducting econometric estimations, helping to detect any outliers or significant variations that might affect the study results.

3.4.2. Model Selection Tests

3.4.2.1. F-Test for comparing the pooled model and fixed effects model

The F-test was conducted to determine the appropriateness of the fixed effects model compared to the pooled model. The null hypothesis (H0) assumes that the country-specific coefficients do not differ significantly, implying that the pooled model is appropriate. In contrast, the alternative hypothesis (H1) suggests the presence of significant individual differences among countries, necessitating the use of the fixed effects mode, as stated by (Baltagi, 2021).

3.4.2.2. Hausman test for comparing the fixed Effects and random effects models

After confirming the suitability of the fixed effects model, the Hausman test was performed to compare it with the random effects model. The null hypothesis (H0) states that the differences

between the fixed and random effects estimators are not significant, meaning the random effects model is preferable. Meanwhile, the alternative hypothesis (H1) posits that significant differences exist, indicating that the fixed effects model is more accurate, as stated by (Hausman, 1978).

3.4.3. Model validity and estimation tests

3.4.3.1. Breusch-Pagan test for heteroscedasticity

The Breusch-Pagan test was employed to detect heteroscedasticity in the model's error terms. The null hypothesis (H0) assumes that the error terms have constant variance, while the alternative hypothesis (H1) suggests the presence of heteroscedasticity, which could lead to inefficient estimates, as stated by (Breusch & Pagan, 1979).

3.4.3.2. Wooldridge test for serial correlation

To check for serial correlation in the panel data, the Wooldridge test was applied. The null hypothesis (H0) assumes the absence of serial correlation, whereas the alternative hypothesis (H1) indicates the presence of serial correlation among error terms, which may compromise the accuracy of statistical estimations, as stated by (Wooldridge, 2010).

3.4.3.4. Pesaran (CD) test for cross-sectional dependence

The Pesaran (CD) test was conducted to assess cross-sectional dependence in the panel data. The null hypothesis (H0) assumes that countries behave independently without mutual influence, while the alternative hypothesis (H1) suggests the presence of cross-sectional dependence, meaning that changes in one country may affect others, as stated by (Pesaran, 2004).

3.4.4. Estimation Method Used

Based on the potential issues identified through the previous tests, the Driscoll-Kraay method was employed for model estimation. This method effectively corrects statistical issues associated with panel data, specifically addressing heteroscedasticity, serial correlation, and cross-sectional dependence, ensuring more reliable and robust estimations, as stated by (Driscoll & Kraay, 1998).

4. Result & discussion

4.1. Results

4.1.1. Descriptive statistics

Table 2 presents descriptive statistics for 11 countries from 2000 to 2023, highlighting economic and environmental differences. Carbon dioxide emissions (Care) range from 10.85 to 1562.90 million tons, reflecting industrialization disparities, with China and Germany showing the highest emissions. Foreign direct investment (FDI) fluctuates between -3.607% and 12.609% of GDP, indicating varying investment attractiveness, with the UK and Mexico experiencing higher inflows. Industrial value added (indv) varies from 16.09% to 48.06% of GDP, with China and Germany leading in manufacturing contributions. GDP per capita (GDPpc) shows significant income gaps, ranging from 3,100 to 63,098, contrasting high-income nations like Australia and Germany with lower-income ones like India and Egypt. Gross fixed capital formation (Grof) varies between 11.52% and 44.52% of GDP, reflecting different investment strategies. Urbanization (Urb) ranges from 27.67% to 87.79%, with France and Mexico being more urbanized than Indonesia and India. These variations highlight the structural differences influencing carbon emissions, emphasizing the need to analyze FDI, industrialization, and sustainability for effective policy formulation.

Table 2. Descriptive Statistics

Variable	Symbol	Minimum	First Quartile	Median	Mean	Third Quartile	Maximum
Carbon dioxide (CO2) emissions from Industrial Processes (Mt CO2e)	Care	10.85	18.18	32.06	137.85	46.94	1562.90
Foreign direct investment, net inflows (% of GDP)	FDI	-3.607	1.467	2.264	2.515	3.401	12.609
Industry (including construction), value added (% of GDP)	indv	16.09	23.08	26.31	28.81	34.11	48.06
GDP per capita, PPP (constant 2021 international $)	GDPpc	3100	11973	18216	27284	49323	63098
Gross fixed capital formation (% of GDP)	Grof	11.52	17.92	21.24	23.38	27.46	44.52
Trade (% of GDP)	Trade	22.11	40.96	50.75	51.28	59.97	89.06
Urban population (% of total population)	Urb	27.67	48.22	76.06	65.85	81.20	87.79
Country	Australia, Brazil, China, Egypt, Arab Rep, France, Germany, United Kingdom, Indonesia, India, Mexico, South Africa.						
The period	From 2000 to 2023						

Source: prepared by the researcher based on the outputs of the R software.

4.1.2. The pooled model, fixed effects model, and random effects model

Tables 3, 4 and 4 show three different estimation models for the relationship between the study variables: The pooled ordinary least squares model, the fixed effects model, and the random effects model, in two cases, the first when the industrial value added (indv) variable is excluded, and the second when it is included with the inclusion of the interaction between it and FDI, and accordingly the most appropriate model is determined in each case based on the F and Hausman tests, where the first is used to compare the pooled model with the fixed effects model, and the second is used in the case of rejecting the fixed effects model. The first is used to compare between the aggregate model and the fixed effects model, and the second is used in the case of rejecting the fixed effects model in order to differentiate between the fixed effects model and the random effects model, and all of the above in order to explain the relationship between FDI and CO2 emissions with the exclusion of industry value added once and once with its inclusion.

4.1.2.1. The three models excluding the industrial value-added variable

Table 3 estimates the pooled, fixed effects, and random effects models while excluding the industrial value-added variable. The dependent variable is carbon dioxide emissions, while the independent variable is foreign direct investment, along with control variables (GDP per capita, gross fixed capital formation, trade openness, and urban population). The results show statistical significance across models, with F-statistics significant at 1%. The explanatory power was around 50%, with R^2 values of 0.58 (pooled model), 0.59 (fixed effects model), and 0.49 (random effects model).

Table 3. Presentation of the results of the pooled model, fixed effects model, and random effects model in the case of excluding the industrial value-added variable (INDV).

	Exclude indv variable								
	Pooled Model			**Fixed Effects Model**			**Random Effects Model**		
Variables	**Value**	**T-value**	**P-value**	**Value**	**T-value**	**P-value**	**Value**	**Z-value**	**P-value**
Intercept	-751.05	-7.1198	<0.0001					-9.2144	<0.0001
FDI	-2.3241	-0.3450	0.7304	-3.25865	-1.2818	0.2011	-1150.9	-2.1085	0.0350
GDPpc	-0.0025517	-2.3126	0.0215	0.00012685	0.0573	0.9543	-5.9131	-0.4189	0.6753
Grof	33.883	17.6860	<0.0001	1.41414	0.6555	0.5128	-0.00093701	3.1213	0.0018
Trade	-0.36555	-0.3518	0.7253	-1.55706	-2.7522	0.0064	7.0564	-2.7468	0.0060
Urb	2.8974	2.5408	0.0117	23.24640	11.3708	<0.0001	-1.7236	9.1152	<0.0001
R-Squared		0.58507			0.59522			0.49712	
F-statistic		72.7584			72.9351		Chisq test		255.04
P-value of F		<0.0001			<0.0001		P-value		<0.0001
Sample	n = 11, T = 24, N = 264								
Dependent variable	Care: Carbon dioxide (CO_2) emissions from Industrial Processes (Mt CO2e)								

Note. In R, the intercept does not appear in the output because it is accounted for within the fixed effects of the units.

Source: prepared by the researcher based on the outputs of the R software.

4.1.2.2. The three models including the industrial value-added variable

Table 4 presents the three models with the industrial value-added variable and its interaction with FDI. The models include the same dependent and independent variables as in the previous case. The results indicate high statistical significance, with F-statistics at 1% significance. The explanatory power exceeded 50%, with R^2 values of 0.59 (pooled model), 0.69 (fixed effects model), and 0.62 (random effects model), suggesting a stronger model fit when industrial value-added is included.

Table 4. Presentation of the results of the pooled model, fixed effects model, and random effects model when all variables are included, with an interaction between foreign direct investment and industrial value-added.

	All variables are included with FDI_indv								
Variables	**Pooled Model**			**Fixed Effects Model**			**Random Effects Model**		
	Value	**T-value**	**P-value**	**Value**	**T-value**	**P-value**	**Value**	**Z-value**	**P-value**
Intercept	-819.3400	-6.2330	1.8740e-09				-1970.7000	-10.6236	<0.0001
FDI	-14.2470	-0.6179	0.5372	45.1466	5.8923	1.2470e-08	48.8870	5.8134	6.1200e-09
indv	3.9440	1.3500	0.1782	18.5160	6.6090	2.3810e-10	17.2430	5.8047	6.4470e-09
FDI_indv	0.4282	0.5167	0.6058	-1.9523	-6.7777	8.9780	-2.1648	-6.8725	6.3100e-

						e-11			12
GDPpc	-0.0015	-1.1993	0.2315	-0.0015	-0.7642	0.4455	-0.0019	-0.9606	0.3367
Grof	31.4110	13.8481	<0.0001	3.9551	1.9615	0.0510	8.4798	4.0238	5.7270e-05
Trade	-1.1237	-1.0171	0.3100	-1.6338	-3.1151	0.0021	-1.6101	-2.8003	0.0051
Urb	3.2208	2.8075	0.0054	28.1348	13.0671	<0.0001	23.9830	10.9412	<0.0001

R-Squared		0.5917		0.6907		0.6209
F-statistic		52.9908		78.4847	Chisq test	419.2670
P-value		<0.0001		<0.0001	P-value	<0.0001
Sample		n = 11, T = 24, N = 264				
Dependent variable		Care: Carbon dioxide (CO2) emissions from Industrial Processes (Mt CO2e)				

Note. In R, the intercept does not appear in the output because it is accounted for within the fixed effects of the units.

Source: prepared by the researcher based on the outputs of the R software.

4.1.3. Model selection

Based on the results presented in Table 5, the fixed effects F test reveals that the differences between the units in the study are statistically significant. Whether excluding the industry value added variable (indv) or including it with its interaction with foreign direct investment (FDI), the F test recorded a value of 194.27 with degrees of freedom (df1 = 10 and df2 = 248) and a significance level of less than 0.0001. These results indicate that the fixed differences between the units are large enough to reject the pooled model and accept the fixed effects model. This result shows that the characteristics of each unit remain constant over time and cannot be ignored when interpreting relationships between variables (Wooldridge, 2010).

Furthermore, the Hausman test supports this conclusion, recording a Chi-square value of 327.08 with degrees of freedom df = 5 and a significance level of less than 0.0001. This suggests that the random effects model is not appropriate, and that using a fixed effects model provides more accurate estimates to capture consistent differences between units (Hausman, 1978).

Table 5. tests results of model selection

Test	Test Statistic	Degrees of Freedom	P-value	Result
		Exclude indv variable		
F test for individual effects	F = 194.27	df1 = 10, df2 = 248	<0.0001	Fixed effects model is the best (pooled model rejected)
Hausman Test	χ^2 = 327.08	df = 5	<0.0001	Fixed effects model is the best (random effects model rejected)
		All variables are included with FDI_indv		
F test for individual effects	F = 232.3400	df1 = 11, df2 = 246	<0.0001	Fixed effects model is the best (pooled model rejected)
Hausman Test	chisq = 3284.0000	df = 7	<0.0001	Fixed effects model is the best (random effects model rejected)

Source: prepared by the researcher based on the outputs of the R software.

4.1.4. Diagnostic tests for the fixed effects model: Cross-sectional dependence, heteroscedasticity, and serial correlation

Diagnosing statistical issues in panel data models is essential to ensure the accuracy of estimates and statistical inferences. Among the key challenges that may affect the reliability of results are cross-sectional dependence, heteroscedasticity, and serial correlation. To assess the impact of these issues on the Fixed Effects model, the Pesaran CD, Breusch-Pagan, and Wooldridge tests were conducted. These tests were applied both when excluding the industrial value-added variable (indv)

and when including it along with its interaction with foreign direct investment (FDI_indv), as presented in Table 6.

Table 6. Tests Results of Cross-Sectional Dependence, Heteroscedasticity, and Serial Correlation

Test	Test Statistic	Degrees of Freedom	P-value	Result
		Exclude indv variable		
Pesaran CD Test	z = 14.025	–	<0.0001	Presence of cross-sectional dependence among units
Studentized Breusch-Pagan Test	BP = 130.94	df = 5	<0.0001	Presence of heteroscedasticity
Wooldridge's Test	F = 1584.2	df1 = 1, df2 = 251	<0.0001	Significant serial correlation
		All variables are included with FDI_indv		
Pesaran CD Test	z = 6.6920	-	<0.0001	Presence of cross-sectional dependence among units
Studentized Breusch-Pagan Test	BP = 316.0500	df = 7	<0.0001	Presence of heteroscedasticity
Wooldridge's Test	F = 1006.9000	df1 = 1, df2 = 251	<0.0001	Presence of serial correlation

Source: prepared by the researcher based on the outputs of the R software.

The results of the Pesaran CD test, as shown in Table 6, indicate a strong cross-sectional dependence among units. The test yielded a statistic of 14.025 when indv was excluded and 6.692 when indv was included, with a p-value of less than 0.0001 in both cases. This finding suggests that the countries under study are not independent of each other, which could impact the accuracy of the estimates (Pesaran, 2004).

Similarly, the Studentized Breusch-Pagan test revealed the presence of heteroscedasticity, with a BP value of 130.94 (df = 5) when indv was excluded and BP = 316.05 (df = 7) when indv was included, both with a p-value of less than 0.0001, as presented in Table 5. These results confirm that the variance of the errors differs across countries, necessitating corrective methodologies to ensure precise parameter estimation (Breusch & Pagan, 1979).

Additionally, the Wooldridge test, according to Table 6, demonstrated a high degree of serial correlation, with an F-value of 1584.2 when indv was excluded and F = 1006.9 when indv was included, both with a p-value of less than 0.0001. This result implies that the errors exhibit serial correlation over time, which must be addressed using an appropriate corrective approach (Wooldridge, 2010).

Based on these findings, addressing cross-sectional dependence, heteroscedasticity, and serial correlation is crucial to improving the accuracy of the analysis. Driscoll-Kraay standard errors provide a suitable solution to these issues, as they correct the estimates in a manner that accounts for all the mentioned sources of dependence. This enhances the reliability of the results and the inferences drawn from panel data (Driscoll & Kraay, 1998). Applying this methodology is a fundamental step in ensuring more precise estimates of the studied economic relationships, especially when dealing with data that covers multiple countries over extended time periods.

4.1.5. Estimation results analysis using the Driscoll-Kraay method

The use of standard error estimates adjusted according to the Driscoll-Kraay method is essential in panel data analysis. This methodology allows for the correction of heteroscedasticity, serial correlation, and cross-sectional dependence, enhancing the accuracy of estimates. This section

presents the estimation results using the Driscoll-Kraay method, as shown in Table 7, by comparing the effect of variables when excluding the industrial value-added variable (indv) and when including it along with its interaction with foreign direct investment (FDI_indv).

Based on Table 7, when the indv variable is excluded, the results indicate that FDI, GDP per capita (GDPpc), gross fixed capital formation (Grof), and trade openness (Trade) all have no significant effect ($p > 0.05$). In contrast, the percentage of the urban population (Urb) has a significantly positive effect on carbon emissions ($p = 0.02842$), suggesting that urbanization leads to increased carbon emissions. This can be explained by the fact that urban areas consume larger amounts of energy for industrial and consumer activities, contributing to higher levels of environmental pollution.

Table 7. Driscoll-Kraay standard error estimates to account for heteroscedasticity, serial correlation, and cross-sectional dependence

Variable	Estimate	t-value	P-value	Result
Exclude indv variable				
FDI	-3.25865	-0.8857	0.37666	Not significant
GDPpc	0.00012685	0.0338	0.97305	Not significant
Grof	1.41414	0.2093	0.83441	Not significant
Trade	-1.55706	-0.9583	0.33885	Not significant
Urb	23.24640	2.2043	0.02842	Significant
All variables are included with FDI_indv				
FDI	45.1466	3.1594	0.0018	Significant
indv	18.5160	3.0228	0.0028	Significant
FDI_indv	-1.9523	-3.1155	0.0021	Significant
GDPpc	-0.0015	-0.8294	0.4077	Not significant
Grof	3.9551	1.1005	0.2722	Not significant
Trade	-1.6338	-2.6459	0.0087	Significant
Urb	28.1348	5.5387	7.8150e-08	Significant

Source: prepared by the researcher based on the outputs of the R software.

When all variables are included along with the FDI_indv interaction, substantial changes in the results emerge. According to Table 6, both FDI ($p = 0.0018$) and indv ($p = 0.0028$) have a significantly positive effect on carbon emissions, implying that increased foreign direct investment inflows and industrial activity lead to greater environmental pollution. However, the interaction between them ($p = 0.0021$) has a significantly negative effect on carbon emissions, suggesting that the relationship between foreign direct investment and carbon emissions becomes less pronounced at higher levels of industrialization. This negative interaction effect reflects the possibility that foreign investments in industrial sectors may introduce more efficient and environmentally friendly production technologies, thereby reducing the negative environmental impact of foreign direct investment.

Additionally, trade openness ($p = 0.0087$) exhibits a significantly negative effect on carbon emissions, indicating that integration into global trade may contribute to improved production efficiency and the transfer of clean technologies. Conversely, the effect of the urban population percentage ($p = 0.0000$) remains significantly positive, implying that increased urbanization exacerbates carbon emissions due to the rising energy demand in urban sectors. Meanwhile, GDPpc and Grof show no significant effect, suggesting that income levels and fixed capital formation do not play a primary role in explaining variations in emissions within the studied sample.

These results reflect the complex relationship between foreign direct investment, industrialization, and environmental sustainability. On one hand, foreign direct investment leads to increased carbon emissions, particularly when concentrated in energy-intensive sectors, supporting the "pollution haven hypothesis" in developing countries. On the other hand, when such investment is directed toward industrial sectors, it may help reduce emissions by adopting cleaner production technologies, which explains the negative effect of the FDI_indv interaction.

The negative effect of trade openness on emissions may reflect improved production efficiency and the adoption of higher environmental standards due to international competition and the transfer of environmentally friendly technologies. In contrast, the significantly positive effect of urbanization on emissions confirms the rising energy consumption in urban areas, increased demand for transportation, and infrastructure that relies on fossil fuels, all of which contribute to higher carbon emissions.

Based on Table 6, the results indicate that incorporating industrial activity into the analysis significantly alters the significance of foreign direct investment's effect, which only becomes significantly positive when indv is included. The findings also highlight the importance of using the Driscoll-Kraay method to correct statistical issues associated with panel data, enhancing the reliability of estimates. These results suggest that the impact of foreign direct investment on carbon emissions depends on the level of industrialization in a country. Industrialization can mitigate the negative environmental impact of foreign investments if environmental policies and clean production technologies are adopted. Therefore, implementing policies that promote the use of clean technology in industrial sectors can contribute to achieving a balance between attracting foreign direct investment and ensuring environmental sustainability.

4.2. Discussion

- Foreign Direct Investment and Carbon Emissions: The study found that FDI and industrial activity significantly increase carbon emissions, particularly in developing countries with less stringent environmental regulations. However, the interaction between FDI and industrial growth has a negative effect, suggesting that higher industrialization levels can mitigate FDI's environmental impact by introducing cleaner production technologies. These findings align with Kwablah (2023) and Siripi et al. (2024), who reported that FDI increases emissions in industrial sectors but can have varying effects over time. In contrast, Pazienza (2015) highlighted that FDI in agriculture and fisheries reduces emissions, emphasizing the role of sector-specific investments.

- Industrial Growth as a Mitigating Factor: This study contributes to the existing literature by demonstrating that industrial growth can help offset the negative environmental impact of foreign direct investment, suggesting that manufacturing plays an interactive role in reducing the adverse effects of foreign direct investment on environmental emissions. This contrasts with some previous studies, such as Saleh and Belfodil (2021), who did not find a stable long-term relationship between industrial growth and emissions in Algeria, with the relationship being limited to the short term only.

- Urbanization and Trade Openness: Urbanization significantly increases carbon emissions due to rising energy consumption and transportation demand, confirming the findings of Chang et al. (2023). In contrast, trade openness has a negative effect on emissions, promoting efficiency and clean technology transfers, aligning with Drissi & Dahmani (2022). Lastly, GDP per capita and gross fixed capital formation had no significant effect on emissions, indicating that income and capital investment alone do not drive emissions variations.

5. Conclusion

This study found that foreign direct investment (FDI) is associated with an increase in carbon emissions, and this may be due to its orientation toward traditional industrial sectors that rely heavily on resource consumption. However, the interaction between FDI and industrial growth may mitigate this effect, perhaps due to the adoption of more efficient and environmentally friendly production technologies in advanced industrial sectors.

The results also showed that trade openness contributes to reducing carbon emissions, which may be a result of improved production efficiency and the transfer of clean technologies between countries. Conversely, the increase in the urban population percentage leads to higher emissions, possibly due to rising energy consumption in cities and increased demand for transportation and infrastructure.

Based on these findings, the following recommendations can be made:

- Directing FDI towards sustainable sectors, such as renewable energy and low-impact industries, which may help reduce negative environmental effects.

- Strengthening environmental regulations to ensure that foreign investments adhere to standards that limit their environmental impact, which may contribute to balancing economic growth and sustainability.

- Encouraging clean industries by adopting policies that support modern technologies and improve resource and energy efficiency, which may help reduce harmful emissions.

- Developing urban planning strategies to limit urban emissions by enhancing public transportation, increasing green spaces, and improving energy efficiency in infrastructure, which may help reduce fossil fuel consumption.

- Leveraging trade openness to support sustainable development by promoting the exchange of clean technologies, which may help countries reduce their environmental footprint.

- Providing financial incentives to companies adopting environmentally friendly production practices, such as tax exemptions and government support, which may encourage the adoption of sustainable production technologies.

- Investing in research and development to foster innovation in technologies that reduce carbon emissions and enhance production efficiency, which may serve as a foundation for achieving long-term environmental sustainability.

Bibliography & References:

1. World bank group. (2025). Foreign direct investment, net inflows (% of GDP). Retrieved 02 28, 2025, from (World bank group: https://data.worldbank.org/indicator/BX.KLT.DINV.WD.GD.ZS

2. Baltagi, B. H. (2021). Econometric Analysis of Panel Data (6th ed ed.). Springer Nature.

3. Breusch, T. S., & Pagan, A. R. (1979). A Simple Test for Heteroscedasticity and Random Coefficient Variation. Econometrica , 47 (5), pp. 1287-1294.

4. Chang, H., Ding, Q., Zhao, W., Hou, N., & Liu, W. (2023, October 20). The digital economy, industrial structure upgrading, and carbon emissionintensity —— empirical evidence from China's provinces. Energy Strategy Reviews , 50.

5. Driscoll, J. C., & Kraay, A. C. (1998). Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data. The Review of Economics and Statistics , 80 (4), pp. 549–560.

6. Drissi, A., & Dahmani, I. (2022, 03 21). Impact of green finance on carbon dioxide emissions level in the world Econometric study (2007-2019). Finance & Markets Review , 9 (1), pp. 545-564.

7. Hausman, J. A. (1978). Specification Tests in Econometrics. Econometrica , 46 (6), pp. 1251-1271.

8. Huo, D., Yang, H., Zhou, X., & Kang, W. (2025, January 17). Key industrial sectors and their evolutionary trends in China's embodied carbon emission network. Alexandria Engineering Journal .

9. Jiang, M., Wang, K., Zhao, Q., Li, S., & Xu, G. (2025, January). Small and medium-sized banks and pollution emissions from industrial enterprises. International Review of Economics and Finance , 97.

10. Kwablah, E. (2023, November 17). Foreign direct investment, gross domestic product and carbon dioxide. Transnational Corporations Review , 15 (4), pp. 59-68.

11. Moustafaui, m. c., Tair, a., & Rimi, o. (2021, 11 11). The impact of foreign direct investment in support of sustainable development dimensions in Algeria - Standard study period (1995-2019). Journal of Advanced Economic Research , 6 (2), pp. 212-228.

12. Pazienza, P. (2015, August 28). The relationship between CO2 and Foreign Direct Investment in the agriculture and fishing sector of OECD countries: Evidence and policy considerations. Intellectual Economics , 9 (1), pp. 55-66.

13. Pesaran, M. (2004). General Diagnostic Tests for Cross Section Dependence in Panels. CESifo & IZA.

14. Rouaba, m. (2021, 10 1). Determinants of carbon dioxide emissions in Algeria during the period 1980–2017: An application of the ARDL model. ournal of New Economy , 12 (4), pp. 234-254.

15. Saleh, H., & Belfodil, k. (2021). To test the relationship between the growth of value added resulting from the industrial sector and the environmental degradation in Algeria, based on the VAR model. Journal of Legal and Economic Studies , 04 (01), pp. 332-350.

16. Shao, M., Dong, X., & Huang, H. (2024, February 19). Measurement of carbon emissions and responsibility sharing for the industrial sector in Zhejiang, China. Heliyon , 10 (5).

17. Siripi, H., Kuuwill, A., & Tamakloe, M.-D. (2024, November 4). Economic growth and environmental sustainability: The role of foreign direct investment and technological innovation on carbon emissions in Ghana. Research in Globalization .

18. Wooldridge, J. (2010). Econometric Analysis of Cross Section and Panel Data (2nd Edition ed.). MIT Press, Cambridge.

19. World bank group. (2025). Carbon dioxide (CO2) emissions from Industrial Processes (Mt CO2e). Retrieved 02 28, 2025, from World bank group: https://data.worldbank.org/indicator/EN.GHG.CO2.IP.MT.CE.AR5

20. World bank group. (2025). GDP per capita, PPP (constant 2021 international $). Retrieved 02 28, 2025, from World bank group: https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD

World bank group. (2025). Gross fixed capital formation (% of GDP). Retrieved 02 28, 2025, from World bank group: https://data.worldbank.org/indicator/NE.GDI.FTOT.ZS

21. World bank group. (2025). Industry (including construction), value added (% of GDP). Retrieved 02 28, 2025, from World bank group: https://data.worldbank.org/indicator/NV.IND.TOTL.ZS

22. World bank group. (2025). Trade (% of GDP). Retrieved 02 28, 2025, from World bank group: https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS

23. World bank group. (2025). Urban population (% of total population). Retrieved 02 28, 2025, from World bank group: https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

24. Zhao, X., Gao, X., Feng, X., & Chen, Y. (2024, November 30). Two-way foreign direct investment, science and technology manpower, and carbon total factor productivity: Empirical evidence from China's manufacturing industry. International Review of Economics & Finance , 97.