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How Do Foreign Direct Investment and Economic Growth Affect Environmental Degradation? Evidence from 47 Middle-Income Countries

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Abstract

This article estimates how economic growth and foreign direct investment affect environmental pollution. Our motivation is that less developed nations must make trade-off decisions between economic growth and environmental pollution. Thus, we employ the Autoregressive Distributed Lag Model (ARDL) to analyze a sample of 47 middle-income countries from 1991-2018. The ARDL is a suitable estimation method because it helps analyze the short-term and long-term impacts of economic growth and foreign direct investment on environmental degradation. Our result shows in the long term that a percentage increase in FDI inflows reduces CO2 emissions by 0.006% in the long-term period. A percentage increase in economic growth also decreases environmental pollution by 0.01%. Our findings support Porter's hypothesis, pollution halo hypothesis, and Environmental Kuznets Curve hypothesis. Finally, this study contributes practical implications for policymakers to sustain economic growth and reduce environmental pollution in middle-income nations.

Keywords

FDI, Economic Growth, Pollution, Middle-income countries, ARDL

JEL Classification

F30, F40

Introduction

Recent studies report that economic developments and Foreign Direct Investments (FDI) adversely cause climate changes and environmental problems. Marques et al (2020) report that acquiring technology through FDI in low-income countries increases environmental pollution in the short term. Foreign investments often aim to maximize profits, so foreign investors prefer countries with fewer environmental protection policies. Besides, the ability to adopt technologies that reduce pollution in low-income countries takes time to adapt. While industrial developments empower economic growth, environmental pollution restrains the sustainable development of economies, especially in countries with low and middle-income economies. Specifically, most studies document a positive impact of fossil fuel-based energy consumption on environmental pollution. Therefore, renewable energy consumption is considered a solution to environmental issues (Chang et al.2015).

According to the Environmental Kuznets Curve hypothesis, there is a positive link between pollution and economic growth because of industrialization processes. However, as wealth levels rise, societies' expectations for improving environmental quality result in environmental legislation, technical improvements, and movements toward cleaner manufacturing practices. As a result, pollution begins to fall as countries aim toward sustainable economic development. According to the Pollution Haven Hypothesis (PHH), foreign direct investment (FDI) can reduce environmental pollution in the host country because when firms from developed countries invest in developing countries, they can relocate their manufacturing operations to take advantage of lower costs and less stringent

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environmental standards, resulting in pollution being transferred from developed countries to developing countries. The "Race to the Bottom" hypothesis proposes that multinational corporations (MNCs) from advanced nations may seek to exploit lower environmental standards and weaker regulations in developing countries to reduce production costs, allowing them to engage in environmentally harmful practices that contribute to increased pollution levels in the nation where they operate. There are several hypotheses on the influence of economic growth and FDI on environmental pollution; in general, the impact of FDI on environmental pollution is mixed. Therefore, this study aims to validate these hypotheses in middle-income nations.

This study is conducted in middle-income countries for the following reasons. Sohag et al (2017) report relatively high environmental pollution in middle-income countries. Globally, more than 4.2 million premature fatalities per year are attributed to ambient air pollution, with approximately 91% occurring in low- and middle-income countries (LMICs), particularly in South-East Asia and the Western Pacific region, which includes China (Huang et al. 2023). Moreover, Middle-income countries have historically attracted significant FDI inflows due to market size, natural resources, and favourable investment climates. These countries often undergo economic development and industrialization, making them attractive destinations for foreign investors seeking new markets and opportunities. Therefore, we examine the effects of FDI and GDP on Pollution in middle-income countries. Our findings contribute long-term solutions towards sustainable economic development by using green technology and regulation of environmental protection commitment for FDI projects.

This study generates the following striking results. Firstly, the results suggest an insignificant relationship between FDI and Pollution in the short term. However, empirical findings show that a percentage increase in FDI leads to around a 0.62% reduction in pollution in the long term. Our findings align with the study of Marques and Caetano (2020) and Porter's hypothesis. However, in the short term, developed countries will transfer outdated manufacturing technology to low-income and developing countries through FDI. Thus, higher FDI investments increase CO2 emissions in the short term, mainly in low-income countries. These findings support the pollution halo hypothesis.

Secondly, our study indicates that economic growth (GDP) positively increases CO2 Pollution, especially in lower-income countries. Economic growth consumes fossil fuels and produces CO2 emissions, resulting in more severe environmental issues. This finding is consistent with Marques and Caetano (2020), Huang et al (2019), and Yang et al (2018). On the other hand, upper-middle-income countries aim for sustainable development, so economic development reduces CO2 emissions in the long term. Our finding aligns with Chang (2015), Shen et al (2020), Marques and Caetano (2020), Hove et al (2019), and the Environmental Kuznets Curve hypothesis. Finally, the Granger Causality Test shows no causal relationship between FDI and CO2. At the same time, there is a one-way causal relationship between CO2 and GDP.

Our study contributes to the growing literature on 17 Sustainable Development Goals in the following way. This study is one of the first to consider the concurrent effects of FDI and economic growth on pollution. Our analysis was carried out in some low and middle-income countries other than from a sample of Central and Eastern European countries by Simionescu et al (2021). Second, Sapkota and Bastolaas (2017) and Le et al (2022) report a mixed association-ship between FDI and economic growth on pollution. This study shows that while FDI and economic growth reduce pollution in the long run, they increase pollution in the short run, especially in less developed countries. Short-term research demonstrating a positive link between economic development, FDI, and CO2 emissions might help policymakers understand the possible environmental difficulties associated with rapid economic expansion and investment inflows. Our empirical evidence supports policymakers in implementing appropriate regulations to reduce negative environmental consequences during the early phases of development. This research also assists policymakers in establishing policies and actions to enable the long-term transition to sustainable development. Ultimately, our results illustrate the significance of technical developments in promoting long-term CO2 emission reductions. Understanding the positive impact of technology transfer and knowledge dissemination might motivate investment in R&D, resulting in developing and accepting cleaner technologies in middle-income nations.

Literature Review

Theories

Marques and Caetano (2020) and Huang et al (2019) explain the impact of FDI on environmental pollution through the pollution haven hypothesis (PHH), the race to the bottom hypothesis, the pollution halo hypothesis, and the Porter hypothesis. Firstly, the pollution halo hypothesis points out that developed countries transfer outdated manufacturing technologies to less developed nations as these countries are striving to attract FDI projects.

Another reason is the tightening of environmental regulations, and the cost of reducing pollution in developed countries is increasing (Farhani & Ozturk,2015). Secondly, the race to the bottom hypothesis indicates the positive effect of FDI on the environment. The race to the bottom hypothesis argues for a trade-off between globalization and environmental costs. Lower-income countries relax their environmental regulations to attract foreign investments and develop local economies.

On the other hand, the pollution Halo and Porter hypotheses conjecture that foreign investments help reduce pollution. The pollution halo hypothesis assumes foreign companies save energy and have cleaner manufacturing processes than domestic companies. In addition, foreign companies will likely transfer environment-friendly technology to the host country due to technology spillover. Porter's hypothesis suggests new technologies that consume fewer raw resources, FDI can improve the environmental quality of the host countries. Such technologies are also known as environmentally friendly technologies. Consequently, foreign investments help reduce the total emissions in host countries. Finally, prior studies explained the relationship between economic growth and environmental pollution using the (EKC) such as Sarkodie and Strezov (2019), Rofiuddin et al (2017), Li et al (2019), Amissah and Clottey (2020). The EKC hypothesis explains an inverse U-shaped relationship between economic development and environmental Pollution (Mercan & Karakaya,2015).

The nexus between FDI and Pollution

Marques and Caetano (2020), Sapkota and Bastola (2017), Zdražil and Mallick (2018), Wang et al (2021), Kayani et al (2021), and Huang et al (2019) indicate a positive relationship between FDI and environmental pollution. Marques and Caetano (2020) report that FDI increases CO2 emissions in middle-income countries because local policymakers do not pay attention to innovation and environmental issues. For a group of Latin American countries, Sapkota and Bastola (2017) also indicates the harmful effects of FDI on Pollution because a percentage increase in FDI contributes to a 0.04% increase in pollution. Wang et al (2021) suggest that FDI has driven the increase in carbon emissions in China because these FDI projects require higher energy intensity and energy consumption.

However, other research shows an inverse relationship between FDI and environmental pollution in middle and low-income countries. Marques and Caetano (2020) demonstrate that promoting green technologies have successfully reduced Pollution through FDI in high-income countries. In addition, environmental regulations force foreign companies to invest in green innovation. For instance, foreign companies or projects committed to conserving natural resources, developing development and production of alternative energy sources, constructing environmental projects, supplying clean water and clean air, or other environmental business activities (Shen et al.2020). Chang (2015) illustrates that FDI can bring more technological innovations and thus helps minimize energy consumption. Thus, energy efficiency helps reduce pollution in the host countries.

As prior studies report mixed findings between FDI and environmental pollution, we propose the following hypothesis:

H1: FDI has a significant impact on environmental pollution.

The Nexus Between Economic Growth and Pollution

Simionescu et al (2021), Demir et al (2023), Šatera and Obršálová (2015). and Yang et al (2018) indicate a positive association between economic growth and pollution. Simionescu et al (2021) show that economic growth was concentrated on fossil energy consumption and environmental pollution in less developed nations. Yang et al (2018) indicate that the degree of industrialization, a proxy of economic growth, increases CO2 emissions, industrial dust, and sulfur dioxide emissions.

On the other hand, Hove et al (2019) explain that economic growth negatively affects pollution because middle-income countries, in the long run, also implement policies such as encouraging clean energy investment, emission reduction targets, carbon pricing systems, and extending environmental standards. Furthermore, as the economies of middle-income nations grow, environmental awareness education will improve, leading to changes in consumer choices; individuals living in these countries will gravitate toward eco-friendly products and services. As a result, as emerging nations' economies grow to a certain amount, CO2 emissions will decrease.

Previous research has demonstrated mixed effects of economic expansion on environmental pollution. Thus, we suggest the following hypothesis:

H2: The relationship between economic growth and environmental pollution is statistically significant.

Methods

Data

This study collects data from middle-income countries based on World Bank classification. We collect data from 1990 because 1991 was marked by significant events, such as the collapse of the two poles in Iran due to the disintegration of the "one pole" of the Soviet Union. The non-existence of the socialist system and the "bipolar" status " of the two poles no longer exist. These events motivate countries to attract foreign investment and increase economic growth. We follow Duong et al (2022) to remove observations with inadequate data to compute the required variables. Thus, we exclude American Samoa, Bosnia and Herzegovina, Cuba, Gabon, Equatorial Guinea and Kosovo, Saint Vincent and the Grenadines due to data limitations. The final sample is a balanced data panel with 1,316 observations from 47 countries from 1991 to 2018. Appendix B reports the list of 47 counties in this study.

Model constructions

There are mixed studies on the effects of domestic credit on pollution. Simionescu et al (2021) indicate that domestic credit to the private sector has only a low but significant impact on pollution, eventually due to policies aimed at economic growth that do not consider environmental challenges. In contrast, Simionescu et al (2021) show that domestic credit to the private sector reduces pollution, which shows that funds prefer environmentally friendly projects. Besides, Obiora et al (2020) indicate that domestic credit to the private sector for all economic types consistently contributes to a rise in carbon emissions due to raised investment into the private sector by banks and other such institutions to increase total carbon emissions.

Much previous research has demonstrated the relationship between the labor force and pollution. Zhou et al (2019) suggest that the labor force increases pollution because an increased labor force increases factory emissions. While Al-Mulali et al (2015) show that pollution would be reduced if much of the workforce is employed in agriculture and services, which use less energy than in the industrial sector.

Population and pollution are closely related. Rofiuddin et al (2019) indicate that population positively affects pollution because increasing population status will impact increasing environmental pollution. While Chen et al (2020) argue that a rising population will decrease pollution because rising residents consume clean energy and public transportation services, decreasing gas emissions that cause pollution and improving air quality.

Prior studies document a negative relationship between renewable energy consumption and pollution. Bhattacharya et al (2018) suggest that developing renewable energy consumption reduces pollution by using more environmentally friendly products and technologies. Yao et al (2019) also demonstrated the ability to consume renewable energy to reduce CO_2 emissions and assist sustainable development.

There is mixed research associated with the impact of trade openness on pollution. Mahmood et al (2019) suggest that the association-ship between trade openness and pollution is positive because rising trade openness also increases the demand for emissions-oriented imports. Moreover, Shahbaz et al (2017) examined 105 countries and grouped them into samples of developed, developing, and underdeveloped groups worldwide. The result indicated an inverted U-form nexus between trade and pollution for all groups. Their study shows that CO_2 emissions increase initially, then decrease after the threshold of commercial openness is reached. However, Sohag et al (2017) report an insignificant impact of trade openness on pollution in lower-middle-income countries.

Our research model includes foreign direct investment, gross domestic product, domestic credit to the private sector, labor force participation rate, population growth, renewable energy, and trade:

$$CO2_{i,t} = \beta_0 + \beta_1 FDI_{i,t} + \beta_2 GDP_{i,t} + \beta_3 DOM_{i,t} + \beta_4 LAB_{i,t} + \beta_5 POP_{i,t} + \beta_6 REN_{i,t} + \beta_7 TRA_{i,t} + \varepsilon_{i,t} \quad (1)$$

where

FDI the net foreign direct investment inflow,

GDP the gross domestic product growth rate,

DOM domestic credit to the private sector,

LAP labour force participation rate,

POP population growth,

REN renewable energy consumption,

TRA trade,

ε error terms,

i the country-specific, and

t the time specific.

All variable definitions are reported in Appendix A.

Estimation methodology

We first tested descriptive returns for this research for multicollinearity checks' median, mean, correlation, and standard deviation. Second, we check the value root test by Augmented Dickey and Fuller (ADF) and Phillips Perron tests for stationarity tests. However, this study selects the optimal lag level with unconstrained VARs before testing for co-integration associations. The latency length criterion is the third step in checking the optimal latency of the model. Fourth, we run the ARLD model to examine the long-term and short-term relationships. In the sixth step, we check Serial correlation-LM, Heteroskedasticity, and Stability tests to test the model's well fit. Finally, we perform the Granger causality test (Engle & Granger ,1987).

Results

Descriptive statistics

Table 1 presents the descriptive statistics of the sample. Foreign direct investment (FDI) grew at an average rate of 6.9%, showing the growth rate of FDI among low-and middle-income countries from 1991 to 2018. These values of FDI are like those of Simionescu et al (2021). In addition, the average GDP growth rate from 1991 to 2018 was 2.2%. These results in terms of GDP are inconsistent with previous studies such as Simionescu et al (2021) and Xie et al (2019). In contrast, CO_2 has an average growth rate of -0.3, showing that CO_2 in low-income, low-middle-high, and middle-high countries decreased by 0.3% between 1991 and 2018.

Table 1. Descriptive statistics.

	Mean	Median	Maximum	Minimum	Std. Dev.	N
CO_2	-0.003	-0.022	3.222	-0.698	0.181	1,316
FDI	0.069	0.008	39.333	-35.499	3.001	1,316
GDP	0.022	0.066	85.472	-42.139	5.749	1,316
DOM	0.490	0.418	49.648	-64.590	4.418	1,316
LAB	-0.097	-0.053	3.770	-3.511	0.561	1,316
POP	-0.017	-0.022	4.676	-3.016	0.289	1,316
REN	-0.413	-0.242	27.608	-27.575	2.823	1,316
TRA	0.080	0.282	62.029	-56.619	8.262	1,316

Source: authors calculation. **Note:** Table 1 reports the descriptive statistics. The sample includes 47 middle-income countries from 1991 to 2018. All variable definitions are reported in Appendix A.

Pearson Correlation Matrix

Table 2 reports the Pearson correlation coefficients of all independent variables. All the coefficient correlations are below 0.5, and the VIF values are less than 5, implying that this study has no multicollinearity issue (Tran et al. 2022; Duong et al. 2022).

Table 2. Pearson Correlation Matrix.

	FDI	GDP	DOM	LAB	POP	REN	TRA	VIF
FDI	1							1,023
GDP	0.039	1						1.016
DOM	0.007	-0.057	1					1.007
LAB	0.006	-0.030	0.031	1				1.004
POP	0.020	0.087	0.011	0.005	1			1.010
REN	-0.001	-0.022	-0.041	0.016	0.037	1		1.004
TRA	0.141	-0.040	0.032	-0.038	-0.014	-0.016	1	1.026

Source: authors calculation. **Note:** Table 2 reports the Pearson correlation matrix. The sample includes 47 middle-income countries from 1991 to 2018. All variable definitions are reported in Appendix A.

Unit Root Test

We used ADF (Dickey-Fuller) and PP (Philips Perron) methods to test the stationary of our variables. According to the ARDL testing model, all variables should be stationary to avoid bias estimations.

We use the LR statistics to select the optimal lag for statistics; LR will modify sequentially until the optimal latency is achieved. ACI represents Akaike, the SC tool for finding Schwarz information fields, and HQ to find Hannan-Quinn information to choose the most optimal latency. Dormann and Griffin (2015) have shown that using too low or too high an optimal lag is almost impossible to capture important information from the model. Table 4 reports that the most probable lag value is 5, so we chose five as the optimal lag of the ARDL model.

When dealing with limited sample quantities, ARDL comes in handy. It permits accurate parameter estimates and statistical inference. ARDL performs dynamic analysis by merging lagged values of model variables, resulting in a more thorough understanding of linkages. ARDL can model both short-run dynamics and long-run equilibrium connections between variables. Endogenous can be explained and reduced (Simionescu et al. 2021).

Table 3. Unit Root Test.

	ADF Test		PP Test	
Variables	t-Statistic	P-value	t-Statistic	P-value
ΔlnCO$_2$	-15.593	<0.00001	-24.537	<0.00001
ΔlnFDI	-20.615	<0.00001	-29.729	<0.00001
ΔlnGDP	-25.494	<0.00001	-30.802	<0.00001
ΔlnDOM	-13.871	<0.00001	-20.410	<0.00001
ΔlnLAB	-6.523	<0.00001	-10.858	<0.00001
ΔlnPOP	-21.222	<0.00001	-4.867	<0.00001
ΔlnREN	-13.624	<0.00001	-23.040	<0.00001
ΔlnTRA	-16.794	<0.00001	-25.246	<0.00001

Source: authors compilation. **Note**: Table 3 reports the Unit Root Tests. The sample includes 47 middle-income countries from 1991 to 2018. The definitions of the variables are in Appendix A. ***, **, and * represent the significant level at 1%, 5%, and 10%, respectively.

Table 4. Lag length criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-13,044.43	NA	158.873	27.771	27.812	27.787
1	-12,379.23	1,317.656	44.211	26.492	26.863	26.633
2	-11,971.61	800.500	21.282	25.761	26.462*	26.028
3	-11,786.70	359.988	16.456	25.504	26.535	25.897*
4	-11,733.55	102.568	16.843	25.527	26.888	26.046
5	-11,626.52	204.718	15.372*	25.435*	27.126	26.080
6	-11,577.48	92.962	15.875	25.467	27.488	26.237
7	-11,522.54	103.216	16.191	25.486	27.837	26.382
8	-11,457.98	120.203*	16.181	25.485	28.166	26.507

Source: authors compilation. **Note:** Table 4 reports the lag length selection criteria. The sample includes 47 middle-income countries from 1991 to 2018. The definitions of the variables are in Appendix A. ***, **, and * represent the significant level at 1%, 5%, and 10%, respectively.

ARDL estimations: Short-run estimates of the ARDL approach

Table 5 reports the short-term ARDL test results. The short-term ARDL test report shows a positive relationship between GDP and CO2. Specifically, a percentage increase in economic growth contributes to a 0.007% increase in CO2. Economic developments focus on industrialization and production, resulting in high fuel consumption. Less developed countries rely on fossil energy to foster economic growth and industrial activities. Thus, C02 emissions also increase significantly, which leads to environmental pollution. Our findings are consistent with the EKC hypothesis, hypothesis 2 and Simionescu et al (2021), and Yang et al (2018).

Table 5. Short-run Equation.

Variables	Coefficient	Std. Error	Prob
D(FDI)	0.0024	0.0026	0.3630
D(GDP)	0.0070***	0.0017	<0.00001
D(DOM)	0.0021	0.0038	0.5753
D(LAB)	0.0170	0.1706	0.9206
D(POP)	1.8485	1.2024	0.1248
D(REN)	-0.0176*	0.0070	0.0119
D(TRA)	-0.0004	0.0011	0.7392

Source: authors compilation. **Note:** Table 5 reports the short-run estimations from the ARDL method. The sample includes 47 middle-income countries from 1991 to 2018. The definitions of the variables are in Appendix A. ***, **, and * represent the significant level at 1%, 5%, and 10%, respectively. Each variable has results for the current year t and the previous year.

Table 5 also indicates a positive relationship between FDI with CO_2. Specifically, a percentage increase in FDI leads to a 0.0024% increase in CO_2 emissions. Marques and Caetano (2020) suggest that countries trade off economic development over environmental costs, so they relax environmental policies to attract investment capital for economic development. Our findings support the race to the bottom hypothesis.

ARDL estimations: Long-run estimates of the ARDL approach

In Table 6, the long-run parameters show that FDI has a statistically trivial association in the long run. Specifically, a percentage increase in FDI inflows reduces CO_2 pollution by about 0.006%. This finding suggests that countries will focus more on environmental remediation after their economies have stabilized in the long term. FDI can also bring more advanced technological innovation that helps reduce energy intensity. Environmental requirements will also stimulate companies to invest in green technology to improve efficiency (Shen et al.2020). Our findings contradict Marques and Caetano (2020) and Chang (2015). Therefore, our findings support Porter's hypothesis, and our findings support hypothesis 1.

Table 6. Long-run Equation.

Variable	Coefficient	Std. Error	Prob
FDI	-0.0062*	0.0022	0.0045
GDP	-0.0143***	0.0013	<0.00001
DOM	-0.0001	0.0003	0.6336
LAB	-0.0120*	0.0047	0.0115
POP	0.0833***	0.0158	<0.00001
REN	-0.0218***	0.0014	<0.00001
TRA	-0.0015***	0.0005	<0.00001

Source: authors compilation. **Note:** Table 6 reports the long-run estimations from the ARDL method. The sample includes 47 middle-income countries from 1991 to 2018. The definitions of the variables are in Appendix A. ***, **, and * represent the significant level at 1%, 5%, and 10%, respectively. Each variable has results for the current year t and the previous year.

Table 6 also indicates that GDP negatively impacts pollution in the long run. For instance, a percentage increase in GDP reduces CO_2 emissions by 0.01%. After stabilizing economic development gradually, less developed nations will introduce policies to protect the environment and solutions to reduce waste and treat pollutants (Hove et al. 2019). Thus, our findings also support hypothesis 2 and support theory the EKC hypothesis.

Table 6 reports a negative impact between the labor force and pollution. Specifically, a percentage increase in total labour participation reduces CO_2 pollution by about 0.012%. Al-Mulali et al (2015) point out that most of the workforce is employed in agriculture and services, which use less energy than in the industrial sector. Therefore, improving organic agriculture activities is a solution to reduce environmental pollution. However, Zhou et al (2019) report that the increasing labor force in factories and industrial zones increases environmental pollution. Therefore, our finding aligns with Al-Mulali et al (2015).

Table 6 reports a negative relationship between renewable energy and pollution at a significant level of 1%. Specifically, a percentage increase in REN inflows reduces CO_2 emissions by about 0.0218%. Bhattacharya et al (2018) suggest that more giant factories use renewable energy to reduce energy costs, subsequently reducing operating costs. Moreover, factories are encouraged to use renewable energy to acquire green credits with a lower interest rate than conventional loans from banking institutions. Our findings are consistent with Bhattacharya et al (2018) and Yao et al (2019).

Table 6 indicates that higher populations positively impact pollution at a meaningful level of 1%. A percentage increase in the total population generates CO_2 emissions by about 0.0833%. Sohag et al (2017) report that population growth is the core factor in explaining CO_2 emission because the concentration of greenhouse gases arises from human activities. Our result is consistent with Rofiuddin et al (2019).

Table 6 reports that the trade ratio reduces pollution. A percentage increase in TRA inflows reduces CO_2 pollution by about 0.0015%. Sohag et al (2017) report that increased openness would reduce CO_2 emissions because updated production technologies have been transferred to less developed nations to improve production efficiency. The latest production technologies also consume less energy and resources, so they help reduce environmental pollution. Finally, table 6 reports that the relationship between domestic credits and pollution is statistically insignificant eventually.

Panel causality results for all countries

Table 7 reports no causal relationship between FDI and CO_2. On the other hand, a one-way causal relationship exists between CO_2 and GDP variables. Specifically, these results support hypothesis 2 and reject hypothesis 1. Table 7 also reports that domestic credit to the private sector (DOM), labor force participation rate (LAB), population growth (POP), renewable energy consumption (REN), and trade (TRA) also had no causal relationship with CO_2.

Table 7. Panel Granger causality results.

Variable	F-Statistic	Probability
FDI->CO_2	0.8234	0.4392
CO_2->FDI	1.0064	0.3658
GDP->CO_2	1.8120	0.1639
CO_2->GDP	11.3767***	<0.0001
DOM->CO_2	0.8939	0.4093
CO_2->DOM	1.5731	0.2078
LAB->CO_2	0.4178	0.6586
CO_2->LAB	0.2225	0.8005
POP->CO_2	1.1240	0.3253
CO_2->POP	2.5989*	0.0748
REN->CO_2	3.6670**	0.0258
CO_2->REN	2.5088	0.0818
TRA->CO_2	1.3028	0.2721
CO_2->TRA	2.0168	0.1335
GDP->FDI	2.1640	0.1153
FDI->GDP	6.0544***	0.0024
DOM->FDI	0.3940	0.6744
FDI->DOM	0.1920	0.8253
LAB->FDI	0.0320	0.9685
FDI->LAB	0.3593	0.6982
POP->FDI	0.5697	0.5659
FDI->POP	0.0782	0.9248
REN->FDI	1.1567	0.3149
FDI->REN	0.2562	0.7740
TRA->FDI	0.6610	0.5165
FDI->TRA	17.0941***	<0.0001
DOM->GDP	0.3039	0.7380
GDP->DOM	0.8936	0.4095
LAB->GDP	0.3663	0.6934
GDP->LAB	1.9179	0.1474
POP->GDP	29.5838***	<0.0001
GDP->POP	3.0523	0.0476
REN->GDP	0.5244	0.5920
GDP->REN	0.8053	0.4472
TRA->GDP	6.0579***	0.0024
GDP->TRA	0.7528	0.4712
LAB->DOM	0.2360	0.7898
DOM->LAB	0.4701	0.6251
POP->DOM	0.3865	0.6795
DOM->POP	1.1215	0.3261
REN->DOM	1.3162	0.2685
DOM->REN	0.0543	0.9472
TRA->DOM	0.0716	0.9309
DOM->TRA	0.9309	0.3945
POP->LAB	0.1572	0.8546
LAB->POP	0.8450	0.4295
REN->LAB	1.0531	0.3942
LAB->REN	0.7901	0.4540
TRA->LAB	0.1904	0.8266
LAB->TRA	0.4720	0.6239
REN->POP	1.8336	0.1603
POP->REN	3.6020**	0.0276
TRA->POP	1.7704	0.1707
POP->TRA	0.7549	0.4703
TRA->REN	1.3413	0.2619
REN->TRA	0.4378	0.6456

Source: authors compilation. **Note:** Table 7 reports the Granger causality test results. The sample includes 47 middle-income countries from 1991 to 2018. The definitions of the variables are in Appendix A. ***, **, and * represent the significant level at 1%, 5%, and 10%, respectively.

Discussion

Table 5 reports the short-term ARDL test results. The short-term ARDL test report shows a positive relationship between GDP and CO_2. This finding explains why industrial activities frequently entail the combustion of fossil fuels, which emit CO_2 into the atmosphere. As a result, when economic activity grows, CO_2 emissions may rise due to increased energy consumption and the usage of carbon-intensive industrial processes. Furthermore, economic growth is frequently associated with increased consumption and consumer expenditure. Increased consumption increases demand for products and services, which may necessitate more energy for production, transportation, and consumption. Therefore, there is increasing energy demand, particularly from fossil fuel sources, which increases CO_2 emissions. Finally, economic growth is frequently associated with creating and extending infrastructure, roads, and transportation networks. These operations may result in higher energy consumption and CO_2 emissions. Our findings are consistent with the EKC hypothesis, hypothesis 2, Simionescu et al (2021), and Yang et al (2018).

Table 5 also indicates a positive relationship between FDI with CO_2. The first FDI inflows into middle-income nations frequently target energy-intensive businesses with significant carbon footprints, such as manufacturing and extractive industries. These industries may include operations that produce considerable volumes of CO_2. Second, FDI might introduce new technology and manufacturing practices to the host nation. In the short term, the transfer and implementation of new technologies may take time and necessitate changes in manufacturing processes. CO_2 emissions may briefly increase during this transition phase while environmentally friendly innovations take effect. Finally, FDI capital also develops infrastructure projects in middle-income nations. FDI leads to the development of infrastructure, roads, and power plants, which can result in higher energy consumption and CO_2 emissions during the building period. Our findings support the race to the bottom hypothesis and Marques and Caetano (2020), Sapkota and Bastola (2017), Wang et al (2021), and Huang et al (2019). Our findings contradict those of Marques and Caetano (2020), Shen et al (2020), and Chang (2015). This discrepancy is related to the fact that these studies are being done in industrialized nations, which frequently have more stringent environmental rules and are investment countries. Thus, there will be less environmental degradation.

Table 6 depicts the long-run inverse connection between GDP and environmental degradation. As nations experience economic growth and technical advancement, the development and acceptance of cleaner and more efficient technologies, which may help reduce energy consumption and CO_2 emissions, typically increases. Furthermore, long-term middle-income nations establish policies such as clean energy investment incentives, emission reduction objectives, carbon pricing systems, and stringent environmental standards. Finally, as the economies of middle-income nations expand, environmental awareness will be raised via education. This might lead to changes in consumption patterns and tastes, emphasizing ecologically friendly products and services, resulting in lower long-term CO_2 emissions. Thus, our findings also support hypothesis 2 and support theory the EKC hypothesis.

Table 6 indicates a long-run inverse connection between FDI and CO_2 emissions. Middle-income host countries can strengthen their environmental regulations and standards to align with global sustainability goals and address environmental challenges by enacting stricter environmental regulations, encouraging FDI to use cleaner production methods, investing in sustainable technology, and implementing environmental management activities, contributing to long-term CO_2 emission reductions. Our findings are inconsistent with Marques and Caetano (2020); Chang (2015). Therefore, it supports Porter's hypothesis, and our findings support hypothesis 1.

Our findings suggest that in middle-income countries, initial increases in GDP are associated with higher CO_2 emissions in the short term. However, over the long term, both GDP and FDI demonstrate a role in reducing CO_2 emissions. In contrast, Essandoh et al (2020) present contrasting results, indicating that FDI positively impacts CO_2 emissions in low-income countries but has negligible effects in high-income nations. They attribute this to low-income countries' tendency to attract capital investments in industries with high energy consumption and environmental pollution. In contrast, developed countries have stringent environmental protection policies for foreign investments, thus limiting the influence of FDI on CO_2 emissions. However, Essandoh et al (2020) also find that GDP only reduces emissions in high-income countries, while the opposite effect is observed in low-income countries, aligning with the Environmental Kuznets Curve (EKC) hypothesis. This finding suggests that low-income countries prioritize national economic development without sufficient awareness of the associated environmental risks. Conversely, as countries reach a certain level of development, they begin to consider long-term economic growth and implement environmental protection policies, reducing CO_2 emissions. These insights contribute to understanding the complex relationship between economic factors, environmental consciousness, and CO_2 emissions.

Conclusion

The problem of environmental pollution in the current stage of economic development is a significant issue that can be directly inferred to our lives for a long time. Therefore, our study expands on previous studies examining the impact of foreign direct investment (FDI) and economic development (GDP) on environmental Pollution (CO_2) in middle-income nations. We employ the ARDL regressions to analyze a sample of 47 middle-income countries from 1991 to 2018. Our findings suggest that in the short term, GDP positively affects pollution because a percentage increase in economic growth contributes to a 0.007% increase in CO_2 emission. Meanwhile, GDP negatively impacts pollution in the long term because a percentage increase in GDP reduces CO_2 emissions by 0.01%. While the relationship between FDI and Pollution in the short run is insignificant, a percentage increase in FDI inflows reduces pollution by 0.006% in the long run. Our findings support Porter's hypothesis, pollution halo hypothesis, and Environmental Kuznets Curve hypothesis.

This study provides recommendations for policymakers to implement sustainable economic development policies while protecting the environment. According to Marques and Caetano (2020), FDI increases CO_2 emissions in middle-income nations because local politicians do not prioritize innovation and environmental concerns. As a result, the government must implement regulations to minimize CO_2 emissions. Firstly, middle-income nations should encourage investment in green industries such as renewable energy, sustainable transportation, and energy-efficient infrastructure to mitigate the short-term environmental effect of economic expansion. Second, encourage energy-saving practices, promote the adoption of energy-efficient technology, and give financial incentives for firms to go green. Next, environmental rules should be strengthened and enforced to guarantee that pollution control criteria are met, and penalties for noncompliance must be implemented. They are raising public awareness of the necessity of environmental conservation and sustainable development. Educate individuals, companies, and governments on the benefits of balancing economic growth with environmental conservation. Finally, financial incentives, tax breaks, and subsidies should be made available to enterprises that embrace sustainable practices and invest in green technology, encouraging the creation of green bonds and funding methods for long-term initiatives.

To mitigate the detrimental impact of FDI, the government should offer financial incentives, tax exemptions, and subsidies to FDI in environmentally friendly industries. Foreign investors may be encouraged to emphasize sustainable and clean technology, renewable energy, energy efficiency, and low-carbon businesses. Encourage collaboration between government agencies and foreign investors to solve environmental concerns, including exchanging experience, resources, and best practices for promoting sustainable development and reducing pollution. Provide foreign investors with accessible and transparent information on environmental rules, sustainable practices, and applicable incentives so that they may make informed judgments and prefer environmentally responsible investment projects.

Although this study extends the literature on 17 Sustainable Development Goals, it has the following limitations. First, the conclusions drawn from this study are limited by the data generated. This article only assesses 47 countries, particularly low- to middle-income countries. Moreover, it uses CO_2 emission to represent environmental degradation. We advise future studies to use additional environmental pollution proxies to generate robust findings.

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Appendix A

Table A: Variable definitions.

Variables		Definitions
Dependent variable		
CO2	CO2 emissions	CO2 emissions come from the blaze of fossil fuels. They consist of carbon dioxide from solid, liquid, and gas fuels and gas flaring (Yang et al., 2018). We estimate the percentage change of CO2 over the previous year.
Independent variables		
FDI	Foreign direct investment	We follow Marques and Caetano (2020) and Duong et al. (2022) to estimate FDI as net FDI inflows over total GDP
GDP	GDP growth	The GDP growth rate over the previous year (Simionescu et al., 2021; Duong et al., 2022).
Control variables		
DOM	Domestic credit to the private sector	DOM refers to other depository corporations' financial resources provided to the private sector (Obiora et al., 2020).
LAB	Labor force participation rate	The labor force participation rate is the proportion of the population aged 15 and older that contribute labor to produce goods and services during a specified period (Zhou et al., 2019)
POP	Population growth	The population is based on the de facto meaning, which includes all residents regardless of legal status or citizenship. We follow Rofiuddin et al. (2019) to estimate the annual population growth rate for year t is the exponential growth rate of the mid-year population from year t-1 to t, expressed in percentage.
REN	Renewable energy consumption	Renewable energy consumption is the share of renewable energy in the total last energy consumption (Bhattacharya et al., 2018).
TRA	Trade	Sohag et al. (2017) and Duong et al. (2022) suggest that the ratio of trade over total GDP motivates economic growth and affects CO2 emissions. The data is from World Bank.

Appendix B

Table B: List of 47 Upper-income countries.

Albania	Dominica	Kazakhstan	Paraguay
Argentina	Dominican Republic	Libya	Peru
Armenia	Ecuador	Malaysia	Russia
Azerbaijan	Fiji	Maldives	Saint Lucia
Belarus	Georgia	Marshall Islands	Serbia
Belize	Grenada	Mauritius	South Africa
Botswana	Guatemala	Mexico	Suriname
Brazil	Guyana	Moldova	Thailand
Bulgaria	Iraq	Montenegro	Tonga
China	Jamaica	Namibia	Turkey
Colombia	Jordan	North Macedonia	Turkmenistan
Costa Rica	Palau	Tuvalu	