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Assessing The FDI-Environment Nexus Using The Load Capacity Factor: A Seemingly Unrelated Regression Approach For G7 And Brics-T



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Abstract

The pursuit of economic growth has intensified countries' efforts to attract foreign direct investment; however, growing concerns regarding the environmental consequences of such inflows underscore the need for broader and more comprehensive ecological indicators. This study contributes to the literature by examining the relationship between foreign direct investment and the load capacity factor, a holistic environmental quality measure that captures both ecological demand and ecological supply, thereby moving beyond traditional pollution-based metrics. Through this focus, the study also engages with the theoretical expectations of the Pollution Haven and Pollution Halo hypotheses. In addition, the study tests the load capacity curve hypothesis, which proposes that environmental quality initially deteriorates as income increases but improves once a certain level of economic development has been achieved.

Using data from G7 and BRICS-T countries for the period 1992–2022, and estimating a Seemingly Unrelated Regression model, the findings reveal a negative and statistically significant relationship between foreign direct investment and the load capacity factor for BRICS-T economies, consistent with the Pollution Haven hypothesis. In contrast, for G7 countries, the relationship between foreign direct investment and the load capacity factor is not statistically significant, whereas per capita income displays the expected nonlinear pattern supporting the load capacity curve hypothesis. Overall, the results indicate that foreign direct investment places additional ecological pressure on emerging economies, whereas environmental quality in advanced economies improves after reaching higher income levels.

Keywords

Foreign direct investment · Load capacity factor · Pollution haven hypothesis · Load capacity curve hypothesis · Seemingly unrelated regression


JEL Classification


Q56 · F18 · C23



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Assessing The FDI-Environment Nexus Using The Load Capacity Factor: A Seemingly Unrelated Regression Approach For G7 And Brics-T

Sustainability, environmental degradation, and global climate change constitute some of the most pressing economic and ecological challenges facing humanity today. The processes of industrialisation and economic development exert substantial pressure on the natural environment. Although rapid economic growth enhances human welfare, it concurrently imposes significant strains on environmental quality and biological capacity. Over the past five decades, for example, global biocapacity has increased by merely 27%, largely owing to improvements in technology and land management; yet this expansion has not kept pace with human consumption, as the ecological footprint of humanity has risen by approximately 190% during the same period (WWF, 2018, p. 30). This divergence reflects a biocapacity deficit—a critical indicator of the gap between the planet's ecological renewal capacity and humanity's demand for natural resources. The widening biocapacity deficit contributes not only to rising global temperatures and increasingly unpredictable climate patterns but also to diminished carbon absorption capacity, accelerated biodiversity loss, disruptions in biological cycles, and more frequent and severe natural disasters (Ganda, 2024, p. 1-2).

Since the onset of the Industrial Revolution, nations' persistent pursuit of industrialisation -coupled with intensive fossil fuel consumption has steadily worsened environmental pollution and ecological degradation. These mounting environmental pressures have prompted countries to adopt production and consumption practices that are either environmentally compatible or less damaging to ecological systems. In this context, the concept of sustainable development emerged and has since become a central focus among researchers, policymakers, and both national and international institutions. While nations have developed policy strategies to advance sustainable development, globalisation and the accompanying expansion of foreign capital flows continue to exert substantial influence on environmental quality. Environmental concerns are among the most frequently raised criticisms surrounding foreign direct investment (FDI).

Historically, it has been suspected that developed countries relocate pollution-intensive production processes to developing economies, a phenomenon widely known as the pollution haven hypothesis (De Beule et al., 2022; Wang et al., 2019). Empirical evidence provides partial support for these concerns. Lawrence Summers, former Chief Economist of the World Bank, explicitly advocated incentivizing the relocation of polluting industries, grounding his argument in several economic justifications (The Economist, 1992, p. 82). Consistent with Summers's position, a substantial body of research demonstrates that FDI inflows to developing economies are associated with increased environmental pollution in host countries (Roy, 2024; Balsalobre-Lorente et al., 2022; Zhu et al., 2016; Liu et al., 2017; Shahbaz et al., 2017; Chung, 2014; Zeng & Zhao, 2009; Akbostancı et al., 2007). Numerous real-world examples further illustrate the scale of ecological degradation that has unfolded over the past half-century. Nevertheless, although the relocation of pollution-intensive industries is widely observed, whether environmental considerations constitute the primary motivation for such relocation remains contested (Lu & Huang, 2008, p. 177-181). Some scholars argue that factors such as low labour costs, access to raw materials, market opportunities, and political stability (Leonard, 1988) play a more decisive role than environmental stringency. At the same time, a contrasting strand of literature suggests that FDI may support environmentally sustainable development by facilitating technology transfer and positive knowledge spillovers that help mitigate environmental degradation, a perspective captured by the pollution halo hypothesis (Soto and Edeh, 2025, p. 16183).

Given the complex and multidimensional environmental effects of FDI, it is unsurprising that the empirical literature remains far from reaching a consensus. Yet understanding how FDI influences

environmental outcomes are essential for identifying policy measures capable of promoting sustainable development. In the context of natural resources, examining the interaction between supply and demand is crucial for comprehensively understanding the intricate dynamics and interdependencies between resource availability and resource use. A holistic analysis encompassing both dimensions enables a deeper exploration of the market forces, economic incentives, and policy interventions that shape resource extraction, allocation, and conservation. Such insights are critical for effective resource management and sustainable development, particularly for economies transitioning towards environmentally conscious growth models (Soto & Edeh, 2025, p. 16183). Policymakers, businesses, and researchers can rely on this understanding when designing strategies that balance economic growth with environmental protection.

Motivated by these considerations, this study investigates the relationship between environmental quality and FDI using the load capacity factor—a comprehensive indicator that incorporates both the supply and demand dimensions of natural ecosystems. The analysis employs panel data techniques using observations for G7 and BRICS-T countries over the period 1992–2022. The findings are expected to offer insights into the comparative environmental performance of advanced and rapidly developing economies and into how different stages of economic development shape environmental sustainability and how industrial expansion can be steered within ecological limits. Furthermore, the study examines the load capacity curve (LCC) hypothesis, which explores the relationship between per capita GDP and the load capacity factor.

The remainder of the article is structured as follows. Section Two outlines the theoretical framework. Section Three reviews the empirical literature. Section Four describes the data, model, and methodology. Section 5 presents the empirical findings, and Section Six concludes with policy recommendations.

Theoretical Explanations on the Relationship Between Environmental Quality and FDI

In the economics literature, the relationship between environmental degradation and economic activity is primarily addressed within the framework of the Environmental Kuznets Curve (EKC). The EKC represents the environmental adaptation of Simon Kuznets' original hypothesis, which posits an inverted U-shaped relationship between per capita income and income inequality. According to the EKC hypothesis, the level of per capita income plays a central role in shaping environmental quality. The EKC suggests a nonlinear relationship between income and pollution (Grossman & Krueger, 1991). At low income levels, countries tend to exhibit higher levels of pollution. However, once a certain income threshold is reached, structural transformations within the economy, technological advancements, and rising environmental awareness contribute to declining pollution and improving environmental quality. Originally formulated by Grossman and Krueger (1991) and later termed the “Environmental Kuznets Curve” by Panayotou (1993), this relationship has since been widely examined in the literature, leading to substantial academic acceptance regarding its validity.

Although the EKC framework does not directly explain how FDI affects the environment, Grossman and Krueger (1991) identified three mechanisms—scale, composition, and technique effects—that theoretically underpin the EKC and offer insight into how investments influence environmental outcomes. These mechanisms illustrate how investments required for economic growth shape the trajectory of environmental impacts. Because investments in a country may originate domestically or internationally, the environmental effects of FDI are evaluated within this framework as well.

The scale effect, which characterises the early stages of economic development, reflects the increase in natural resource use, environmental waste, and emissions associated with the expansion of

production. At this stage, economies rely heavily on natural resources—often fossil fuels—resulting in environmental degradation and ecological damage. The use of traditional, low-efficiency, and pollution-intensive technologies that prioritise output quantity further exacerbates environmental pollution (Başar & Temurlenk, 2007, p. 2; Udemba, 2021, p. 34372; Yandle et al., 2004, p. 3). The composition effect emerges as economies expand and undergo structural transformation from industrial production towards services and knowledge-based sectors. Because these sectors typically rely less on natural resource inputs, this shift is associated with reductions in pollution and environmental degradation (Başar & Temurlenk, 2007, p. 2–3). Finally, the technique effect, which explains the downward-sloping portion of the EKC, reflects the adoption of cleaner and more efficient technologies as economies industrialise. Rising income levels allow countries to allocate greater resources to research and development, enabling the development and diffusion of environmentally friendly technologies. As income and technology advance, older, polluting technologies are replaced with cleaner alternatives (Bo, 2011, p. 1323), contributing to improved environmental quality.

Two hypotheses derived from the EKC framework explicitly address the environmental effects of FDI: the pollution haven hypothesis and the pollution halo hypothesis. Both builds upon Dunning's OLI (Ownership, Location, and Internalisation advantages) paradigm, specifically the theory of location advantages. According to this theory, multinational enterprises seek to maximise their competitiveness by relocating production processes to host countries that offer favourable macroeconomic conditions, strong infrastructure, advantageous tax regimes, or lenient environmental policies (Dunning, 1979; 1981).

According to the pollution haven hypothesis (Copeland & Taylor, 1995), firms headquartered in developed countries relocate production to developing economies with lax or weak environmental regulations “pollution havens” to avoid the rising costs associated with stringent pollution control measures at home (Scriciu, 2015). The logic underlying the hypothesis is that environmental regulations impose significant costs on firms, prompting them to shift production to locations where compliance costs are lower. Such relocation may lead to environmental degradation in host countries (Van Tran et al., 2024, p. 5). Historically, concerns have been raised that developed economies tend to transfer pollution-intensive industries to developing countries (De Beule et al., 2022; Wang et al., 2019). As noted previously, the establishment of such industries has even been encouraged in some cases. Moreover, developing country governments may lower environmental standards to attract foreign investors or retain domestic firms (Demena & Afesorgbor, 2020, p. 3). However, in response to rising global concerns about environmental degradation and climate change, many countries have begun implementing deterrent regulatory mechanisms—such as pollution taxes—which may discourage FDI inflows due to increased costs for firms (Soto & Edeh, 2025).

In contrast, the pollution halo hypothesis argues that FDI can enhance environmental quality in host countries. The hypothesis suggests that FDI inflows facilitate the transfer of knowledge, advanced technologies, and green innovations, thereby helping mitigate environmental degradation (Padhan & Bhat, 2024, p. 800). Letchumanan and Kodama (2000) contend that FDI contributes to environmental welfare by introducing advanced technologies and environmentally friendly products and production processes into developing economies. The empirical literature also provides evidence that foreign firms in developing countries often exhibit better environmental performance than their domestic counterparts. For instance, Zhu et al. (2016) showed that multinational enterprises tend to be more environmentally conscious due to superior management practices and the use of cleaner, advanced technologies; Eskeland and Harrison (2003) reported that U.S.-owned facilities in developing countries use not only more energy-efficient but also cleaner energy sources; Zeng and Eastin (2012) found that FDI inflows promote environmental awareness in developing countries; and Yi et al. (2023) demonstrated a positive relationship between FDI and ecological quality, largely driven by modern and green technological inputs.

The intense policy and academic debates surrounding the EKC have motivated the development of new hypotheses, one of the most recent being the load capacity curve (LCC) hypothesis (Pata & Kartal, 2023). Contrary to the EKC, the LCC hypothesis posits a U-shaped nonlinear relationship in which environmental quality initially declines during the early stages of economic development—due to reliance on traditional energy sources and excessive natural resource extraction—but subsequently improves once income exceeds a certain threshold. The validity of the LCC hypothesis implies that countries, upon reaching a specific income level, acquire the ability to reduce their ecological footprint and enhance their biocapacity. Within this framework, both environmental degradation and quality can be examined simultaneously (Doğan & Pata, 2022, p. 2). The LCC hypothesis is grounded in the notion of countries' sustainability capacity, which is measured using the load capacity factor (LCF) (Pata, 2021). LCF reflects the relationship between the production of natural resources (biocapacity) and their consumption (ecological footprint). Siche et al. (2010) introduced LCF by calculating the ratio of biocapacity to ecological footprint, arguing that this approach enables a more robust assessment of environmental conditions compared to earlier indicators¹. Building on this, Pata (2021) empirically examined the determinants of LCF for the first time using a dynamic ARDL approach (Doğan & Pata, 2022, p. 2). A value of 1 constitutes the threshold for environmental sustainability. LCF values below 1 indicate unsustainable environmental conditions, whereas values above 1 suggest that existing natural resources are sufficient to support the population and meet human needs (Awosusi et al., 2022, p. 3). Thus, achieving environmental sustainability requires LCF values exceeding unity.

Literature Review

Although numerous studies on environmental degradation or quality demonstrate that industrialisation and therefore investment constitute a major driver of environmental emissions (Chancel, 2022), the relationship between FDI and environmental quality remains complex. This relationship may depend on several factors, including the type of FDI, the nature of investment, institutional arrangements, and technology transfer.

In this study, the load capacity factor (LCF) is employed as an indicator of environmental quality. Therefore, the literature review focuses specifically on studies examining the relationship between LCF and FDI, while excluding earlier works that rely on more traditional environmental indicators, such as carbon dioxide emissions or the ecological footprint. To the extent accessible, these relevant studies are summarised below.

Latif and Faridi (2023) investigated the impact of FDI on LCF in Asian countries. Using data from 1996 to 2020, the authors applied the two-step system generalised method of moments (GMM). Their findings reveal that FDI harms environmental quality by reducing LCF.

¹A substantial body of empirical research examining the relationship between the environment and FDI (Ren et al., 2014; Al-Mulali et al., 2015; Zhang and Zhou, 2016; Bakirtas and Cetin, 2017; Rahman et al., 2019; Pavlović et al., 2021; Teng et al., 2021; Ma et al., 2023; Zeng et al., 2024) has relied primarily on carbon dioxide emissions as an indicator of environmental quality. However, although carbon dioxide represents a major component of greenhouse gas emissions, it may fail to adequately capture and assess the broader extent of environmental degradation, as it does not encompass other critical environmental dimensions such as soil conditions, mining activities, and forestry (Ulucak and Apergis, 2018: 21–22). This limitation has increasingly been addressed using the ecological footprint, a comprehensive economic ecological metric developed to evaluate global sustainability. Designed in 1990 by Mathis Wackernagel and William Rees, the ecological footprint measures “the biologically productive land and water area required, under prevailing technology and resource management practices, to produce the resources consumed by an individual, community, or activity and to absorb the waste generated—particularly carbon emissions” (Global Footprint Network, 2025). Nevertheless, the ecological footprint reflects only humanity's demand for natural resources and the associated environmental pressures, without accounting for the ecosystem's capacity to respond to or supply these demands. Therefore, a more comprehensive indicator that incorporates biocapacity is needed for a more accurate assessment of sustainability (Altıntaş and Kassouri, 2020: 12).

Yıldırım et al. (2024) analyse whether environmental regulations exert a moderating effect on the relationship between FDI and environmental quality in BRICS countries. Using second-generation panel data techniques and data for the period 1992–2020, the authors assess the influence of FDI, real national income, renewable energy consumption, and environmental stringency on LCF. Their results indicate that rising FDI worsens environmental quality, thereby supporting the pollution haven hypothesis for BRICS countries. However, when the moderating role of environmental regulation is considered, environmental policy stringency mitigates the negative impacts of FDI on environmental quality, demonstrating the regulatory function's effectiveness. In contrast to these findings, Ullah et al. (2024), using a BRICS-T sample that includes Türkiye, found that FDI positively affects LCF. Employing the NARDL technique for the period 1990–2018, they show that a negative shock to FDI improves LCF in both the short and long run, whereas positive FDI shocks enhance environmental quality only in the long run. According to the authors, the overall results suggest that FDI improves environmental quality in BRICS-T countries, thereby supporting the pollution halo hypothesis.

Ganda (2024) examines how FDI, material footprint², economic growth, and information and communication technology affect LCF in 37 Sub-Saharan African countries. Using data from 1970 to 2019 and employing robust econometric techniques (FM-OLS, D-OLS, and DSUR), the study finds a negative relationship between FDI and LCF. The author argues that although FDI may offer economic advantages, it can intensify environmental stress and weaken the region's ecological sustainability.

Soto and Edeh (2025) investigated the relationship between pollution and FDI in Spain over a long period (1961–2018). Using an ARDL model, they find that FDI exerts a significant negative effect on LCF in both the short and long run. Their findings validate the pollution haven hypothesis and indicate that FDI in Spain does not contribute to green technology diffusion for cleaner production. The results also support both the EKC and LCC hypotheses in the Spanish context.

Saleem et al. (2024) explored the effects of renewable energy, FDI, and external debt on LCF in Brazil for the period 1970–2021. Using the A-ARDL technique, they conclude that FDI reduces LCF and thus adversely affects ecological sustainability.

Unlike most studies, Famanta et al. (2024) examined the impact of green FDI on environmental quality. Using balanced panel data for 34 LDCs from 2003 to 2021 and estimating models through PCSE and FGLS, the authors find that green FDI positively influences LCF.

Ayad et al. (2024) analyse the impact of FDI on environmental quality in 16 MENA countries using data from 1990 to 2018. Based on PMG-ARDL estimations, their findings indicate a negative long-run effect of FDI on LCF, supporting the pollution haven hypothesis for the region. The study also tests U-shaped and inverted N-shaped relationships between per capita GDP and environmental sustainability, ultimately identifying an N-shaped relationship, thereby supporting the EKC hypothesis.

Annor et al. (2025) examined the environmental effects of FDI for 47 Sub-Saharan African countries over the period 1996–2021 using the two-step system GMM technique. Their results indicate that FDI has a statistically significant positive effect on LCF, suggesting that FDI contributes to improving ecological capacity in the region.

Kartal et al. (2025) investigated the determinants of environmental quality in E7 countries using LCF as the environmental indicator and panel data from 1990 to 2022. Employing panel data techniques and the CS-ARDL approach, they found that FDI exerts an environmentally supportive effect in host countries. As a robustness check, when ecological footprint is used instead of LCF, the positive effect of FDI on environmental quality remains consistent.

²Material footprint is an ecological term that captures the production, consumption, disposal, and movement of all types of materials, including minerals and fossil fuels.

Although many studies analyse multiple countries using panel data methods, there are also single-country studies. For example, Topal (2024) tested the LCC hypothesis for Türkiye. Using time-series data for 1973–2022 and estimating an ARDL model, the author finds that FDI negatively affects environmental quality and validates the pollution haven hypothesis for Türkiye. Moreover, the results indicate that the income-environment relationship does not follow a U-shape, rendering the LCC hypothesis invalid for Türkiye.

Additional single-country examples include China, Brazil, and Russia. Güler et al. (2025) assessed the impact of FDI on China's sustainable development goals using Fourier bootstrap ARDL and FMOLS estimators. They found consistent evidence supporting the pollution haven hypothesis for one of the world's largest FDI hubs. Saint Akadiri et al. (2025) analyse how Nigeria's LCF is affected by economic growth, FDI, resource dependence, and urbanisation over the period 1970–2022, using wavelet quantile regression. Their findings indicate that economic growth consistently deteriorates environmental quality across quantiles, while FDI exerts adverse ecological effects, particularly in the middle and upper quantiles, reflecting the concentration of foreign investment in pollution-intensive sectors, such as mining and carbon-intensive industries. Ali et al. (2025) empirically investigated the extent to which FDI influences Russia's LCF using data from 1994 to 2022. Employing necessary condition analysis (NCA), DOLS, FMOLS, CCR, and Prais-Winsten regressions, they find that economic growth and FDI contribute to environmental degradation in Russia, whereas renewable energy and environmental goods exert beneficial effects.

Overall, the literature shows that the use of LCF as an indicator of environmental quality is relatively recent (particularly within the last two years). The available studies suggest that FDI may reduce LCF, though some research, albeit limited, shows positive effects. The scarcity of studies and the diversity of findings indicate that no consensus has yet emerged regarding the direction of the FDI-LCF relationship. Therefore, this study is expected to contribute to the literature in several ways. First, it compares newly industrialising countries with fully industrialised economies a distinction that is valuable for understanding environmental dynamics across development stages. Second, to our knowledge, this is the first study to employ the Seemingly Unrelated Regression technique to analyse the relationship among the variables under consideration, offering an additional methodological contribution to the literature.

Data and Methodology

In this study, the relationship between FDI and LCF is examined for G7 and BRICS-T countries. Additionally, the validity of the LCC hypothesis, which focuses on the relationship between income and LCF, is also investigated for both country groups. The significant roles of these countries within global economic and environmental dynamics have influenced the selection of the sample. Furthermore, comparing G7 and BRICS-T countries is particularly important in the context of environmental issues, as these groups represent advanced industrial economies and rapidly developing nations. This contrast enables an examination of how different stages of economic development affect environmental sustainability and how industrial expansion can be guided within ecological constraints.

The study uses annual data for the period 1992–2022. The selection of this period is motivated by the availability of data for the Russian Federation, one of the BRICS-T members, the increased international attention to environmental issues following the 1992 Rio Earth Summit, and the global rise in FDI since the 1990s.

Table 1*Variables*

Variable	Abbreviation	Unit	Source
Load capacity factor	LCF	Global hectare per capita	Global Footprint Network ³
Per capita income	GDP	Constant 2015 US \$	World Development ⁴ Indicators
Foreign Direct Investment	FDI	Net FDI/GDP	World Development Indicators

Table 1 summarises the variables, their units, and their sources. The dependent variable used to test the hypotheses is the load capacity factor (LCF), which represents a comprehensive measure of environmental sustainability. This variable offers advantages over carbon dioxide emissions, a commonly used indicator in the applied literature. Because LCF is defined as the ratio of biocapacity to ecological footprint, it accounts for both the demand and supply sides of environmental degradation. Biocapacity, representing the resources provided by nature, and the ecological footprint, reflecting human demand on these resources, are measured through components such as built-up land, carbon footprint, cropland, fishing grounds, forest products, and grazing land. In this study, LCF is calculated by taking the ratio of biocapacity to ecological footprint, both obtained from the Global Footprint Network database.

The independent variables used in the analyses are per capita income and foreign direct investment. Data for these variables were obtained from the World Bank's World Development Indicators (WDI) database.

Descriptive statistics for the variables are presented in **Table 2**. An examination of the descriptive statistics reveals that the average LCF for BRICS-T countries is above 1, whereas the average for G7 countries is approximately half of that value. This difference is primarily attributable to the high biocapacity of countries such as Brazil and Russia, which possess extensive forested areas. As expected, the average income level of G7 countries is approximately 6.5 times higher than that of BRICS-T countries, whereas income variability is considerably greater among BRICS-T members. There is no remarkable difference between the two groups in terms of FDI. Regarding the Jarque–Bera statistics, the null hypothesis of “normal distribution” cannot be rejected only for the GDP variable in BRICS-T countries across the entire dataset.

Table 2*Descriptive Statistics*

	BRICS-T			G7		
	LCF	GDP	FDI	LCF	GDP	FDI
Mean	1.072	5930.523	1.993	0.538	38469.01	1.989
Maximum	4.431	14055.10	9.660	2.373	64342.12	12.609
Minimum	0.222	549.2351	-1.756	0.121	27987.43	-0.894
Std. Dev.	1.127	3184.392	1.512	0.589	7649.005	2.072
Coefficient of Variation	1.051	0.537	0.759	1.095	0.199	1.042
Jarque-Bera	85.001	3.947	94.325	171.645	50.597	710.157
JB Prob	0.000	0.14	0.000	0.000	0.000	0.000
Observations	186	186	186	217	217	217

To test the LCC and Pollution Halo hypotheses for BRICS-T and G7 countries, analyses are conducted using the model presented in Equation (1). To minimise heteroskedasticity, reduce the influence of outliers, and obtain elasticity estimates, the LCF and GDP variables are included in the model in their natural logarithmic

³<https://data.footprintnetwork.org/#/>

⁴<https://databank.worldbank.org/source/world-development-indicators>

forms. Since the FDI variable contains negative values reflecting net foreign direct investment flows, its logarithm is not taken.

$$\ln LCF_{i,t} = \beta_0 + \beta_1 \ln GDP_{i,t} + \beta_2 \ln GDP_{i,t}^2 + \beta_3 FDI_{i,t} + \varepsilon_{i,t} \quad (1)$$

Under the load capacity curve (LCC) hypothesis, which implies a U-shaped nonlinear relationship between income and the ecological sustainability indicator (LCF), the income coefficient is expected to be negative, whereas the coefficient of the squared income term is expected to be positive, with both coefficients being statistically significant. For the Pollution Haven and Pollution Halo hypotheses, inference is based on the coefficient of FDI: a negative and statistically significant coefficient supports the Pollution Haven hypothesis, whereas a positive and statistically significant coefficient supports the Pollution Halo hypothesis.

In the first stage of panel data analysis, tests are conducted for slope homogeneity, cross-sectional dependence, and stationarity. The results indicate that slope coefficients are heterogeneous. In this case, the classical model, which assumes no variation in parameters across units, and fixed-effect or random-effect panel models, which assume only the intercept varies, are considered inappropriate. Estimating heterogeneous slope parameters under homogeneity assumptions may lead to serious biases (Tatoğlu, 2012, p. 33). Furthermore, cross-sectional dependence is detected among units. Therefore, among the heterogeneous methods that account for cross-sectional correlation, the Seemingly Unrelated Regression (SUR) model, which permits the cross-sectional dimension to be smaller than the time dimension, is selected as the appropriate estimation technique. Although heterogeneous panel estimators such as AMG and CCE are widely employed to account for unobserved common factors, their desirable properties rely on asymptotic conditions where both the cross-sectional (N) and time (T) dimensions tend to infinity.

First introduced by Zellner (1962), the SUR model provides a system-based solution for panel data models when correlations exist across cross sections. This model enables separate estimations for each unit within a panel where parameters differ across units but error terms are correlated (Tatoğlu, 2012, p. 52). Zellner proposes a procedure that yields asymptotically more efficient estimators than individual Ordinary Least Squares (OLS) estimations. In the SUR framework, all equations in the system are estimated simultaneously using Aitken's Generalised Least Squares (GLS) method. This estimator relies on the variances and covariances of the residuals obtained from the OLS regressions for each unit (Zellner, 1962, p. 348).

Findings

In the first stage of the analyses, the homogeneity of the parameters was tested using the Swamy S (1970) and Pesaran & Yamagata (2008) tests. For both tests, the null hypothesis states that the parameters are homogeneous. The results of the homogeneity tests for the two country groups are presented in Table 3. As shown in the table, the probability values for all test statistics are below 1%, indicating that the null hypothesis is rejected for the Swamy S test, Pesaran & Yamagata (2008) delta, and adjusted delta tests for both country groups. Consequently, the parameters are heterogeneous across units in both groups.

Table 3
Homogeneity Tests

	BRICS-T		G7	
	Swamy S Test			
χ^2	80983,15	(0,000)	54592,64	(0,000)
	Pesaran Yamagata Test			
Δ	13,294	(0,000)	17,8	(0,000)

	BRICS-T		G7	
Adj Δ	14,516	(0,000)	19,101	(0,000)

Note: Values in parentheses represent the probability values associated with the test statistics.

To test for cross-sectional correlation among the units, the Breusch & Pagan (1980) Lagrange Multiplier (LM) test, the Pesaran et al. (2008) Bias-Adjusted Lagrange Multiplier test, and the Pesaran (2004) CD test were employed. The results of the cross-sectional dependence tests are presented in Table 4. Although all three tests were conducted, the LM test should be considered due to the structure of our sample ($N < T$). According to the LM test results, the null hypothesis of “cross-sections are independent” is rejected at the 1% significance level for both country groups. This indicates cross-sectional dependence among the units.

Table 4

Cross-Sectional Dependence Tests

	BRICS-T		G7	
LM	32,56	(0,0054)	145	(0,000)
LM Adj	8,501	(0,000)	60,87	(0,000)
LM CD	3,03	(0,0024)	10,97	(0,000)

Note: The null hypothesis for all tests is “cross-sections are independent.” Values in parentheses represent the probability values associated with the test statistics.

The presence of cross-sectional dependence necessitates the use of second-generation unit root tests for stationarity analysis. Given the structure of our dataset ($N < T$), the SUR-based Multivariate Augmented Dickey-Fuller (MADF) test was identified as the appropriate unit root test (Tatoğlu, 2020, p. 80). The MADF test results are presented in Table 5. An examination of the results reveals that, for both country groups, the calculated test statistics for all variables exceed the relevant critical values at the 5% significance level. These findings indicate that all variables under investigation are stationary at levels.

Table 5

MADF Unit Root Tests

	BRICS-T	G7
lnLCF	75,768	28,386
lnGDP	47,904	31,614
lnGDP ²	45,057	31,003
FDI	55,765	106,250

Note: The null hypothesis of the test is “the series contain a unit root.” at the 5% significance level and the appropriate degrees of freedom, the critical values are **26.904** for the BRICS-T group and **24.045** for the G7 group.

The model constructed to test the LCC and Pollution Halo/Pollution Haven hypotheses was estimated using the SUR method. The SUR estimation results are presented in Tables 6 and 7. Table 6 reports the R^2 values and Wald statistics (chi-square) obtained from the separate estimations for each unit. As shown in the table, according to the Wald statistics, the models are generally found to be statistically significant for all BRICS-T countries except Russia. Similarly, the R^2 values representing the explanatory power of the models are quite high for all BRICS-T countries other than Russia.

When the results for the G7 countries are examined, the models are statistically significant at the 10% level for Italy, at the 5% level for the United Kingdom, and at the 1% significance level for all other countries. However, compared to the BRICS-T group, the explanatory power of the models is observed to be lower in the G7 countries.

Table 6*SUR Model (R² and Wald Statistics)*

BRICS-T			G7		
Equations	R ²	χ^2	Equations	R ²	χ^2
lnLCF1 (Brasil)	0,9283	396,21***	lnLCF1 (Canada)	0,6282	106,16***
lnLCF2 (China)	0,9761	1490,25***	lnLCF2 (France)	0,4356	26,23***
lnLCF3 (India)	0,9743	1219,27***	lnLCF3 (Germany)	0,8028	155,11***
lnLCF4 (Russia)	0,1162	2,88	lnLCF4 (Italy)	0,1711	7,30*
lnLCF5 (South Af.)	0,8554	203,09***	lnLCF5 (Japan)	0,7420	121,85***
lnLCF6 (Turkey)	0,9676	953,55***	lnLCF6 (UK)	0,1882	8,81**
			lnLCF7 (USA)	0,5683	48,69***

Note: ***, **, and * denote the statistical significance of the models at the 1%, 5%, and 10% levels, respectively.

Table 7 reports the coefficient estimates of the SUR model. Alongside the separate estimations for each unit, the table also presents the mean group estimates obtained from the means of these individual estimates. An examination of the mean group estimates shows that, for the BRICS-T countries, the coefficients of the income variables are statistically insignificant, whereas the coefficient of the FDI variable is negative and statistically significant at the 1% level. For the G7 countries, the coefficient of FDI is insignificant, whereas the coefficient of lnGDP is negative and that of lnGDP² is positive, with both coefficients statistically significant at the 1% level. Based on these findings, the Pollution Haven hypothesis is validated for the BRICS-T countries, whereas the load capacity curve hypothesis is confirmed for the G7 countries.

When the unit-specific results presented in Table 7 are evaluated, it is observed that for China, India, Russia, and Turkey, among the BRICS-T countries, the coefficient of lnGDP is significant and negative, whereas the coefficient of lnGDP² is significant and positive. Among the G7 countries, the same pattern is observed for France, Japan, the United Kingdom, and the United States. Consequently, the LCC hypothesis is confirmed for these countries. On the other hand, the income variables are insignificant for Brazil, South Africa, and Italy, whereas for Germany, the coefficient of lnGDP is significant and positive, and the coefficient of lnGDP² is significant and negative. Considering the absolute magnitudes of the coefficients, economic activity in Turkey appears to exert a stronger effect on the load capacity factor than other BRICS-T countries. Nevertheless, when comparing the G7 and BRICS-T countries, a similar observation can be made for the G7 group as well.

Regarding the effects of FDI on the load capacity factor, the coefficient of FDI is found to be statistically significant, negative, and at the 1% level for Brazil and China among the BRICS-T countries. Among the G7 countries, the FDI coefficient is negative and significant for France and the United States. These findings support the Pollution Haven hypothesis for these countries. Conversely, the coefficient of FDI is positive and significant for Canada and Japan; thus, the Pollution Halo hypothesis is confirmed only for these two developed countries.

Table 7
SUR Model (Coefficients)

BRICS-T				G7			
	Variable	Coefficient	z		Variable	Coefficient	z
Mean Group Estimators	lnGDP	-2,824	-1,329	Mean Group Estimators	lnGDP	-17,424***	-3,630
	lnGDP ²	0,134	1,142	lnGDP ²	0,829***	3,577	
	FDI	-0,008***	-2,718	FDI	0,004	1,275	
	Constant	13,651	1,479	Constant	90,523***	3,643	
lnLCF1	lnGDP1	6,894	1.008	lnLCF1	lnGDP1	-8,264	-0.678
Brasil	lnGDP ² 1	-0,421	-1.102	Canada	lnGDP ² 1	0,365	0.630
	FDI1	-0,025***	-5.000	FDI1	0,007*	1.750	
	Constant	-26,63	-0.871	Constant	47,186	0.736	
lnLCF2	lnGDP2	-1,056***	-3.758	lnLCF2	lnGDP2	-22,422***	-2.929
China	lnGDP ² 2	0,037**	2.176	France	lnGDP ² 2	1,092***	2.951
	FDI2	-0,029***	-3.625	FDI2	-0,01**	-2.500	
	Constant	5,16***	4.558	Constant	114,395***	2.886	
lnLCF3	lnGDP3	-2,851***	-5.691	lnLCF3	lnGDP3	18,572***	3.181
India	lnGDP ² 3	0,177***	5.057	Germany	lnGDP ² 3	-0,861***	-3.086
	FDI3	-0,002	-0.250	FDI3	-0,0002	-0.100	
	Constant	10,305***	5.868	Constant	-101,209***	-3.315	
lnLCF4	lnGDP4	-5,236*	-1.680	lnLCF4	lnGDP4	28,281	1.077
Russia	lnGDP ² 4	0,296*	1.682	Italy	lnGDP ² 4	-1,396	-1.092
	FDI4	0,003	0.429	FDI4	0,016	0.941	
	Constant	23,39*	1.701	Constant	-144,797	-1.074	
lnLCF5	lnGDP5	-4,358	-0.429	lnLCF5	lnGDP5	-75,033***	-10.561
South Africa	lnGDP ² 5	0,21	0.354	Japan	lnGDP ² 5	3,638***	10.545
	FDI5	0,003	0.750	FDI5	0,034***	2.615	
	Constant	21	0.483	Constant	384,786***	10.527	
lnLCF6	lnGDP6	-10,335***	-6.516	lnLCF6	lnGDP6	-25,07**	-2.426
Turkey	lnGDP ² 6	0,539***	6.195	UK	lnGDP ² 6	1,198**	2.435
	FDI6	0,003	0.333	FDI6	0,003	1.000	
	Constant	48,682***	6.781	Constant	129,627**	2.388	
				lnLCF7	lnGDP7	-38,035***	-5.949
				USA	lnGDP ² 7	1,768***	5.953
				FDI7	-0,019**	-2.111	
				Constant	203,674***	5.914	

Note: ***, **, and * denote the statistical significance of the models at the 1%, 5%, and 10% levels, respectively.

Conclusion and Recommendations

Although the importance of FDI in the economic growth process of nations is undeniable, discussions persist regarding the disadvantages it brings over time within the industrialisation process. The most prominent of these disadvantages relates to the environment. Concerns that FDI contributes to environmental degradation, particularly in developing countries, have not only been expressed in academic

and policy circles but have also been observed in practice. In this study, the FDI-environment relationship was analysed by considering the load capacity factor (LCF), a more comprehensive and recent indicator of environmental quality. The BRICS-T group, representing developing economies, and the G7 group, representing developed economies, were selected as the sample using data from 1992–2022. The model was estimated using the Seemingly Unrelated Regression method within the framework of panel data analysis techniques. According to the empirical findings, while FDI and LCF are negatively and statistically significantly related at the 1% level for the BRICS-T countries, no relationship was found between FDI and per capita income. Yıldırım et al. (2024) similarly demonstrated that increasing foreign investment negatively affects LCF in BRICS countries, whereas Ullah et al. (2024) found a positive FDI-LCF relationship for BRICS-T economies. For the G7 countries, the FDI-LCF relationship was found to be insignificant, while per capita income was negatively associated with LCF and the square of per capita income was positively associated with LCF. Taken together, these findings suggest that the Pollution Haven hypothesis is validated for the BRICS-T countries, whereas the LCC hypothesis is confirmed for the G7 countries.

An evaluation of the results reveals that the outcomes differ substantially between the two country groups. The finding that FDI adversely affects environmental quality in the BRICS-T countries indicates that FDI policies in these economies should be revisited and restructured to promote environmental sustainability. Considering that rapidly growing economies such as the BRICS-T hold a significant share of global income and population, foreign investments pose a threat to environmental sustainability. Thus, these countries should strive to attract environmentally friendly and green growth enhancing investments rather than polluting ones. In this context, first, countries may implement stricter environmental regulations. There is empirical evidence regarding the impact of stringent environmental policies on the environment. Yıldırım et al. (2024) showed that the negative effects of foreign investment on environmental quality in BRICS countries become positive when environmental regulations improve (environmental policy stringency was used as a moderator variable). Therefore, investments made by foreign investors may benefit the environment when they comply with strict environmental standards. Second, incentives can be provided to firms that contribute to the diffusion of efficient and green technologies into the country. Such incentives should also discourage FDI inflows that are inconsistent with social sustainability objectives. Third, the establishment of key infrastructure can attract foreign investment into the clean technology sector. Moreover, strategic investments in education and workforce training to develop expertise in clean technologies may further attract foreign investors. Fourth, it is important for BRICS-T governments to develop economic, political, and social relations with countries and investment institutions that possess advanced environmental technologies and practices to protect environmental quality.

The validation of the LCC hypothesis for the G7 countries indicates a negative relationship between per capita income and environmental quality. However, because the coefficient of per capita income squared is positive, this relationship will reverse beyond a certain point, leading to improvements in environmental quality, as suggested by the LCC hypothesis. In this process, several significant steps may be taken to balance economic growth with pollution control. These measures may include encouraging the adoption of cleaner technologies and the use of renewable energy sources in place of older, pollution-intensive methods. Stricter regulations and laws may also be introduced to reduce environmentally harmful practices, accompanied by penalties for businesses that fail to comply. Public awareness and participation constitute another essential component in the fight against environmental pollution. Educating the public about the importance of environmental protection and encouraging environmentally friendly choices are vital for sustainability. In this regard, transitioning from a “take-make-dispose” model of linear consumption towards a circular economy emphasising reuse and recycling would contribute to both national and global economies, as well as to the biocapacity of nature.

Naturally, this study has several limitations. It focuses solely on BRICS-T and G7 countries. Broader and more diverse samples may be used in future research, such as countries receiving the highest levels of FDI or groups like the G20. Future studies may also classify countries by income groups to investigate whether the relationship changes when income levels are considered. Additionally, although the SUR approach was used in this study, future research may explore how FDI affects LCF using alternative methodologies (e.g., asymmetric tests). Finally, many variables that significantly influence the FDI-environment relationship, such as institutional indicators, including control of corruption, rule of law, and government effectiveness, were not included and may be considered in future work.



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