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Can Environmental Policy Stringency Enhance Load Capacity Factor? Evidence from Common Correlated Effects Mean Group Estimation

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Abstract

Environmental policy has become an essential instrument for promoting ecological sustainability; however, empirical evidence on its effectiveness remains inconclusive, particularly for OECD countries. This study investigates the impact of Environmental Policy Stringency (EPS), economic growth, foreign direct investment (FDI), and industrialization on the Load Capacity Factor (LCF), an overall measure of ecological sustainability, in nine OECD countries between 1990 and 2020. The empirical analysis is based on a second-generation panel econometric approach. The Pesaran Cross-Sectional Augmented IPS (CIPS) unit root test and the Westerlund cointegration test are used to confirm the existence of a long-run relationship between the variables when slope heteroscedasticity and cross-sectional dependence are detected. The primary estimation technique is the Common Correlated Effects Mean Group (CCEMG) estimator, and the Mean Group (MG) estimator is used as a robustness check.

Furthermore, the results indicated that the greater the stringency of environmental policies, the better the ecological sustainability, as evidenced by improvements in the Load Capacity Factor, thereby supporting the Porter Hypothesis. There is also a positive influence of FDI; this means that technology transfer and environmentally friendly production methods outweigh pollution-intensive investment. Economic growth and industrialization, on the other hand, have a negative impact on the LCF, indicating that production and consumption patterns remain resource-intensive despite environmental regulations. These results are robust and stable, as confirmed by the robustness analysis. The study makes a significant contribution to the environmental sustainability literature by applying an integrated sustainability indicator (Load Capacity Factor), and by providing recent empirical evidence from OECD countries, based on a second-generation panel estimation technique. The results guide developing and implementation of policies that promote both economic development and long-term ecological sustainability.

Keywords: Environmental Policy Stringency; Ecological Sustainability; LCF; OECD; Common Correlated Effects Mean Group.

1. Introduction

The 21st century has found one of its greatest challenges to be balancing the economy with ecology. Climate change, biodiversity loss, environmental degradation, and the reduction of natural resources have amplified because of rapid industrialization, globalization, technological advancements, and economic growth that have improved people's living conditions (Fatima et al., 2023; Ullah et al., 2023; Safdar et al., 2026). These challenges are threatening the resiliency of the ecosystem and sustainability of economic development, and governments and international organizations, including the SDGs and Paris Climate Agreement, have responded by establishing environmental governance frameworks (Muhammad et al., 2025; United Nations, 2015; IPCC, 2023). The question has therefore shifted to identifying policies that help economic development while also defensive the environment (Rockström et al., 2009; OECD, 2016).

The OECD countries are leaders in environmental governance, as they have high levels of industrialization, economic output, technological innovation, and energy use (Zafar et al., 2025). These economies have been introducing tougher environmental legislation and investing substantial sums in green technology. However, they are still placing a strain on the natural environment through their output and consumption. The OECD framework is primarily relevant for evaluating the potential of stricter environmental policies to boost ecological sustainability, as it leads the way in implementing environmental policies and achieving carbon neutrality without negatively affecting economic growth (Zafar et al., 2026; OECD, 2016; Duran & Saqib, 2024).

To assess ecological sustainability, a suitable measurement framework is necessary. The traditional criteria for environmental sustainability include ecological footprint and carbon dioxide (CO_2) emissions. All these measures reflect environmental degradation but do not account for the Earth's capacity to restore natural resources (Amer et al., 2024; Raihan et al., 2026). To overcome this, a new indicator, the LCF, has emerged, which accounts for both ecological demand and supply by dividing bio-capacity by ecological footprint. The high (>1) LCF value means ecological sustainability, whilst a value less than one means ecological deficit. As a result, LCF has become a more holistic indicator of ecological sustainability than traditional environmental indicators (TEIs) (Siche et al., 2010; Pata & Isik, 2021; Duran & Saqib, 2024).

Figure 1 illustrates the development of the LCF in the nine OECD countries from 1990 to 2020, providing a preliminary picture of how ecological sustainability has developed in the countries analysed. The figure shows significant variation over time and across countries. Canada and Sweden have consistently relatively high LCF values, reflecting high ecological capacity. The specific countries[1] have relatively low LCF values throughout the study period. The differences indicate that progress towards ecological sustainability has been uneven across OECD economies and underscore the importance of understanding what contributes to these differences.

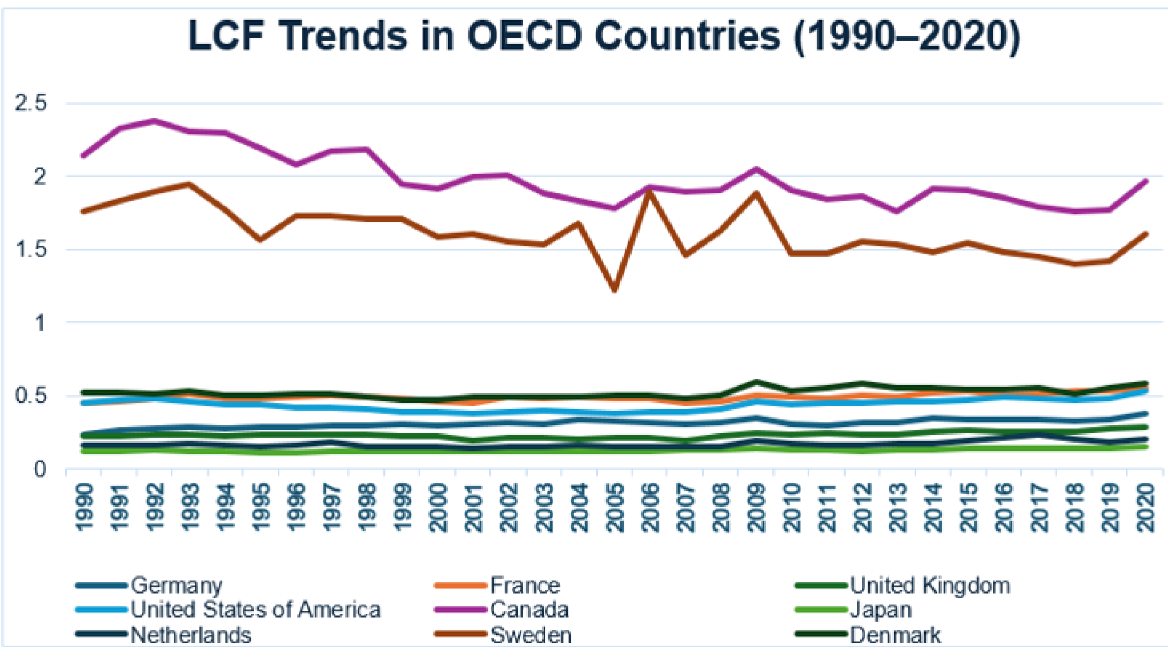


Figure 1: Trends in the LCF across selected OECD countries

The EPS is one of main policy levers that can affect ecological sustainability. The term EPS refers to the size of the costs governments impose on environmentally damaging activities through regulation, environmental taxes, carbon pricing, and/or emission standards (Dmytrenko et al., 2026; OECD, 2016). The Porter Hypothesis describes the potential for environmental

[1] "Germany, France, the United Kingdom, the United States, Canada, Japan, the Netherlands, Sweden and Denmark"

policies to rouse innovation, efficient resources, and cleaner production and to improve environmental performance. Their effectiveness, however, varies across countries, and their empirical impact is mixed, influenced by institutional quality, technological capability, and production conditions (Javed et al., 2025; Nathaniel et al., 2025; Duran & Saqib, 2024).

The importance of environmental policy, but other macroeconomic factors also affect ecological sustainability. The direct impact of GDP, FDI, and industrialization on environmental outcomes has been extensively documented. Economic growth can be either positively or negatively related to environmental quality. Technological improvements and greater investment in cleaner production processes, on the one hand, do improve environmental quality. The scale effect can lead to environmental deterioration because of high resource, energy, and pollution levels (Duran & Saqib, 2024). Likewise, the ecological effect of FDI is debatable. The Pollution Haven Hypothesis (PHH) suggested the choice of country where multinationals locate their activities depends on how lax the country's environmental laws and institutions are, while the Pollution Halo Hypothesis holds that FDI can help to diffuse help tools and better environmental management practices (Cole et al., 2017; Nathaniel et al., 2025). The division of industrialization is the same. Besides boosting productivity and economic transformation, it can also drive up fossil fuel use, natural resource depletion, and environmental stress without technological progress and good environmental management (Javed et al., 2025; Duran & Saqib, 2024). The differences among the views indicate that the relationships between the level of environmental policy and ecological sustainability, economic growth, FDI, and industrialization are not clear.

Although substantial advances have been made, there are still some gaps in the literature on this topic. First, the data on CO_2 emissions used in most studies are not ecological sustainability data per se; only a few are based on the more comprehensive LCF. Second, the stringency of environmental policy has been investigated across the G7, G20, BRICS, and international samples, but there is less evidence for the OECD. Third, the literature has primarily focused on environmental policy in conjunction with renewable energy, green innovation, financial development, and natural resources, with less attention paid to the synergies between environmental policy and economic growth, FDI, and industrialization. Finally, some previous studies still use predictable panel estimators that fail to reason for CD, and slope heterogeneity, possibly important to partial and unreliable estimates. Given these research gaps, the current study investigates the links between the stringency of environmental policy, economic growth, FDI, and industrialization and the LCF for 9 OECD countries during the period 1990–2020. The CCEMG estimator is the most dominant because it can handle cross-sectional dependence, unobserved common factors, and heteroscedasticity in the slope coefficients. A robustness check is done by applying the MG estimator to check the reliability and stability of the empirical results.

The study therefore makes some significant contributions to the environmental sustainability literature. First, it continues this line of research by proposing the use of the LCF as a single indicator that addresses both ecological demand and ecological supply. Second, it presents additional empirical evidence to the literature on the interaction between environmental

EPS, GDP, FDI, and industrialization in OECD countries, where the evidence remains rather scarce. Third, the use of second-generation panel estimators yields more reliable estimates that account for CD and slope heterogeneity, increasing the power of the empirical inferences. The rest of the paper is prepared as follows. A literature review is involved in Section 2, as are hypotheses for research. The description of the data, the specification of the model, and the econometric method are provided in Section 3. The empirical consequences are summarized in Section 4, which includes a robustness analysis. Finally, in Section 5, the study's findings are summarized, and policy approvals are provided.

2. Literature Review

2.1 Environmental Policy Stringency (EPS) and LCF

EPS has become an important policy tool to achieve ecological sustainability. The Porter Hypothesis suggests that it is possible to develop environmental policies which promote innovation, improve resource efficiency, encourage the use of clean production techniques and reduce environmental pressures without compromising economic competitiveness (Porter & van der Linde, 1995). Environmental policies in OECD countries have shifted from command-and-control to market-based approaches, with growing attention to sustainable development principles and an increase in the number of countries implementing policies on environmental taxes, emissions trading schemes, and carbon pricing (OECD, 2016). This is supported by recent empirical studies showing that environmental policy has a direct effect on environmental sustainability. Duran and Saqib (2024) found that a more stringent environmental policy in the G20 countries increases LCF by fostering green innovation and cleaner production. Similarly, Javed et al. (2025) found that environmental policy positively affects ecological sustainability in the G7 countries; while Nathaniel et al. (2025) found that environmental policies direct impact the environmental performance of BRICS economies. However, other studies have found that policies do not work the same in all countries, as institutional quality, technological capacity, and the enforcement of regulations vary from country to country. The other mixed evidence shows that more empirical studies are needed on the link between EPS and ecological sustainability, mainly in OECD countries.

2.2 Economic Growth and LCF

There has been a longstanding debate in environmental economics between the concepts of economic growth and ecological sustainability. The EKC theory holds that environmental degradation worsens as income rises. However, once a threshold is crossed, technological advancements, structural changes, and improved environmental institutions relieve environmental effects as income continues to grow (Ching et al., 2023; Kumar & Datta, 2024). The Load Capacity Curve (LCC) suggests that GDP could finally exceed the ecosystem's capacity if regeneration does not keep pace with use. The scale effect is the pressure on the environment; the composition effect is the shift in production towards less polluting sectors; and the technique effect is the reduction in environmental pressures because of technological progress. There is limited empirical evidence. Because of this, it has been observed that with the rise in income, environmental sustainability is achieved through the adoption of clean technologies and awareness of environmental issues; It is noticed that growth of economic activity leads to more consumption of resources and ecological deficits, especially in very industrialized economies (Tangto, 2025; Pata & Isik, 2021; Duran & Saqib, 2024). The growth–environment relationship remains unclear due to these contrasting results.

2.3 Foreign Direct Investment and Load Capacity Factor

There is debate over technology transfer, capital accumulation, and industrial development, as well as their environmental impact. The PHH predicts that pollution activity would shift to countries with relatively weak environmental regulations, leading to a rise in pollution. The Pollution Halo Hypothesis also suggests that FDI may contribute to environmental benefits by transferring cleaner technologies, introducing new production processes (Cole et al., 2017), and implementing the most modern and effective environmental management practices. There is some empirical support for both views. Some research indicates that FDI led to environmental degradation due to amplified industrial activity and energy use, while other research suggested that FDI improved environmental sustainability by promoting technological innovation and environmental efficiency (Nathaniel et al., 2025; Duran & Saqib, 2024). Given the strong environmental regulations implemented in OECD countries, the environmental consequences of FDI warrant further empirical investigation.

2.4 Industrialization and Load Capacity Factor

Although industrialization is well known to be a significant contributor to economic development, it also imposes significant stress on natural ecosystems. The more industries that are produced, the more energy they require, the more fossil fuels that need to be used, and the more natural resources that need to be extracted; the more environmental degradation result. In many countries, however, the environmental effects of industrial growth can be lessened through improvements in green manufacturing, clean technologies, and resource efficiency. Previous studies have found direct and negative effects of industrialization on environmental sustainability (Wang & Azam, 2024; Kartal, 2022). With the digitalization of the world, green industrial transformation has emerged as a pressing issue in industrial growth. It is considered a strategic approach that can not only boost the industry's environmental performance but also provide insights into cleaner production practices and technological advancements (Javed et al., 2025; Duran & Saqib, 2024). Therefore, the impact of industrialization on ecological sustainability depends heavily on the pace of technological development and the level of environmental regulation.

2.5 Hypothesis Development

The existing literature suggests that environmental policy stringency, economic growth, FDI and industrialization are key determinants of ecological sustainability. However, the theoretical and empirical evidence remains mixed, particularly regarding their effects on the load capacity factor.

Building on the Porter Hypothesis, the EKC, the PHH and Pollution Halo hypotheses, and previous empirical findings, this study develops the following load capacity factor:
H1: Environmental policy stringency positively affects the LCF.
H2: Economic Growth significantly affects the LCF.
H3: Foreign Direct Investment significantly affects the LCF.
H4: Industrialization significantly affects the LCF

3. Data and Methodology

3.1 Data Description

This study examines the factors of ecological sustainability of nine countries over the period 1990–2020. Ecological sustainability is measured using LCF, which captures the balance between ecological footprint and biocapacity. The EPS is employed as the primary explanatory variable, while GDP, FDI, and IND are incorporated as control variables. Data were obtained from internationally recognized databases and transformed into a balanced panel suitable for econometric analysis.

Table 1: Variable Description

Variable	Symbol	Measurement	Source
Load Capacity Factor	LCF	Bio-capacity/ecological footprint	GFN
Environmental Policy Stringency	EPS	Composite index measuring the stringency of environmental policies	OECD
Economic Growth	lnGDP	Natural logarithm of Gross Domestic Product (constant US$)	WDI
Foreign Direct Investment	FDI	Net FDI inflows as a percentage of GDP	WDI
Industrialization	IND	Industry value added as a percentage of GDP	WDI

3.2. Model Specification

3.2.1. Functional Model

$$LCF = f\,(EPS,\ lnGDP,\ FDI,\ IND)$$

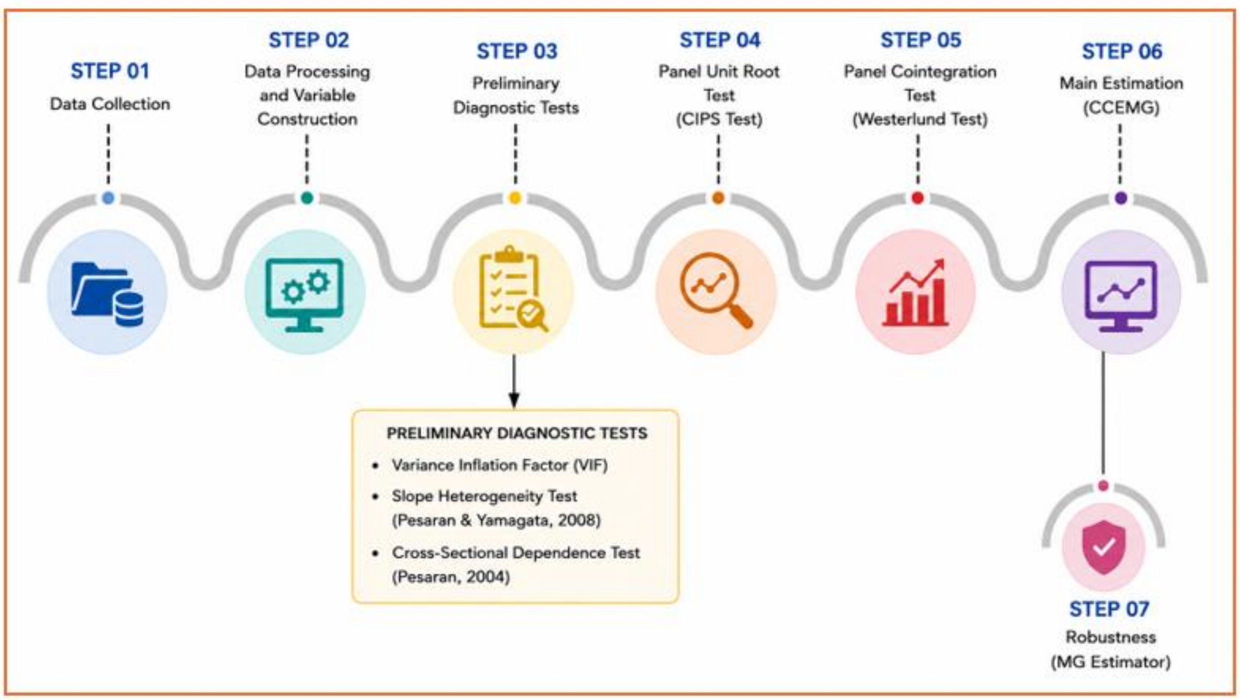
3.2.2. Econometric Model

$$LCF_{it} = \beta_0 + \beta_1 EPS_{it} + \beta_2 lnGDP_{it} + \beta_3 FDI_{it} + \beta_4 IND_{it} + \varepsilon_{it}$$

Where, $LCF, EPS, lnGDP, FDI\ and\ IND\ are\ represent\ variables.$ i denote country, t denotes time period, β_0 is the intercept, $\beta_1 to\ \beta_4$ are slope coefficients, and ε_{it} is the error term.

3.3. Estimation Strategy

In this study, different econometric analyses are used, such as: First, multicollinearity among the explanatory variables is assessed using a VIF test. Second, the Pesaran and Yamagata (2008) slope heterogeneity test is used to assess whether the slope coefficients across economies differ. Third, the Pesaran (2004) CSD-test is applied to investigate whether any shocks are common to all panel units or whether there are interdependencies between the different panel units. Fourth, the Pesaran (2007) CIPS unit root test is conducted to identify the variables' integration order, accounting for CSD. Fifth, the Westerlund (2007) error-correction based cointegration test is used to investigate the long-run equilibrium relationship among the variables. The last one is the use of the CCEMG estimator as the primary estimator for long-run coefficients. The MG method, on the other hand, is used as a robustness check on the empirical results to assess their consistency and reliability. Figure 2 shows the overall empirical procedure used in this study. The descriptive statistics describe the basic information about the dataset (Gul et al., 2023; Gul et al., 2023).



Source: *Author's illustration*
Figure 2*: Flow of Empirical Analysis*

3.4. Slope heterogeneity Test

The test is used regulate whether slope coefficients are equal among cross-sectional units (countries) or whether they differ significantly. The heterogeneity leads to biased and inconsistent estimators. Therefore, this test helps to justify the use of heterogeneous estimators such as CCEMG and MG (Pesaran, 2021; Bersvendsen & Ditzen, 2021). Thus, the following Pesaran and Yamagata (2008) test used:

$$\Delta = \sqrt{\mathrm{N}}\left(\frac{N^{-1} \quad \hat{S} - K}{\sqrt{2k}}\right)$$

$$\Delta_{adj} = \sqrt{\mathrm{N}}\left(\frac{N^{-1} \quad \hat{S} - E(\bar{\bar{Z}}_{it})}{\sqrt{var(\bar{Z}_{it})}}\right)$$

Where;

N denotes the number of CS-unit. Therefore, k is number of independent and $\hat{S}$ shows Swamy's test statistics.

$$H_0: homogeneous' slope$$
$$H_1: heterogeneous' slope$$

The test examines whether slope coefficients are equal across countries. Rejection of the H_0 shows heterogeneity among panel units and supports the use of heterogeneous panel estimators such as CCEMG.

3.5. Cross-Sectional Dependence (CSD) Test

The CSD test is employed to examine whether OECD countries are influenced by common shocks arising from technological diffusion, international trade, and global energy market fluctuations.

$$CS = \sqrt{\frac{2T}{N(N-1)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}}$$

Where; in N indicates a CS unit as well as T represents the time. Similarly, $\hat{\rho}_{ij}$indicates pairwise correlation coefficient of residuals.

$$H_0: NO\ CSD, \qquad and\ H_1: CSD\ Exists$$

Therefore, the Ho assumes cross-sectional independence. A significant CS tests show the presence of common shocks and spillover effect among countries. So, second-generation panel techniques become necessary.

3.6. Panel Unit Root Test (CIPS)

Given the presence of CD, first-generation panel unit root tests may produce biased results. Therefore, the Cross-Sectionally Augmented IPS (CIPS) test proposed by Pesaran (2007) is employed to determine the order of integration while accounting for CD.

CADF Regression

$$\Delta \mathrm{y}_{\mathrm{it}} = \mathrm{a}_{\mathrm{i}} + \mathrm{b}_i \mathrm{y}_{,\mathrm{it}-1} + \mathrm{c}_i \bar{y}_{t-1} + \mathrm{d}_i \Delta \bar{y}_t + \sum_{j=1}^{p} \gamma_i j \Delta \mathrm{y}_{\mathrm{i,t}-1} + \varepsilon_{\mathrm{it}}$$

CIPS statistic:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i$$

Thus, hypotheses:

$$H_0 = b_i = 0\ and\ H_i = b_i < 0$$

The H_0 situations that all panel-series contain a unit root. Rejection of the H_0 point to that at least one panel is stationary. The CIPS test accounts for CSD by augmenting the standard ADF regression with cross-sectional averages.

3.7. Westerlund Cointegration Test

After establishing stationary properties, the Westerlund (2007) error-correction-based panel cointegration test is used to examine the existence of a long-run relationship among the variables. Thus, the ECM model:

$$\Delta y_{it} = a_i + \delta_{it} + \emptyset_i (y_{it-1} - \partial_i x_{it-1}) + \sum \gamma_{ij}\, \Delta y_{it-j} + \sum \emptyset_{ij}\, \Delta x_{it-j} + \epsilon_{it}$$

The γ_{ij} represents the error-correction coefficient

$$H_0 = \gamma_i = 0 \; and \; H_i = \gamma_i < 0$$

Thus, Ho shows no cointegration. The rejection uses the existence of a stable long-run equilibrium relationship among ecological sustainability, EPS, economic growth, FDI, and industrialization.

3.8. Common correlated effects Mean Group (CCEMG)

The dataset shows the CSD and slope of heterogeneity, the CCEMG estimator proposed by Pesaran (2006) is selected as the primary estimation technique.

Thus CCEMG equation:

$$\mathrm{LCF}_{it} = a_i + \beta_i' \mathrm{X}_{\mathrm{it}} + \gamma_i' \bar{Z}_t +_{ui}$$

Thus,

$$\bar{Z}_t = (\overline{LCF_t}, \overline{EPS}_t, \overline{lnGDP}_t, \overline{FDI}_t, \overline{IND}_t)$$

Thus, CCEMG controls for unobserved common factors by augmenting the regression with cross-sectional averages while allowing slope coefficients to change across countries. Therefore, it generates consistent estimates in the presence of CSD and heterogeneity.

3.9. Mean Group (MG) Estimator: Robustness Check

To verify the stability of the Main findings, the Mean Group estimator developed by Pesaran and Smith (1995) is used as a robustness check.

$$\mathrm{LCF}_{it} = a_i + \beta_i' \mathrm{X}_{\mathrm{it}} +_{ui}$$

The MG estimator is obtained as:

$$\hat{\beta}_{MG} = \frac{1}{N} \sum_{i=1}^{N} \hat{\beta}_i$$

The MG estimator estimates separate regression for each country and calculates the arithmetic mean of country-specific coefficient. Consistency of signs and significance across CCEMG and MG estimator confirms the robustness of the empirical outcomes.

4. Results and Discussion

In Table 2 describes descriptive statistics. The average LCF is 0.654, showing that the countries in the sample, on average, have an ecological deficit (a value below 1). The mean EPS value is 2.421, meaning that environmental regulatory efforts are moderate across the sample countries. The average value of lnGDP is 10.598, with a low standard deviation of 0.189, suggesting that economic development is relatively similar. FDI shows substantial variation, ranging from -30.658 to 85.979, and a large standard deviation of 8.993, showing significant differences in FDI inflows across countries over time. The average for Industrialization (IND) is 23.591, with a moderate range of variation among the samples. The correlation matrix of the study variables is given in Table 3. The results show that LCF is negatively related to EPS (-0.092) and FDI (-0.067); but there is a weak positive correlation between LCF and lnGDP (0.081) and IND (0.176). Economic growth (0.400) is positively associated with the use of environmental policies, suggesting that the more developed a country is, the stricter its policies will be. EPS is negatively correlated with industrialization (-0.317), suggesting that the more industrialized an economy is, the more difficult it is to implement strict environmental regulations. Besides, industrialization shows a relatively strong negative correlation with economic growth (-0.580), suggesting structural differences between the countries sampled. Most importantly, the correlation coefficients are not high enough to suggest serious multicollinearity among the explanatory variables, with all below 0.80. As shown in the reported VIF values in Table 3, this finding is further confirmed. These results are further supported by Figure 3, a scatterplot matrix of the pairwise relationships among variables. The graphical patterns suggest low-to-moderate relationships among the explanatory pairwise and no indication of excessive linear dependence, further confirming that there is no concern about multicollinearity in the dataset.

Table 2: Descriptive Statistics

Variables	Obs	Mean	SD	Min	Max
LCF	279	0.654	0.639	0.113	2.375
EPS	279	2.421	1.056	0.083	4.889
lnGDP	279	10.598	.189	10.24	11.015
FDI	279	3.78	8.993	-30.658	85.979
IND	279	23.591	4.257	16.273	34.554

Table 3: Matrix of Correlation

Variable	(1)	(2)	(3)	(4)	(5)
(1) LCF	1.000				
(2) EPS	-0.092	1.000			
(3) lnGDP	0.081	0.400	1.000		
(4) FDI	-0.067	0.012	0.120	1.000	
(5) IND	0.176	-0.317	-0.580	-0.168	1.000

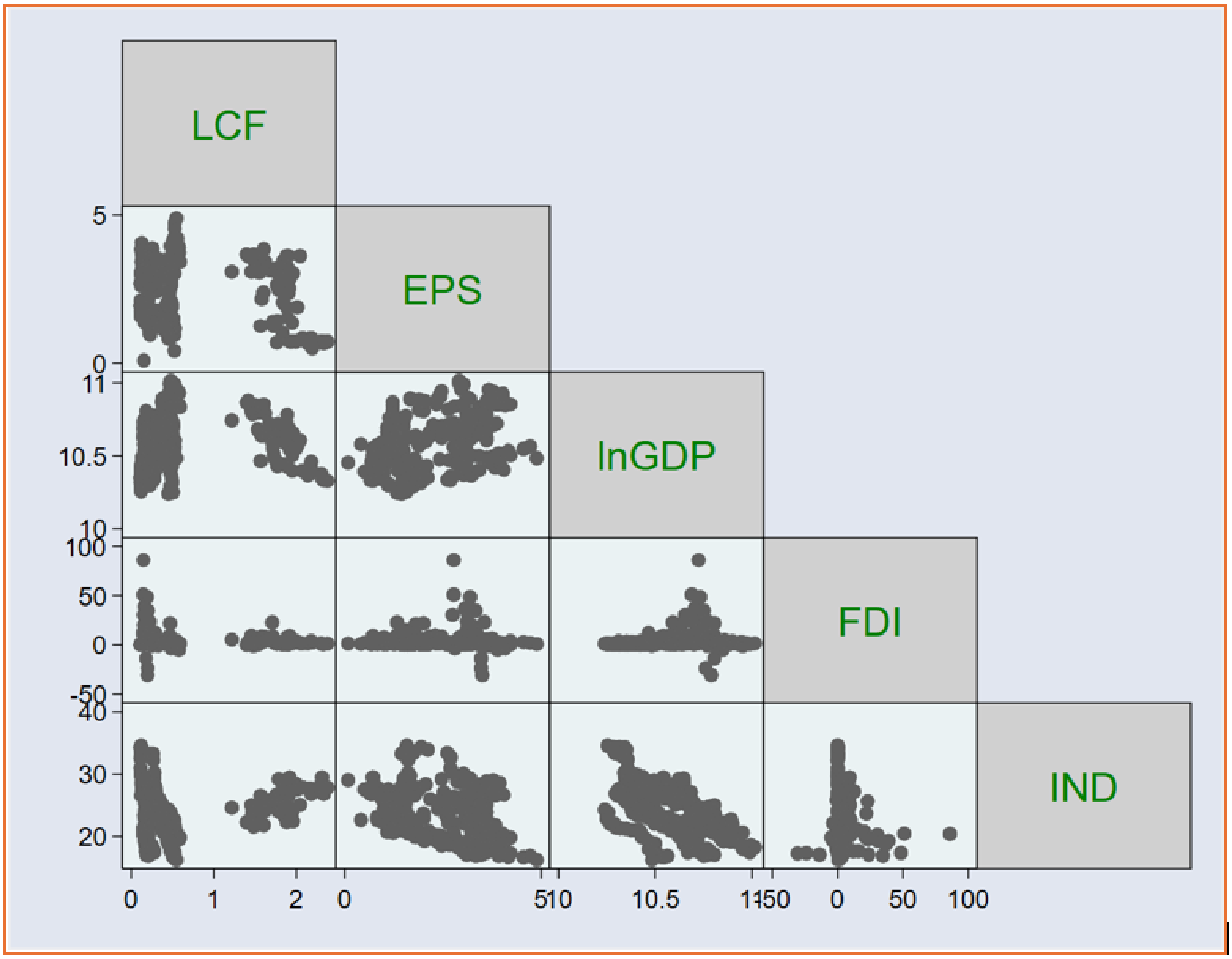


***Figure 3**: Scatterplot Matrix of the Study Variables*

Table 4 reports the multicollinearity and slope homogeneity test results. The mean VIF value of 1.36 and individual VIF values below 10 indicate the absence of multicollinearity among the explanatory variables. Furthermore, the significant Delta (7.046) and Adjusted Delta (7.847) statistics ($p < 0.01$) reject the H_0 of slope homogeneity, confirming the presence of slope heterogeneity across countries. Figure 4 further supports this finding by illustrating the variation in country-specific coefficients for EPS, lnGDP, FDI, and IND across panel units. Therefore, heterogeneous panel estimators such as the CCEMG estimator are appropriate for the empirical analysis.

Table 4: Variance Inflation Factor and Slope Homogeneity Results

Test	Statistic	Value	p-value
Multicollinearity (VIF)	lnGDP	1.64	-
	IND	1.55	-
	EPS	1.21	-
	FDI	1.03	-
	Mean VIF	1.36	-
Slope Homogeneity Test	Delta (Δ)	7.046	0.000
	Adjusted Δ	7.847	0.000

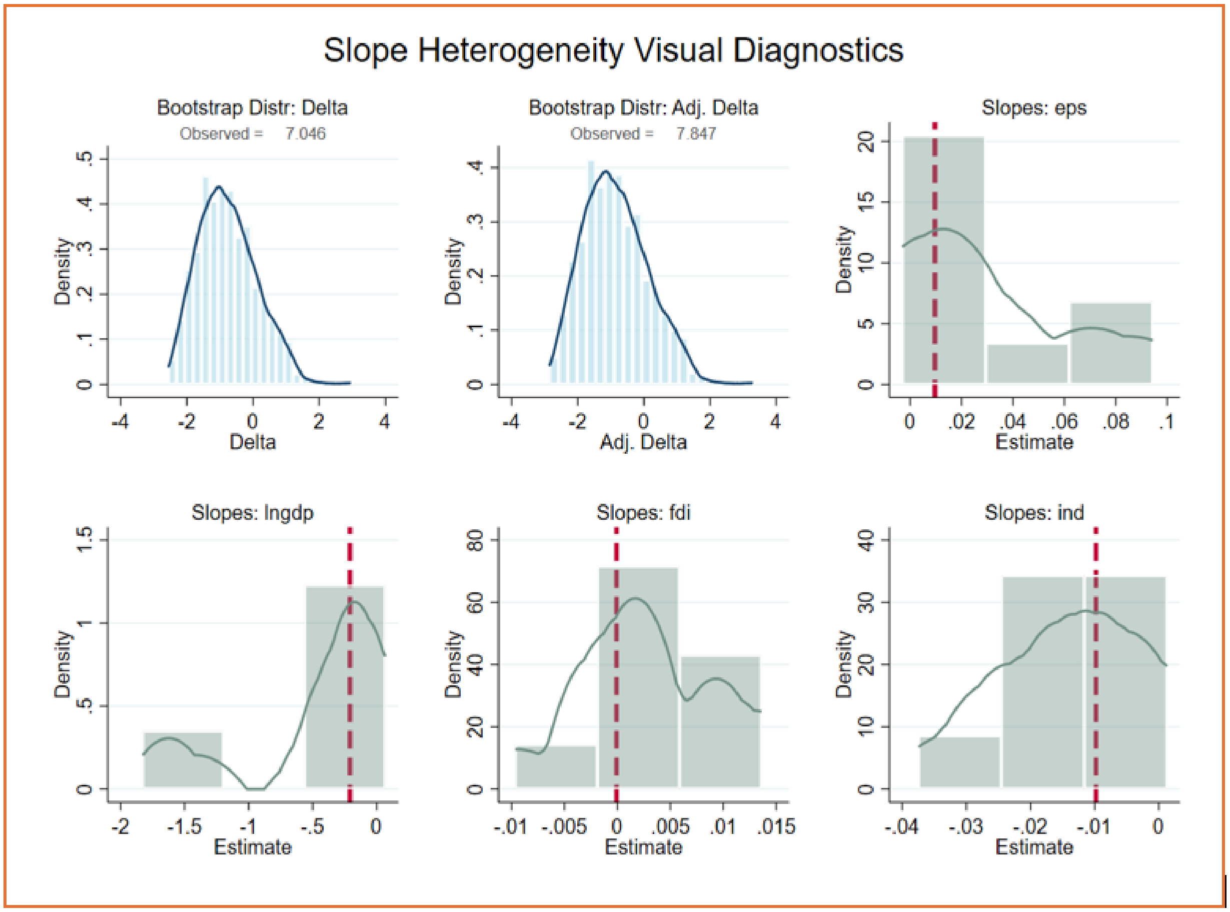


Figure 4: Slope Heterogeneity Diagnostics

The results of the CSD test are reported in Table 5. The CD statistics are highly significant ($p < 0.01$) for all variables, implying that all sampled countries are affected by common shocks and interdependencies. Based on this discovery, second-generation panel econometric methods are needed. Thus, the Pesaran (2007) CIPS unit root test is used. As shown in Table 6, the variables are stationary at levels for EPS and FDI, but after first differencing, they are stationary for LCF, lnGDP, and IND. So the variables have I (0) and I (1) as their exhibited values. Because none of the variables are second-order integrated, the Westerlund (2007) cointegration test is used to examine the long-run relationship among the variables. The findings in Table 7 strongly suggest cointegration. In particular, the significant Gt, Pt, and Pa statistics show that the H0 of no cointegration is rejected, implying that ecological sustainability, EPS, lnGDP, FDI, and industrialization are in a stable long-run equilibrium relationship among the countries under consideration.

Table 5: Cross-Sectional Dependency Test Results

Variables	CD Statistic	p-value
LCF	10.81	0.000
EPS	28.22	0.000
lnGDP	32.39	0.000
FDI	12.05	0.000
IND	25.19	0.000

Notes: *The H_0 of the Pesaran (2004) CD test. To reject of H_0 indicates the presence of CD among panel units. The panel consists of 9 countries and is unbalanced, with an average of 34.88 observations per country. All variables exhibit statistically significant CD at the 1% significance level.*

Table 6. Pesaran CIPS Panel Unit Root Test Results

Variables	Level	1st Diff	Order of integration
LCF	-1.253	-6.015***	I(1)
EPS	-2.587***	-4.473***	I(0)
lnGDP	-1.953	-3.747***	I(1)
FDI	-3.219***	-6.172***	I(0)
IND	-1.946	-4.878***	I(1)

Notes: *The H_0 of the Pesaran (2007) CIPS test is that all panels contain a unit root (non-stationary). Rejection of H_0 indicates stationarity. ***, **, and * significant level.*

Table 7. Westerlund (2007) Error-Correction-Based Panel Cointegration Test Results

Test Statistic	Value	Z-value	P-value
Gt	-3.361	-2.876	0.002
Ga	-11.716	0.486	0.686
Pt	-18.316	-10.958	0.000
Pa	-18.916	-3.803	0.000

The results of the CCEMG estimator are given in Table 8. The Wald statistic is 29.79, with a corresponding p-value < 0.01, indicating that the model is jointly significant. The findings indicate that EPS has a positive and significant relationship with ecological sustainability. The discovery indicates that environmental laws do contribute to ecological sustainability by promoting better resource use, cleaner manufacturing, and more sustainable environmental flows. The result is similar to that of Ahmed et al. (2024), who explained that strict environmental policies can foster sustainable outcomes by enhancing environmental governance and green innovation. Economic growth (lnGDP) has a negative, statistically significant relationship with ecological sustainability, indicating that increases in economic activity are associated with decreases in ecological sustainability in the sampled countries. This discovery suggests continued reliance on resource-intensive activities and environmental exploitation, resulting in ecological pressure and reduced ecological carrying capacity. This corroborates the findings of various studies, including Wang et al.'s (2023) study, on the trade-off between high economic growth and environmental sustainability in developing economies. Moreover, FDI has a positive, statistically significant effect, indicating that FDI also positively affects ecological sustainability. The discovery is consistent with the Pollution Halo Hypothesis, which posits that foreign investors introduce clean technology, efficient management, and environmentally friendly production processes. This finding is similar to Khan et al. (2023), who reported that FDI contributes to environmental sustainability through technology transfer and innovation diffusion.

Lastly, ecological sustainability is negatively affected by industrial expansion, as shown by the negative data in IND. The discovery indicates that industrial processes remain based on high-energy production and resource extraction, placing additional pressure on the environment and contributing to ecological degradation. This aligns with Li and Ullah (2024), who reported negative environmental impacts from unsustainable industrial growth in emerging economies. The CCEMG results indicate that environmental policy stringency and FDI have positive effects on ecological sustainability, whereas economic growth and industrialization have negative effects. The results are significant in terms of the need to improve environmental laws, promote sustainable FDI, and advance cleaner industrial production to achieve long-term ecological sustainability. The Mean Group (MG) estimator is used to produce the following robustness results: Table 9. The overall picture is similar to that obtained from the CCEMG. The positive relationships between EPS and FDI and ecological sustainability persist, while the negative relationships between lnGDP and IND and ecological sustainability are observed. The results for both estimators were consistent, with the same signs and significance levels of coefficients, thus ensuring robustness and reliability of the basic empirical results.

Table 8: Main Estimation Results: CCEMG

Variables	Coefficient	Std. Error	z-Statistic	p-Value
EPS	0.0236**	0.0107	2.20	0.028
lnGDP	-0.3361**	0.1641	-2.05	0.040
FDI	0.0031**	0.0015	2.08	0.037
IND	-0.3026*	0.1546	-2.06	0.057
Constant	1.7022	1.6962	1.00	0.316
Model Statistics				
Wald χ^2	29.79			
Prob > χ^2	0.0000			

Notes: ****, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.*

Table 9. Robustness Results: Mean Group (MG) Estimator

Variables	Coefficient	Std. Error	z-Statistic	p-value
EPS	0.0286**	0.0116	2.47	0.013
lnGDP	-0.4945**	0.2240	-2.21	0.027
FDI	0.0049**	0.0014	1.21	0.052
IND	-0.0143***	0.0041	-3.45	0.001
Constant	6.1648**	2.6412	2.33	0.020
Model Statistics				
Wald χ^2	29.36			
Prob > χ^2	0.0000			

Notes: ****, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.*

5. Conclusion and Policy Implications

The effects of EPS, economic growth, FDI, and industrialization on LCF have been studied for 9 OECD countries during 1990- 2020. The CCEMG estimator was used, with the MG estimator as a robustness check, to account for CD and slope heterogeneity across countries. Diagnostic tests validated second-generation panel estimation methods, and the Westerlund cointegration test validated a stable long-run relationship between the variables. The empirical results confirm that the stringency of environmental policy positively affects ecological sustainability, thus supporting the Porter Hypothesis. In contrast, FDI positively affects the LCF, as predicted by the Pollution Halo Hypothesis. Economic growth and industrialization, however, have a strong negative impact on ecological sustainability, underscoring that even with better environmental governance; ecological resources remain under stress because of economic expansion and industrial activities. These results are consistent across alternative estimators, as shown by the robustness analysis. However, the analysis is restricted to nine OECD countries, and only a subset of the variables is included as explanatory variables. Further studies could examine additional factors (including renewable energy, green innovation, institutional quality, and financial development) and larger country samples, as well as nonlinearity, to gain a fuller picture of ecological sustainability.

5.1. Policy Implications

The results show that the path to a truly sustainable economy in OECD countries lies in a more comprehensive policy framework that firmly links environmental policy with sustainable economic development. Governments should continue to strengthen environmental policy stringency, in particular by improving the effectiveness of market-based instruments such as carbon pricing, environmental taxation, stricter emission standards, and incentives for green innovation to promote cleaner production and enhance resource efficiency. Policymakers must also encourage FDI for environmental sustainability and boost industrial transition by increasing the use of low-carbon technologies, energy-saving industrial processes, renewable energy, and circular economy techniques. These integrated policies alleviate ecological stress, improve the

LCF, and ensure sustainable economic development without sacrificing environmental protection.

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