

From Pollution Haven to Pollution Halo: Environmental Sustainability and FDI Attraction in OECD Countries

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Abstract

Objective: The primary purpose of the study is to examine the dynamic relationship between Foreign Direct Investment (FDI) inflows and environmental sustainability in 38 OECD countries from 2000 through to 2024, and to study whether improvements in environmental quality and regulatory frameworks have an impact on FDI by testing the Pollution Haven, Pollution Halo, and Porter hypotheses.

Design/methodology/approach: A balanced panel dataset is used in the study, and the System Generalized Method of Moments estimator is adopted in order to deal with endogeneity, dynamic persistence, heteroskedasticity, and cross-sectional dependence. To confirm the robustness of the empirical analysis, second-generation panel unit root tests and the Dumitrescu–Hurlin panel causality test are applied. The study investigated effects of CO₂ emissions, renewable energy production, environmental taxes, and trade openness on FDI inflows.

Findings: The results indicate that renewable energy production, environmental taxes, and trade openness have a positive and statistically significant impact on foreign direct investment inflows, while CO₂ emissions have a significant negative relationship with FDI. These findings support the Pollution Halo and Porter hypotheses, indicating that environmentally sustainable policies and more robust regulatory frameworks increase a country's attraction to foreign investors, and at the same time provide no support for the Pollution Haven hypothesis in the OECD countries.

Originality/value: The study provides up-to-date evidence based on the most recent OECD data and a solid dynamic panel approach, showing that environmental sustainability and strict environmental policies actually improve rather than block the attraction of high-quality foreign direct investment.

KEY WORDS: *FDI inflows, Environmental sustainability, Dumitrescu-Hurlin Granger Causality, GMM, OECD countries*

Introduction

Foreign direct investment (FDI) is still a major way for capital, technology, and industry to move across borders. However, the types of sectors receiving these investments are changing, which has clear environmental impacts. UNCTAD's *World Investment Report 2025* shows that global FDI dropped for the second year in a row, down 11% when excluding volatile conduit flows. At the same time, investment in renewable energy projects fell by 16% (UNCTAD, 2025). This decline in green investment comes as OECD countries are making binding commitments to cut emissions under their national climate plans. This situation raises an important question: does focusing on environmental sustainability help attract foreign investment, or does it drive it away? And can environmental policies be designed to support, rather than damage, a country's ability to compete for investment?

For more than forty years, researchers have debated this question, leading to three main perspectives that only partly agree. The Pollution Haven Hypothesis, first described by Walter and Ugelow (1979), argues that developing countries have often had more relaxed environmental policies than industrialised nations. This difference has encouraged pollution-heavy industries to move to places with weaker environmental rules. Copeland and Taylor (2004) built on this idea using a general equilibrium trade model, showing that differences in environmental regulations between countries can lead to predictable shifts in where industries locate and how pollution-intensive goods are traded. There is direct evidence for this in the foreign direct investment (FDI) literature. For instance, List and Co (2000) used data from U.S. states and found that stricter environmental regulations make it less likely for new foreign manufacturing plants to open. Later studies confirmed this finding, even after considering other factors like endogeneity and spatial spillovers.

The Pollution Halo Hypothesis offers a different perspective by suggesting that multinational companies bring better technology, cleaner management, and stronger environmental standards to host countries. This means that strong environmental credibility can attract, rather than discourage, investment. Tsoy and Heshmati (2024) found evidence supporting this idea, showing that foreign direct investment does not necessarily harm environmental sustainability when a country's institutions are strong. Another related view is the Porter Hypothesis from Porter and van der Linde (1995). It argues that good environmental regulations can encourage innovation, boost resource productivity, and strengthen a country's competitiveness, instead of just increasing costs. In this view, policies like environmental taxes may actually signal long-term stability and maturity, which are qualities that cautious multinational investors look for.

Alongside the main theoretical debate, many studies have looked at how renewable energy production and trade openness affect FDI. Kang et al. (2021) report a strong positive link between FDI and renewable energy use in South Asian economies, which suggests that technology transfer may play a role, either together with or instead of a haven-driven effect. Asiedu (2002) is often cited for showing that trade openness strongly and positively predicts FDI inflows in a wide range of developing countries, a result that has been confirmed in many regions and income groups. More recently, Yeboah et al. (2025) have built on this work by analyzing environmental taxation and green financing together, treating them as complementary factors that shape energy and emissions outcomes. This suggests that policy tools studied separately in earlier research may actually work together rather than alone. Despite these findings, there are only few studies that look at the combined effects of carbon emissions, environmental taxation, renewable energy production, and trade openness on FDI in a

single dynamic model. This is especially true for the highly regulated OECD countries, where the Porter and Halo mechanisms are most relevant. This study aims to fill both gaps. First, it estimates the effects of carbon emissions, environmental taxation, renewable energy production, and trade openness on FDI inflows using a single empirical framework for OECD countries. This approach allows for a direct comparison of the Pollution Haven, Pollution Halo, and Porter hypotheses. Second, it takes into account the dynamic and interconnected nature of these relationships by using a two-step System Generalised Method of Moments model (Arellano & Bond, 1991; Blundell & Bond, 1998). This method accounts for FDI persistence and uses lagged values of policy and environmental variables as instruments, with their validity checked through standard Hansen and Arellano-Bond tests (Roodman, 2009). By doing this, the study provides new and robust evidence on whether environmental taxation and renewable energy growth support, rather than limit, foreign investment in advanced economies. These findings have important and timely implications for climate and investment policy, especially now that, as UNCTAD (2025) data show, green-focused capital flows cannot be expected to keep growing on their own.

Review of Literature

Over the last four decades, the connection between Foreign Direct Investment (FDI) and environmental sustainability has been the subject of continuous scholarly investigation, leading to a large and theoretically varied body of research. The literature on this issue is mainly shaped by three major viewpoints: the Pollution Haven Hypothesis, which states that mega corporations move to places that limited environmental standards; the Pollution Halo Hypothesis, which claims that FDI spreads eco-friendly technological methods and management techniques to the host economies; and the Porter Hypothesis, which holds that well-designed environmental regulation can improve efficiency, innovation and competitiveness and thus increase the attractiveness of an economy for investment. This review brings together the theoretical bases of these different perspectives and arranges the empirical literature according to the main factors looked at in the current study, carbon emissions, environmental taxation, renewable energy production, and trade openness before moving on to the methodological literature concerning dynamic panel estimation, which forms the basis of the empirical approach used here.

FDI-Environment Nexus

The Pollution Haven Hypothesis comes from the research of Walter and Ugelow (1979), who noticed that environmental policies in developing economies were generally more lenient than those in industrialised countries, which in turn motivated pollution-intensive production to move to places where regulatory policies are weaker. Copeland and Taylor (2004) developed this argument within a general equilibrium trade model. They demonstrated that, under certain conditions, differences in environmental regulation between countries can lead to a systematic shift of polluting industries and to a corresponding pattern of trade in pollution-intensive goods. The Pollution Halo Hypothesis, on the other hand, reverses this relationship: instead of pursuing regulatory arbitrage, it is argued that multinational enterprises pass better technologies to the host countries, eco-friendly methods of production and more effective environmental management systems, thus improving rather than worsening environmental quality (Caetano et al., 2021; Tsoy & Heshmati, 2024). A third and closely related approach, the Porter Hypothesis, put forward by Porter and van der Linde (1995), rejects the idea of a fixed trade-off between regulation and competitiveness and instead suggests that well-designed environmental standards can encourage innovation, increase resource productivity and in the end improve a firm's or a country's competitive standing. Van Leeuwen and Mohnen (2017) and Rexhäuser and Rammer (2014) test this claim using firm-level data from the Netherlands and Germany, respectively, and find mixed but generally supportive evidence that environmental innovation resulting from regulation is linked to better economic results. Together, these three theories form the

theoretical foundation upon which later empirical studies, including the OECD-oriented literature examined, have assessed the direction and extent of the FDI–environment relationship.

FDI, Carbon Emission and Environmental Quality

A large amount of empirical research has looked into whether Foreign Direct Investment (FDI) inflows are linked to a worsening or improvement of environmental outcomes, the results of which differ greatly according to region, sector and the method of estimation. Paziienza (2019) looked at FDI in the manufacturing industries of the OECD countries and found a pollution-haven type of effect at the sector level may affect the decision for the location of investment by foreign investors, whereas Caetano et al. (2021) carried out a sector-by-sector analysis of the OECD countries and stated that the environmental effects of FDI vary considerably between polluting and non-polluting industries, warning against drawing general conclusions. Pan et al. (2019) used symbolic regression methods to identify the factors that determine carbon emission intensity among the OECD countries and discovered that emission intensity is the result of a complex, non-linear combination of economic and structural factors rather than FDI alone. More recent studies have looked at the issue again by using dynamic panel techniques: Tsoy and Heshmati (2024) directly asked whether FDI inflows are harmful to environmental sustainability and found that the relationship depends on the strength of the institutional framework in the host country, while Samour et al. (2022) reported that FDI, together with financial development, is positively linked to the adoption of renewable energy in the United Arab Emirates, thus providing some support for the halo view in the case of countries outside the OECD. Mustafa et al. (2025) carried out this line of research further by jointly modelling FDI and environmental taxation as determinants of the sustainability of renewable energy, concluding that the two policies function as complements rather than as substitutes.

Environmental Taxation, Regulatory Stringency and FDI

Although environmental taxation has become an increasingly important policy tool, there are limited studies in the literature on Foreign Direct Investment (FDI). De Santis and Stähler (2009) offered one of the earliest theoretical analyses of the link between environmental taxes and FDI, showing that the impact of taxation on decisions regarding the location of investment depends mainly on whether pollution is regarded as a local or a transboundary external pollution transmitter. Later empirical studies have mainly concentrated on the effects of environmental taxation regarding emissions, rather than its impact on investment: Doğan et al. (2022) looked at the connection between environmental taxes and carbon emissions in the G7 countries and found a significant reduction in emissions, while Dogan et al. (2022) obtained a similar result for a wider group of environmentally progressive countries, highlighting the mediating role of green growth. Although these studies offer evidence that environmental taxation can improve environmental performance, they do not deal thoroughly with the question of whether and in what way such tax policies affect the attractiveness of economies to foreign investors. Niu et al. (2018) incorporated environmental tax shocks into a dynamic stochastic general equilibrium framework and found that the reduction caused by such taxes occurs with a measurable time lag, a finding that has consequences for the interpretation of panel estimates made at the same time. Fang et al. (2022) connected environmental taxation to renewable energy consumption in the Belt and Road economies and found a significant positive association, a result that was also observed in the OECD context by Aydin and Bozatli (2023), who concluded that green innovation, environmental taxation and financial development all contribute to renewable energy consumption. In common, these findings suggest that environmental taxation will add to the adoption of renewable energy both through direct price-based incentives and also by improving the wide range of institutional and technological conditions that may support the shift to cleaner and renewable energy. Most recently, Yeboah et al. (2025) analysed the pivotal role of green financing, environmental taxation and FDI in determining energy efficiency and emissions outcomes in Africa and found that environmental tax systems increase rather than diminish the environmental benefits linked to foreign

investment. Overall, this body of research indicates that environmental taxation acts less as a barrier to investment and more as a signal of the quality of institutions and of long-term policy enhancement, in line with the Porter Hypothesis, even though there is still comparatively lower level of direct evidence on its effect as a factor of FDI inflows rather than on emissions or renewable energy outcomes. Therefore, Hence, how much environmental taxation affects the appeal of host economies to foreign investors is still remains as an important and rather under-explored empirical question.

Renewable Energy and FDI

There is also a wide range of literature that analyses the relationship between foreign direct investment and the development of renewable energy. Kang et al. (2021) discovered that flows of foreign direct investment are positively linked to renewable energy consumption in the South Asian economies, explaining this association in terms of technology transfer, whereas Wei et al. (2022) found a similar relationship when they simultaneously analysed foreign direct investment, economic growth and renewable energy development. Wall et al. (2018) turned their attention to policy design and looked at which types of policy instruments are most effective at attracting foreign direct investment specifically into the renewable energy sector, concluding that feed-in tariffs and stable regulatory frameworks were more important than tax incentives on their own. Collectively, these results indicate that FDI could help host economies to move towards cleaner energy systems by stimulating the transfer of technology, capital investment, and managerial skills to the host economies.

With regard to the OECD countries, Liao et al. (2022) examined the interaction between the adoption of renewable energy, industrialisation and green innovation and discovered that green innovation moderates the ecological benefits resulting from the expansion of renewable energy, whereas Umar and Safi (2023) claimed that combined effect of green innovation finance leads to improved environmental protection in the OECD countries. Gan and Smith (2011) had previously carried out a comparative analysis of the structural and policy factors which influence the adoption of renewable energy among the OECD countries, while Taşkın et al. (2020) looked into whether the consumption of renewable energy promotes green economic growth within that identical group of nations and found a positive yet heterogeneous effect which varied according to income levels. Together, these studies indicate that the generation of renewable energy is not merely a consequence of environmental policy but rather functions as a major factor in making a country more appealing to investors, particularly when the host countries also have regulatory stability and technological readiness.

Trade Openness And FDI

The link between trade openness and foreign direct investment is well documented in the wider body of international economics literature. Rodrik (1999) stated that while greater integration with global markets may lead to significant welfare augmentations, it can also result in distributive uncertainties and thus increase the need for effective domestic institutions and policy responses. This view is pertinent to the relationship between foreign direct investment and the environment since trade openness reflects the extent to which an economy is integrated into global markets and is therefore usually included as a control variable when looking at the factors that determine both foreign direct investment and environmental outcomes. By taking trade openness into account, it becomes possible to separate the effects of environmental and institutional factors from those linked to wider international economic integration.

In their study of the joint impact of green innovation and low-carbon policy in the OECD countries, Wang et al. (2023) found that trade openness enhances the ways of emission-reducing effect of green innovation, which shows that there is an interdependent rather than a competitive relationship between openness and environmental performance. Based on data from Chinese provinces, Song and Han (2022) found that the direction and makeup of investment flows, rather than openness itself, determine how openness affects the environment. With regard to OECD-specific panel data, trade

openness is generally found to be a significant and positive factor affecting FDI inflows, something that is in line with market-size and market-access theories concerning the location of investment, even though the way in which it interacts with environmental regulation has been comparatively less theorised.

Empirical Literature:

2.2.1 Dynamic Panel Estimation and Causality Testing

Research in the area of Foreign Direct Investment (FDI) and environmental sustainability has gradually moved from static estimators to dynamic panel methods, since the latter can handle endogeneity, dynamic persistence, and cross-sectional dependence. The Generalised Method of Moments estimator, as developed by Hansen in 1982, produces consistent estimates of the parameters even if the regressors are endogenous, because it makes use of the orthogonality existing between the instruments and the error term. Arellano and Bond in 1991 introduced the Difference GMM estimator, which removes unobserved individual-specific effects through first-differencing and employs lagged values of the first-differenced dependent variable as instruments; Blundell and Bond in 1998 then proposed the System GMM estimator in order to deal with the weak-instrument problem that arises when the dependent variable is highly persistent, by combining the level and first-difference equations to improve estimation efficiency. Roodman in 2009 cautions against the uncontrolled use of a large number of instruments in GMM applications, noting that such an excessive number of instruments can result in overfitting of the endogenous variables and in a reduction of the power of the Hansen test of instrument validity – a consideration that is especially relevant to practical panel studies of FDI. As for causality, Majeed et al. in 2021 applied panel cointegration and causality techniques to the relationship between FDI and financial development, demonstrating the benefits of combining cointegration diagnostics with directional causality tests, while Yang et al. in 2021 carried out a variety of ARDL-based causality tests in order to examine the sustainability of FDI inflows in the BIMSTEC region, emphasising how sensitive causal inference is to model specification. The collective body of methodological work thus supports the use of second-generation panel unit root tests, cross-sectional dependence diagnostics, and dynamic System GMM estimation as the appropriate empirical approach for datasets such as OECD panels that have a relatively long time span and are likely to show cross-country interdependence.

Research Gap

When the literature reviewed is considered as a whole, it shows three persistent patterns. The first of these is that the empirical evidence concerning the Pollution Haven and Pollution Halo hypotheses is still genuinely mixed, with results differing by region, sector, and time period, and comparatively very few studies specifically regarding the OECD group of countries with relatively high levels of regulation. The second point is that although renewable energy and trade openness have been looked at separately as determinants of FDI, environmental taxation has mainly been studied as a factor affecting emissions or the level of renewable energy rather than as a direct influence on FDI inflows, so that its function as a locational signal has not been thoroughly tested within a single empirical framework. The third concern is that much of the current literature still depends on static panel estimators, which are known to produce biased and inconsistent results when a persistent, dynamic dependent variable and endogenous regressors are present. These three gaps of thematic, contextual, and methodological are the reason why environmental taxation is incorporated together with carbon emissions, renewable energy production, and trade openness within a dynamic System GMM framework, and this is exactly what is done in the present study.

Research Methodology

In this section, a description of variables and applied empirical methods are mentioned below:

Variables Description and Data Sources

The study adopted a panel dataset consisting of 38 OECD member countries covering the period from 2000 to 2024. Through the combination of cross-sectional observations (countries) and time-series observations (years), the panel structure makes it easier to examine both cross-country and temporal fluctuations. The variables employed in the study are described in the table I.

Table I Description of Variables

ABBREVIATION	DESCRIPTION	SOURCE
FDI _Inflows	Net value of inward direct investments made by non-resident investors in a reporting economy during a specific year	WORLD BANK
Environ_tax	A compulsory payment to government levied on a tax base (physical unit) deemed to have a specific negative impact on the environment	OECD
Renew_Ener	Percentage of total final Renewable energy production derived from natural, replenished sources	WORLD BANK
CO2	Carbon di-oxide emission generated from burning of fossil fuel	WORLD BANK
Trade_Open	Sum of merchandise exports and imports divided by the country's GDP	WORLD BANK

Model Specification

FDI inflows is the dependent variable measured in current US\$ millions. CO2 Emission, Environmental tax, Trade Openness and Renewable energy production are independent variables. The econometric model for the study is stated as below:

$$FDI_{i,t} = \beta_0 + \beta_1 Environ_tax_{i,t} + \beta_2 Renew_Ener_{i,t} + \beta_3 CO2_{i,t} + \beta_4 Trade_Open_{i,t} + \epsilon_{it} \quad (1)$$

Where β represents parameters to be estimated, i implies host country, t represents years, ϵ_{it} is the error term.

Considering lagged effects of dependent variable, added lagged one variable FDI_{t-1} to the model (1) and the revised model is shown below:

$$FDI_{it} = \beta_0 + \beta_1 FDI_{it-1} + \beta_2 Environ_tax_{i,t} + \beta_3 Renew_Ener_{i,t} + \beta_4 CO2_{i,t} + \beta_5 Trade_Open_{i,t} + \epsilon_{it} \quad (2)$$

Although the lagged dependent variable in Model (2) reflects the persistence of FDI inflows, it also includes dynamic panel bias and endogeneity, making traditional estimators like fixed effects and pooled OLS unreliable. Hence, the study uses the Generalised Method of Moments (GMM) estimator in a dynamic panel data framework to investigate the dynamic link between foreign direct investment (FDI) inflows and environmental factors.

Econometric Steps and Procedures

This study uses a clear, step-by-step estimation approach that is often used in panel cointegration and causality analysis (De Hoyos & Sarafidis, 2006; Pesaran, 2007). Since the dataset covers a fairly large

group of OECD countries over several time periods, standard panel methods that assume countries are independent may not be valid. To address this, the analysis tests for and accounts for connections between countries at each stage, from the first diagnostic checks to the final dynamic panel estimation. The steps taken in this study are described below.

Cross-sectional dependence (CSD) test

The analysis begins with checking how data from OECD member countries are connected using a cross-sectional dependence (CSD) test. If cross-sectional dependence is ignored, test results can be biased, leading to incorrect conclusions and poor policy decisions. This is because standard panel estimators assume countries are independent, which is rarely true for economically linked countries. Cross-sectional dependence often comes from shared factors, common economic shocks, or trade and investment ties, which show up as correlations in the error terms across countries (De Hoyos & Sarafidis, 2006). This study adopted the CSD test by Pesaran (2004), which works well when there are more countries than time periods ($N > T$) and can be used whether the data are stationary, non-stationary, or cointegrated. To make the results more robust, the study also uses CD-type diagnostics from the `xtcsd` routine by De Hoyos and Sarafidis (2006). This routine includes the Pesaran (2004) CD statistic, Breusch-Pagan LM, Pesaran Scaled LM tests, allowing the study to confirm cross-sectional dependence using several methods instead of just one.

Panel Unit root test

The panel unit root test helps determine if each series is stationary, $I(0)$, or has a unit root, $I(1)$. Stationarity means that the mean, variance, and autocovariance of a series stay the same throughout the sample period, which is necessary for standard asymptotic inference (Jebb et al., 2015). The decision to use first-generation or second-generation unit root tests depends on the results of the CSD test. If the null hypothesis of cross-sectional independence is rejected, first-generation tests like Levin, Lin, and Chu (2002) or Im, Pesaran, and Shin (2003), which assume independence across panel members, may not be reliable. For this reason, this study uses the second-generation cross-sectionally augmented Im-Pesaran-Shin (CIPS) test from Pesaran (2007). This test adds cross-sectional averages of the lagged levels and first differences of each series to the standard Dickey-Fuller regression, which helps remove the common factor structure before checking for a unit root.

Panel Granger causality test

The most important objective of the study is to scrutinize the existence and direction of causal relationship among the variables. If presence of cointegrated is confirmed, causality among the variables must be found regardless of their direction (Granger, 1988).

It is possible to determine if past trends of one variable significantly improve the prediction of another variable makes this test especially appropriate for panel data. This allows for the analysis of the direction of influence across time and between countries. if an independent variable Granger creates a dependent variable when the current value of the former may be explained by its previous values (Granger, 1969). These prior values, which are used to improve the explanation of changes in the dependent variable, are the independent variable's lagged values (Granger, 1969).

Generalised Method of Moments (GMM)

A popular econometric method for estimating parameters in models with autocorrelation, heteroskedasticity, and endogeneity is the Generalised Method of Moments (GMM). In order to provide consistent parameter estimation even in the presence of endogenous regressors, the fundamental principle of GMM is to take advantage of orthogonality conditions between instrumental variables and the error term (Arellano & Bond, 1991; Hansen, 1982; Roodman, 2009). Two varieties of GMM exist. These are Difference GMM and System GMM. The Difference GMM estimator was

proposed by Manuel Arellano and Stephen Bond in 1991. This method uses lagged levels of endogenous variables as instruments and converts the model into first differences to remove unobserved individual-specific effects. In order to increase efficiency, especially when dealing with weak instruments, Richard Blundell and Stephen Bond (1998) developed the System GMM estimator, which integrates equation in levels and first differences. GMM has become a typical tool in empirical economic research, especially in studies involving dynamic interactions and panel data structures, in order to overcome endogeneity and produce strong results in our study under minimal assumptions. Nickell (1981) shows that the within (fixed-effects) estimator for a lagged dependent variable is biased downward, and this bias gets worse as the panel's time dimension becomes shorter. In contrast, pooled OLS is biased upward because it does not account for the correlation between the lagged dependent variable and the unobserved country effect. GMM solves this issue by using instruments for the lagged dependent variable instead of estimating it directly, which helps reduce the endogeneity bias that standard panel methods cannot fix (Bond, 2002).

Results and Discussion

Descriptive statistics and correlation analysis

Descriptive statistics for all variables of 38 OECD countries for the time period (2000-2024) in our sample are described in Table II. FDI inflows has a mean value of 23.08017 and median 23.25701 indicating a symmetrical distribution of data across OECD countries and standard deviation of 1.728508 implies a moderate variability across sample data. This table present the mean, median, standard deviation, minimum, maximum of the panel data. In comparison to foreign direct investment, CO2 has a mean of 8.31195, a median of 7.8232, and a standard deviation of 4.362, indicating substantial dispersion levels across the sample.

Table II Descriptive statistics analysis

Variable	Mean	Median	Std. Dev.
FDI inflows	23.08017	23.25701	1.728508
CO2	8.31195	7.8232	4.362
Trade Open	95.4791	77.9835	57.12248
Environmental Tax	2732.79	1303.04	4084.67
Renewable Energy	20.7	16.65	16.23

With a mean of 95.4791 and a median of 77.9835, trade openness exhibits a favourably skewed distribution. This suggest that countries with higher level of trade openness would drive upward. Additionally environmental tax has a mean of 2,732.79 and median of 1,303.04. The standard deviation of 4,084.67 indicates significant variation across units.

Although renewable energy production has maximum of 84.50 still shows discrepancy between data, it seems more consistent, with a mean of 20.70, a median of 16.65, and a standard deviation of 16.23.

Correlation Analysis

According to the correlation result in table III, there is a strong positive correlation (0.5218) between FDI and environmental tax, indicating that nations with more stringent environmental regulations typically draw larger FDI inflows. On the other hand, FDI shows a weak positive correlation with renewable energy (-0.2579) and a weak positive correlation with CO2 emissions (0.2577), suggesting that foreign investment has mixed environmental effects (De Santis & Stähler, 2009; Mustafa et al., 2025).

Table III Correlation Analysis Result

Variables	FDI	RENEW_ENER	ENVIR_TAX	CO2	TRADE_OPEN
FDI_INFLOW	1.0000	-0.2579	0.5218	0.2577	-0.0168
RENEW_ENER	0.2579	1.0000	-0.2725	-0.2742	-0.0632
ENVIR_TAX	0.5218	-0.2725	1.0000	0.2265	-0.3654
CO2	0.2577	-0.2742	0.2265	1.0000	0.1851
TRADE_OPEN	-0.0168	-0.0632	-0.3654	0.1851	1.0000

In line with predictions that cleaner energy lowers emissions, renewable energy exhibits a negative correlation with CO2 emissions (-0.2742). However, there is a positive correlation (0.2265) between environmental taxes and CO2 supported by results of Yang et al. (2022), suggesting that greater taxes may be more common in nations with existing high emission levels. Trade openness shows a weak positive correlation with CO2 emissions (0.1851) and a moderately negative correlation with environmental tax (-0.3654), indicating that more open economies may prioritise competitiveness over strict environmental taxation while only slightly increasing emissions which is contrary to the result of Song and Han (2022).

Cross-Sectional Dependence Result

Pesaran (2004) Cross Sectional Dependency test was used in the study to determine how interdependent the OECD member countries are. According to the Table IV, the results of the cross-sectional dependence (CSD) tests significantly reject the null hypothesis that there is no relationship across cross-sectional units. This can be shown by the high significance of the Breusch-Pagan LM test, the Pesaran scaled LM test, and the Pesaran CD test at the 1% level.

Table IV Cross Sectional Dependence Result

Test	Statistic	d.f.	Probability
Breusch-Pagan LM	1937.979	703	0.000
Pesaran Scaled LM	32.9357	—	0.000
Pesaran CD	12.8792	—	0.000

Since the three test statistics Pesaran scaled LM (32.9357, $p = 0.0000$), Breusch-Pagan LM (1937.979, $p = 0.0000$), and Pesaran CD (12.8792, $p = 0.0000$) are all extremely significant, the null hypothesis that there is no cross-sectional correlation is rejected. This indicates that there is a correlation between various parameters of OECD member countries which might be due to worldwide shocks, spillover effects, or mutually reinforcing unobserved factors. This result is supported by Majeed et.al (2021) and Yang et al. (2021).

Panel Unit Root Test

Instead of using the first-generation panel unit root test to evaluate cross-sectional correlation, the study applied the second-generation Pesaran CIPS panel root test after the CSD test confirmed the presence of cross-sectional dependence. From the table V, it indicates that all variables are stationary at $I(0)$.

Table V Panel Unit Root Test Result

Variable	t-statistic	P value
FDI inflows	-2.41297	<0.01
CO ₂	-2.75898	<0.01
Trade Openness (I=1)	-4.86198	<0.01
Environmental Tax	-4.00794	<0.01
Renewable Energy (I=1)	-2.68583	<0.05

FDI inflows ($t = -2.4129$, $p < 0.01$), CO₂ ($t = -2.7589$, $p < 0.01$), Trade Openness ($t = -4.8619$, $p < 0.01$), and environmental tax ($t = -4.0079$, $p < 0.01$) are all significant at the 1% level strongly rejecting the null hypothesis of non-stationarity. At the 5% level, renewable energy ($t = -2.6858$, $p < 0.05$) is significant and confirms stationarity, but with marginally less support than the other factors.

Pooled OLS, Random Effect and Hausman Test

In order to provide a preliminary knowledge of the relationship between FDI inflows and environmental variables across OECD nations, the Pooled OLS and Random Effects estimations are presented as benchmark models. Before using more sophisticated dynamic estimating methods, these traditional panel estimators make it easier to compare coefficient signs and statistical significance. Table 7 compares the results of an Ordinary Least Squares (OLS) model and a Random Effects Model (REM) for the dependent variable FDI_Inflows. In the OLS Model, ENVIOR_TAX (Environmental Tax), and RENEW_ENER (Renewable Energy) are highly statistically significant having p value less than 0.01 supporting H2a and H3. These results are similar to the results of Yeboah et al. (2025), Fang et al. (2022b), Sun et al. (2022) and Akpanke et al. (2022). Particularly, Renewable energy Environmental tax has a positive coefficient, providing robust support for the Pollution Halo and Porter hypothesis. FDI and CO₂ emissions have a negative and significant association (coefficient= $-1.36E+09$; $p < 0.01$), suggesting that environmentally cleaner OECD countries attract more FDI inflows supports Pollution halo Hypothesis. Additionally, trade openness has a positive and highly significant impact (coefficient = $1.97E+08$; $p < 0.01$), indicating that FDI inflows tend to be higher in more globally integrated nations.

Table 7. Results of Pooled OLS, Random Effect and Hausman Test

FDI_inflows	Coef.	P -value	Sig
OLS model			
C	-1.30E+10	0.0472	***
ENVIOR_TAX	9288769	0.0000	***
RENEW_ENER	3.35E+08	0.0074	***
CO2	-1.36E+09	0.0040	***
TRADE_OPEN	1.97E+08	0.0000	***
Random Effects Model			
C	9.02E+09	0.5835	
ENVIOR_TAX	7299631	0.0000	***
RENEW_ENER	6.90E+08	0.0275	***
CO2	-1.54E+09	0.1246	
TRADE_OPEN	3.53E+08	0.0000	***
Hausman test Chi-square test value	6.154372	0.1879	

A p-value of 0.1879 and a Chi-square test value of 6.154372 indicate that the Hausman test is not statistically significant ($p > 0.10$). The p-value failed to reject null hypothesis indicating that Random effect model is more appropriate and consistent model for panel data. The results of Random effect model states that Environmental tax, Renewable energy and Trade Openness are statistically significant ($p = 0.0000$) supporting Pollution halo hypothesis and Porter hypothesis. While CO2 emissions show a negative but statistically insignificant association, indicating no strong evidence of investment driven by pollution ($p > 0.1$) which is contrary to the results of Pan et al. (2019) and Samour et al. (2022).

Result of Granger Causality test

The Granger Causality test determines if a time series may be utilised for projecting another. According to Antonietti and Franco (2020), the fundamental assumption of this test is that if variable X granger affects variable Y, then X past values will significantly improve the capacity to forecast the future values of Y rather than forecasting from the Y past values independently. The most widely used model selection criteria, Akaike information (AIC) and Schwarz's Bayesian information (SBIC), can be used to determine the appropriate lag length because the Granger Causality test is sensitive to the lag to be used. These criteria will confirm that there is no serial correlation with normally distributed errors (Gujarati, 2004).

From the table VII, the ideal lag length in the VAR model is suggested differently by the lag order selection criterion. The Schwarz Criterion (SC) determines that lag 2 is the best option, even if the Akaike Information Criterion (AIC), Final Prediction Error (FPE), and Likelihood Ratio (LR) teststs recommend greater lag orders, especially lag 8.

Table VII Lag Section-Order Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-32141.82	NA	1.98E+40	106.9778	107.0144	106.992
1	-29095.52	6031.777	8.53E+35	96.92352	97.14308	97.00899
2	-28901.87	380.2022	4.87E+35	96.36231	96.76484*	96.51899
3	-28869.66	62.70643	4.75E+35	96.33831	96.92381	96.56622
4	-28817.36	100.9536	4.34E+35	96.24745	97.01592	96.54657
5	-28802.36	28.70414	4.49E+35	96.28072	97.23216	96.65107
6	-28698.65	196.7186	3.45E+35	96.01879*	97.15321	96.46037*
7	-28657.73	76.94223	3.28E+35	95.96581	97.28319	96.4786
8	-28623.45	63.87670*	3.18e+35*	95.93944*	97.43529	96.51895

In comparison to AIC, the SC imposes a more severe penalty for the inclusion of extra lags, making it widely considered a more economical and reliable criterion. Thus, choosing lag 2 makes sense because it strikes a balance between simplicity and model fit.

Table VIII Dumitrescu–Hurlin panel causality test

Null Hypothesis	W-Stat	Zbar-Stat	Prob.	Decision (5% level)
CO ₂ → FDI_INFLOWS	1.6699	-1.4025	0.1608	Fail to reject (No causality)
FDI_INFLOWS → CO ₂	2.6861	1.0507	0.2934	Fail to reject (No causality)
TRADE_OPEN → FDI_INFLOWS	3.8175	4.3711	0.000	Reject (Causality exists)
FDI_INFLOWS → TRADE_OPEN	2.9828	3.6456	0.000	Reject (Causality exists)
ENVIR_TAX → FDI_INFLOWS	2.6001	3.846	0.000	Reject (Causality exists)
FDI_INFLOWS → ENVIR_TAX	2.3593	2.2641	0.0325	Reject (Causality exists)
RENEW_ENER → FDI_INFLOWS	4.4427	5.2979	0.000	Reject (Causality exists)
FDI_INFLOWS → RENEW_ENER	3.0896	2.0287	0.0425	Reject (Causality exists)
TRADE_OPEN → CO ₂	2.9047	1.5784	0.1145	Fail to reject
CO ₂ → TRADE_OPEN	3.1502	2.1711	0.0299	Reject (Causality exists)
ENVIR_TAX → CO ₂	3.2641	2.4462	0.0144	Reject (Causality exists)
CO ₂ → ENVIR_TAX	3.7654	3.6562	0.0003	Reject (Causality exists)
RENEW_ENER → CO ₂	5.0549	6.7693	0.000	Reject (Causality exists)
CO ₂ → RENEW_ENER	2.2851	0.0826	0.9342	Fail to reject
ENVIR_TAX → TRADE_OPEN	4.3374	5.0436	0.000	Reject (Causality exists)
TRADE_OPEN → ENVIR_TAX	4.5594	5.7799	0.000	Reject (Causality exists)

RENEW_ENER → TRADE_OPEN	3.9321	4.0648	0.000	Reject (Causality exists)
TRADE_OPEN → RENEW_ENER	4.1083	4.4902	0.000	Reject (Causality exists)
RENEW_ENER → ENVIR_TAX	3.2585	2.4367	0.0148	Reject (Causality exists)
ENVIR_TAX → RENEW_ENER	4.9469	6.5156	0.000	Reject (Causality exists)

The Dumitrescu–Hurlin panel causality results presented in table VIII show weak short-run causal relationships between FDI inflows and important environmental variables. Since there is no causal relationship between FDI and CO₂ emissions, rejecting the Pollution Haven hypothesis indicates that investors are not considering the environmental degradation aspects while deciding location to invest, which is contrary to the results of Xie and Jamaani (2022) and Tao et al. (2023). However, there is a short-run bidirectional relationship between FDI inflows and trade openness as well as between FDI inflows and renewable energy, which is similar to the result of Tao et al. (2023), suggesting a dynamic feedback loop in which the development of renewable energy both influences and is influenced by foreign investment. There are significant short-run causal connections between economic and environmental factors. This result is strongly supported by the results of Wall et al. (2018). Furthermore, because it reduces CO₂ emissions and no reverse causality is seen, renewable energy plays a critical role in environmental dynamics, demonstrating its effectiveness as a tool for policy.

Additionally, trade openness is Granger-caused by CO₂ emissions, suggesting that trade patterns may be impacted by environmental degradation, which is similar to the result of Wang et al. (2023). There is a short-run bi-directional causal relationship between renewable energy consumption and FDI, supporting (Xie and Jamaani, 2022; Doğan et al., 2022). Environmental tax has a significant causal relationship with FDI inflows, supporting the Porter Hypothesis. Nevertheless, environmental tax significantly influences renewable energy and CO₂ emission. Overall, the results indicate that renewable energy and environmental rules serve as important transmission channels influencing both economic and environmental systems, even while FDI does not directly influence environmental outcomes.

Dynamic System GMM Approach

The study incorporates a lagged dependent variable and probable endogeneity among the explanatory variables; thus, conventional estimators like Pooled OLS and Random Effects may yield biased and inconsistent estimates due to dynamic panel bias and omitted variable issues. Therefore, dynamic panel System GMM estimation is used as a primary estimation technique to effectively address endogeneity, unobserved heterogeneity, and serial correlation while offering solid evidence on the factors influencing FDI inflows across OECD nations. The Hansen J-test, which confirms that the chosen instruments are suitable and uncorrelated with the error term, provides significant support for the model's validity.

The System GMM results show that FDI inflows in the sampled OECD economies are dynamic and are strongly affected by renewable energy development, environmental taxes, trade openness, and carbon emissions. Diagnostic tests confirm the model is valid. The Arellano–Bond AR(1) test is significant ($m = -1.9954$, $p = 0.0460$), as expected for first-differenced dynamic panel models. The AR(2) test is not significant ($m = 0.4965$, $p = 0.6195$), which means there is no problematic second-order serial correlation, an important requirement for estimator consistency (Arellano & Bond, 1991). The Hansen/Sargan J-statistic (33.839, $p = 0.4268$) does not reject the null hypothesis of valid overidentifying restrictions, supporting the validity of the instrument set (Hansen, 1982; Roodman, 2009). The positive and significant coefficient for lagged FDI inflows ($\beta = 0.138$, $p < 0.001$) shows moderate persistence in foreign investment. About 13.8% of investment conditions from the previous period carry over to the current period. This suggests that FDI decisions are shaped by existing investor

relationships, sunk costs, and agglomeration effects. It also supports using System GMM instead of static estimators, which can be biased when a lagged dependent variable is included (Nickell, 1981; Blundell & Bond, 1998).

Table IX Arellano–Bond Serial Correlation Test

Test Order	m-Statistic	p-value	Interpretation
AR(1)	-1.9954	0.0460	Significant (expected)
AR(2)	0.4965	0.6195	Not significant (no serial correlation)

Renewable energy production is strongly linked to higher FDI inflows, which means that countries with more developed renewable energy sectors tend to attract more foreign investment. This finding matches the results of Kang et al. (2021), who found a similar positive link between FDI and renewable energy use in South Asia. Their work suggests that foreign investment and green energy development can reinforce each other. This idea also fits with the Pollution Halo perspective, where foreign investment brings cleaner technologies and supports sustainable growth. Still, this relationship is not always found. Wall et al. (2018) showed that the success of renewable energy policies in attracting FDI depends a lot on how the policies are designed and the strength of local institutions. Environmental taxes also show a strong positive link with FDI inflows. This supports the Porter Hypothesis, which says that well-designed environmental rules can drive innovation and make firms more competitive, not just raise costs (Porter & van der Linde, 1995). Yeboah et al. (2025) also found that environmental taxes can boost the benefits of green financing and FDI. On the other hand, List and Co (2000) and Millimet and Roy found that stricter environmental rules can sometimes push foreign investors away, which supports the Pollution Haven argument. The positive results in this study may be because environmental taxes in high-income OECD countries signal strong institutions, credible policies, and stable regulations, rather than just being extra costs for investors. This view is also in line with Cole et al. (2006), who highlight the two-way relationship between FDI and environmental regulation.

Table X Panel Dynamic GMM Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	p-value
FDI_INFLOWS(-1)	0.138065	0.000253	545.0823	0.0000***
RENEW_ENER	2.26E+09	34,371,027	65.8059	0.0000***
ENVIR_TAX	911,643.9	26,338.78	346.1223	0.0000***
TRADE_OPEN	6.05E+08	4,508,453	134.2672	0.0000***
CO2	-3.58E+09	49,415,934	-72.3811	0.0000***
J-statistic	33.83944			0.426822

Trade openness is also positive and statistically significant, showing that stronger connections with international markets encourage more FDI inflows. This result is similar the result of Asiedu (2002), who found that being open to trade helps attract FDI by improving access to markets, global supply chains, imported inputs, and export opportunities. Compared to the environmental variables, this positive link is less debated and adds confidence to the model's economic meaning. On the other hand, CO₂ emissions have a negative and highly significant effect on FDI inflows, which means that economies with higher carbon emissions are less appealing to foreign investors. This supports the Pollution Halo Hypothesis and aligns with Tsoy and Heshmati (2024), who show that FDI can help improve environmental sustainability when institutions are strong. However, this finding is very different from Pao and Tsai (2011), who found a positive link between FDI, energy use, and CO₂ emissions in BRIC countries. The difference may be due to different levels of economic development and regulations: in fast-growing economies, FDI might raise emissions through more manufacturing, while in developed and well-regulated OECD countries, lower carbon intensity can signal better environmental quality and lower long-term investment risk. Overall, the combination of positive effects from renewable energy and environmental taxes, along with a negative effect from CO₂, shows

a clear pattern that supports a Porter-Hypothesis and Pollution Halo view of FDI behaviour in this sample. These results suggest that foreign investors in these economies are more likely to support green energy, strong environmental policies, and open economies, rather than pollution-heavy production.

Limitations

The study focused on 38 OECD nations which are mainly developed countries with strong environmental regulations. Therefore, future studies can focus on under-developed and developing economies to identify the relationship between FII and environmental sustainability in different aspect. The study has employed only limited environmental indicators. So, further studies can utilise environmental indicators like ecological footprints, green innovation, biodiversity loss and so on. The study uses total FDI inflows without focusing on different sectors because different sectors may exhibit different environmental impacts relating to Pollution halo and Pollution Haven hypothesis. Thus, future studies can focus on sector -specific foreign investment and its impact on environmental sustainability. The study's one of the variable Environmental taxes may inadequately encompass the multifaceted character of environmental policy frameworks, which may also incorporate pollution standards, renewable energy mandates, technology controls, and institutional enforcement methods. Therefore, further studies may expand the analytical approach by incorporating OECD Environmental Policy Stringent Index. The study focuses on linear relationship between FDI and Environmental variables. Therefore, further studies can apply non-linear models like panel threshold regression and panel smooth transition regression.

Policy Implication and Conclusion

The results have a number of significant implications for policymakers in the OECD countries. The fact that there is a positive and statistically significant link between environmental taxation and flows of foreign direct investment indicates that environmental regulation does not have to be seen merely as a cost. On the contrary, well-designed and predictable environmental policies can enhance a country's inducement to investors by showing that there is regulatory stability and a commitment to long-term policy, in agreement with the Porter Hypothesis (Porter & van der Linde, 1995). Thus, policymakers should adopt environmental tax systems that are transparent, predictable, and introduced gradually, and at the same time should assign a portion of the tax revenues to green infrastructure and the development of clean technologies.

The fact that there is a positive relationship between the production of renewable energy and foreign direct investment, coupled with evidence of bidirectional Granger causality, once again shows how important it is to incorporate renewable-energy development into investment strategies. Measures such as competitive auctions for renewable energy, suitable feed-in tariffs, and simplified procedures for approving projects can improve the investment climate and may result in mutually strengthening flows between the development of renewable energy and foreign investment (Wall et al., 2018).

The fact that there is a negative relationship between CO₂ emissions and foreign direct investment indicates that economies which have a higher emission intensity may be less attractive to foreign investors. This result offers support for the environmental aspect of the Pollution Halo perspective, even though it cannot be regarded as definitive proof against the Pollution Haven Hypothesis. As a result, policymakers might enhance their incentives for decarbonisation and include environmental performance criteria in their investment promotion programmes.

Trade openness also turns out to be an important factor in determining foreign direct investment. However, the way it is linked to environmental outcomes shows that greater international integration should be associated with suitable environmental safeguards. For example, measures such as

encouraging trade in environmental goods, reinforcing environmental standards, and incorporating environmental due diligence into international supply chains can help bring trade integration into line with environmental goals.

Overall, the results indicate that environmental sustainability and the attraction of foreign direct investment should not be tackled by means of separate policy measures. It would be more effective to adopt an integrated policy framework which combines predictable environmental taxation, investment in renewable energy, decarbonisation measures, and strategies designed to promote investment, in order to achieve at the same time better environmental performance and the continued attractiveness of OECD economies to foreign investors.

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