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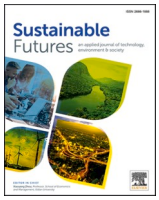

Balancing growth and sustainability: The impact of Greenfield investment on trade adjusted carbon emissions

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ABSTRACT

In the last two decades, the surge in carbon emissions has escalated environmental damage and is a major concern globally. Recognized as a significant threat to humanity, unchecked environmental degradation can potentially hinder the achievement of sustainable development. As a result, accurate monitoring of carbon emissions becomes imperative for formulating effective climate policies. Taking into consideration, this study has taken the newly developed consumption-based carbon emissions measure to study the pollution haven hypothesis and examine the link between Greenfield Investment (GFI) inflows to host nations and their environmental impact for 85 developing countries from 1990 to 2020. The results show a positive correlation between Greenfield investment and Consumption-based Carbon Dioxide Emissions (CCO_2) in sampled nations. Similarly, energy usage and export damage the environment because developing countries rely on conventional and old methods of energy usage. The results were further analyzed for low, lower middle, and upper middle income countries as well. The subsample outcome shows that Greenfield investment has a more damaged environment in low income countries as compared to lower middle and upper middle income countries. These insights underscore the urgency for developing countries to adopt environmentally conscious policies to attract international investors. It also emphasizes the need for stringent regulations aimed at curbing environmental pollution and complying with the Sustainable Development Goals (SDGs). Similarly, low and lower middle income countries to attract Greenfield investment, may also focus more on strict environmental pollution policies. Industries must be shifted from conventional energy methods to renewable energy sources. Sustainable Development Goals; 7, 12, and 13 can be achieved by host countries, alluring investors to invest in terms of Greenfield in renewable energy resources, which would be used in automobile transportation, to shift industries from conventional energy resources to renewable energy resources. The same Greenfield investment would also be used in bringing efficient machinery for more production in industries with minimal environmental pollution.

1. Introduction

To promote economic growth and development, international capital flows, notably Foreign Direct Investment (FDI), must be used effectively. Most nations do this through encouraging economic expansion, often at the expense of environmental regulations [1]. Ignoring the negative repercussions of pollution intensifies climate warming and climate change globally. Developing countries place more emphasis on attracting FDI, which increases economic activity in a host country. Ultimately, the natural environment is negatively impacted by FDI [2]; even though it increases capital stock, per capita income, employment opportunities, socioeconomic status, and technical advancements [3,4]. Intergovernmental Panel on Climate Change (IPCC, 2019) [5], defines climate change as a problem when global temperature exceeds pre-industrial levels by 1.5 °C. Edenhofer et al., [6] state that there is a consensus among the majority of environmentalists that the average global temperature should not rise by more than 2 °C per year. Since Carbon Dioxide (CO_2) emissions are the main contributor to global warming, climate change, and environmental pollution; all nations are more aware of the negative effects of CO_2 emissions. Though energy efficiency and Gross Domestic Product (GDP) move neck to neck in developed countries [7] these nations have closely monitored this issue and

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improved the environmental regulations, while developing nations and emerging economies are still at fault. To reap the rewards of economic prosperity, developing nations must establish clean, green, and environmentally friendly pollution reduction strategies [8,9].

According to the literature, the Pollution Haven Hypothesis (PHH) has received much attention from scholars and practitioners. According to the PHH, those countries can only draw FDI by emphasizing economic growth and having lax environmental protection laws. According to Mani and Wheeler [10], developing nations pay a higher price for pollution than industrialized nations do. The issue with developing nations is that they have lax environmental protection laws, which has led developed countries to move their operations there [11]. Developing nations draw FDI, which primarily takes the form of investments in industries and the manufacturing sector. High CO_2 emissions are caused by trade and investment in developing nations [12]. The industrialized nations have safeguarded their natural environments, against large CO_2 emissions, by regulating their businesses, in accordance with effective environmental legislation. However, Neequaye and Oladi [13] have opined that countries with effective pollution protection regulations are less appealing to foreign investors.

Globalization has caused multinational corporations to view developing nations as safe havens for their investments, which can lead to environmental pollution (He, 2006). Developing countries with low labor costs, a wealth of natural resources, and laxer, less protective environmental regulations have all drawn investments from multinational corporations to emerging countries. According to Destek and Okumus [3], FDI is considered the top source of funding for major investment ventures and the transfer of contemporary technologies. Inbound FDI aids in the economic development of the developing nations; however, the ineffective environmental regulations of these nations, affect the environment negatively [14]. Air pollution reduction is a significant problem in these nations because of the inadequate environmental regulations there. Less focus on environmental pollution primarily brought by CO_2 emissions also makes climate change worse. Significant weather disturbances due to climate change worldwide have harmfully affected, both developing and developed countries [15]. The Sustainable Development Goals (SDGs) were established by the United Nations for its member nations to address the economic and environmental crises, but unfortunately, that is yet a mirage.

According to Azam and Raza's [2] analysis, developing nations have recently used FDI to solve their financial woes. FDI aids in the introduction of cutting-edge high technology to address the issues of air pollution and supports economic expansion. The influx of FDI into host nations and its effects on the economy and environment is still up for debate. FDI is typically sparked by a host country's rich natural resources and affordable labor. The issue with foreign investors is that global firms and corporations from industrialized nations exploit environmental protection laws, causing pollution to increase. The investors benefit from low-cost production while developing countries profit from industry hubs, which encourages more polluting firms to relocate there (Nunneenkamp, 2001). Investments in developing countries (host) should be established in cutting-edge production techniques that less pollute the environment [16]. This study thus seeks to revisit PHH and ascertain if there are rising or falling combinations of FDI and environmental pollution.

FDI has many modes and GFI is considered as the most important mode because it is the newly established asset by any foreign investor in the host country. The establishment of a new plant etc., by a foreign firm that starts working with the help of local skilled labor and local resources i.e., raw materials and the data of GFI, is calculated as the subtraction of M&A data from FDI inflow data of a host country. The goal of the current study is to look into Greenfield Investment (GFI) as a mode of FDI as a potential new factor influencing the newly established trade adjusted carbon dioxide (CCO_2) emission. The causal relationship is to be determined between GFI inflows to host countries and environmental pollution caused by CO_2 emission, using trade-adjusted CCO_2 emissions for a sample of 85 developing countries (list given in Appendix) over the period 1990–2020. Sustainable growth is both necessary and unachievable without preserving a green and clean environment, for the welfare of a society. Prior studies have mostly concentrated on production or territory-based CO_2 emissions, neglecting to account for the nation's imports and exports. This study used the index for trade-adjusted carbon emissions as fossil fuel emissions plus imports minus exports. This study is unique from the rest of the studies due to the GFI mode of FDI. Another reason is that, in literature, this mode of FDI is ignored and the analysis is never done for the relationship between GFI and environmental pollution caused by CO_2 emission. The reason for using this mode of FDI is that developing countries attract more GFI as compared to other modes of FDI [17,18].

To the best of the authors' understanding, four aspects of this study set it apart from others. Therefore, the newly created trade-adjusted CCO_2 emission was used in the current study, while taking GFI as the target independent variable. First, unlike earlier research studies, this study used trade-adjusted CCO_2 emissions to quantify environmental pollution. This study used GFI which is a more reliable and accurate variable than FDI. Second, unlike past research that only examined one regional sample, our study includes developing nations with further analysis of the low-income, lower-middle-income, and upper-middle-income sampled countries. Third, while earlier research focused on looking at the FDI impact, we assessed the effects of Greenfield investment and trade-adjusted carbon emission. The data of GFI is based on real investment data i.e., for each host country Merger & Acquisition (M&A) data is subtracted from FDI inflow data while other researchers used Greenfield project data. Fourthly, we used the system GMM for the analysis of results while Random Effect was used for the robustness of results, and also looked at Granger causality across all sampled nations. Lastly, the current study used the GFI data by taking the difference between total inward FDI and M&A based on the study of Raza et al. [4].

2. Literature review

The link between FDI based as GFI and CCO_2 emissions under PHH has been the subject of numerous research, for various samples of developed, developing, and least-developed nations. Cole and Fredriksson [19] emphasize that while FDI increases per capita income, it also contributes to environmental pollution. The authors used 3SLS and fixed effect models for selected OECD countries from 1982 to 1992. The study revealed that PHH is valid and FDI has a positive impact on the urban population and also leads to high inflation. The current study highlighted the case of total FDI of the sampled countries by ignoring the FDI inflow or outflow. Tamazian and Rao [20] used panel data from 24 Transitional economies for the decade of 1993–2004. Random effect and GMM techniques were applied and the results confirmed that energy use, trade, and GDP increase the CO_2 emissions, while FDI has not influenced the carbon emissions. The study assessed the validity of the Environmental Kuznets Curve (EKC). Omri et al. [21] worked on the sample data from MENA, LAC, sub-Saharan African, European, and Central Asian countries. The authors used the GMM technique on the sampled data from 1990 to 2011. The study found that FDI, trade openness, Exchange rate, Urbanization, and capital stock increase CO_2 emissions. The authors analyzed that FDI is responsible for polluting the environment in these sampled countries. This study explored the findings of different regions by taking FDI inflows but still ignored the main issue of FDI which is to be divided into either modes or types for more in-depth results in these regions.

Neequaye and Oladi [13] used the sample data from 2002 to 2008 for 27 developing Countries and applied a Fixed effect for the final results. The study confirmed that FDI increases CO_2 emissions and also found that EKC is valid. Based on income, Shahbaz et al. [22] selected a sample of developed and developing nations from 1975 to 2012 and observed that PHH is valid. The Granger causality outcome demonstrates a bi-directional causality between CO_2 emissions and FDI; and between

energy use and CO_2 emissions. Taking the sample of ASEAN countries from 1980 to 2010, Zhu et al. [23] used a fixed effect technique and found that CO_2 emissions are reduced by FDI. They further found that trade openness decreases CO_2 emissions while energy use and high GDP escalate CO_2 emissions. The authors further proved that the Halo Pollution Hypothesis is valid and EKC is not valid, for the sampled data.

Within 14 Latin American nations between 1980 and 2010, Sapkota and Bastola [24] presented enticing strategies centered on foreign investment in energy efficiency that might further enhance economic progress and air pollution. The study's findings demonstrated the EKC and PHH's reliability for both high- and low-income nations, as well as for the entire sample. It was found that FDI boosted CO_2 emissions and supported PHH in 17 Latin American economies, from 1971 to 2011. The study split the sample into low, middle, and high income countries, but it was only high-income countries where the beneficial effect of FDI on CO_2 emissions was proven [25]. Behera and Dash [26] examined the sample countries of South and Southeast Asian countries for a time period of 1980–2012. The study applied Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) techniques and found that FDI, primary energy use, and urbanization increase CO_2 emissions. The study analyzed that FDI is responsible for polluting the environment which further haphazard society's wellbeing.

According to Mikayilov et al. [27], increasing energy efficiency is an appropriate environmental strategy to lower overall CO_2 emissions without impairing economic growth. This is possible by enhancing optimal investment in the infrastructure and implementing the policies of energy conservation to prevent irrational use of energy. According to Solarin and Al-Mulali's [28] research, there is no correlation between inward FDI and environmental degradation in a sample of 20 nations between 1982 and 2013. To put it another way, Tajudeen et al. [29] point out that increasing energy efficiency is one of the most affordable and easily scalable ways to support sustainable growth. These policies include reducing power loss during distribution and transmission procedures, utilizing less energy-intensive technologies, and varying tariff structures are all ways to manage energy use.

Miniesy and Tarek [14] explored the validity of PHH and also showed that FDI surges CO_2 emissions. They utilized the data from 1996 to 2016 of sampled developing nations of Asia and applied the Fixed Effect technique. Albulescu et al. [30] analyzed that FDI does not affect air pollution while the authors did not find the validity of PHH but found the validity of EKC. The authors used the Quantiles regression model for the period 1980–2010 using data from 14 Latin American countries. To et al. [31] concluded that between 1980 and 2016, FDI caused CO_2 emissions to increase in 25 emerging Asian economies. Further research shows that CO_2 emissions are negatively impacted by both oil usage and per-capita income.

Rafique et al. [32] worked on the data of BRICS from 1990 to 2017 using the AMG technique for full analysis. The authors were of the view that financial development, technological innovation, and FDI have adverse effects, while other control variables affect CO_2 emissions positively. Azam and Ozturk [8] analyzed the impact of FDI on CO_2 emission, using a sample of 17 Asian nations for the years 1980 to 2014, and discovered that it increases CO_2 emissions. The study further found that CO_2 emissions from economic expansion and trade openness contribute to environmental pollution. Similarly, Asharf et al. (2021) assessed that GFI worsens the environmental quality of developing countries whereas the M&A improves the air quality of industrialized countries. The authors also revealed that GFI improves the air quality of industrialized nations especially, in the case of transport shows improvement in reducing CO_2 emissions.

Awan et al. [33] assessed the data of 10 emerging countries from 1996 to 2015 and applied the Method of Moments Quantile Regression (MMQR). They found that FDI is significant and has a positive impact on carbon emission till 0.50th quantiles but becomes insignificant above 0.50th quantiles. Similarly, renewable energy usage has a significant impact and reduces carbon emissions at all quantile levels. Wang and Zhang [34] assessed the impact of FDI on carbon emission effectiveness for a sample of 30 provinces of China. The study applied the fixed effect technique and revealed that FDI negatively impacts carbon emissions. Additionally, each FDI channel has a negative effect on CO_2 emission efficiency, as shown by the interaction between FDI and the channels, which also negatively influence on efficiency of carbon emission. Similarly, Khan et al. [35] investigated the quality of institutional FDI and reduction in carbon emission in the 39 Belt and Road Initiative nations and 107 developing nations for the period of 2002 to 2019. The study confirmed that FDI increases carbon emissions in developing nations, whereas reducing carbon emissions in Belt and Road countries. Further analysis confirmed that the rule of law, political and economic stability, control over corruption, and quality of institutions have either no or very weak impact on carbon emissions. The authors showed how FDI affects carbon emissions and pollutes the environment of the sampled countries. The authors left the space for future work to find out the impact of any mode of FDI on environmental pollution.

Castellani et al. [36] were in favor of GFI and suggested that such investment would have a positive impact on the environment if green-tech investment is used. The authors used European firms' data from the years 2003–2014 and confirmed the positive aspect of GFI and the environment if and only if green-tech investment is made in the region. Similar results were found by Zeraibi et al. [37]. The study revealed that in BRICS nations there is a GFI to enhance carbon footprint if more resources of renewable energy are invested in industrial sectors. Such investment in terms of GFI would strengthen the sampled nations' renewable energy potential.

Mahmood et al. (2023) confirmed that FDI is responsible for the environmental damage and there is a dire need to attract FDI with cleaner production machinery of the latest technologies with more energy efficient in a host country. Caetano and Marques [38] acknowledged that FDI and trade are crucial for pollution and cause more CO_2 emissions. The authors highlighted the case of middle income and high income countries using the Non-Linear panel ARDL model and concluded that FDI causes environmental degradation that leads to human health threats. Uctum et al. [39] highlighted the case of outward GFI for developed and developing countries and explored that M&A may cause less pollution as compared to GFI. The authors also revealed there is a positive relationship between FDI and reduction in environmental pollution for the case of full sampled analysis but in the case of developing countries, GFI outflow reduces CO_2 emissions in home countries and a similar case is also found by Ashraf and Doytch [40]. The authors work out on the GFI data that developed countries invest i.e. outward GFI of developed countries which is considered as their investment in developing countries and left the space for practitioners to find out the GFI inflow of host developing countries on carbon emissions.

Bialek and Weichenrieder [41] predicted that GFI has a worse impact by making the environment dirtier than M&A. The authors worked on 2619 German firms' investments in GFI and M&A forms of FDI from year 2005 to 2011 by using a conditional Logit estimations strategy. The study also revealed that there is a dire need for discussion on choosing either GFI or M&A for investment in other countries. Ly-My et al. [42] assessed that GFI is more harmful to the environment than M&A in emerging economies as compared to developing countries sample. The study used the panel data of 91 countries from year 2005–2020 by using ARDL and Dynamic Fixed Effect (DEF) techniques for the analysis of results. The study further analyzed that in developing countries sampled assessment M&A has a positive relationship with the environment. Moreover, the authors were not in favor of any foreign investment because of its deteriorated role in polluting the environment. The author's main theme of research was to find out whether GFI acts as a catalyst for economic growth and further search out the relationship between GFI and environmental pollution. The study left a gap in the impact of GFI on trade-adjusted carbon emissions.

Nepal et al. [43] documented that GFI is a very favorable investment if and only if renowned investment firms make investments in

developing countries. The study used data from Asian countries from year 2000–2018 by applying Dynamic Common Correlated Estimator for the final analysis of the sampled countries. The authors concluded that more factors of institutions like the latest and efficient technology usage can also improve the performance of investment even better to help in decreasing CO_2 emission.

The Logic behind a collection of the above literature is what the researchers have shown in their applied research findings. Those results were discussed and the gaps that researchers left were also mentioned. To sum up the above discussion, on applied side research many researchers either used total FDI data or inflows FDI data for analyzing the relationship with environmental pollution. Some researchers used outflow FDI data and tried to find its relationship with carbon emission. In the literature, some researchers show different regional-based empirical results about the impact of FDI on carbon emissions. Therefore the current study tried best to analyze the linkage of GFI with consumption-based carbon emissions for sampled data of 85 developing countries.

3. Data and variables

This research used the data i.e. mainly extracted from the World Development Indicators (World Bank, 2023), and trade-adjusted CCO_2 emissions-related data is extracted from the Global Carbon Atlas (2023). The current research employed a sample of 85 developing nations (Table 1) over a time-lapse of 1990 to 2020. The sampled developing countries chosen for this study are based on the World Bank Altas Method (2023). The variables of this study are given in Table 2, which also mentions the definition, abbreviation, and sources for each data variable as well.

3.1. Empirical model

This study employs CCO_2 emission as a dependent variable to fulfill the research goal, which is also employed by Safi et al. [44] to quantify the impact of population, financial stability, and GDP on CCO_2 emission. Knight and Shor [45] looked at the relationship between several indicators of CCO_2 emissions and concluded that exports and imports had an impact on both production and consumption-based carbon emissions. The empirical model might be described as follows, based on the investigations of Azam and Raza [2], the authors included industry value as a controlled variable. The general form is given as:

$$P_{it} = \beta_{it} + \beta_1 P_{it-1} + \beta_2 Q_{it} + \beta_3 R_{it} + \mu_{it} \quad (1)$$

where P_{it} represents the CCO_2emissions of country i in time t, Q_{it} is a target variable, R_{it} is a set of control variables and μ_{it} varies across countries and time. This equation assumes that there is no existence of heterogeneity and endogeneity, the model is linear in terms of variables and coefficient.

Rearranging Eq. (1), we obtain

$$CCO_{2it} = \beta_{it} + \beta_1 CCO_{2it-1} + \beta_2 GFI_{it} + \beta_3 ENG_{it} + \beta_4 EXP_{it} + \beta_5 PoP_{it} + \beta_6 GDP_{it} + \beta_7 IND_{it} + \mu_{it} \quad (2)$$

Dependent variable is CCO_{2it}, CCO_{2it-1} is a lagged independent variable, GFI_{it} as Greenfield investment is the target independent variable while ENG_{it} as energy usage, EXP_{it} as export, PoP_{it} as population, GDP_{it} as economic growth and IND_{it} as industry valued added are control variables. The random-effects model is also referred to as an error component model in the current body of literature. The country's unique intercept value in Eq. (2) is written as β_{it},

Where $\beta_{it} = \beta_0 + \upsilon_i$.

Substituting β_{it} in Eq. (2) results in the following Equation:

$$CCO_{2it} = \beta_0 + \beta_1 CCO_{2it-1} + \beta_2 GFI_{it} + \beta_3 ENG_{it} + \beta_4 EXP_{it} + \beta_5 PoP_{it} + \beta_6 GDP_{it} + \beta_7 IND_{it} + (\mu_{it} + \upsilon_i) \quad (3)$$

whereas $\sigma_{it} = \mu_{it} + \upsilon_i$ is substituted in Eq. (3). σ_{it} is an error term composed of two effects, i.e., μ_{it}, which is an individual-specific effect, while υ_i is a time series and error component effect.

Thus, Eq. (3) becomes

$$CCO_{2it} = \beta_0 + \beta_1 CCO_{2it-1} + \beta_2 GFI_{it} + \beta_3 ENG_{it} + \beta_4 EXP_{it} + \beta_5 PoP_{it} + \beta_6 GDP_{it} + \beta_7 IND_{it} + \sigma_{it} \quad (4)$$

The last equation employed in the analysis of the system using the generalized method of moments (GMM) approach is Eq. (4).

3.2. Assessment approach

We must evaluate the Stationarity features of data before we may investigate long-term data empirically. To check Stationarity, we used the panel unit-root test described by Im, Pesaran, and Shin (IPS). We used Im et al. [46] IPS panel-unit root test for the Stationarity checking of the series because it is common to verify the Stationarity test of all variables before performing more empirical analysis on the data under examination. If the panel data is balanced, then the IPS test performs best and is also acceptable for dynamic heterogeneous panel outcomes because it allows for nation-level heterogeneity, including individual effects and specific patterns of residual serial correlations.

Additionally, the IPS test manages the errors' cross-sectional dependence, which is a second benefit. Other tests, like Quah [47] and Levin, Lin, and Chu [[48] (2002], are founded on pooled regressions, however, the IPS test assesses a collection of independent tests rather than pooling data. This study also used random effects (RE), as advised by the Hausman [49], and compared the results of RE and System GMM. Wooldridge [50] mentioned that when independent variables are associated with residuals then the problem of endogeneity arises. Therefore Arellano and Bond [51] first highlighted the case of endogeneity and gave the idea of a moment estimation technique to solve the problem of endogeneity. Later on, Arellano and Bover [52] confirmed that this problem still prevails and introduced the instrumental variable method to control endogeneity. Once the problem of endogeneity is controlled, that further reduces the chances of biased outcomes, due to this reason this study used the GMM technique. System GMM, proposed by Blundell and Bond [53], overcomes the endogeneity problem by incorporating instrumental factors into the model. The System GMM technique uses a standard group of first differences equations using the proper lag levels as instruments, as well as an additional equation in levels using accurate first differences with lags as the instruments. The validity of additional instruments, as well as the absence of second-order autocorrelation, are both required for system GMM to work.

Hansen [54] has validated the instrument's validity which provides an over-identification collection of constraints and guarantees that the instrument collection is proper in all cases. The Sargen/Hansen test of over-identification and AR (2) test for autocorrelation, proposed by Arellano and Bond [51] and Arellano and Bover [52], is also used to confirm the absence of serial correlation. The over-identification Sargan/Hansen test, which verifies the instrument's validity, and Arellano-Bond (AR2) autocorrelation, which verifies the lack of second-order autocorrelation. This study model's validity is ensured by the high p-values of these tests in robust estimations. Moreover, over the system GMM estimator improves substantially the estimate of the impact of Greenfield investment on trade adjusted carbon emissions relative to the model which focuses on within-country changes in this area, adding information on cross-country variation. This study follows the system GMM technique for the analysis of the final results.

For time-series data, [55] established a model of causation between two variables. The panel data set still had a causality problem, and Dumitrescu and Hurlin [56] presented the most recent development to overcome it. This method was used to conclude Granger causality in the study, and the outcomes were examined.

Table 2
List of Variables, definition and Sources.

Variables	Depiction	Label	Source
Greenfield Investment	Total new investment in the host country i.e. FDI inflows minus M&A	GFI	WDI, 2023
Trade Adjusted Carbon Dioxide Emissions	Fossil fuel emissions plus imports minus exports.	CCO_2	Global Carbon Atlas (2023)
Industry Value added	Mining, manufacturing, construction, electrical, water, and gas industries all value addition.	IND	WDI, 2023
Export	products and services exported	EXP	WDI, 2023
Energy Usage	oil equivalent in kilograms per person	ENG	WDI, 2023
Population	Yearly percentage increase	PoP	WDI, 2023
Economic Growth	The% rise in gross domestic output per year.	GDP	WDI, 2023

Table 3
Correlation matrix.

Variables	GFI_{it}	ENG_{it}	EXP_{it}	Pop_{it}	GDP_{it}	IND_{it}	CCO_{2it}
GFI_{it}	1						
ENG_{it}	0.635	1					
EXP_{it}	0.618	0.331	1				
Pop_{it}	0.142	0.316	−0.123	1			
GDP_{it}	0.599	0.607	0.592	0.292	1		
IND_{it}	−0.291	0.312	−0.212	0.314	0.223	1	
CCO_{2it}	−0.234	−0.354	−0.102	−0.542	−0.376	−0.282	1

Table 4
Stationarity Testing.

Variables	**At Level**		**At 1st Difference**	
	constant	constant & trend	Constant	constant & trend
GFI_{it}	−2.88**	−3.60**	−6.80**	−6.73**
ENG_{it}	−1.29	−2.30	−1.81**	−2.85**
EXP_{it}	−1.07	−2.28	−4.47**	−4.48**
PoP_{it}	−1.83	−2.30	−4.12**	−4.22**
CCO_{2it}	−1.46	−1.80	−5.23**	−5.67**
GDP_{it}	−3.37**	−3.55**	−6.20**	−6.15**
IND_{it}	−1.64	−2.19	−4.87**	−5.01**

Note:.
** $p < 0.05$ representing the significance of variables.

4. Results and discussion

STATA 17.0 version is used for the analysis of this study. STATA is considered a powerful tool that is widely used for secondary data analysis and is authentic software that gives accurate results. Furthermore, the result and discussion section is divided into subsections and each section includes a detailed discussion about the results.

4.1. Correlation result

Correlation matrix Table 3 shows the relationship of all variables either positive or negative that exhibits different conclusions.

The correlation between GFI and ENG is 63.5 % which shows a strong relationship between these two important variables. Theoretically, Greenfield investment and energy usage are directly related while the correlation between GFI and carbon emission is about 23 % which shows an inverse relationship and is confirmed theoretically as well. Similarly, carbon emission is inversely associated with energy usage, export, population, economic growth, and industry value added. On the other hand, export is negatively correlated about 12 % with population whereas 21 % with industry value added but is positively associated with GDP of about 59 %.

4.2. Unit root test

Stationarity testing is a pre-requisite for any of the panel data sets to evaluate full results. All variables' Stationarity is first verified using constants only, and then at both the level and the initial difference using both constants plus trend terms.

Stationarity testing is a crucial part of empirical economic data analysis. If the data do not possess the properties of Stationarity then the results might be biased and the researcher would suggest wrong policy implications. Most of the economic indicators are unit root at the level and will give wrong output if regress [57]. Similarly, in panel data heterogeneity is the main issue, and mostly this issue is ignored in many studies. The IPS test is the most pertinent test employed in this investigation. The IPS test used in this study solved the issue of heterogeneity. The results of the unit root test highlighted in Table 4 show that, the majority of the variables were regarded as stationary at the first difference for both constants only and constant plus trend terms. According to the results, GFI and GDP are the only two variables that are stationary at level (Null hypothesis is rejected) suggesting a long-term impact on carbon emission. Whereas the rest of the variables are non-stationary at level (Null hypothesis is accepted) and then become stationary (Null hypothesis is rejected) at first difference.

4.3. Final results of full sample data

RE, along with the system GMM technique, are used to interpret full results as shown in Table 5. Small p-values of less than 0.05, show that coefficients are statistically significant which means that the null hypothesis is rejected in favor of the alternative hypothesis. A 5 % level of significance in regression results refers to the threshold used to determine whether a particular result is statistically significant or insignificant. It is a criterion for determining whether the observed relationships in the data are statistically significant or insignificant. For the robustness

Table 5
Comparison of Full Sample Results.

Variables	Random Effect	SYS-GMM
Constant	0.5148354 (0.291)	0.54684 (0.128)
GFI_{it}	0.00606** (0.015)	0.00477** (0.031)
ENG_{it}	0.315337** (0.000)	0.4611808** (0.006)
EXP_{it}	0.0010939** (0.013)	0.0059233** (0.025)
PoP_{it}	0.0250019** (0.001)	0.021206** (0.045)
GDP_{it}	0.0014259** (0.004)	0.0039787** (0.003)
IND_{it}	−0.006806 (0.990)	−0.0038489 (0.347)
Countries	85	85
Observations	1975	1896
Wald Chi^2	565.21	×××
Prob>Chi^2	0.000	×××
AR (2) P-value	×××	0 0.468
Sargan/Hansen P-value	×××	0 0.187

Note:.
** $p < 0.05$ representing the significance of variables at 5 %.

Table 6
Comparison of Income Based Sample Results.

Variables	Low income countries SYS-GMM	Lower middle income countries SYS-GMM	Upper middle income countries SYS-GMM
Constant	0.5851 (0.329)	0.4528 (0.286)	0.4293 (0.251)
GFI_{it}	0.0761** (0.032)	0.0572** (0.024)	0.0468** (0.036)
ENG_{it}	0.0357** (0.012)	0.0418** (0.022)	0.0618** (0.031)
EXP_{it}	0.0199** (0.011)	0.0523** (0.032)	0.0592** (0.019)
PoP_{it}	0.0519** (0.028)	0.0326** (0.026)	0.0126** (0.019)
GDP_{it}	0.0129** (0.013)	0.0378** (0.037)	0.0398** (0.027)
IND_{it}	−0.0686 (0.452)	−0.0848 (0.438)	−0.0389 (0.571)
Countries	20	40	25
Observations	576	1143	687
AR (2) P-value	0.354	0.386	0.463
Sargan/Hansen P-value	0.193	0.178	0.214

Note:.
** $p < 0.05$ representing the significance of variables.

Table 7
The Dumitrescu and Hurlin [56] Granger Causality Test.

Null Hypothesis	Z-statistic	P-value
CCO_2 —> GFI	8.6227	0.000
GFI —> CCO_2	17.6415	0.000
CCO_2 —> ENG	22.2906	0.000
ENG —> CCO_2	12.8043	0.000
CCO_2 —> EXP	8.7076	0.000
EXP —> CO2	12.5113	0.000
CCO_2 —> IND	6.3399	0.000
IND —> CCO_2	9.3513	0.000
CCO_2 —> PoP	16.2228	0.000
PoP —> CCO_2	43.3389	0.000

of findings, RE technique results are preferred implemented by the Hausman [49]. The findings of all sampled developing countries are that GFI raises pollution and has an encouraging influence on the emission of CCO_2. The coefficient value of GFI has about 0.0061 % relationship with CCO_2 emission which shows a very little but consistent impact on carbon emission. This coefficient value is statistically significant and has a positive relationship with the dependent variable. This conclusion is supported by the investigations conducted by Miniesy and Tarek [14] and Azam and Ozturk [8]. According to the findings of these authors, FDI has a significant and positive impact on carbon emissions. The outcomes of RE and GMM are almost the same which shows the robustness. FDI in terms of GFI has the potential to boost economic growth and reduce carbon emissions only if innovative and new technologies are transferred to host countries. These results are in line with the outcomes of the Khan et al. [35]. Kwilinski et al. [58] justified that GFI in terms of green innovation especially in renewable energy will boost economic growth and will also lower CCO_2. The authors were also of the view that EU countries have the capability to lesser CCO_2 by adopting the latest green technologies and renewable energy resources.

Similarly, energy consumption also has a significant and positive effect on carbon emissions, increasing pollution in these sampled countries. The coefficient value of energy usage is 0.351 % which shows a very high impact on CCO_2 emission. The population of developing countries relies mostly on oil usage for making foodstuff and other necessary items. Due to the high usage of oil, its production is prioritized and during its production process, the industries make the environment dirtier. These results are also confirmed by Khan and Raza (2022), the authors were of the view that an increase in traditional energy usage has a major positive impact on increasing carbon emission. The results of this study are also checked by RE and system GMM which yield the same outcome. A sustainable clean environment can be achieved through renewable energy consumption and encouraging trade with other countries. There should be a policy of implementing carbon pricing on industries for the promotion of a cleaner environment through renewable energy resources [59]. Population plays a very major role in polluting the environment and is proved by the results of this study. The coefficient value of the population is about 0.025 %, confirming the important relationship with carbon emission. This study analyzed that population has a significant and positive impact on increasing carbon emissions. The RE and system GMM results revealed that an increase in population will damage the environment badly. These outcomes are also backed by the studies of Zhu et al. [23] and Rafique et al. [32]. The authors of these studies were of the view that if the population is not controlled then there will be an adverse impact of huge pollution on the environment.

Another variable, GDP is positively related to CCO_2 emissions. Theoretically, GDP is considered as the main indicator that increases CCO_2 emissions [8]. Generally when in developing countries more industries are set and planned without following environmental pollution policies then there will be a positive impact on environmental pollution. Lastly, there is a negative and statistically insignificant relationship between industrial value-added and CCO_2 emissions. The results of this study are confirmed by the outcome of the study of Awan and Azam [60] and Awan et al. [33].

4.3.1. Robust analysis

Robustness checking of results is a very important phase in the analysis section. This philosophy is used to confirm the results by another authentic technique and if the operation is successfully done, it is called robustness [61]. In this study, the robustness of results is checked by the Random Effect (RE) technique for more accurate and authentic outcomes. This study first confirmed the RE through the Hausman test (1978), used as a robust test. In applied economics research, if the magnitude and sign of the estimated coefficients are not changed by any two methods used for analysis, then it means that the true causal effect of the regressors may be used for policy implication and economic insight.

The robust analysis of the RE technique confirmed almost the same coefficient values of the system GMM technique. GFI, ENG, EXP, PoP, GDP except IND all have statistically significant and positive impacts on CCO_2 emissions. From the analysis, it is confirmed that GFI in terms of old technologies used in industries will have an adverse impact on the environment. But if the host government regulates her bodies and allows those investors who have intentions to invest in the form of GFI in technologically advanced machinery, will protect the environment from pollution. Similarly, in developing countries, huge populations and their constant increase in size have polluted the environment. Rafique et al. [32] in their research highlighted the adverse impact of a huge population on carbon emissions declaring it as the need of a day that every country must reshape population policy and strict restrictions on controlling population will save the environment from more disasters.

4.4. Final results of sampled based data

The results of Table 6 are based on the income categories as low income, lower middle income and upper middle income developing countries.

According to income-based sample data, GFI encourages environmental pollution in developing nations with low, lower, and upper medium incomes. These results are in line with the outcomes of the studies of Zeraibi et al. [37] and Caetano and Marques [38]. However, Zeraibi et al. [37] believed that BRICS has the potential to reduce further carbon footprint by adopting GFI, especially in renewable energy resources for the industrial sector. The impact of GFI is greater in low income countries as compared to lower middle income and upper middle income countries. In the case of middle income countries, there is still a 100 percent chance that FDI leads to environmental pollution [38]. Upper middle income countries can reduce more of the carbon emission by adopting high-level technologies in their industries [1]. Other variables, energy consumption, and GDP have a significant impact on lower-middle and low-income nations. Similarly, population has a favorable and statistically significant relationship with emissions of CCO_2.

It has been discovered that trade exacerbates environmental deterioration, which may be connected to higher energy consumption as a result of the export of energy-intensive items, which raises pollution [62]. The link between industrial added-value and CCO_2 emissions is statistically insignificant and negative. Similar findings were also made by Neequaye and Oladi [13] and Shahbaz et al. [22], showing that investment in these nations pollutes nature and increases carbon dioxide emissions. The justification and clarification for these findings are due to many reasons. The first reason is that low and lower middle income countries mostly rely on foreign investment and have the potential to attract more investment due to loss of environmental pollution policies [2]. The second reason is that these nations have an abundance of natural resources and have skilled labor with minimum wages which compels investors to invest in these countries [1].

4.5. Causality test result

In the last, Dumitrescu and Hurlin [56] test was used to conclude causality, which is the latest test currently used in panel data set literature. This test is used for balanced and unbalanced panel data sets.

According to the findings of this research shown in Table 7, the null hypothesis is, that CCO_2 does not cause GFI. It is accepted with a high p-value but rejected otherwise. Similarly for each of the variable,s the same concept of a null hypothesis is drawn and either null is accepted or rejected with the p-value. The test was conducted for sampled developing countries and gives PHH validity. These outcomes are in line with the results of Tang and Tan [63], Musah et al. [64] and Iqbal et al. [65] studies. The authors of these studies were also of the opinion that CCO_2 and GFI are bi-causal.

5. Conclusion

This paper takes the study of 85 developing countries for 1990–2020 time series. There is a big influence of GFI, GDP, population, and industrial value added in these sampled countries. The analysis is also checked for the income-based sampled countries. GFI, energy usage, GDP, and population have a positive and statistically meaningful impact on carbon emissions, except for industrial value added which has a negative effect. The reason for GFI is that developing nations have a wealth of natural resources that entice many international investors who make investments there while disregarding environmental pollution laws.

In a similar vein, GFI also contributes significantly to rising environmental pollution in the sample of developing nations, which is accounted for by the fact that these nations are in the beginning phase of their economic development. The situation of wealthy nations differs from that of poor nations, where GFI has a statistically negligible impact on atmospheric contamination. This indicates that using cutting-edge equipment and enacting stringent environmental pollution laws makes all of this possible in industrialized nations. Similarly, there must be a complete check on the foreign investors and compelled them to follow environmental protection policies regulated and imposed by the governments. The authors of this study conclude that employing cutting-edge technologies can significantly reduce emissions of pollutants linked to climate change; as a result, they advise developing countries to increase the amount of energy they use from renewable sources. Through these precautionary measures, SDG 13 can be achieved, which is about urgent action to combat climate change and its impact. Further industries must be shifted from conventional-based energy usage to renewable sources of energy and efficient use of high-level technologies will be more beneficial in controlling environmental deterioration. Thus SDG 7 which is about affordable and clean energy can be accomplished. The sampled developing countries may impose heavy duties and tariffs on the imported energy-intensive machinery and also encourage energy-efficient machinery that will lead saving pollution. The host countries must invite and give space to the investors with modern and efficient technologies in case of bringing FDI to the homeland, especially GFI because the new investment will have a positive impact on the environment if and only if the latest technology with more efficient machinery is used for production that will have minimum impact on air quality. Similarly, energy saving automobiles of technological advance versions must be used in auto industries to reduce air pollution. Air pollution mainly comes from transportation, waste burning, and industrial activities. Thus bringing the latest technologies can achieve SDG

12, which is about the reduction of air pollution associated with responsible production and consumption.

This study contributes to highlighting the case of developing countries that attract foreign investment mainly Greenfield investment as a mode of FDI. The developing countries mainly rely on investment from other developed nations besides governments' loose policies of air pollution bring harm to the environment, leading to the conduction of this current study which looks into the matter of trade-adjusted carbon emission. This study is limited using a sample of 85 developing countries taking yearly data. Future studies may take more developing countries with monthly or bi-annually data leads to more insight analysis. Similarly, the practitioners may also consider the comparison of developed and developing countries analysis and may also highlight the case of more regional sampled countries analysis. This study has taken balanced panel data with 31 years' time period, therefore, a large timeframe period with either balanced or unbalanced panel data will give more insightful results and will be beneficial for practitioners. A future study with a comparison of Merger and Acquisition (M&A) and GFI would be more fruitful if taken into consideration by researchers.

CRediT authorship contribution statement

Ali Raza: Writing – original draft, Validation, Methodology, Investigation, Conceptualization. **Kamran Azam:** Writing – review & editing, Supervision. **Asad Ul Islam Khan:** Formal analysis. **Waqar Badshah:** Data curation.

Declaration of competing interest

None.

Data availability

The data that has been used is confidential.

Appendix

Table 1

Table 1
List of developing countries.

Sampled Countries (85)	Azerbaijan, Argentina, Albania, Brazil, Bangladesh, Bolivia, Belarus, China, Cambodia, Costa Rica, Colombia, Dominican Republic, El Salvador, Ecuador, Guatemala, Georgia, Honduras, Haiti, Indonesia, India, Iraq, Iran, Jordan, Kenya, Kazakhstan, Kyrgyz Republic, Lebanon, Moldova, Malaysia, Myanmar, Mongolia, Nepal, Philippines, Pakistan, Syria, Sri Lanka, Thailand, Tajikistan, Turkmenistan, Turkey, Uzbekistan, Vietnam, Venezuela, Angola, Cameroon, Algeria, Benin, Zimbabwe, Jamaica, Tunisia, Botswana, Congo, Dem. Rep., Congo, Rep., Egypt, Moldova, North Macedonia, Russian Federation, Ukraine, Cote d'Ivoire, Eritrea, Gabon, Ghana, Kenya, Mozambique, Namibia, Mauritius, Nigeria, Senegal, South Africa, Morocco, Sudan, Tanzania, Togo, Zambia, Bulgaria, Mexico, Nicaragua, Panama, Paraguay, Peru, Romania, Uruguay, Uganda, Tonga, Vanuatu.

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