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Green or brown? Unravelling the Sectoral FDI's Impact on Carbon Emissions and Environmental Performance

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Abstract: The need to tackle climate change is recognized as a worldwide challenge, necessitating a unified effort to effectively address this problem. This study investigates the environmental influence of foreign direct investment flows directed towards manufacturing, construction and electricity generation sectors. The study focuses on carbon emissions and environmental performance index as the main indicators of environmental health, examining data spanning from 2013 till 2022 across 19 countries. The empirical analysis employs robust System GMM and Difference GMM econometric techniques for regression analysis. The findings of the paper indicate that FDI flows into construction, manufacturing and electricity generation sector result in pollution with a particularly significant influence on increase in carbon emissions and mostly insignificant effect on environmental performance index. Moreover, findings show that population growth and GDP contribute significantly to carbon emissions while good regulatory quality significantly mitigates ecological pollution. The study highlights the importance of designing measures to attract sectoral FDI which benefits the environment.

Keywords: Sectoral FDI, Carbon Emissions, Environmental Performance Index, Sustainable Development.

JEL Classification: F6, F62, F64.

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1. Introduction

Global efforts are being made by countries through signing various agreements since the United Nations introduced its Sustainable Development Goals in 2015 (Morton et al., 2017) to achieve sustainable growth by diminishing the impact of economic activities on the environment. For this purpose, it is critical to allocate the required funds and resources to industries that reduce the environmental pollution (Ren et al., 2022). The transition to greener production is slow as revealed in the United Nations Climate Change Conference (COP 28) held in 2023 where countries are still behind in achieving the global temperature targets set for 2030 (Jiang et al., 2024).

As they provide resources and growth prospects, emerging and developing nations across the globe have been the beneficiaries of foreign direct investment (FDI) for a the last four decades (Appiah-Otoo et al., 2023). Many studies have examined the potential for economic growth that FDI offers, in addition to the effects that FDI has on the environment (Abbasi et al., 2022; Akadiri & Adebayo, 2022; Awan & Azam, 2022; Ibrahiem & Hanafy, 2020).

FDI can take place in different types of sectors, such as manufacturing, infrastructure, tranport, mining, agriculture, construction, and energy (Zhao et al., 2024).Therefore it makes it critical to investigate the impact of FDI by type to understand its impact on the environment. Most analyses of the environmental impact of globalization focus on a holistic perspective of FDI (Ibrahiem & Hanafy, 2020; Ibrahim & Ajide, 2021; Jorgenson et al., 2022; Kamal et al., 2023; Mahmood & Haider/Hassan, 2022; Song et al., 2024; Zhong et al., 2024).(Abbasi et al.(2022) show that carbon dioxide intensity of FDI has an inverse effect on environmental degration in Turkey while Kamal et al(2023) suggests that Chinese FDI has a detrimental effect on environment of Belt and Road countries.;; . However, limited studies have looked at the influence of sectoral FDI on the environment (Adjei-Mantey & Adams, 2023; Feng et al., 2023). Historically, research has shown that manufacturing

(Chontanawat et al., 2020; Zhou & Li, 2022), construction (Onat & Kucukvar, 2020), and energy sectors (Jenkins et al., 2018) contribute significantly to the environmental degradation of countries.

The current research first investigates whether air quality is displaying a diminishing effect irrespective of endogenous and exogenous factors. Additionally, the study examines the effects of sector specific FDI inflows on pollution for sample countries and determine if a 'Pollution Halo' or 'Pollution Haven' effect exists. The influence of FDI inflows in these sectors is underexplored, and the research conducted in this study can show if FDI flows can change the relationship between construction sector, manufacturing sector, electricity generation sector and carbon emissions which prior literature has shown is positive.

Based on the discussion as mentioned earlier, the following research questions emerge:

RQ1: How has the air quality changed over the past two decades?

RQ2: How does FDI in energy-intensive sectors affect carbon emissions?

RQ3: What is the linkage between FDI and changes in the Environmental Performance Index of host countries?

This paper makes several contributions to the existing literature. First, it looks at the influence of sectoral FDI on the environmental performance of countries across the globe, which is an underexplored research area. Secondly, based on our best knowledge this is the first study to employ two measures in context of sectoral FDI and its influence on environmental performance, namely carbon emissions which is commonly used and Environmental Performance Index (EPI)[1], This study makes theoretical contribution to the Pollution Haven Hypothesis by showing that sectoral FDI flows can also lead to increase in environmental degradation.

The rest of the research is divided as follows: section 2 provides a brief insight of air quality in selected countries irrespective of prevalent endogenous and exogenous elements section 3 provides the theoretical background, literature review, and hypothesis development; section 4

[1] Yale and Columbia universities created this index in partnership with the Center for Earth Sciences.

explains about data collection, selection of variables and econometric modelling; section 5 presents the empirical results and discussion; section 6 provides the conclusion and policy implications; and lastly section 7 has the bibliography.

2. Air quality

The study aims to investigate the disaggregated influence of FDI on air quality Every year, a world air quality report is released by IQAir, which is the world's largest platform to acquire real-time air quality data (Health,2020). The report consists of details related to public and private monitoring stations established in various countries to obtain data on air quality from different world cities (Singer et al., 2018). Around the world, governmental agencies, academic institutions, commercial enterprises, non-profit, non-governmental organizations, universities, and citizen scientists also run monitoring stations and sensors. Figure 1 shows the average PM (Particulate Matter) of 2.5 µg/m3 of high-income countries over almost twenty years. According to WHO guidelines released in 2021, a value of less than 5 PM 2.5 µg/m3 is considered safe. Effective air quality monitoring started in 2010 during which most countries had a PM 2.5 µg/m3 value more significant than 5. In 2010, Chile had the highest PM 2.5 µg/m3 value, which was 25.

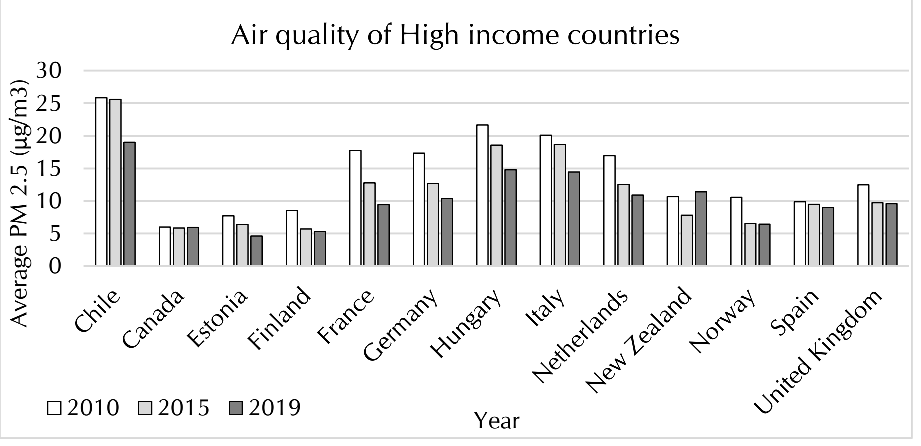
Furthermore, in 2015, many countries had significantly low PM2.5 µg/m3 levels which indicates a commitment to pollution reduction that eventually led to the signing of Paris Climate Conference of 2015. However, very few countries have managed to keep levels below 5. Additionally, figure 2 summarizes the air quality of the sample's low- and middle-income countries. The value for PM 2.5 µg/m3 is significantly higher for these countries compared to high-income countries, given that manufacturing industries, motor vehicle emissions, and the production of electricity from fossil fuels continue to be significant sources of air pollution in these nations.[2] In contrast, high-income countries have various regulations to control the economic activities that cause pollution.

The above determinants of air pollution help in developing a mechanism that air pollution emerges due to carbon intensive industries such as manufacturing, electricity production, construction, and many others. This is because there is one common air pollutant in all these industries

[2] These represent those countries which are included in the sample.

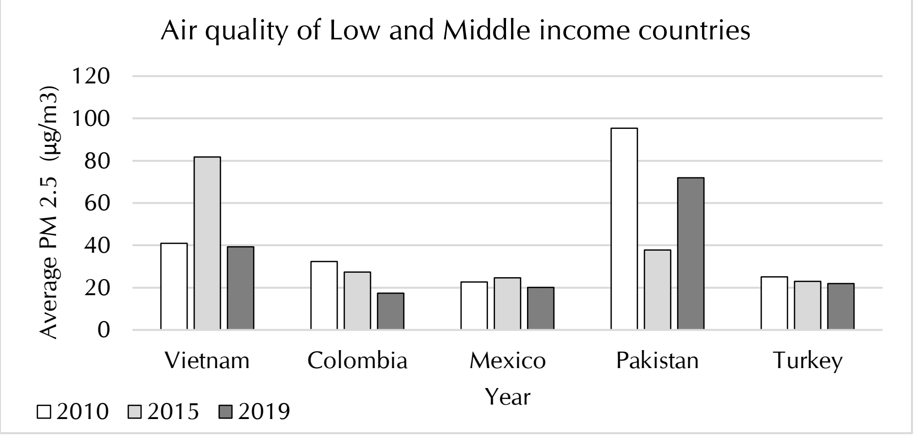
that makes air quality deadly: carbon monoxide, commonly known as carbon emissions. Which makes it even more important to study the effect of sectoral FDI on carbon emissions to further validate the Pollution Haven and Pollution Halo hypotheses.

Figure 1: Air quality of high-income countries[3]



Source: Author's own illustration

Figure 2: Air quality of low and middle-income countries[4]



Source: Author's illustration

[3] These countries have been categorized according to the World Bank guidelines 2023.
[4] These countries have been classified according to the World Bank's income classification for 2023.

3. Theoretical background, literature review and hypothesis development

3.1 Theoretical background

The environmental consequences from FDI are a topic of considerable debate for every era (past, present and future). Two most relevant theories describe these effects: Pollution Halo (PHL) (Kisswani & Zaitouni, 2021) and Pollution Haven (PHH) (Bashir, 2022). According to the PHH theory, foreign investors relocate their polluting enterprises to developing and undeveloped nations to avoid paying for pollution mitigation costs (Kamal et al., 2023). As a result, polluting sectors that were previously active in affluent economies relocate to developing nations, where they thrive (Bulus & Koc, 2021). The idea has received considerable support from empirical evidence given in previous research (Destek & Okumus, 2019). There are studies however which have refuted the PHH hypothesis and found evidence in favor of the PHL hypothesis, which holds that FDI generates "pollution halos" by spreading effective management practices, knowledge transfer, and technology transfer to developing nations (benzerrouk et al., 2021; Christoforidis & Katrakilidis, 2022).

3.2 Literature review

3.2.1 FDI and environment

An analysis of earlier studies shows that while the relationship between FDI and carbon emissions has been studied, most of these studies have concentrated on developed countries. Mixed empirical results have come from widespread research on the relationship between FDI and CO2 emissions (Christoforidis & Katrakilidis, 2022; Rehman et al., 2022; Zameer et al., 2020). According to a study on East Asian nations by (Zugravu-Soilita, 2017) , highly polluting firms that relocate there and weak environmental restrictions cause FDI to boost carbon emissions positively and significantly. On the other hand, research has supported the PHL theory, which holds that FDI promotes economic expansion and lessens environmental harm in China (Zhuang et al., 2022), South Korea (Hille et al., 2019) and Pakistan (Bakhsh et al., 2017). Moreover, prior research has investigated how clean energy mediates the relationship between FDI and environmental quality, and the results indicate that FDI in clean energy can enhance environmental quality (Rej et al., 2023).

Additionally, Doytch et al. (2024) evaluated the effect of sectoral FDI on forest land and found that FDI in services harms the forest environment while FDI in transportation helps the forest environment.

3.2.2 FDI for manufacturing and environment

Pazienza (2019) looked at the direction and strength of the effects of FDI from OECD countries on the environment, particularly the amount of CO2 produced by burning sectoral fuels. They discovered that FDI positively impacted the environment because of technology spillovers. This result was supported by (Sun et al., 2020) which conducted a study on the manufacturing sector in China and through empirical analysis proved that FDI in manufacturing sector contributed to increased carbon emissions. FDI inflows, especially in the energy and services industries, are more ecologically beneficial than inflow stock. Without FDI's polluting effects, energy transition is possible. Furthermore, A study on the Norwegian manufacturing industry by (Rezza, 2013) showed that environmenal stringency laws play a pertinent role in regulating the type of FDI which enters the host country, which means that environmental quality plays a significant role in determining whether host countries become pollution halos or pollution havens for foreign firms.

Based on the review of the literature, this study proposes the following hypothesis:

H1a: FDI in manufacturing positively affects carbon emissions.

H1b: FDI in manufacturing negatively affects the environmental performance index.

3.2.3 FDI for construction and environment

Scarce literature is available on the influence of FDI flows in construction industry and their impact on environment. A study by (Gong & Kong, 2022) explained the nonlinear impact of real estate development on environmental pollution by using a spatial mediation model that included two significant mediating variables: industrial structure and population density. Findings revealed that construction and real estate development significantly impact environmental pollution. Based on the above literature, this study proposes the following hypothesis:

H2a: FDI positively affects carbon emissions.

H2b: FDI has a nonlinear effect on the environmental performance index.

3.2.4 FDI for electricity production and environment

(Farooq et al., 2023) conducted a study on GCC countries and showed that FDI in electricity production positively influenced carbon emissions effectively creating pollution havens for foreign firms. Another study by (Tariq et al., 2023) studied the effect of FDI on renewable electricity consumption and showed a non-linear influence of FDI inflows on adoption of renewable energy. Furthermore, (Ofori et al., 2023) highlighted the need for stringent environment policies to attract green FDI in the electricity generation sector which will promote inclusive green growth.

Based on the above discussion, this research proposes the following hypothesis:

H3a: FDI in the electricity sector has a positive effect on carbon emissions.

H3b: FDI in the electricity sector has a negative effect on the environmental performance index.

3.3 Control variables

Population growth has been considered in this study since prior research has demonstrated that population disparities among nations have a significant impact on the environment (E. Rehman & Rehman, 2022). In addition, the study takes a comprehensive approach by examining GDP per capita (Ahmad et al., 2021), the use of fossil fuels (Mensah et al., 2019) and renewable energy (Akadiri & Adebayo, 2022), and regulatory quality (Zakari & Khan, 2022).

4. Methodology

4.1 Variable sources and data description

Table 1 shows the variables used for data analysis, which are taken from the World Bank, OECD, NASA, and Our World in Data. Multiple databases have been used to gather data related to 19 countries[5] located in different regions of the world.

Table 1: Variable source and description

	Variable	Description	Variable source	Source
Dependent variables	Carbon emissions (CO_2)	Co2 emissions metric tons per capita	(Wang & Zhang, 2021)	WDI
	EPI	Environmental performance index	(S. A. R. Khan et al., 2020)	NASA database
Independent variables	CFDI	Foreign direct investment in construction	(Rej et al., 2023)	OECD
	MANU	Foreign direct investment in manufacturing	(Pazienza, 2019)	OECD
	ELE	Foreign direct investment in electricity and gas	(Doytch et al., 2024)	OECD
Control variables	Population growth (POP)	Percentage change in population	(H. Khan et al., 2022)	OECD
	GDP per capita	GDP/population	(Ahmad et al., 2021)	WDI
	Fossil fuel energy used	Total energy consumed from fossil fuels	(Mensah et al., 2019)	Our World in Data
	Renewable energy	Energy consumed from renewable resources	(Akadiri & Adebayo, 2022)	WDI
	Regulatory quality (IQ)	Regulatory quality	(Zakari & Khan, 2022)	WDI

Source: Author's own calculations

4.2 Descriptive Statistics.

The summary statistics are shown in table 2, it shows varying levels of carbon emissions metric tonnes per capita which indicates the diverse sample of countries from across the globe in which some have contributed to environmental degradation while others have achieved significant decline in emissions. Similarly, EPI has a high standard deviation which implies that some countries have high scores on the environmental performance index while others have poor environmental performance index.

[5]UK, Canada, Columbia, Poland, Spain, Estonia, Hungary, Norway, Netherlands, Pakistan, Turkey, Vietnam, Germany, Finland, France, Italy, Chile, NewZealand

Table 2: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2	190	1.619	.656	-.341	2.763
EPI	190	67.291	14.996	20.1	90.68
CFDI	190	6.273	1.969	1.294	10.696
ELE	186	6.696	1.916	-1.778	10.556
MANU	190	8.015	2.163	-1.609	12.52
PG	190	.666	.656	-1.153	2.246
GDP	190	2.519	3.416	-11.325	11.737
EFF	190	4.349	1.366	.077	6.043
RE	190	2.929	.589	1.584	4.116
RQ	190	.996	.8	-.733	2.087

Source: Author's own calculations

4.3 Model specification

To analyze the effect of sectoral FDI on EPI and carbon emissions, this study has adopted the following model:

$$\boldsymbol{Co2it = f(MANUit, ELEit, CFDIit, Xit)} \quad \textbf{(i)}$$

Where CE_{it} is Carbon emissions for country i at time t, $MANU_{it}$ is FDIin manufacturing sector for country i at time t, ELE is FDI in electricity and gas sector for country i at time t, $CFDI_{it}$ is FDI in construction sector for country i at time t and Xit is a vector of control variables which control for country-level effects.

$$\boldsymbol{EPIit = f(MANUit, ELEit, CFDIit, Xit)} \quad \textbf{(ii)}$$

EPI is environmental performance index at time t for country i, $MANU_{it}$ is FDIin manufacturing sector for country i at time t, ELE is FDI in electricity and gas sector for country i at time t, $CFDI_{it}$ is FDI in construction sector for country i at time t and Xit is a vector of control variables which control for country-level effects.

Sectoral FDI effect on environment and growth

$$\boldsymbol{lnCo2it = \beta_0 + \beta_1 MANUit + \beta_2 ELEit + \beta_3 CFDIit + \beta_4 PGit + \beta_5 GDPit + \beta_6 EFFit + \beta_7 REit + \beta_8 RQit + \varepsilon it} \quad \textbf{(iii)}$$

$$\boldsymbol{EPI = \beta_0 + \beta_1 MANUit + \beta_2 ELEit + \beta_3 CFDIit + \beta_4 PGit + \beta_5 GDPit + \beta_6 EFFit + \beta_7 REi + \beta_8 RQit + \varepsilon it} \quad \textbf{(iv)}$$

4.4 Estimation strategy

This study used OLS and FE regression analysis for empirical analysis for which White test (Astivia & Zumbo, 2019) and Cumby-Huizinga Test (Firdousi et al., 2023) was used to check for autocorrelation, the Wald Test (Xu et al., 2022) was used to check for inter-group heteroscedasticity, and Pesarans's Test (Pesaran, 2021) was used to check for cross-sectional dependence between groups. Table A1-A6 in the appendix section displays the findings from these regression techniques.

Since the OLS and FE post-estimation test results showed serial correlation, heteroscedasticity, and cross-sectional dependence, this study used robust dynamic system GMM and difference GMM techniques according to the conditions defined by Arellano and Bond which state that the number of variables should be greater than the number of periods (Arellano & Bond, 1991; Cheng & Bang, 2021) These methods use the regressors' lagged values to eliminate serial correlation, increasing the efficiency of the GMM estimator (Anser et al., 2020).

5. Results and discussion

The robust dynamic two-step system GMM and difference GMM estimation approach, which rely on the validity of instruments and difference values of the dependent variables are used to obtain the results summarized in tables 3-4. The model's validity and accuracy are evaluated using the Arellano Bond test (Al-Malkawi & Ishaq Bhatti, 2020) and the Sargan test (Kiviet & Kripfganz, 2021). Because the p-value of AR (2) is higher than the 5% significance level, there is no autocorrelation in the data. Sargan tests likewise produce reliable results in accordance with the recognized p-value standards. These numbers show that the findings are robust to issues with autocorrelation and heteroscedasticity. Table 3 shows the results from the Robust system GMM and Difference GMM estimation of equation iii.

FDI inflows in construction sector has a significantly positive impact through both types of estimations, which indicates that FDI inflows in the construction industry increase air pollution in the sample countries; this result supports the PHH and previous literature because it explains the linkage that increased construction might lead to the use of excessive energy which further contributes to higher carbon emissions (Ali et al., 2020). Similarly, table 4 shows that FDI in construction industry negatively influences the environmental performance index raking of countries which is again consistent with literature because it suggests that FDI in construction leads to environmental degradation (Woon et al.,2023). FDI in the manufacturing sector and electricity positively influences carbon emissions when robust difference GMM is applied, which shows that manufacturing activities and the electricity sector produce a lot of carbon emissions (Wei et al., 2020). However this result is in contrast with (Pazienza, 2019), who concluded that FDI could result in technology transfer leading to a reduction in carbon emissions.

Furthermore, table 4 shows that the lagged EPI significantly affects the current EPI in both models, indicating the persistence of environmental performance over time. The impact of FDI in the manufacturing sector on EPI varies across both model estimates, conversely it is insignificant, . Moreover, as discussed earlier this research has consistent results with previous literature that suggests if investments are made in green technologies and recycling then it is possible that manufacturing sector might contribute towards improving environmental quality (Pazienza, 2019). Furthermore, investments in the electricity sector positively affect EPI, suggesting that FDI in this sector may contribute to better environmental outcomes because FDI might be directed towards environment friendly sources of electricity production.

The control variables such as population growth and GDP have a significant effect on carbon emissions; higher population leads to more emissions which is supported by literature as well (Mahmood & Haider/Hassan, 2022) because of more consumption and economic activity taking place, similarly, higher GDP implies more carbon emissions because GDP is related to increased levels of consumption, investment, and trade, where all require increased use of energy (Abbasi et al., 2022).Population growth and GDP have negative impacts on EPI in the difference GMM model, notably with GDP's effect being statistically significant. This is supported by existing literature which suggests that population growth is often associated with increased environmental degradation through overuse and misuse of natural resources, leading to issues such as deforestation, water pollution, soil erosion, and increased CO2 emissions (Awan & Azam, 2022).

Electricity from fossil fuels and renewable energy investments show negative associations with EPI, with renewable energy being statistically significant in the difference GMM model this result is counterintuitive to previous literature however, renewable energy might hurt environment if the production of renewable energy technologies, such as solar panels and wind turbines, are resource-intensive and involve the emission of greenhouse gases (Sayed et al., 2021). Moreover, extracting and processing materials such as silicon, rare earth metals, and steel require significant energy, often sourced from fossil fuels, leading to carbon emissions (Omri & Belaïd, 2021) . Regulatory quality significantly impacts the difference GMM model, indicating that better regulation can improve environmental performance (Ibrahim & Ajide, 2021).

The tables also include post-estimation tests to check for serial correlation and over-identification, indicating the models' robustness. The results contribute to the literature by highlighting the complex relationship between FDI and environmental outcomes, suggesting that the sectoral composition of FDI and the quality of governance and regulations play crucial roles in influencing a country's environmental performance. This analysis should be contextualized within the broader literature on environmental economics and the impacts of FDI on host country environmental policies and outcomes.

Table 3: Influence of sectoral FDI on carbon emissions

VARIABLES	(1)	(2)
	CO2-Sys GMM	CO2-Diff GMM
L.CO2	0.9350***	0.4863***
	(0.0500)	(0.0563)
CFDI	0.0084**	0.0072***
	(0.0039)	(0.0018)
MANU	0.0042	0.0066***
	(0.0035)	(0.0022)
ELE	0.0027	0.0037***
	(0.0028)	(0.0013)
PG	0.0571***	0.0192
	(0.0211)	(0.0200)
GDP	0.0100***	0.0036***
	(0.0012)	(0.0009)
EFF	0.0922**	0.1457**
	(0.0380)	(0.0613)
RE	-0.1902***	-0.3332***
	(0.0668)	(0.0691)
RQ	-0.1229	0.0076
	(0.0839)	(0.0487)
Constant	1.0064**	
	(0.4246)	
Observations	167	146
Number of country	19	19

VARIABLES	**(1)**	**(2)**
	CO2-Sys GMM	**CO2-Diff GMM**
Post estimation commands		
AR(2)	0.590	0.337
	(P-value is insignificant thus there is no serial correlation)	(P-value is insignificant thus there is no serial correlation)
Sargan test	0.058	0.067
	(P-value is insignificant thus there is no issue of over-identification)	(P-value is insignificant thus there is no issue of over-identification)
Hansen test	0.995	0.898
	(P-value is insignificant thus there is no issue of over identification of instruments)	(P-value is insignificant thus there is no issue of over identification of instruments)

Source: Author's own calculations
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Influence of sectoral FDI on EPI

VARIABLES	**(1)**	**(2)**
	EPI-Sys GMM	**EPI-Diff GMM**
L.EPI	0.6416***	0.4428***
	(0.0720)	(0.0789)
CFDI	-0.0863	-0.0910
	(0.4450)	(0.5101)
MANU	0.3778	-0.0846
	(1.0480)	(0.5340)
ELE	0.6124	0.7635
	(0.8736)	(0.6530)
PG	-0.4259	-9.2061***
	(4.3902)	(3.5290)
GDP	-0.1014	-0.3367***
	(0.1735)	(0.1031)
EFF	-2.7280	-0.1355
	(4.8656)	(11.6413)
RE	-12.4232	-18.6112*
	(8.4007)	(10.0701)
RQ	2.3392	46.1613***
	(4.1006)	(7.3204)
Constant	62.3842	
	(48.0421)	
Observations	167	146
Number of country	19	19

VARIABLES	(1)	(2)
	EPI-Sys GMM	EPI-Diff GMM
Post estimations		
AR(2)	0.015 (P-value is insignificant thus there is no serial correlation)	0.012 (P-value is insignificant thus there is no serial correlation)
Sargan test	0.055 (P-value is insignificant thus there is no issue of over-identification)	0.057 (P-value is insignificant thus there is no issue of over-identification)
Hansen test	0.986 (P-value is insignificant thus there is no issue of over identification of instruments)	0.997 (P-value is insignificant thus there is no issue of over identification of instruments)

Source: Author's own calculation
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Conclusion, policy implications and future research direction

6.1 Conclusion

This research has considered the effects of sector-wise FDI flows on carbon emissions and environmental performance index. A balanced panel data of 19 countries from the 2013-2022 period was selected. The OECD database was used to obtain data for sectoral FDI inflows in the manufacturing, construction, and energy sectors.

The study employed system GMM and different GMM estimation techniques to test for the possible effect that FDI flows to the manufacturing, construction, and energy sectors can have on carbon emissions and EPI. FDI flows to the manufacturing sector had a significantly positive influence on carbon emissions, while the influence on EPI was mixed under different estimation strategies but insignificant. Similarly, FDI flows to construction and energy positively affected carbon emissions but had an insignificant effect on environmental performance. Overall, the results showed that FDI in construction sector significantly increases carbon emissions, while it decreases EPI compared to other sectors pertaining to the FDI in this sector might be the most harmful to the environment. Evidence of the PHH was shown in the results through the measure of regulatory quality, which had a negative effect on carbon emissions and a significantly positive influence on countries' environmental performance. Thus, when polluting firms are located in countries with less stringent regulations, adverse environmental impacts are possible.

The contribution of this paper is two-fold; this paper has assessed the differential impacts of FDI on carbon emissions and environmental performance index which is a novel index. Moreover, this research has shown that FDI flows in manufacturing, construction and energy sectors all contribute towards environmental degradation. Furthermore, findings highlight that the presence of strong regulatory quality is important in managing FDI because otherwise, it might lead polluting firms to locate to the host country.

6.2 Policy Implications

The influence of sectoral FDI in manufacturing, construction, and energy sectors on carbon emissions and environmental performance is comprehensive. Research indicates that FDI can have both positive and negative effects on the environment, depending on various factors, including the level of environmental regulation, the type of technology transfer, and the economic development stage of the host country.

In the manufacturing sector, FDI can lead to increased carbon emissions if it involves the transfer of pollution-intensive industries to countries with less stringent environmental regulations. However, it can also have positive effects by introducing cleaner and more efficient production technologies, thus potentially reducing emissions, and improving environmental performance through the pollution halo hypothesis (Pazienza, 2019).

Likewise, construction sector FDI often results in increased resource use and carbon emissions due to the nature of construction activities. However, it can also contribute to environmental performance improvements if it involves the development of green buildings and sustainable urban infrastructure that incorporate energy-efficient technologies and materials (Woon et al.,2023).

Moreover, energy sector FDI can significantly impact carbon emissions, primarily when it supports the development of renewable energy projects. While renewable energy FDI generally reduces carbon emissions by replacing fossil fuel-based energy production, it is essential to acknowledge the environmental impacts associated with the production and installation of renewable energy technologies themselves.

The net effect of FDI on carbon emissions and environmental performance in these sectors is thus determined by a balance between introducing technologies and practices that reduce environmental impacts and the potential for increased pollution and resource use due to economic expansion and the nature of the investments. Effective regulatory frameworks, technology transfer mechanisms, and sustainable development policies are crucial for maximizing the positive environmental impacts of FDI while minimizing its adverse effects.

6.3 Future research direction

There are a few limitations of this paper which future researchers can address. This paper takes FDI flows in just three sectors; future researchers can also consider the agriculture and services sectors. Moreover, due to limited data availability, the analysis was limited to 19 countries worldwide. Future researchers can use more countries to draw comparisons between developing and developed countries or conduct threshold analysis.

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Appendix

Table A1: OLS estimation of influence of FDI on carbon emissions

VARIABLES	(1)	(2)	(3)	(4)
	CO2	CO2	CO2	CO2
CFDI	0.0561**	0.0151	0.0165	0.0566***
	(0.0240)	(0.0307)	(0.0345)	(0.0186)
ELE		0.0704**	0.0710**	-0.0171
		(0.0318)	(0.0325)	(0.0179)
MANU			-0.0026	-0.0046
			(0.0286)	(0.0159)
PG				-0.0748
				(0.0501)
GDP				0.0092
				(0.0077)
EFF				-0.0335
				(0.0250)
RE				-0.2976***
				(0.0591)
RQ				0.6199***
				(0.0378)
Constant	1.2668***	1.0446***	1.0527***	1.8461***
	(0.1575)	(0.1826)	(0.2037)	(0.2615)
Observations	190	186	186	186
R-squared	0.0283	0.0553	0.0554	0.7413
Post-Estimations				
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity				chi2(1) = 3.40 Prob > chi2 = 0.0653 Greater than 5%, insignificant (therefore there is no issue of heteroskedasticity)
Cumby-Huizinga Test, to check for autocorrelation				152.470*** less than 5%, significant (therefore there is issue of serial correlation)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A2: OLS estimation of influence of FDI on EPI

VARIABLES	(1)	(2)	(3)	(4)
	EPI	EPI	EPI	EPI
CFDI	1.2156**	-0.0815	-0.1963	0.3795
	(0.5484)	(0.6890)	(0.7747)	(0.5196)
ELE		2.1548***	2.1084***	0.2896
		(0.7131)	(0.7287)	(0.5001)
MANU			0.2101	-0.1656
			(0.6415)	(0.4457)
PG				-5.0062***
				(1.4030)
GDP				-0.3915*
				(0.2155)
EFF				0.0498
				(0.6991)
RE				-0.8476
				(1.6537)
RQ				12.1446***
				(1.0591)
Constant	59.6654***	53.0582***	52.4034***	58.6006***
	(3.6043)	(4.0984)	(4.5693)	(7.3188)
Observations	190	186	186	186
R-squared	0.0255	0.0725	0.0730	0.6049
Post estimations				
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity				chi2(1) = 3.08 Prob > chi2 = 0.0792 Greater than 5%, insignificant (therefore there is no issue of heteroskedasticity)
Cumby-Huizinga Test, to check for autocorrelation				48.619*** less than 5%, significant (therefore there is issue of serial correlation)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A3: Fixed Effects estimation of influence of FDI on carbon emissions

VARIABLES	(1)	(2)	(3)	(4)
	CO2	CO2	CO2	CO2
CFDI	-0.0109	-0.0116	-0.0116	-0.0008
	(0.0114)	(0.0116)	(0.0116)	(0.0056)
ELE		0.0120	0.0120	0.0052
		(0.0098)	(0.0099)	(0.0048)
MANU			-0.0003	-0.0058
			(0.0142)	(0.0069)
PG				-0.0192
				(0.0154)
GDP				0.0001
				(0.0016)
EFF				0.2310***
				(0.0387)
RE				-0.5851***
				(0.0380)
RQ				-0.0053
				(0.0479)
Constant	1.6869***	1.6040***	1.6065***	2.3441***
	(0.0721)	(0.0947)	(0.1420)	(0.2649)
Observations	190	186	186	186
R-squared	0.0053	0.0140	0.0140	0.7824
Number of country	19	19	19	19
Post estimations				
Wald test				0.0000 (there is issue of heteroskedasticity)
Wooldridge F-Test				0.0000 (significant it implies there is presence of serial correlation)
Pesaran's test of cross sectional independence				0.0052 (significant, thus there is cross sectional independence)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A4: Fixed effects estimation of influence of FDI on EPI

VARIABLES	(1)	(2)	(3)	(4)
	EPI-FE	EPI-FE	EPI-FE	EPI-FE
CFDI	-0.0103	-0.0194	-0.0071	0.1882
	(0.7476)	(0.7519)	(0.7527)	(0.7361)
ELE		0.2630	0.1854	0.1109
		(0.6336)	(0.6409)	(0.6288)
MANU			0.7710	0.2343
			(0.9166)	(0.9110)
PG				-1.3707
				(2.0358)
GDP				-0.0811
				(0.2168)
EFF				-2.0964
				(5.0958)
RE				-5.4336
				(5.0069)
RQ				18.7909***
				(6.3081)
Constant	67.3550***	65.3355***	59.5864***	71.0253**
	(4.7374)	(6.1426)	(9.1931)	(34.9134)
Observations	190	186	186	186
R-squared	0.0000	0.0010	0.0053	0.0905
Number of country	19	19	19	19
Post estimations				
Wald test				0.0078 (there is issue of heteroskedasticity)
Wooldridge F-Test				0.0018 (significant it implies there is presence of serial correlation)
Pesaran's test of cross sectional independence				0.0000 (significant, thus there is strong cross sectional independence)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A5: Random effects estimation of influence of FDI on carbon emissions

VARIABLES	(1)	(2)	(3)	(4)
	CO2-RE	CO2-RE	CO2-RE	CO2-RE
CFDI	-0.0094	-0.0104	-0.0105	-0.0004
	(0.0113)	(0.0115)	(0.0115)	(0.0064)
ELE		0.0130	0.0128	0.0054
		(0.0097)	(0.0098)	(0.0055)
MANU			0.0008	-0.0060
			(0.0139)	(0.0078)
PG				-0.0314*
				(0.0175)
GDP				-0.0000
				(0.0019)
EFF				0.1271***
				(0.0389)
RE				-0.5858***
				(0.0424)
RQ				0.1123**
				(0.0506)
Constant	1.6780***	1.5971***	1.5922***	2.7038***
	(0.1679)	(0.1795)	(0.2096)	(0.2966)
Observations	190	186	186	186
Number of country	19	19	19	19

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A6: Random effects estimation influence of FDI on EPI

VARIABLES	(1)	(2)	(3)	(4)
	EPI-RE	EPI-RE	EPI-RE	EPI-RE
CFDI	0.2563	0.1701	0.0753	0.3339
	(0.6799)	(0.6885)	(0.6961)	(0.5439)
ELE		0.5443	0.4142	0.3134
		(0.6054)	(0.6178)	(0.5187)
MANU			0.7311	-0.0281
			(0.7824)	(0.4868)
PG				-4.2140***
				(1.4786)
GDP				-0.3077
				(0.2128)
EFF				-0.0521
				(0.8090)
RE				-1.4563
				(1.8665)
RQ				12.3252***
				(1.2250)
Constant	65.6832***	62.3563***	57.9657***	58.9318***
	(5.1368)	(6.0052)	(7.7677)	(8.4506)
Observations	190	186	186	186
Number of country	19	19	19	19

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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