Sustainability in Action: An Examination of Human Capital, Green Finance, Green Growth, and Environmental Taxation on Load Capacity Factors

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ABSTRACT

The UN has established the Sustainable Development Goals as a sustainable future in which environmental, economic, and social priorities should be in a cycle. This research examines the role of Human Capital, Green Finance, Green Growth, and Environmental Taxation in enhancing the Load Capacity Factor (LCF), an important indicator of Renewable Energy Efficiency and sustainability, using panel data of 30 countries over the period 2010-2020 and sophisticated econometric techniques. The study shows that GF is a key driver of investment in renewable energy and efficiency, whereas Human Capital highly increases the use and optimization of green technologies. Environmental taxation induces cleaner energy behavior and provides funds for green reinvestment; its performance relies on the governance and economic situation. Growth strategies are of mixed effects and rely on the policy favoring the local priorities of the economy. Globalization and FDI promote green technology transfer and green infrastructure development in emerging economies and eco-innovation to be a driving force behind GF to sustainability outcomes. Policy suggestions involve the integration of GF with taxation, human capital investment, and scaling renewable infrastructure. Enhancements in LCF support SDG 3 (Good Health and Well-Being), emphasizing the intersectionality of economic development, environmental sustainability, and public health.

Keywords: *Load Capacity Factor, Human Capital, Green Finance, Green Growth, Green Energy, Economic Globalization.*

1. Introduction

The UN Sustainable Development Goals offer guidance to countries in shaping the world more just and sustainable environmentally. Sustainable development is, thus, a top agenda of the global order. Among all the SDGs, "Good Health and Well-Being" (SDG 3) intersects with environmental sustainability as the health of ecosystems is the mirror image of the health of human beings. This comes into play because, in the current world where there is a record high of climate change, and the resources are diminishing along with the energy demand that is very high. It is among the major metrics that ascertain the efficiency of an energy system, particularly for RE systems-the Load Capacity Factor gauges a real energy generated by a power plant relative to its potential maximum production, thus stating evidently the efficiency and sustainability of energy systems (Tufail et al., 2024) Enhancing LCF is vital to the assurance that RE systems are operated at their optimum capacity, contributing not only to energy security but also to environmental sustainability. Thus, Green Finance is part of sustainable development since it supports the financing of projects that ensure environmental sustainability while lowering carbon emission. It summarizes investment in RE, eco-innovation, and energy-efficient technologies, all factors that are crucial for maximizing the LCF of energy systems (Bilal & Shaheen, 2024) GF is especially significant in developing countries since funds for Green Energy projects are usually limited. GF serves to offset the impacts of climate change while facilitating Economic Globalization by channeling financial flows into sustainable energy alternatives (Tufail et al., 2024) Additionally, the green tax in the form of carbon taxes and an emissions trading scheme provides business and consumers with an incentive to adopt cleaner technologies as well as reducing the overall environmental impact. The revenue from environmental taxes may also be reinvested in green plans to drive more efficient energy infrastructure to support sustainable initiatives (Sabbaghi, 2024).

Environmental taxation is also a popularly known policy for attaining sustainability. Carbon emissions and other pollutants can be taxed to actually act as economic incentives for industries to scale down their footprint on the environment (Guan et al., 2025) Not only do cleaner technologies promote taxes like these, but revenue gathered through them can be directed towards further RE projects or other eco-friendly initiatives (Q. Zhang et al., 2024). Environmental taxation is more effective in LCF development, particularly when there is an overall tax framework for emissions reduction and the promotion of clean energy generation (Sichone-Phiri & Zangewa, n.d.). Success stories are evident in the case of nations such as Sweden and Denmark (Altıntaş et al., 2024), who have successfully implemented carbon taxation to encourage companies to invest in RE and eventually improve their efficiency regarding energy consumption systems (Dai et al., 2024). These factors the Human Capital, Green Finance, Green Growth, and environmental taxation can be combined to achieve synergies in the energy systems that improve the load factor of the system as well as contribute to the attainment of SDG 3 (Bozatli & Akca, 2024). Worldwide, as countries change bases towards curbing carbon emissions, the shift towards RE is a call for boosting the demand for embracing a comprehensive approach to sustainability. Policy-makers need to acknowledge the interdependence of these variables and adopt policies that encourage Human Capital development, enhance GF, and encourage the adoption of eco-friendly technologies. By doing so, they can enhance the efficiency of energy systems, minimize their footprint on the environment, and tribute ultimately to improved health outcomes for populations globally (Tufail et al., 2024). It would then look at exploring the interconnection of Human Capital, Green Finance, Green Growth, and environmental taxation with regards to their aggregated effects on augmenting LCF. So far, existing research studies have highlighted that each of the mentioned factors significantly contributes to making sustainable energy systems operational in various economies worldwide (Tufail et al., 2024) but their potential interactions for raising the efficiency levels of RE systems are lacking. The study fills the gap and attempts to offer empirical evidence about how these variables may work in harmony to bring about sustainable energy, thus leading to the realization of SDG 3, specifically within the areas of energy sustainability and public health (Bilal & Shaheen,

2024). This paper will employ data from 30 countries, covering the time between 2010 and 2020. sourced from the World Bank and the Footprint Network among other sources. This range of countries comes from a very diverse economic and environmental context and, therefore, provides a wide view of the interaction of HCU, GF, and ET in different regions. Advanced econometric techniques such as panel data regression, causality tests, and robustness checks will be applied to give an effective understanding of the relationship among the variables. The outline of the paper is structured with the following methodology: the succeeding section reviews existing literature on relationships between Human Capital, GF, GG, ET, and LCF. Third, the methodological approach regarding research methodology of variable operationalization, sample determination, and bases of the data used would be presented in this section. Finally, Investigation of data obtained shall be summarized with results regarding regression analysis results and causality tests. Finally, the paper concludes with recommendations and suggestions for policymakers and suggestions for further and future research.

2. Literature Review

For the world's energy agenda, sustainability is the overarching mission, and for energy generated by renewables, systems will be at the core of the world's efforts to address climate change and for economic growth. The Load Capacity Factor is a key metric of the effectiveness and efficiency of RE systems in the global shift towards a more sustainable energy future. (Altıntaş et al., 2024; Soto, 2024) LCF offers measurement of the actual supply of energy from RE systems against their highest possible potential and is hence a key indicator for evaluation of wind, sun, and other possible types of RE. Several determinants have been identified in recent years that affect LCFs, varying from Human Capital, GF, GG, and ET to eco-innovation (Dai et al., 2024). These variables, both in isolation and in combination, are instrumental in enhancing RE efficiency, which has a direct bearing on LCF. This section discusses the literature on the inter-relationships between these variables, outlines major gaps in current research, and indicates how this Research seeks to fill these gaps (Bilal & Shaheen, 2024). The

Dependent and Independent Variable Relationship Human Capital and Load Capacity Factor: Human Capital, in terms of the knowledge, skills, and experience of the labor force, is a critical element in the determination of RE system development, implementation, and optimization. Human Capital makes a multi-level contribution to improving LCF, from technology conception and installation to operation and maintenance. As per (Tufail et al., 2024) Human Capital plays the central role in the deployment of sophisticated RE technologies, such as high-efficiency solar panels and wind turbines, contributing directly to an increased LCF by increasing the efficiency of energy production (Soto, 2024). Training and education programs in renewable technologies also play a critical role in creating a workforce possessing skills and competencies in maximizing energy systems and other technical issues (Sabbaghi, 2024). Research has established that the higher the Human Capital in a country, the more effective its RE systems will be. For example, (Dai et al., 2024) established that investment in the development of Human Capital for the RE industry leads to enhancements in LCF since there is increased technical know-how to plan and manage energy systems. Besides the above elements, Human Capital encourages innovation in RE technologies, further advancing LCF in aspects of increased performance and lower cost-effectiveness in RE systems (Sabbaghi, 2024). Green Finance and Load Capacity Factor: Green Finance refers to the investment in environmentally friendly projects, such as RE projects. The presence of Green Finance is a significant parameter in building loads because it brings the required capital to build and expand RE technologies. (Y. Zhang, 2024) Green Finance, through channels like Green Bonds, climate finance, sustainable investment funds, facilitates the shift to RE by lowering a cost of capital for energy projects, thereby making them economically more feasible (Bilal & Shaheen, 2024). Additionally, Green Finance Fuels R&D on new RE technologies that would further improve LCF by maximizing the efficiency of energy systems (Javed et al., 2024). For instance, investment in R&D has enabled the development of modern wind turbines and solar panels, which can generate more energy per unit capacity and improve LCF (Tufail et al., 2024) Green Finance further enables the diffusion of advanced RE

technologies to be developing countries where the RE system is mostly inefficient (Yang et al., 2024) and underdeveloped (Black et al., 2023) By supporting the diffusion of these technologies, Green Finance can significantly benefit the LCF of these regions; hence, enhancing the performance in closing the development gap between advanced and developing economies (Dai et al., 2024). Green Growth also encourages the development of effective energy technologies, like intelligent networks, and energy storage, mechanisms that include energy savings and enhance RE utilization to enhance LCF (Sabbaghi, 2024). Moreover, government incentives, subsidization, and tax relief for RE projects lead to Green Growth policies that enhance access to these technologies (Oanh, 2024) hence making them adoptable, and thus improving LCF (Tufail et al., 2024). The more effective RE systems become as nations implement Green Growth approaches, the greater their LCF and the stronger their energy security (Dam et al., 2024). Environmental Taxation and Load Capacity Factor: Environmental taxation, including carbon taxes and emissions trading schemes, provides a monetary incentive for RE technologies to be implemented because fossil fuels are rendered more costly. This tilts the economic scale in favor of RE, which is less costly environmentally. As (Sabbaghi, 2024) puts it, carbon taxes provide a strong economic incentive that encourages the uptake of RE technologies because they lower the price of fossil fuels and make cleaner energy sources more desirable. Environmental taxes drive the transition to cleaner, more efficient energy systems by charging the price of carbon-emitting energy sources, encouraging this transition directly and thus improving LCF (Sun & Waqas, 2024). Environmental taxes produce revenues that can be used to invest in RE projects, thus providing additional financial inputs towards the development and deployment of RE technologies. (Y. Zhang, 2024) adds that revenues generated from environmental taxes can be utilized to finance R&D in RE that results in the creation of more efficient technologies that enhance LCF (Dai et al., 2024). The study of Khan, S., Bangash, R., & Ullah, U. (2023) evaluates various models using the business risk metric Value at Risk (VaR) to identify the most suitable framework for the KMI-30 stock market. The results indicate that although

past banking experiences may not directly influence customers, several mediating factors play a significant role in shaping their willingness to adopt RAAST (Ullah, U., Khan, J., Shah, J. A., & Baloch, R. 2023). This study explores key themes including investment behavior, the efficient market hypothesis, and stock price prediction in the context of the anticipated second wave of COVID-19 (Khalil & Ullah). Eco-Innovation and Load Capacity Factors, LCF: It refers to introduction and implementation of new technologies and processes that minimize environmental effects and improve the sustainability of energy systems. Eco-innovation is highly central to enhancing LCF by maximizing the efficiency and the effectiveness of RE systems. (Bilal & Shaheen, 2024) contend that eco-innovation enhances sophisticated RE technologies, i.e., more efficient solar panels and wind turbines (Özkan et al., 2024), which enhance energy systems directly by augmenting LCF (Degirmenci & Aydin, 2024). In addition, it allows the use of renewable sources of energy in existing energy grids (Adebayo & Samour, 2024) in a way that enhances the total efficiency and capacity of energy systems (Sabbaghi, 2024).

Eco-innovation also enables the lowering of RE technologies' costs, thereby enhancing their adoption and deployment for better LCF. (Bilal & Shaheen, 2024) observe that "eco-innovation reduces the cost of production of RE systems" which consequently leads to an increase in its adoption and use. They, by investing in eco-innovation, not only improve the efficiency of the RE systems but also help shift to a greener future for energy consumption, thus increasing LCF and supporting the energy security. Globalization, FDI, and Population Density: External drivers of globalization, FDI, and population density influence the LCF of RE systems. Globalization makes it possible for transfer of know-how, technologies, as well as best practices that are geared towards improving RE systems' efficiency (Sichone-Phiri & Zangewa, n.d.). FDI provides the capital necessary to plan RE systems, hence bolstering LCF as it improves the electricity generating capacity (Famanta et al., 2024). During a crisis, risk variables for small and midcap ETFs rise, whereas those for large cap ETFs decrease (Shaheen et al., 2024).

Population density is also a driving factor for LCF of RE systems. Highly populated regions demand more energy and thus more energy-efficient systems to satisfy the demand for energy. This will result in the implementation of more sophisticated RE technologies, increasing the overall energy system efficiency and capacity (Emre Caglar et al., 2024) thus raising LCF Thus, globalization, FDI, and population density are significant external determinants that shape the LCF of RE systems by inducing technology adoption, generating capital for infrastructure investment, and influencing energy demand.

2.1. Research Gap

Although Human Capital, Green Finance, Green Growth, Environmental Taxation, and Eco-Innovation significantly donate to the optimization of renewable-energy systems, a important gap is found in the literature about the combined effects of these variables on the LCF. Most of the studies focused on the individual effects of the variables without considering their interrelations and cumulative impact on RE performance. Further, although the impact of these factors has been discussed in developed countries, their influence in developing countries is still a relatively under-researched area (Adebayo & Samour, 2024) especially since RE systems are still at a nascent point of development in these countries and may have different implications for LCF (Sichone-Phiri & Zangewa, n.d.). Besides, although eco-innovation is considered to be one of the significant drivers of RE efficiency, its influence on LCF is not well studied. Fill this gap by researching the cumulative impacts of Human Capital, Green Finance, Green Growth, environmental taxation, and eco-innovation towards LCF by focusing specifically on better countries.

3. Research Methodology

The paper specifies a complete overview of the research methodology in detailing the approach applied in studying the connection between Human Capital, Green Finance and Green Growth, and environmental taxation in enhancing LCF. In the Asian region, these tactics are essential for creating an atmosphere that supports digital economic growth and optimising the advantages of financial development, technological innovation, financial inclusion, and globalisation

(Mateen et al., 2025). Highlighting the need for better waste management techniques while providing policymakers with practical insights into using fintech, renewable energy, and green finance for sustainable development (Khan et al., 2025). Recent research is based in the context of sustainability. Here, different factors which contribute to improvement in the Load Capacity Factors of the energy system will be explored. (Dai et al., 2024) Human Capital, Green Finance, Green Growth, and environmental taxation are all examined, and possible mediating and moderating effects are taken into account.

3.1. Operationalization of the Variables

The Load Capacity Factor is an indicator of how efficiently energy can be produced, compared to what an energy system could potentially provide. It reflects the extent to which an energy system is effective in using the resources available (Dai et al., 2024). LCF can be operationalized using the measure of ecological footprint and biocapacity taken from Footprint Network (2020), in which the demand for resources was compared with Earth's ability to regenerate them. The above measure can assess the sustainability of energy systems in that a greater LCF shows better efficiency with RE resource utilization (Bilal & Shaheen, 2024). Greater LCF on a sustainable energy system indicates greater management of resources and lesser impacts on the environment.

3.1.1. Independent Variables

Human Capital is the most crucial driver of Economic Development and Green Growth. Its implementation is done with the assistance of the World Bank's Human Capital Index, which consists of years of schooling, education quality, and replacements to education (World Bank, 2020). It is an overall measure that will include the sustainability and innovation abilities of Human Capital. (Degirmenci & Aydin, 2024) Educated and highly educated populations are likely to practice green measures and embrace green technology (Tufail et al., 2024).

Green Finance is a financing of the environment to green the world, particularly targeting RE. This idea is practiced by studying international financial flows to clean energy projects. World Bank statistics, 2020, are used for this study. This work provides useful tools for investors, advisors,

and regulators to reduce irrational decision-making while advancing behavioural finance theory by contextualising these distortions within emerging markets, a hitherto understudied topic (Malik et al., 2025). It represents the integration of national economies, facilitated by both trade, investment, and financial flows. Calculated as trade relative to GDP according to the data of the World Bank (2020), this concept is thus operationalized through the ratio. Economic globalization therefore promotes the spreading of knowledge, capital, and technology, further aiding the dissemination and embedding of green technologies and sustainable practices (Sichone-Phiri & Zangewa, n.d.). GN or Green Energy refers to the use of renewable funds such as solar, wind, and hydropower. It's quantified by measuring the percentage of RE utilization and total RE production by using World Bank's statistics in 2020. Transition to Green Energy is an important strategic step for decreasing greenhouse gas emissions while meeting the imperative to ensure sustainability. A higher percentage of RE implies that a country believes in greater environmental sustainability and less reliance on fossils (Bilal & Shaheen, 2024). ET, Environmental taxes are taxes charged on harmful environmental activities, for instance, carbon emission and depletion of natural resources. For this paper, the World Bank's 2020 report was used in quantifying the environmental tax, communicated as the measurement of the gross domestic product of a given country through the derivation of funds from environmental taxes. The role of environmental taxes in moderating the Green Finance-greens energy nexus. Environmental taxes, in encouraging firms and governments to invest in clean energy technologies, are critically important in terms of sustainability promotion (Y. Zhang, 2024) Eco-innovation refers to the creation of new products, processes, or services that are environmentally sustainable. It is measured through the percentage of GDP spent on R&D activities about environmental technologies and sustainable practices. The World Bank (2020) data will be used. Eco-innovation is a key mediator in the correlation between Green Finance, Green Growth, and Load Capacity Factors; in that it can improve the sustainability and efficiency of energy systems through technological innovation in the area of Green Energy (Tufail et al., 2024).

The KOF Globalization-Index utilizes social, economic, and political globalization indicators that are combined to operationalize globalization (KOF, 2020). Energy consumption, technological diffusion, and Green Energy adoption are factors expected to change appropriately to the impact on globalization. FDI links foreign entities' investments made in each country's economy. In practice, this measure is calculated in terms of the entry of FDI data from the World Bank (2020). Such, Green Energy infrastructure, as well as sustainable practices in general, will be promoted and realized through FDI. The operationalization of population density would be in the form of number of people/square kilometers of land area using the World Bank (2020) data. The higher population density makes energy demand and sustainability issues tougher for those countries to deal with.

3.2. Sample Selection, Data Collection, and Limitations

3.2.1. Sample Selection

The sample selected for research consists of 30 nations from various geographical locations as well as varying degrees of economic growth. They have been chosen to cover the entire spectrum of energy systems, policies, and practice for sustainability. The timeframe for this research is between 2010 and 2020. It takes into account all the new trends related to Human Capital, Green Finance, Green Energy, and Environmental Taxation.

3.2.2. Data Collection

Secondary sources of data are used in this study, which include some of the most reliable international organizations, such as the World Bank and the Footprint Network. The KOF Institute. These institutions offer pertinent and current data regarding Human Capital, Green Finance, Green Growth, and other variables of interest. The yearly data from 2010 to 2020 is gathered to achieve a large sample size that can be utilized in statistical analysis. The data are readily available, meaning they can be used in academic purposes.

4. Data Analysis and Results

4.1. Descriptive Statistics

The descriptive statistics of the major variables required in this study, which are very important in understanding the correlation between human capital, green finance, green growth, and other factors influencing load capacity, are shown in Table 1.

Table 1: *Descriptive Statistics*

Variable	Obs	Mean	Std. Dev.	Min	Max
LCF	330	0.647	0.637	0.11	3.298
HUC	330	2.895	0.545	1.76	3.774
GF	330	7.419	1.228	4.55	9.05
GG	330	10.128	7.009	0.08	32.09
EG	330	4.047	0.486	3.11	5.104
GEN	330	18.432	17.04	0.1	86
ET	330	13.995	5.025	2.31	25.82

Human capital HUC presents close-bounded means (mean=2.895, standard deviation=0.545), with schooling and skill-related improvement almost uniform across other nationalities. The fairly moderate variety of Green Finance GF (mean = 7.419, standard deviation = 1.228) accounts for country-wide policy dynamics and differences in supporting financial ecosystem development (Tufail et al., 2024). In stark contrast, GG and GEN vary significantly. GG is said to vary between 0.08 and 32.09 (mean=10.128), whereas the GEN one also varies from 0.1 to 86 (mean=18.432, standard deviation=17.04), evincing contradiction in growth strategies and renewable energy deployment (Sabbaghi, 2024; Y. Zhang, 2024). Environmental Taxes (ET) average 13.995 with a standard deviation of 5.025, which suggests further divergence among environmental tax regimes. Economic Globalization (EG), compared in the context of countries, appears more homogenous (mean = 4.047), implying a minimal level of international integration (Sichone-Phiri & Zangewa, n.d.).

Table 2: *Correlation Matrix and VIF Values*

	VIF	LCF	HUC	GF	GG	EG	GEN	ET	EINO	GL	FDI	PDT
LCF		1.00										
HUC	3.09	0.07	1.00									
GF	1.27	-0.03	-0.19	1.00								
GG	1.48	-0.04	-0.14	-0.03	1.00							
EG	1.31	-0.26	0.17	-0.28	0.12	1.00						
GEN	1.69	0.18	-0.62	0.06	0.15	-0.18	1.00					
ET	1.58	0.11	0.26	-0.32	-0.36	0.22	-0.16	1.00				
EINO	1.76	-0.15	0.51	0.03	0.13	0.03	-0.28	0.07	1.00			
FDI	1.51	0.09	0.47	-0.12	0.15	0.00	-0.18	0.18	0.36	0.07	1.00	
PDT	1.61	-0.58	-0.31	0.09	0.21	0.22	0.16	0.09	0.15	0.15	-0.18	1.00

4.2. Cross-Sectional Dependence Analysis

Tests for CSD assess the impact of any unobserved variables or common shocks which traverse countries and hence influence the panel dataset. Results of the CD test are represented in Table 3. Utilizing p-values from the table would identify the incidence of variables' CSD or otherwise. CSD Test Result Variables considered in study. The cross-sectional dependence test tests for cross-sectional correlation of the residuals from the panel data model between countries. It is a crucial diagnostic because cross-sectional dependence can influence the validity of statistical inferences as well as the robustness of model estimates. Each variable has test statistic along with its corresponding p-value, along with average joint t-statistic, mean correlation (ρ), and mean absolute

correlation. Green Finance (GF) produced a test statistic of -0.083 with p = 0.933 showing no statistically significant evidence of CSD; similar to the other factor, the weak residual correlations underpinned by weak correlation (Tufail et al., 2024). Like GF, the Green Growth (GG) produced no statistically significant evidence of CSD with a test statistic of -0.963 and p = 0.336, with weak relationships (Y. Zhang, 2024). Economic Globalization (EG) did not have any statistically significant evidence of CSD with a test statistic of 0.032 and p = 0.974, the mean for $\rho = 0$ which, with the mean absolute ρ of 0.24 showing weak residual correlations (Sabbaghi, 2024). The Green Energy (GE) test statistic was 0.866 with p-value of 0.386 showing no statistically significant

evidence for CSD; this is also evidenced by weak relationships with a means of $\rho = 0.01$ and mean absolute $\rho = 0.28$, (Sichone-Phiri & Zangewa, n.d.). Environmental taxes (test statistics = 0.742, p = 0.458) did not have statistically significant evidence of CSD, and its mean $\rho = 0.01$ and mean absolute $\rho = 0.22$ (Bilal & Shaheen, 2024). Eco-innovation did not show any CSD with weak negative correlations (test statistic = -0.583, p = 0.56). Finally, Globalization did not show a substantial CSD (test statistic = 0.059, p = 0.924), which means that there is no residual correlation between countries (Tufail et al., 2024). In general, the non-significant CSD indicates minimal to no cross-country residual correlations between all variables.(Sabbaghi, 2024).

Table 3: *Cross-Sectional Dependence*

Variable	CD-Test Statistic	p-value	Average Joint T	Mean ρ	Mean Absolute ρ
LCF	-1.875	0.061	11	-0.03	0.27
HUC	-0.846	0.398	11	-0.01	0.24
GF	-0.083	0.933	11	0	0.26
GG	-0.963	0.336	11	-0.01	0.25
EG	0.032	0.974	11	0	0.24
GEN	0.866	0.386	11	0.01	0.28
ET	0.742	0.458	11	0.01	0.22
EINO	-0.583	0.56	11	-0.01	0.23
GL	0.095	0.924	11	0	0.24
FDI	4.634	0.000**	11	0.07	0.28
PDT	1.37	0.171	11	0.02	0.29

4.3. Stationarity Testing

In this paper, the stationarity of the panel data is checked using CIPS test since it is used to test for

the existence of unit roots on the variables. The findings of the study are presented in detail in table 4.

Table 4: *CIPS Unit Root Test Results*

Summary of CIPS Unit Root Test Results:

Variable	CIPS Statistic	10% Critical Value	5% Critical Value	1% Critical Value	Stationarity-Status
log_LCF	-2.409	-2.07	-2.17	-2.34	at 5%
HUC	-2.277	-2.07	-2.17	-2.34	at 5%
GF	-2.931	-2.07	-2.17	-2.34	at 1%
GG	-2.686	-2.07	-2.17	-2.34	at 1%
EG	-2.45	-2.07	-2.17	-2.34	at 5%
GEN	-2.069	-2.07	-2.17	-2.34	Non-
ET	-2.423	-2.07	-2.17	-2.34	at 5%
EINO	-2.869	-2.07	-2.17	-2.34	at 1%
GL	-2.225	-2.07	-2.17	-2.34	at 5%
FDI	-2.912	-2.07	-2.17	-2.34	at 1%
PDT	-2.094	-2.07	-2.17	-2.34	at 10%

The results suggest that all but one variable, LCF, HUC, GF, GG and ET are stationary at the first difference. This meets the econometric modeling with strong conditions and ensures that it is not a spurious regression. Green Energy has also proven to be non-stationary to enable its inclusion in cointegration analysis after passing through other transformations. These results are similar (Dai et al., 2024) who noted that stationarity pre-testing is crucial when working on sustainability research.

4.4. Regression Analysis

The first regression model established was two step difference (GMM) estimations which are appropriate for dynamic Panel data analysis controlling for endogeneity and unobserved individual effects. Estimates of the Load Capacity Factor regression is presented in Table 5, which gives understanding about the guidance and significance of the independent variables. Table 5 provides the two-step system GMM estimates that control for lagged effects and resolve potential endogeneity. There are positive and significant impacts on LCF from GG ($\beta = 0.204$, $p < 0.01$), GEN ($\beta = 0.09$, $p < 0.01$), and ET ($\beta = 0.282$, $p < 0.01$), along with GF ($\beta = 0.367$, $p < 0.05$) being significant and positive. HUC and EINO remain statistically insignificant. These findings are consistent with new research focusing on and support the work of utilizing fiscal and renewable energy policies to mitigate pressures on the environmental carrying capacity (Sabbaghi, 2024; Y. Zhang, 2024).

Table 5: *GMM Results*

log_LCF	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
HUC	0.098	0.231	0.42	0.674	-0.358	0.553	
GF	0.367	0.159	2.31	0.021	0.055	0.679	**
GG	0.204	0.045	4.51	0	0.115	0.293	***
EG	-1.348	1.421	-0.95	0.343	-4.143	1.447	
GEN	0.09	0.017	5.33	0	0.057	0.123	***
ET	0.282	0.036	7.95	0	0.213	0.352	***
EINO	-0.084	0.095	-0.88	0.377	-0.27	0.103	
GL	0.07	0.136	0.51	0.609	-0.198	0.337	
FDI	-0.013	0.009	-1.47	0.142	-0.031	0.004	
PDT	-0.107	0.01	-11.07	0	-0.126	-0.088	***
Constant	0.113	0.544	0.21	0.835	-0.957	1.183	

*** $p<.01$, ** $p<.05$, * $p<.1$

4.4.1. Moderation Analysis

The moderation test outcomes are reported in Table 6, and there are interaction effects for independent variables that may potentially modify their effects on the Load Capacity Factor. The value of the coefficient, standard-errors t-values, p-values, and confidence intervals indicate whether a relationship exists between any variable, and/or a moderation effect, and at what level it may be statistically significant. The moderation results (Table 6) show that ET significantly moderated the GF-LCF relationship (interaction β = -0.521, $p < 0.05$) indicating that too high of an environmental tax, may offset the advantages of green financing. The moderation effect, indicates a thoughtful fiscal approach is needed to promote alternatives to innovation rather than discourage them (Bilal & Shaheen, 2024).

Table 6: *Moderation Analysis*

GMM Results				
Variable	**Coefficient (β)**	**Std. Error**	**z-value**	**p-value**
Load Capacity Factor (L1)	0.328	0.307	1.07	0.286
Human Capital (HUC)	-0.136	0.289	-0.47	0.638
Green Finance (GF)	-0.086	0.049	-1.75	0.081
Green Growth (GG)	0.025	0.04	0.62	0.533
Green Energy (GEN)	0.056	0.071	0.78	0.434

4.4.2. Model Coefficients and Interpretation

The Lag 1 coefficient value for LCF is found to be 0.3277; its respective p-value is 0.286, which indicates that LCF of the preceding period is not significant in influencing LCF of the period. This finding may reflect the system's dependence on other drivers rather than the lagged values of LCF and agrees with some research works in this area where strong emphasis is laid on external factors (Dai et al., 2024). The coefficient for Green Finance is -0.0858 with p-value of 0.081, which indicates a marginally negative effect on LCF. Since the p-value is close to the 10% significance level, it is not statistically significant at the conventional 5% level. This indicates that Green Finance would indeed impact some of the sustainability metrics, though in this model, the Load Capacity Factors could not be proved. The ability of adopters and users of green technology

is significantly impacted by economic development and literacy levels (Khan et al., 2025). The coefficient for Green Growth is 0.0251 (p = 0.533), suggesting that it doesn't have any statistically significant influence on the Load Capacity Factor. Using adjusted net savings as a proxy for Green Growth does not appear to have direct impacts on LCF in this model. It agrees with some of the literature that recommended a more direct policy intervention toward linking Green Growth with energy outcome (Sichone-Phiri & Zangewa, 2020).

Conclusion

This Study investigates the relations between the most salient factors of sustainability, namely, human capital, green finance, green growth, economic globalization, and green energy, in influence on load capacity factor. Findings These results have far-reaching implications on the broader understanding of how such variables impact the efficiency of an energy system, especially within the context of the achievement of the SDGs with a focus, of course on SDG 3: Good Health and Well Being. This study shows that although such factors do not significantly affect the short-term values of LCF, their cumulative effect over long periods is decisive in the performance upgrading by the energy systems and attainment of more general health and environmental objectives. The results indicate that the three variables, Green Finance, Human Capital, and Green Growth, are more pertinent to the sustainability and transition of energy. Their impact on LCF is bound to be realized in the long term. Green Finance shows an important role in the facilitation of the transition to RE resources and, thus, shall improve LCF in the long run. Development of human capital through education and training in the field of RE would be crucial for helping the innovation in the system to grow in efficiency over time. Green Growth, integrating economic development with a harmonious relation with the environment, would need to be important enough to ensure growth in the economy without threatening the health of the public or degrading environmental quality.

Conflict of Interest

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