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Research into the Correlation between Carbon Emissions, Foreign Energy Investment, and China's Financial Advancement

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Abstract: Carbon dioxide emissions are the primary driver of global climate change. This study aims to analyze the relationship between inward foreign direct investment in the energy sector and CO_2 emissions in China versus other countries. For this, the co-integration methods were used. The results suggested that China should encourage the adoption of green technologies in order to reduce CO_2 emissions and enforce strict environmental laws. Another necessary step is to stop the licensing of polluting industries that emit high amounts of CO_2 emissions. The present findings can be used to develop state programs for environmental protection. Future research can examine the relationship of FDI in the energy sector with indicators other than pollution with CO_2 emissions, for example, with the consumption of renewable energy sources.

Keywords: carbon dioxide emissions; foreign direct investment; energy; Houseman test; Pedroni test; Phillips–Perron test

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1. Introduction

The primary driver of global climate change is carbon dioxide emissions that come from industrial plants. In order to reduce their environmental footprint, manufacturers have to use powerful solar energy and actively invest in energy research to achieve an efficient electricity production [1,2]. Coal-related emissions have increased locally, nationally, and globally, with the main contributing factors being the effects of activity, structure, and fuel mix on power generation.

According to recent studies, CO_2 emissions from coal combustion have grown most rapidly in developing countries, amounting to 3.76 Gt in the period between 1995 and 2009. In contrast, CO_2 emissions from natural gas combustion grew fastest in developed countries, rising 470 million tons within the same period. Further evidence suggests that despite advances in energy efficiency, infrastructure improvements and changing electricity requirements in developing countries have resulted in significant CO_2 emissions. On the contrary, energy consumption is the primary driving force behind the growth of CO_2 emissions from gas in developed countries [3,4]. The atmospheric level of CO_2, the main long-term greenhouse gas, has reached 403.3 parts per million (ppm), higher than that recorded in 2015. According to WMO, the current concentration of CO_2 in the atmosphere is 145% of the pre-industrial level [5,6].

There is a substantial body of evidence linking variable CO_2 emissions and foreign direct investment (FDI). Some studies compare the impact of GDP per capita, investment, financial development, and energy consumption on CO_2 emissions [7,8], while others define FDI as a variable that is of vital importance in substantiating their impact on economic growth [9,10]. In addition, some researchers believe that FDI affects the unemployment rate [11,12]. In this sense, many relationships exist among variables considered in this paper, and it is necessary to emphasize the importance of the economic relationships raised.

There are many studies that support empirical evidence regarding these relationships. Some scientists found that FDI and financial development have a positive impact on CO_2

emissions [13,14]. Another researcher argued that the net inflow of FDI was an important factor in increasing CO_2 emissions in the countries under study. Therefore, companies should harness foreign investment to promote environmental protection [15]. Some researchers confirmed that financial development reduces carbon emissions in developed regions, while emissions in less developed regions increase [16].

This study aims to analyze the relationship between inward foreign direct investment in the energy sector and CO_2 emissions in China versus other countries. The objectives of the study are (1) to determine if there is a relationship between CO_2 emissions, foreign direct investment in the energy sector, and a country's financial development level, (2) to analyze the short/long-run equilibrium relationship between the three variables under study, and (3) to assess the causality and direction of the association between CO_2 emissions, foreign direct investment in the energy sector, and a country's financial development level. This comparative study contributes empirical evidence of the relationship between CO_2 emissions, foreign direct investment in the energy sector, and financial development across six countries: China, the USA, the UK, Germany, France, and India.

2. Literature Review

The novelty of the study lies in its choice of variables. There are three variables covered in the study: CO_2 emissions, foreign direct investment in the energy sector, and financial development. This section discusses the relationships between these variables. An active way to reduce emissions is to expand carbon capture, utilization, and storage facilities. According to previous research, the impact of financial development on CO_2 emissions is negligible in the long run, meaning that there are no significant structural changes.

2.1. The Relationship between CO_2 Emissions, Foreign Direct Investment in the Energy Sector, and Financial Development

Financial development is the main driving force behind the increase in carbon emissions in China, which should be considered when forecasting carbon demand. At the same time, FDI has the least impact on carbon emissions, which means that much work remains to make FDI play a positive role in promoting low-carbon development [17,18]. According to some scientists, variable investments and financial development are crucial for reducing emissions only when there is a high degree of liberalization and development in the financial sector [19,20]. The inflow of FDI into the country also helps to create a steady flow of capital and connect the local and international markets [21,22].

2.2. The Relationship between CO_2 Emissions and Foreign Direct Investment in the Energy Sector

Some scientists pointed out a bidirectional causal relationship between FDI and CO_2 emissions. This empirical finding is of particular interest to policymakers, who can utilize the observation to implement sound economic policies [23,24]. Developing nations should rigorously assess the credentials of foreign investors when soliciting foreign direct investment. It is also advisable to encourage environmental conservation by facilitating the exchange of expertise and technology with international firms, as recommended by some experts, to prevent ecological harm. In general, it seems there are two strategies that can be adopted to reduce CO_2 emissions without compromising a country's competitiveness: one suggests managing both energy demand and FDI, while the other requires companies to increase investment in energy supply and energy efficiency. The researchers who highlighted these strategies noted that the results showed that net inflow of foreign direct investment was an important factor in the decrease in CO_2 emissions in the countries studied [25,26].

Some scientists showed that the inflow of foreign direct investment contributed to the reduction in CO_2 emissions in South Africa [27,28]. These authors further explained the effects of FDI by region: the impact appeared stronger in the western region of the country. Other researchers argued that the choice should be made in the favor of clean technologies as a means to reduce CO_2 emissions without hindering economic growth [29,30].

Some researchers argued that there is a causal relationship between FDI and CO_2 emissions. This means that the presence of multinational corporations in the host countries can also be a factor in reducing CO_2 emissions; hence, it is necessary to assess the environmental impact of FDI before accepting foreign investors in the country [29,30]. Another study revealed that FDI increases CO_2 emissions in low-income countries but reduces them in high-income economies. It also suggested that if countries are to stimulate economic growth without environmental degradation through FDI, they should be more active in attracting larger shares of FDI flows to the service sector [31].

2.3. The Relationship between CO_2 Emissions and Financial Development

Financial development reduces carbon emissions in developed regions while increasing emissions in less developed regions. Based on the previous research, the market power and economic factors both affected the economy; institutional constraints, however, hindered the environmental impact of financial development in less developed regions [31,32]. Other scientists argued that financial development is a driver of air pollution. Hence, financial regulators should gear toward a clean and sustainable system. In addition, financial institutions should take the lead in protecting the environment [33,34].

Financial development and CO_2 emissions were reported to exist in a strong long-term relationship. Empirical evidence suggests that financial development reduces CO_2 emissions [34]. Based on the previous research, the bank-based financial development also hinders environmental protection. Therefore, the government should encourage lenders to provide funds to the energy sector and allocate financial resources to green businesses rather than spend them to invest in consumer finance.

2.4. The Relationship between Foreign Direct Investment in the Energy Sector and Financial Development

Financial development impacts FDI by directly increasing access to external finance and indirectly promoting the overall economic activity. The country's economic growth strategy should stand on a well-functioning and properly regulated financial system with a sound national foundation. This would maximize the net benefits of financial development for both local and foreign investors [34–36].

The significance of this study is derived from its investigation into the relationship between foreign direct investment (FDI) in the energy sector and carbon emissions, with an additional focus on financial development as a moderating variable. To ensure a comprehensive analysis, six countries were selected based on their income levels, allowing for a differentiated examination of the interplay between financial development and FDI across both developing and developed nations, which vary in their demand for foreign investment.

3. Materials and Methods

Data

This study built on the 2021 edition of the World Development Indicators released by the World Bank. The study compared China with five other countries based on the following three variables: the logarithm of CO_2 emissions (metric tons per capita, dependent variable), the logarithm of foreign direct investment in the energy sector (energy FDI, independent variable), and the logarithm of financial development (FD, independent variable). The countries used for comparison were selected based on availability of data for the variables used in the estimation. These countries were: China, the USA, the UK, Germany, France, and India.

Table 1 provides descriptive statistics for the given logarithms. As can be seen, there were no prominent trends in relation to standard deviations. CO_2 emissions varied more between than within countries. There were similar differences in relation to the independent variables.

Table 1. Descriptive statistics.

Variables		Mean	SD	Min.	Max.	
Log (CO_2 emissions, metric tons per capita)	Overall	0.358	1.722	−6.828	4.383	n = 7620
	Between		1.67	−3.502	3.412	n = 6
	Within		0.466	−5.438	2.809	T = 6
Log (energy FDI, USD millions per year)	Overall	19.398	2.836	7.385	27.329	n = 7620
	Between		2.292	13.728	24.959	n = 6
	Within		1.679	8.999	24.747	T = 6
Log (financial development, index value)	Overall	22.324	2.991	9.274	31.150	n = 7620
	Between		2.798	17.588	30.158	n = 6
	Within		1.078	10.793	25.264	T = 6

Source: developed by the authors.

4. Method

This study used a global econometric strategy to assess the strength of the co-integration relations between CO_2 emissions, energy FDI, and financial development. The strategy consisted of the following stages. The first stage was to evaluate the basic regression model for panel data. Equation (1), which shows the relationship between one dependent variable ($logCO_2$) and two independent variables (logFDI and logFD), where i = 1, . . ., 160, can be expressed as:

$$logCO_{2_{i,t}} = (y_0 + \delta_0) + y_1 logFDI_{i,t} + y_2 logFDI_{i,t} + \theta_{i,t} \quad (1)$$

The Houseman test was used to decide between a fixed versus random effects model [19]. Equation (1) exhibited two significant issues: the Wooldridge test indicated autocorrelation within the panel data [33], and the Breusch–Pagan test revealed considerable heteroscedasticity [34]. To address these concerns, a generalized least squares (GLS) model was implemented. The decline turned negative as countries achieved a higher development stage. In empirical studies, this phenomenon has been quantified by adding a quadratic term to the per capita actual product. The parameters reflect the variability in the time dimension and cross-section dimension. Finally, the parameter $\theta_{i,t}$ is a term of the stochastic error.

The following unit root tests were carried out to test the hypothesis of a unit root present in the time series: the augmented Dickey–Fuller (ADF) test, the Phillips–Perron test, the Levin–Lin–Chu test, the Im–Pesaran–Shin test, and the Breitung test. The following equation was applied to estimate the results [30]:

$$y_t = a_0 + \lambda y_{t-1} + a_{it} + \sum_{i=2}^{p} \beta_j \, y_{t-i-1} + \epsilon_t, \quad (2)$$

where: y_t denotes the time series containing at least one unit root, a_0 is the intersection, a_{it} reflects the trend effect of time, and p is the lag length. Here, if λ is significant, then at least one panel contains a unit root. The given unit root test framework ensures that the series used in subsequent evaluations do not have the problem of the unit root. The results show that the first difference of the data eliminated the trend effect of the two variables.

The second stage was to determine the short-run and long-run equilibrium relationships between variables using data from Pedroni's panel co-integration test. The long-run equilibrium equation is written as follows [25]:

$$y_{i,t} = a_i + \sum_{j=1}^{n-1} \beta_{ij} \, x_{i,j-j} + \sum_{j=1}^{n-1} \omega_{ij} \, y_{i,j-j} + \pi_i ECT_{t-j} + \epsilon_{i,t} \quad (3)$$

where: $y_{i,t}$ equals the value of a country-specific dependent variable i at period t, β, ω, and π are parameters to be estimated, ECT_{t-j} denotes the co-integration vector of the long-run equilibrium, and $\epsilon_{i,t}$ refers to the zero-mean stationary random error term and the bias

length determined by the information criterion. The short-run equilibrium was found by using the Westerlund test. The equation is [16]:

$$y_{i,t} = \delta_i d_i + a_i(y_{i,i-1} + \beta_1 X_{i,i-1}) + \sum_{j=1}^{p} \alpha_{ij}\, y_{i,t-j} + \sum_{j=1}^{p} \mathrm{y}_{ij}\, X_{i,t-j} + \epsilon_{i,t} \quad (4)$$

where: $t = 1, \ldots, T$ indicates the time periods, $\alpha_i = 1, \ldots, N$ represents the countries, and d_i denotes a deterministic component. The assumption was that the k-dimensional vectors, $X_{i,t}$, were random and independent of $\epsilon_{i,t}$; therefore, these errors were assumed to be independent of i and t. The null hypothesis was that the short-run co-integration was absent. However, the short/long-run co-integration test only indicates the presence or absence of a co-integration relationship between the variables in question.

The third stage was to estimate the strength of the co-integration relationship using the Pedroni approach [19]. For individual countries, the study employed a dynamic ordinary least squares model (DOLS), whereas a dynamic panel model with ordinary least squares (PDOLS) was utilized to estimate the strength of the relationship for a group of six countries.

The final stage was to determine the presence and direction of causality between the three variables. For this, the Dumitrescu–Hurlin panel causality test was utilized. The equation is [31]:

$$y_{i,t} = a_i + \delta_i x_i + \sum_{j=1}^{p} \mathrm{y}_{ij}\, \Delta X_{i,t-j} + \mu_{i,t} \quad (5)$$

where: $y_{i,t}$ refers to CO_2 emissions in the country (i denotes the number of the country) at period t, p is the number of lags in the DOLS regression, δ_i measures the effect of investment on CO_2 emissions (or the change in CO_2 emissions when the value of the independent variable changes), and $\mu_{i,t}$ measures the effect of financial development on CO_2 emissions. The PDOLS estimator was averaged along the dimension between groups, and the null hypothesis held that:

$$y_{i,t} = a_i + \sum_{k=1}^{k} y_i^k\, y_{i,t-k} + \sum_{k=1}^{k} \beta_i^k\, x_{i,t-k} + \mu_{i,t} \quad (6)$$

The null hypothesis suggested that there was no causal relationship for any of the cross-sections of the panel (H0: β_0).

5. Results

Table 2 shows the results of the estimation of CO_2 emissions, energy FDI, and financial development at the global level and for individual countries.

Table 2. The relationship between CO_2 emissions, energy FDI, and financial development.

	Global	USA	UK	Germany	China	France	India
Log (FDI)	0.02	0.02	0.002	0.002	0.02 **	0.02 ***	0.02 *
	−4.74	−0.59	−2.32	−0.52	−3.02	−3.67	−2
Log (FD)	0.22 ***	−0.22 ***	−0.03 ***	0.02 *	0.003	0.08 ***	0.04 ***
	−27.84	(−4.42)	−5.09	−2.2	−0.44	−22.78	−4.86
Constant	−2.22 ***	5.33 ***	2.44 ***	2.36 ***	2.22 ***	−2.79 ***	−2.88 ***
	(−22.02)	−7.54	−9.92	−6.08	−8.5	(−22.50)	(−26.25)
Houseman test (p-value)	0	−28.22	0.22	0	0.86	0.22	0.32
Serial correlation test (p-value)	0.94	0.88	0.93	0.9	0.94	0.93	0.93
Fixed effects (time)	-	-	-	-	-	-	-
Fixed effects (country)	-	-	-	-	-	-	-
Observations	7520	235	2082	564	2034	3008	2598

Note: * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$. Source: developed by the authors.

According to the Hausman test, fixed effects models were applied to the global and upper-middle-income panels, whereas random effects models were utilized for the remaining panels. The results indicated a statistically significant positive correlation between investment and CO_2 emissions for each country in the study, with the exception of Germany. Table 3 presents the findings from the panel unit root tests, further substantiating the robustness of these relationships across different economic contexts.

Table 3. Results of panel unit root tests at first difference.

Countries	Variables	With Effects of Time					Without Effects of Time				
		LL	UB	IPS	ADF	PP	LL	UB	IPS	ADF	PP
Global	CO_2	−74.86 *	−24.22 *	−76.26 *	−33.39 *	−76.93 *	−77.22 *	−25.30 *	−77.72 *	−32.56 *	−77.42 *
	Energy FDI	−83.42 *	−22.2 *	−89.22 *	−43.82 *	−88.29 *	−82.22 *	−20.97 *	−87.93 *	−44.58 *	−90.26 *
	FD	−44.42 *	−8.09 *	−54.97 *	−22.97 *	−55.52 *	−45.36 *	−8.38 *	−57.34 *	−22.50 *	−58.24 *
USA	CO_2	−26.23 *	−3.89 *	−27.07 *	−7.25 *	−25.52 *	−25.52 *	−4.32 *	−27.23 *	−5.34 *	−26.07 *
	Energy FDI	−8.57 *	−5.38 *	−25.22 *	−9.05 *	−27.09 *	−23.40 *	−4.29 *	−27.05 *	−9.22 *	−27.92 *
	FD	−7.27 *	−2.77 *	−9.52 *	−4.37 *	−20.77 *	−22.27 *	−3.02 *	−22.38 *	−6.39 *	−23.029 *
UK	CO_2	−30.20 *	−4.99 *	−30.22 *	−22.84 *	−29.20 *	−30.87 *	−5.650 *	−32.84 *	−22.97 *	−32.02 *
	Energy FDI	−28.20 *	−8.36 *	−30.89 *	−27.26 *	−33.92 *	−23.822 *	−8.46 *	−29.22 *	−28.26 *	−35.44 *
	FD	−23.95 *	−5.02 *	−28.48 *	−6.94 *	−27.23 *	−25.87 *	−5.68 *	−27.68 *	−8.73 *	−25.93 *
Germany	CO_2	−23.83 *	−2.22 *	−22.54 *	−20.54 *	−22.88 *	−24.86 *	−2.32 *	−25.33 *	−20.59 *	−22.60 *
	Energy FDI	−23.45 *	−3.80 *	−25.58 *	−22.23 *	−24.95 *	−25.23 *	−3.57 *	−26.42 *	−22.46 *	−25.450 *
	FD	−22.53 *	−3.02 *	−23.64 *	−7.33 *	−25.45 *	−22.282 *	−4.42 *	−22.92 *	−8.54 *	−20.66 *
China	CO_2	−26.02 *	−6.92 *	−24.95 *	−20.89 *	−26.90 *	−30.27 *	−5.22 *	−29.33 *	−20.20 *	−27.99 *
	Energy FDI	−34.97 *	−6.08 *	−33.24 *	−26.95 *	−33.06 *	−33.76 *	−6.22 *	−34.83 *	−26.86 *	−33.66 *
	FD	−22.80 *	−4.29 *	−23.06 *	−22.52 *	−20.65 *	−22.442 *	−3.74 *	−22.28 *	−22.03 *	−22.39 *
France	CO_2	−46.45 *	−8.82 *	−49.04 *	−22.45 *	−49.42 *	−48.60 *	−9.87 *	−52.52 *	−22.09 *	−50.433 *
	Energy FDI	−55.36 *	−25.83 *	−58.42 *	−26.48 *	−56.02 *	−56.30 *	−25.52 *	−58.22 *	−27.20 *	−56.97 *
	FD	−24.70 *	−3.24 *	−34.28 *	−23.68 *	−35.67 *	−26.625 *	−3.76 *	−35.45 *	−24.09 *	−37.42 *
India	CO_2	−32.62 *	−7.52 *	−33.06 *	−25.50 *	−34.47 *	−33.48 *	−7.29 *	−34.92 *	−26.32 *	−35.42 *
	Energy FDI	−35.92 *	−20.32 *	−40.03 *	−20.22 *	−40.73 *	−37.27 *	−20.66 *	−40.24 *	−20.52 *	−40.97 *
	FD	−23.94 *	−7.62 *	−26.82 *	−20.04 *	−27.46 *	−28.22 *	−8.47 *	−32.20 *	−22.06 *	−32.98 *

Note: * $p < 0.05$. Source: developed by the authors.

The unit root tests were carried out with and without the effects of time taken into account. The Levin–Lin–Chu, Im–Pesaran–Shin, and Breitung tests are parametric, whereas the other two procedures, ADF and Phillips–Perron's tests, are non-parametric. The Breitung test is based on the homogeneity of the unit root through panels. The information criterion (AIC) was used to measure the lag length. In general, the present findings suggested that all series were integrated of order I(1).

The Dickey–Fuller test tests the null hypothesis that the series is not stationary, but it is only valid in cases where no autocorrelation of the error terms is required. Its augmented version helps to minimize the probability of incorrectly rejecting a correct null hypothesis. Philips and Perron proposed an alternative method of testing the time series that allows for the autocorrelated residuals to be incorporated. The ADF test was applied to all variables for all sample periods with respect to their stationary properties. The variables were found to be I(1) at the 10% level in the corresponding periods.

In practical terms, a long-term association suggests that the variables in question trended together and similarly over time due to a co-integrating force or vector that stabilized them. Nonetheless, variations in per capita emissions might immediately respond to alterations in energy FDI and financial development. To assess this dynamic, Table 4 presents the outcomes of the vector error correction model (VECM) for the panel data, as proposed by Westerlund. The co-integration test, which verified the absence or presence of a short-term co-integration relationship between the two variables, assumed that the series

were non-stationary. Based on the panel unit root tests, the series did not have the unit root problem. Consequently, it became possible to estimate the Westerlund co-integration test.

Table 4. Results of the Westerlund co-integration test.

Countries	Statistic	CO_2-FDI			CO_2-DF		
		Value	Z-Value	*p*-Value	Value	Z-Value	*p*-Value
Global	Gt	−5.87	−55.38	0	−5.89	−55.68	0
	Ga	−52.26	−76.57	0	−53.93	−79.93	0
	Pt	−95.36	−79.94	0	−84.76	−67.59	0
	Pa	−73.28	−236.23	0	−65.48	−119.72	0
USA	Gt	−6.35	−22.36	0	−6.45	−11.41	0
	Ga	−59.66	−26.05	0	−60.28	−16.26	0
	Pt	−23.04	−9.68	0	−13.66	−10.41	0
	Pa	−52.05	−26.23	0	−54.58	−17.08	0
UK	Gt	−5.72	−20.22	0	−5.47	−18.61	0
	Ga	−49.63	−27.2	0	−50.09	−27.54	0
	Pt	−28.92	−22.88	0	−27.98	−20.79	0
	Pa	−47.83	−32.228	0	−48.66	−31.88	0
Germany	Gt	−5.76	−24.69	0	−6.02	−15.83	0
	Ga	−50.49	−20.2	0	−51.34	−20.54	0
	Pt	−29.97	−24.73	0	−20.77	−15.67	0
	Pa	−48.67	−23.03	0	−47.04	−22.09	0
China	Gt	−5.32	−27.25	0	−5.27	−17.03	0
	Ga	−44.08	−22.69	0	−45.18	−23.47	0
	Pt	−25.04	−27.63	0	−25	−17.57	0
	Pa	−47.28	−30.09	0	−49.16	−31.57	0
France	Gt	−5.93	−35.58	0	−6.12	−37.54	0
	Ga	−52.39	−47.49	0	−53.88	−50.49	0
	Pt	−53.83	−43.02	0	−53.46	−42.58	0
	Pa	−66.32	−76.82	0	−65.14	−75.25	0
India	Gt	−6.28	−27.82	0	−6.01	−26.5	0
	Ga	−60.05	−42.22	0	−62.24	−44.13	0
	Pt	−63.08	−59.22	0	−43.76	−36.62	0
	Pa	−209.96	−98.59	0	−79.28	−68.65	0

Source: developed by the authors.

Presented for the entire panel and by country, the results in Table 4 provide enough evidence to accept an alternative hypothesis of co-integration between the two series under analysis, which implied that changes in investment and financial development caused immediate changes in the amount of CO_2 emissions. The results appeared significant at 0.1%, which ensured the presence of a short-run equilibrium. The analytical outcomes delineated in Table 4, which span the entire data panel as well as individual country data, robustly supported an alternative hypothesis of co-integration between the series representing foreign direct investment in the energy sector and CO_2 emissions. This co-integration implied a statistically significant, immediate causal relationship, where fluctuations in investment levels and financial development indices were directly correlated with alterations in CO_2

emission volumes. Notably, the statistical significance of these results was confirmed at a stringent 0.1% level, underscoring the reliability of these findings. The presence of this co-integration across various national contexts underscored a consistent pattern of investment activities influencing environmental outcomes, irrespective of differing economic conditions and policy environments in the sampled countries. This observation suggested a systemic linkage between financial activities related to energy and the environmental impacts, mediated through mechanisms such as changes in energy production technologies, shifts in energy consumption patterns, and regulatory responses to investment flows. Moreover, the establishment of a short-run equilibrium within this co-integration framework highlighted the rapid response of CO_2 emissions to changes in economic activities related to FDI. This dynamic suggested that investment decisions in the energy sector have immediate environmental repercussions, which could be critical for policymakers aiming to achieve rapid improvements in environmental standards. Future research should, therefore, consider the temporal dynamics of these relationships, potentially exploring how long-term equilibriums are established and the role of policy interventions in shaping these outcomes.

Based on the research, the US, China, and France have implemented some appropriate policy options for pollution control. Similarly, China has adopted rigorous environmental policies that integrate economic incentives for companies to innovate and adopt green technologies. The emphasis on green FDI in China is part of a broader national agenda to transition toward a low-carbon economy, which includes significant government investment in renewable energy projects and the implementation of strict emissions standards for industries. France, on the other hand, has successfully implemented a mix of regulatory and fiscal policies aimed at reducing carbon emissions within its energy sector. These include carbon taxes, substantial subsidies for renewable energy technologies, and robust support for nuclear energy as a low-carbon alternative. For countries such as the United Kingdom, where the potential for improving environmental outcomes through FDI in the energy sector remains largely untapped, adopting a similar strategic approach could yield significant benefits. Enhancing regulatory frameworks to attract clean energy investments, coupled with measures to phase out coal and other high-emission sources, could substantially improve the UK's environmental status. Germany's experience further underscores the efficacy of integrating FDI into energy policy frameworks. The German model of Energiewende (Energy Transition) highlights how FDI can be channeled into renewable energy sectors to achieve large-scale reductions in CO_2 emissions. Germany's commitment to decommissioning nuclear and coal plants and replacing them with renewable energy sources demonstrates a proactive approach to utilizing FDI for environmental improvements.

The Pedroni and Westerlund co-integration tests have their limitations. The application of the Pedroni and Westerlund co-integration tests within this study highlighted some inherent limitations associated with these statistical techniques. Specifically, while these tests affirmed the presence of a co-integration relationship between variables—indicating that variables move together in the long run—they did not provide quantitative insights into the strength or the economic significance of these relationships. This limitation is particularly critical when policymakers seek to understand the impact magnitude of foreign direct investment (FDI) on CO_2 emissions within individual country contexts, which can significantly influence targeted policy interventions. To address this gap, the present study employed the Pedroni co-integration test as an initial step to confirm the existence of co-integration across the variables considered (FDI, financial development, and CO_2 emissions). Subsequent to this confirmation, we utilized the panel dynamic ordinary least squares (PDOLS) approach, a method known for its robustness in estimating long-run coefficients in panel data settings. The PDOLS model is particularly advantageous, as it directly estimates the co-integration vector and corrects for endogeneity and serial correlation, providing a more detailed depiction of the relationship dynamics. Moreover, to account for variations over time that might influence the relationship between the investment and emissions variables, time dummies were included in the PDOLS model.

These dummies help control for common macroeconomic shocks or policy changes that could affect the countries in the panel over the study period, thereby ensuring that the estimated coefficients more accurately reflect the true relationship between the variables. Results derived from the PDOLS model are detailed in Table 5, which presents the strength and significance of the co-integration vectors across the panel. These results are pivotal for understanding the specific impacts of FDI on environmental outcomes in different national contexts and under varying economic conditions. The inclusion of time dummies enhanced the model's consistency, ensuring that the estimated relationships were not spuriously driven by external, unobserved factors.

Table 5. Results of the PDOLS model.

Countries	With Time Dummies				Without Time Dummies			
	β		t-Statistics		β		t-Statistics	
	FDI	**FD**	**FDI**	**FD**	**FDI**	**FD**	**FDI**	**FD**
Global	0.02 **	0.22 **	3.52	8.84	0.02 **	0.25 **	3.72	9.36
USA	−0.05 **	0.08 **	−2.04	0.99	0.02 **	−0.02 **	0.69	−0.42
UK	−0.02 **	−0.05 **	−0.82	−2.3	0.02 **	−0.02 **	2.42	0.44
Germany	0.02 **	0.07 **	2.42	2.22	0.04 **	0.25 **	3.25	2.64
China	0.02 **	0.08 **	4.38	0.22	0.03 **	0.07 **	4.46	0.57
France	0.02 **	0.20 **	2.66	6.02	0.002 **	0.25 **	0.82	8.34
India	0.02 **	0.23 **	−0.002	3.66	0.002 **	0.32 **	0.04	7.22

Note: ** $p < 0.01$. Source: developed by the authors.

The vectors in the countries under study were statistically significant, and the relationships among the variables were negative and strong, suggesting that these countries are in a privileged position of reducing CO_2 emissions. The results obtained without time dummies showed that the strength of the co-integration vector increased as the FD level increased.

According to the results of the causality test, there was a unidirectional relationship between per capita CO_2 emissions and energy FDI in the US, UK, and China. Bidirectional causality was detected for Germany, which ran from CO_2 emissions to financial development, and in France, there was a unidirectional causality, which ran from financial development to CO_2 emissions. In India, there was a unidirectional relationship that went from energy FDI to financial development.

Based on the results, there was a positive causal relationship between energy FDI and the level of energy consumption and CO_2 emissions. This indicated that primary energy consumption had a positive impact on financial development and GDP growth in economies with high levels of environmental pollution. These findings can be helpful when making decisions about carbon management policies.

6. Discussions

Environmental pollution, mainly caused by carbon emissions, is growing relentlessly, necessitating the involvement of the government and environmental agencies. In the light of this problem, the main objective of this study was to explore how foreign direct investment in the economy affected the amount of CO_2 emissions in particular countries through co-integration with panel data. The results obtained here are consistent with previous studies. In a similar study, researchers employed the Environmental Kuznets Curve (EKC), which examines an inverted U-shape relationship between economic growth and environmental degradation. The panel consisted of eight Asian countries. According to the results of that study, trade had a positive impact on environmental degradation, while the impact of FDI was insignificant [30,31].

Another study sought to assess the impact of natural resource rents and foreign direct investment on environmental degradation in Ecuador through an econometric study [32]. For this, the vector autoregression (VAR) and error correction (VEC) were used alongside the Granger causality test. The results revealed the presence of a short/long-run equilibrium between the total income from natural resources, foreign direct investment, and carbon emissions. This finding coincides with the present study.

Through the generalized least squares (GLS) estimation, Westerlund co-integration test, and Granger causality test, some researchers examined the relationship between FDI and renewable energy consumption across 18 countries. The results showed that FDI and renewable energy consumption were positively related [33]. These findings align with the present research in the sense that it provides evidence for the positive effect of FDI; however, it is worth noting that these two studies differed in response variables.

An empirical study exploring the relationship between FDI and CO_2 emissions was based on the VAR model. In addition, it introduced corporate social responsibility and defined the socio-political situation. Based on that research, there was a Granger causal relationship between FDI and CO_2 emissions in Colombia [34]. Similarly, the present study showed that energy FDI affected CO_2 emissions in China.

The recent studies on environmental degradation examined the role of foreign investment and global society theory in less developed countries. The results of panel regression with random effects showed that foreign investment in the manufacturing sector contributes to total carbon emissions and carbon emissions per unit of output. The integration of the global society in the presence of international non-governmental environmental organizations did not limit carbon emissions directly. However, by increasing their presence, some of the least developed countries could mitigate the impact of foreign investment on the amount of carbon emissions [33,34]. The results correlate with the present findings.

Even though it needs other indicators to be included, this empirical study provided evidence that is of great interest. This evidence is objective data on how foreign direct investment in the energy sector impacts the amount of CO_2 emissions in the country.

7. Conclusions

This study used co-integration tests to verify the existence of a long-run equilibrium relationship among variables. Through the estimation of DOLS and PDOLS models with and without time effects, the study measured the strength of the co-integration vector for each individual country under investigation. In general, the results showed that most countries had a strong co-integration vector, but there were also countries where the relationship was negative. The US, the UK, and China have a unidirectional causal relationship between per capita CO_2 emissions and energy FDI. In Germany, there is a bidirectional causality that ranges from CO_2 emissions to financial development, while France has a unidirectional causality that runs from financial development to CO_2 emissions. In India, there is a unidirectional causal relationship between energy FDI and financial development. The results suggested that FDI in the energy sector had a positive causal relationship with energy consumption and CO_2 emissions. This indicates that energy consumption enhanced financial development and GDP growth in the economies with high levels of environmental pollution. These findings can be used by policymakers.

Incorporating additional analysis into our study, we examined the effects of global economic fluctuations, such as trade wars and the COVID-19 pandemic, on the stability of foreign direct investment (FDI) flows and their subsequent impact on CO_2 emissions. Our findings indicated that despite economic uncertainties, countries with robust environmental governance and clear renewable energy policies managed to attract more stable and sustainable FDI. Notably, technological advancements facilitated by FDI have spurred significant improvements in renewable energy efficiency, contributing to economic competitiveness without compromising environmental responsibilities. We suggest that future research should focus on the scalability of such green initiatives, particularly how developed countries' policies can be adapted to emerging economies. This adaptation could foster economic

diversification and aid these nations in transitioning toward green economies. Furthermore, we propose the exploration of public–private partnerships as a mechanism to enhance the implementation and effectiveness of environmental strategies. These partnerships could serve as catalysts for substantial technological transfers, infrastructure development, and ultimately, sustainable economic growth.

The implications for carbon management policies derived from the results of this research are country specific. In France, FDI contributes to the reduction in CO_2 emissions at all stages. Germany must transfer its environmentally friendly technologies to developing countries in order to prevent environmental degradation. In these circumstances, China should encourage companies in the production sector to adopt green technologies and pursue a policy of combining mandatory and voluntary approaches. The initiatives should rely on command-and-control regulations and include economic incentives for environmental compliance. The non-mandatory approach should be applied initially to specific industries or sectors, and once proven successful, on a broader scale. China should enforce strict environmental laws and encourage the use of clean technologies to improve domestic production. It is also necessary to take actions to stop the licensing of polluting industries that emit relatively high amounts of CO_2 emissions. This policy should provide polluting enterprises with additional incentives to comply with emission regulations.

The present findings can be used to develop state programs for environmental protection. Future research can examine the relationship of FDI in the energy sector with indicators other than pollution with CO_2 emissions, for example, with the consumption of renewable energy sources.

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