Does Income Inequality Matter in Nexus of Green Finance and Environmental Quality? An SEM Analysis Approach

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This study used the Structural Equation Modeling approach to investigate the relationships among Green Finance, Renewable Energy Consumption, Ecological Footprint, and Income Inequality. Data from the years 2001 to 2022 of a total of 126 countries globally were analyzed using Structural Equation Modeling approach. The objective was to examine the impact of Green Finance on Ecological directly and through mediation of Income Inequality indirectly. This study's results demonstrate crucial links that exist between sustainable finance, environmental sustainability, and socioeconomic inequalities. These results point towards the importance of socioeconomic development for these factors. Moreover, Green Finance exhibited potential for alleviating the Ecological Footprint syndrome, and Renewable Energy induced differential effects on ecological degradation as well as Income Inequality. Economic Development and Urbanization as control variables have significant and insignificant positive effect respectively on Ecological Footprint. The policy recommendations as proposed covered a range of strategies for dealing with environmental and social issues. This will involve promoting green finance ventures, enabling renewable energy infrastructure expenditures and investments, supporting sustainable urbanization measures, as well as enhancing public awareness of the interdependence between environmental and social factors. Incorporating these suggestions into policy frameworks would mean stakeholders could contribute towards achieving harmony in terms of environmental sustainability and socioeconomic equity.

1. Introduction

Finance is now a critical tool, along with promoting responsible environmental behavior and economic well-being, of pursuing sustainable development. Prior to this, finance was seen as important in securing the future from an endowment perspective (Brandi et al., 2020). As well as Li et al. (2019a) and Nouira et al. (2016) also have investigated the same phenomenon. Green finance is also another concept at the heart of that transformation as it refers to various financial mechanisms aimed at facilitating environmentally favorable projects. Appearing as the promise of an economic development and ecological preservation nodal point, this phenomenon represents a very welcome sign, which announces optimism for a more sustainable or just world.

Therefore, the present paper has attempted to unravel the intricate relations among green finance, income inequality, and ecological footprint in a manner that would offer readers of this work an overview of these dynamics. While the world is facing many urgent environmental challenges, green finance has emerged as a ray of light in showing us how sustainability can be realized through revolutionary means. Mehroush et al. (2024) emphasized the use green energy and green finance for sustainable development.

The extraordinary capacity of this research finding to motivate the authorities in developing green policies, to diminish carbon dioxide emissions and also achieve sustainable development goals has captured the attention of both academics and practitioners. Finally, even though the relevance of such a financial instrument in terms of environmental quality is becoming more and more important as time goes by, there is lack of accurate information on the real impact and this suggests further research about this phenomenon.

IEA (2017) demonstrates the core of green finance is the future it offers towards a greener and sustainable populated indicated in. The impact of ESG goes beyond just driving investments in renewable energy projects to also influencing sustainable business practices across a diverse range of sectors within the economy. Green finance alongside renewable energy and political stability is key actor in achieving SDG 13 by combating carbon emissions (Behera et al., 2024). However, more detailed analysis of the complex connection between green finance and environmental sustainability reveals a much richer and paradoxical view than this broad conclusion might suggest. It is these complexities that warrant further examination by researchers.

While the capacity of green finance to revolutionize environmental sustainability is well known, its effects on income inequality are a matter of debate and discussion. The above studies raise hopes that green finance could contribute to lessen income inequalities (Del Río González, 2009), and it seems there is little solid proof for this claim. This is an imperative linkage that must be understood since the relationship between green finance and income distribution can show how it affects overall wealth redistribution. The association between income distribution and ecological footprint is now one of the most popular lines for research, illustrating overall global trends related to issues such as social justice and sustainability.

While the relationship between income inequality and environmental is a contentious one, a different argument states that there is a positive correlation, as advocated in Torras and Boyce's

(1998) quotation given earlier. Cho (2023) and Çatık et al. (2024) advocated in favor of strong relationship between income inequality and environmental sustainability. Others, however, point to the importance of a more differentiated view that considers the complex interaction between socio-economic conditions and measures regarding their possible success. Given this context, the present paper seeks to explore the intricate nexus between green finance, income inequality and ecological footprint. Therefore, the main objective of this study is to investigate interdependencies among these variables and their influences on sustainable development objectives. Using this as a basis, the research will test these hypotheses through an extensive literature review and empirical analysis to offer valuable insights into the mediating dynamics.

This ambitious work has many implications for global policy, with its inclusive approach to all stakeholders and beyond mere academic interest. The aim of this study is to examine the complex relatedness between green finance, income inequality and ecological footprint. In doing so, the aim of the publication is to offer policy-makers actionable recommendations for equitable and sustainable development. Furthermore, the research results contribute toward providing useful insight into one of the ongoing debates on green finance. Another study shared illuminating views make people able to understand and explore the dynamics between environmental responsibility and economic fairness. This paper is the result of a deep inquiry into how we can work together to co-create a future that is sustainable, regenerative, and just. Our goal, in promoting collaboration and supporting an interdisciplinary approach, is to illuminate the potential of green finance to support change while improving lives and enabling future generations to thrive on a healthy planet.

2. Literature Review

2.1 Green Finance and Ecological Footprint Nexus

Evidence highlighting green finance's role in environmental sustainability as well as economic development goals. This aspect has been supported by a range of studies, which emphasized the significance of the discussed issue as an argument for environmental-oriented regulations and CO2 emissions lowering to advance sustainable development goals (Mehroush et al., 2024; Brandi et al., 2020; Nouira et al., 2016). Afzal et al. (2024) supported the argument relating to strong negative impact of green finance investment on ecological footprint. Various financial instruments exist within green finance, such as green bonds and equity and investment funds. They all have an essential function in promoting sustainable projects. As reported by the IEA in 2017, this solution could potentially decrease the volume of CO2 emissions by about 12.4% and reduce fossil fuel consumption by around 26%.

At the same time, it encourages these efforts to be funded by private sector investment. Apart from that, insufficient attention has been paid to the relationship between green finance and environmental sustainability. Thus, more research is required to understand the impact of it on environmental quality in a holistic manner. This in turn will enable the stakeholders, which may include organizations or governments, to use green finance as a way of ensuring environmental concerns are factored in their strategies while keeping the environmental risks at bay (Del Río González, 2009).

Finally, recent research results evidence that applying green finance has a positive influence on the development of the green economy and a decrease in CO_2 emissions as well., etc., as demonstrated by the above-cited examples provided by Li et al. (2019b), Sachs et al. (2019) and Dikau et al. (2018). Bilal & Shaheen (2024) argue that ecological degradation may be lowered by investment in green finance through encouraging the consumption of renewable energy. The significant association between the afore-mentioned eco-friendly private investment and the reduction of CO_2 emissions was found in research conducted by Azhgaliyeva et al., 2018.

Referring to this, Alexander & Delabre (2019) emphasized green finance as an important tool supporting the attainment of the targets from both the Paris Agreement and Sustainable Development Goals. As evidenced in this work, the domain of green finance is one that is inherently linked to sustainable economic ventures. As Wang et al. (2021), emphasize, this is one of the vital tools helping invest in advanced technologies and ensure environmental quality. According to recent research by Saeed Meo and Karim (2021), there is an indirect positive influence of GF with environmental sustainability. At the same time, Guild (2020) conducted his study in Indonesia and found that there was a close relationship between green finance and sustainability. Recently, Wang and Zhi (2016) demonstrated in a study, the link between GF and environmental degradation is negative.

The current study primarily concentrates on funding measures to uphold socially desirable ventures in general and environmentally oriented projects chargeable with the obligation or liability of emission control & depletion in more particular (Chi & Yang, 2023; Jahanger et al., 2023). This research paper also reports encouraging benefits of renewable energy projects such as these contribute in decreasing carbon emissions and dependence on the non-renewable sources besides other advantages reported by Meo and Karim (2022). More recent research has shown the increasing significance of analyzing company environmental performance, especially in financing (Al Mamun et al., 2022; Sharif et al., 2022; Wu & Liu, 2023). It has been found from recent research that green finance policies have a remarkable impact on reducing industrial emissions and stimulating investment in environmental protection.

Green bonds have the ability to finance the transfer to a low-carbon economy and offer steadfast support for ongoing, long-term infrastructure initiatives in a given country. Sartzetakis, (2021) and Shen et al. (2021). emphasized the importance of green finance, financial development and energy consumption in reducing carbon emissions and achieving sustainable development; all these will create high-quality work for people involved in farming as this sector also implies farm-to-fork products. According to research by Khan et al. (2022), a substantial decrease in the negative effects on the environment is possible thanks to a fairly broad understanding of green finance. This claim is also supported by evidence from some scholars including Afzal et al. (2024), Al Mamun et al. (2022) and Meo & Karim (2022). Despite this, it is essential to mention that there exist situations when green finance has no effect or even an adverse one. According to the study of

Wang and Zhi (2016), green finance is crucial for adequately dealing with environmental hazards and ensuring resources remain matched with economic expansion. Hence, according to the last publication given by Adenle, the Paris climate conference (COP21) reiterated the need for green finance not just in terms of encouraging renewable energy but ensuring sustainable development.

Various ways of thinking have been used in previous studies to study the effect of green finance on environmental quality. Zhou et al. (2020), investigated the effect of the "green finance development index" in China. Their discovery showed that green finance was very important in driving and achieving the environmental impacts. In a recent study by Li et al. (2022), a panel data analysis has been done with the time period of 1990 to 2020 and multiple countries. In this way, our results contribute to the understanding of green financing in terms of how well it can address environmental degeneration. Given the above analysis, it is inconsequential emphasizing how critical green finance is in ensuring environmental sustainability and reducing degradation. Although the relationship with environmental quality is complex, empirical evidence suggests that these impacts are positive. The deployment of green finance strategies benefits stakeholders that strive to upgrade and support sustainable development. More research is needed to better understand the dynamics of green finance and how it affects environmental quality.

H_1: Green Finance is negatively related to Ecological Footprint

2.2 Green Finance and Income Inequality Nexus

The relationship between green finance and income inequality is gaining increased attention. A lot of studies have explored the linkage between income inequality and environmental quality, while little has been done about how green finance affects income inequality. This current literature review, therefore, undoubtedly represents a comprehensive look at the existing research and suggests promising new lines of future inquiry. Based on recent research by Topcu and Tugcu (2020), the findings showed that renewable energy production has largely reduced income inequality in developed countries. The results reveal that a 1% increase in renewable energy capacity ownership leads to income inequality decreasing by 0.02%. For example, in Apergis's 2015 study of the issue, "the results are unaltered to find an effect of only 0.01% arising from renewable penetration on income inequality," denoting that the resulting values were correlating as well.

Evidence to the contrary can also be found in an investigation by Tugcu and Topcu (2018), which managed to establish a significant and positive relationship between renewable energy consumption as one of our main indicators on income inequality across OECD countries. According to a study, no positive impacts were found. The study by Ocetkiewicz et al. (2017) found that renewable energy production did not have any significant effect on income inequality among European countries. In India, Reddy and Balachandra (2006) has done research in line with the current research findings. Finally, there are studies confirming an association between income inequality and other factors such as economic growth, the rate of employment in various sectors, or even the carbon price. Renewable energy production can have a positive effect on growth. In fact, several studies demonstrate this concept. This claim is supported by Apergis (2015) as well. Moreover, other researchers including Heavner and Del Chiaro (2003) and Hillebrand et al. (2006) also show that renewable energy leads to job opportunities for establishing new renewable resources, thus the resultant effect of an increase in unemployment by other sources would be negated. According to Kammen et al. (2004), the clean energy industry is providing an enormous amount of job opportunities. The potential for carbon pricing to increase income inequality was also found by Parry and Williams (2010) in a scholarly draft for research publication. However, Grunewald et al. (2017) presented a contrasting view, suggesting that the revenue generated from carbon pricing could be utilized to mitigate income inequality through the implementation of targeted social policies.

Substantial research has also taken place in the context of income inequality's association with green or renewable energy finance. However, the available literature still lacks in examining whether green finance dampens income inequality. Our goal with this review was to change that. There are several relevant limitations in the present research. What is quite common across many of the research publications on the effect of renewable energy on income inequality, is a focus often diverted from other important aspects such as green bonds and carbon pricing. As well, most of the previous studies mainly rely on aggregate data and often overlook the possible impacts on different income classes. It is safe to say that despite these limitations, there exists adequate evidence suggesting that green finance has the ability to attenuate income inequality. Further work is needed to examine how other modes of green finance affect income distribution. Studying the effects on different income groups will also be a critical component that can only be done with disaggregated data.

H_2: Green Finance is negatively related to Income Inequality

2.3 Income Inequality and Ecological Footprint Nexus

Very much of a focus was on the correlation between income inequality and ecological footprint, since previous research has explained how income distribution affects environmental degradation. Although initiated by Boyce (1994), who found different levels of radiation at the bottom and top of the Var valley, the research has thus far not resulted in any firm conclusion. The interpretation that stands at the center of this controversy revolves around inequality and how it affects environmental quality. To some, this amounts to saying that inequality can be a way of safeguarding our environmental resources. However, others argue that inequality may also have an unintended consequence on the environment.

Study by Torras and Boyce (1998), proposes that the fair distribution of income leads to better preservation of the environment. By contrast, the Environmental Kuznets Curve (EKC) posits that with rising income levels there should be a reduction in its environmental degradation. Meanwhile, when writing a scholarly draft for research publication, Magnani (2000) offers one counter-argumentation to the EKC was that environmental preservation is determined by two effects, the absolute and relative ones. Study of Çatık et al. (2024) finds the strong impact of income distribution on environmental quality. Indeed, as in terms of writing scientific articles authors often include such points in their drafts. A study by Eriksson and Persson (2003) reveal that the effect of income inequality on ecology depends on how strong democracy is. Interestingly, for robust democracies, the research showed a falling in equality resulted in less pollution as well.

In fact, in weaker democracies, a reduction of inequality is even associated with increasing pollution levels. Baek and Gweisah (2013) enter a scholarly draft for a research publication with the proof focusing on exhibiting the connection between high income inequality, low each capital pay, and development in discharges. Similarly, Wu and Xie (2020) found that income inequality has a substantive influence on CO_2 emissions in OECD nations but not in non-OECD countries.

Kazemzadeh et al. (2021) conducted a recent study on this issue and found that there is a linear relationship between the income dispersion degree and the EF based on different quantiles. The papers released by Ravallion et al. (2000) reveals that controlling climate change, achieving equity and economic growth is all a matter of delicate balance. Regardless, there are some studies which question that claim of negative effect of inequality over the environment. A critical analysis of Boyce's (1998) hypothesis is presented in a scholarly draft for research publication by Scruggs (1998). Yang et al. (2020) finds the opposite result: that income inequality results in a decrease in degradation. Recent studies by You et al. (2020) and Uddin et al. (2020) demonstrate the variability of the income distribution-emission relationship in different contexts at distinct periods.

In a recent work from Chen et al. (2020), it was identified that lower income inequality makes a significant influence on reducing CO_2 emissions in developing economies. However, the researchers could not identify a similar trend in developed economies (Langnel et al., 2021). Various aspects of West African states according to Gulzar et al. (2020) and Papakonstantinidis (2017), the main motivation behind pollution in developing countries is poverty and inequality due to their reliance on fossil fuels as a source of energy. As previous studies have found, the consequences of environmental degradation are particularly relevant for developing countries. As an example, in the following research papers published by Kong and Khan (2019), as well as Ullah and Awan (2019) argue that increasing inequality within Asia is one of the major causes that stop reaching poverty reduction and environmental goals. According to Grottera et al. (2017) and Cho (2023), fair income distribution may positively impact environmental protection and poverty reduction.

In the final analysis, there is a coherent link between income inequality and the ecological footprint causing broad ramifications to the environment, well-being of human beings and economy. It is the task of policymakers to analyze their environmental policies' macroeconomic income distribution impact so as to derive longer-term sustainability gains. Additional research is needed to determine the existence of such a relationship in other environments and identify policy measures that can address it. The findings discussed above can thus be considered the basis for future research and investigation in this area.

H_3: Income Inequality is positively related to Ecological Footprint.

H_4: Income Inequality mediates the relationship between Green Finance and Ecological Footprint.

3. Data and Methodology

3.1 Data and Variables

This study uses a comprehensive panel data set comprising six variables across 126 countries over the period from 2001 to 2022. These variables are collected from reputable sources such as the World Bank's World Development Indicators (WDI), the International Renewable Energy Agency (IRENA), and the Global Footprint Network. In this study, the dependent variable is the Ecological Footprint (EFP), the independent or primary explanatory variable is Green Finance (GF), and the mediator variable is Income Inequality (II). Our study incorporates three control variables: Renewable Energy Consumption (REC), Economic Development (ED), and Urbanization (URB). Green Finance Support (GF2) has been incorporated to assess the resilience of the findings.

Table No 1: Variable Source and Description

Variables	Symbol	Unit	Source
Ecological Footprint	EFP	Ecological Footprint per capita	Global Footprint Network
Green Finance	GF	Public Investments (2021 million $) by Country/area, Technology and Year	IRENA
Income Inequality	II	Gini index	WDI
Economic Development	ED	GDP per capita (Constant $ 2015)	WDI
Urbanization	URB	Urban population (% of total population	WDI
Renewable Energy Consumption	REC	Renewable energy consumption % of total energy consumption	WDI

3.2 Methodology

3.2.1 Analytical Framework

This study argues that public investment in green finance plays a crucial role in promoting eco-friendly activities and mitigating environmental degradation. A focus on green finance promotes environmental sustainability and helps address income inequality, which is linked to a reduction in the ecological footprint. As a result, income inequality has a significant impact in this particular context.

Figure 1 demonstrates the relationship between green finance (X), ecological footprint (Y), and income inequality (M). This study aims to investigate the potential indirect impact of green finance on the ecological footprint by examining the role of income inequality as a mediating factor. Within this framework of sustainable finance and ecology, the inclusion of a third variable in the original X → Y relationship allows for a deeper understanding of the connection or the identification of any potential spurious links. Mediation analysis, as explained by Judd and Kenny (1981), adds value to a study by investigating the mediating process. In this analysis, it is observed that there is a causal sequence from green finance to income inequality to ecological footprint. This suggests that green finance has an impact on income inequality, which subsequently affects the ecological footprint.

Figure No 1: Mediation Modelling of Green Finance, Income Inequality, and Ecological Footprint. Source: Authors' Construction

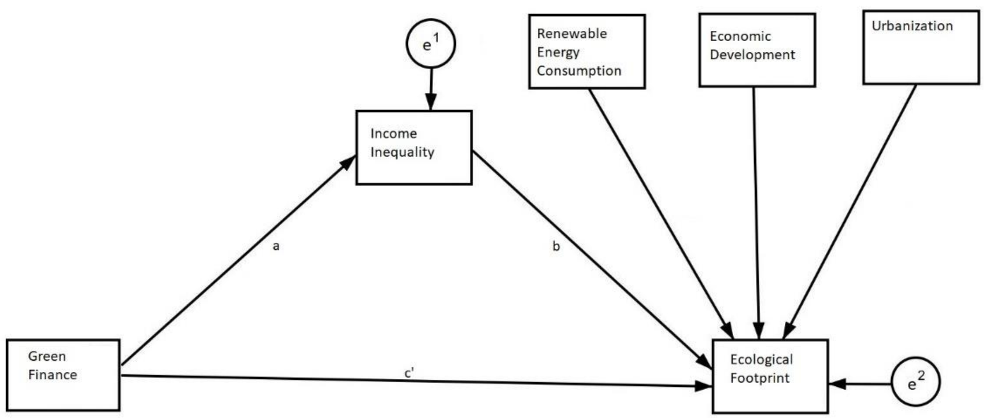

Figure 1 utilizes established notation in mediation modeling, as described by previous research (MacKinnon et al., 2007; Kenny et al., 1998; Baron & Kenny, 1986). In this framework, a denotes the connection between green finance and income inequality, b represents the association between income inequality and the ecological footprint adjusted for green finance, and c′ signifies the relationship between green finance and the ecological footprint adjusted for income inequality. The residuals in the income inequality and ecological footprint models are represented by e1 and e2, respectively. The equations and coefficients pertaining to Fig. 1 are extensively discussed in the "Empirical models" section. Our study examines the impact of green finance on the ecological footprint, considering both direct and indirect effects through income inequality.

3.2.2 Empirical Models

For the first time, to our best knowledge, we also investigate green finance and direct as well as indirect effects via income inequality into the ecological footprint. Use of Empirical models: Based on the study, a mediation hypothesis is proposed that examines how green finance acts as an independent variable while intervening in the relationship between ecological footprint and different variables. The purpose of the current research was to evaluate the mediational effect of green finance on the relationship between it and ecological footprint. Researchers engaged in the statistical mediation field have distinguished three main approaches. These approaches are the causal steps, the difference in coefficients and the computation of product of coefficients (MacKinnon et al., 2007). In accordance with the study conducted by Pei et al (2022), we outline three models:

$$EFP_{it} = \psi_0 + \psi_1 GF_{it} + \psi_2 Z_{it} + \gamma_t + e_{it} \quad (1)$$

$$II_{it} = \eta_0 + \eta_1 GF_{it} + \eta_2 Z_{it} + \gamma_t + \tau_{it} \quad (2)$$

$$EFP_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_2 II_{it} + \alpha_3 Z_{it} + \gamma_t + v_{it} \quad (3)$$

Within the three empirical models discussed, equations (1) and (3) hold significant influence over the ecological footprint, while equation (2) serves as the determining factor for income inequality. The intercepts $\psi0$, $\eta0$, and $\alpha0$ come into play. The role of these intercepts is crucial for these equations to work out conveniently. The above study analyzes the association among ecological footprint per capita, and public outlay in inclusion of green financial system whereas modification is intrigued within mediation Gini coefficient beside different confounding factors. In addition, the study includes time fixed effects (γt) and random disturbances (eit, τit, vit). Where $\sum$ is the relationship between green finance and ecological footprint represented by $\psi1$.

Similarly, the coefficient $\alpha1$ in Eq. (3) takes into account the mediator when examining the relationship between green finance and ecological footprint. Additionally, $\alpha2$ represents the coefficient that considers the mediator's impact on ecological footprint, adjusted for green finance. Lastly, $\eta1$ in Eq. (2) signifies the coefficient that relates green finance to the mediator, specifically income inequality. The paths of c’, a, and b are shown in Figure 1 by the equations (1), (2), and (3):

In Equation (1), the coefficient represents the overall effect of Green Finance on Ecological Footprint. Whereas, the coefficient $\alpha1$ shows direct effects which originated from green finance toward an ecological footprint when it is coupled with income inequality. Mediation could be computed utilizing the production coefficient methodology, which equals $\eta1 * \alpha2$. Alternatively, the total effect is the addition of the mediation in the direct effect (i.e., $\psi1 =(\eta1 * \alpha2) + \alpha1$).

3.2.3 Analytical Approach

Structural equation modelling (SEM) framework is used to achieve the aims of the study. SEM has been a popular technique in the social, behavioral, and economic sciences to determine linear associations between variables. Several sources provide detailed explanations and alternative ways of considering SEM, like Satorra (1990) and Mackinnon et al. (2007), among others. Alternatively, the mediation modelling method analyses the interaction or interplay between the explanatory variable (X) and outcome variable (Hayes et al. 2013; Baron and Kenny 1986). In their study, Hojnik et al. (2018) provide an explanation that the mediation equations hint at such an important intervening mechanism. For this specific instance, the intermediary mechanism is income inequality as it plays a mediating role between the explanatory variable (green finance) and the explained variable (ecological footprint). Hence, the mediator variable, income inequality, is considered significant to mediate a large part of the relationship between the predictor green finance and the outcome ecological footprint.

Given this information, data is then analyzed through Stata version 18 using the structural equation SEM routine. SEM has been chosen due to its ability to produce reliable mediation effects estimates, which Cheung and Lau (2008) have already sufficiently demonstrated. The procedure has been conducted in separate steps. This approach has been adopted in the light of the recommendations of Anderson and Gerbing (1988).

The structural model proposed in this study to access the possible relationship between non-renewable energy and carbon emissions is shown in Eq. 2. Moreover, the regression model is considered to evaluate the robustness of the alleged connection (Eq. 3). In addition, given the non-normal distribution of the data, an approach using the Satorra-Bentler robust standard error technique (Satorra, 1990) is required to examine mediation (i.e., indirect effect). This approach aligns with the requirements for valid parameter estimates—fitting the model, sampling variability of the fitted values and parameters of interest, and hence the null distribution of test statistics. This evaluation will finally decide on the suitability of both models.

Three critical fit indices for evaluating data/model compatibility in structural equation modelling analyses are the Tucker–Lewis index (Bentler and Bonett, 1980; Tucker and Lewis 1973), comparative fit index (Bentler, 1990), and root mean square error of approximation (Steiger 1990). RMSEA is an absolute fit index as it assesses the difference between a pre-specified model and a saturated fully optimal empirical model. In contrast, CFI and TLI are fit indices that measure the incremental improvement of a hypothesized model compared to a baseline model, which represents the worst fit.

4. Results and Discussions

This section provides empirical findings that address important gaps in the health-energy literature in Asia and the Pacific. This study investigates the potential relationship between green finance, income inequality and ecological footprint. Additionally, it aims to determine if this relationship differs among different income groups. The estimations begin with the presentation of descriptive statistics and correlations among the study variables followed by structural and regression models in Table 4. This is followed by the analysis of effect decomposition in Table 5, and the examination of diagnostics in Tables 6 and 7. Table 8 provides a comprehensive summary of the hypotheses validation. Robustness results are available upon request.

Based on initial assumptions, it is anticipated that green finance will have an uneven impact on the ecological footprint. If the use of green finance continues to rise, it may have a positive impact. However, it is important to consider the potential consequences such as increased income inequality and ecological degradation. Nevertheless, the utilization of green finance to address lower income inequality has a detrimental effect on reducing ecological footprint. It is anticipated that there will be a positive impact on ecological footprint due to income inequality, as higher levels of income inequality pose a risk to environmental sustainability. The statements are supported by the literature, as discussed in the section on "Literature review and hypothesis development." Renewable energy is a catalyst for positive change, as the more we embrace its consumption, the less harm we inflict on the environment. Therefore, it is anticipated that the ecological footprint will decrease as awareness and emphasis on the use of renewable energy increase. Similarly, it is anticipated that the combination of population density and environmental regulations will lead to a decrease in environmental degradation.

Table No 2: Summary Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
EFP	2,772	3.441717	3.314961	0.272523	43.71318
II	2,772	38.00047	8.157118	23.2	64.8
GF	2,772	101.2005	411.4762	0	11966.86
REC	2,772	34.82696	27.86419	0	95.35
ED	2,772	13038	18825.57	255.1003	112417.9
URB	2,772	57.02676	23.40178	8.461	100

Table 2 presents a comprehensive summary of the variables in the dataset. The Ecological Footprint (EFP) has an average of 3.44 and a standard deviation of 3.31, suggesting significant variability. The measure of Income Inequality (II) indicates an average score of 38.00 and a standard deviation of 8.16, which indicates a wide range of income distribution. Green Finance (GF) has a mean score of 101.20 and a large standard deviation of 411.48, indicating a broad involvement in green financial operations. The average Renewable Energy Consumption (REC) is 34.83, with a standard deviation of 27.86, indicating a diverse range of dependence on renewable energy.

The Economic Development (ED) variable has a mean value of 13038 and a substantial standard deviation of 18825.57, indicating a significant level of economic variety. The Urbanization (URB) index has an average value of 57.03 and a standard deviation of 23.40, suggesting variations in urban development levels among countries. These figures illustrate the diversity of the sample and provide important reference points for further research or policy interventions targeting environmental sustainability and socioeconomic disparities.

Table No 3: Correlation Analysis

	lnEFP	lnII	lnGF	lnREC	lnED	lnURB
lnEFP	1					
lnII	-0.2754	1				
lnGF	0.1869	-0.1333	1			
lnREC	-0.4685	0.3043	-0.0605	1		
lnED	0.8367	-0.2636	0.2549	-0.5053	1	
lnURB	-0.04	-0.1353	-0.0249	-0.0302	-0.0751	1

Table 3 presents the correlations among all the variables. The relationship between the Ecological Footprint (lnEFP) and Income Inequality (lnII) is weak and negative (-0.2754), meaning that higher income inequality might slightly reduce the ecological footprint. There is a weak positive relationship (0.1869) between lnEFP and Green Finance (lnGF), indicating that greater involvement in green finance might slightly increase the ecological footprint. The study concludes that there is a moderate negative correlation (-0.4685) between lnEFP and Renewable Energy Consumption (lnREC), suggesting that an increase in renewable energy usage will lead to a decrease in the ecological footprint.

There is a notable and significant positive relationship (0.8367) between lnEFP and Economic Development (lnED), indicating that as economic development increases, so does the ecological footprint. This demonstrates the environmental consequences of economic growth. The correlations between Urbanization (lnURB) and other variables are relatively weak and negative, suggesting that there may not be a strong direct relationship between urbanization and these variables. In general, the correlation matrix offers valuable insights into the relationships between variables, indicating potential avenues for further analysis within the framework of structural equation modeling.

Table No 4: SEM Empirical Results

		Coef	std. err.	z	P>z	[95% conf. intrvl]	
Structural							
lnII							
	lnGF	-0.0086	0.0015	-5.54	0.000	-0.0117	-0.0056
	_cons	3.6537	0.0061	590.9	0.000	3.6416	3.6658
lnEFP							
	lnII	-0.1839	0.0515	-3.57	0.000	-0.2849	0.0829
	lnGF	-0.0067	0.0032	-2.06	0.039	-0.0130	0.0003
	lnREC	-0.0308	0.0104	-2.94	0.003	-0.0513	0.0102
	lnED	0.46196	0.00914	50.53	0.000	0.4440	0.4798
	lnURB	0.020005	0.02276	0.88	0.380	-0.0246	0.0646
	_cons	-2.30499	0.24653	-9.35	0.000	-2.7881	-1.8218
	var(e.lnII)	0.041536	0.00142			0.0388	0.0444
	var(e.lnEFP)	0.164775	0.00565			0.1540	0.1762
Log likelihood = -11115.412							
LR test of model vs. saturated: chi2(3) = 217.16				Prob > chi2 = 0.0000			

4.1 Main Mediation Analysis

The SEM regression results in Table 4 reveal substantial relationships between variables. There is a negative association between higher levels of Green Finance (lnGF) and income inequality (lnII), as indicated by a coefficient of -0.0086613 ($p < 0.001$). The Ecological Footprint (lnEFP) model shows that higher income inequality (lnII) is linked to a decrease in ecological footprint (coefficient: -0.1839195, $p < 0.05$). Additionally, increased participation in green finance activities (lnGF) and higher consumption of renewable energy (lnREC) are both associated with a reduction in ecological footprint (coefficients: -0.0066966, $p < 0.05$ and -0.030797, $p < 0.01$, respectively). In contrast, there is a strong positive relationship between economic development (lnED) and ecological footprint (coefficient: 0.4619602, $p < 0.001$), indicating that economic expansion has major environmental effects.

The variable of urbanization (lnURB) does not demonstrate a statistically significant direct impact on the ecological footprint ($p > 0.05$). Variance in error terms represents the unexplained variation in endogenous variables, which is valuable for evaluating the adequacy of the model and finding potential areas for enhancement. The SEM findings offer valuable insights into the intricate interplay among economic, environmental, and social issues, hence deepening our comprehension of how variables impact income inequality and ecological footprint within the research framework.

4.2 Direct and Mediation Effects

An overview of total direct and indirect effects observed in the structural equation model can be found in Table 5. The study has uncovered an interesting finding: taking part in green finance activities causes income inequality to decrease. Furthermore, the analysis shows a negative direct effect of Green Finance (lnGF) on Income Inequality (lnII), and its estimated coefficient is equal to -0.0086613. From the results, all direct effects of Ecological Footprint (lnEFP), Income Inequality (lnII), Green Finance (lnGF), and Renewable Energy Consumption (lnREC) are highly significant in this study. The correlation between ecological footprint and income inequality is very strong, where there is an inverse proportional relationship between them, since a higher degree of income equality results in a reduction of ecological footprint.

Table No 5: Decomposition of Effects

		DV: lnEFP					
		Coefficient	**std. err.**	**z**	**P>z**	**[95% conf. intrvl]**	
Direct effects							
	lnGF	-0.0067	0.003244	-2.06	0.039	-0.01305	-0.00034
Indirect effects							
	lnGF	0.001593	0.000531	3	0.003	0.000553	0.002634
Total effects							
	lnGF	-0.0051	0.003247	-1.57	0.116	-0.01147	0.00126

On the other hand, actively participating in green finance activities and increasing renewable energy consumption have been found to be effective in reducing ecological footprints. It is worth mentioning that the relationship between lnGF and lnEFP is only marginally significant ($p = 0.039$), indicating a relatively weaker impact when compared to other variables. In addition, there is an observed indirect effect between the natural logarithm of Green Finance (lnGF) and the natural logarithm of Ecological Footprint (lnEFP), which is mediated through the natural logarithm of Income Inequality (lnII). This suggests that a portion of Green Finance's impact on Ecological Footprint is influenced by its effect on Income Inequality. The coefficient for this indirect effect is 0.001593, with a p-value of 0.003. Therefore, participation in green finance activities can potentially impact ecological footprint by influencing the distribution of income.

A structural equation model (SEM) is an approach that accounts for the overall impact of all factors, including indirect and direct pathways (Adeleye et al., 2023; Salam et al. 2023). The total effect of lnGF on lnII is equivalent to its direct effect, since there are no indirect effects connecting lnGF. While analyzing the Ecological Footprint (lnEFP), it is necessary to consider the impact of lnGF together with the combined influence derived from its direct effect and indirect consequence, mediated by lnII. From the analysis, it was learned that the relationship between lnGF and lnEFP is negative, but the overall effect is weak, with a coefficient of -0.0051036 and a p-value of 0.116. In summary, the results of this study stipulate important and comprehensive results for the inter-relationship among variables in the SEM model. This study proves that consideration of mediating effects is very imperative.

The model fit criteria proposed by Hu and Bentler (1999) are met: the RMSEA is less than 0.06, and both the CFI and TLI are greater than 0.95. Based on the findings of the study, it can be concluded that the majority of the variation in ecological footprint rate can be attributed to the regressors. In general, the models exhibit a strong fit, showing no notable deviations from the expected models. Through conducting robustness tests, it was observed that when the independent variable was replaced with support for green finance, the outcomes remained consistent.

Table No 6: Overall Goodness of Fit

Fit statistic	Value	P	Description
Likelihood ratio			
chi2_ms(3)	217.161	0.000	model vs. saturated
chi2_bs(9)	2326.031	0.000	baseline vs. saturated
RMSEA	0.019		
Comparative fit index (CFI)	0.952		
Tucker-Lewis index (TLI)	0.943		
Standardized root mean squared residual (SRMR)	0.019		
Coefficient of determination (CD)	0.916		
Wald test for lnII			
chi2	30.7	0.000	df: 1
Wald test for lnEFP			
chi2	4076.81	0.000	df: 5

The likelihood ratio tests reveal significant chi-square values (chi2_ms = 217.161, p = 0.000; chi2_bs = 2326.031, p = 0.000), indicating a significant deviation of the model from both the saturated model and the baseline model. The findings demonstrated in Table 6 indicate that the specified model offers a more accurate representation of the data when compared to models that do not incorporate relationships between variables. The observed data is effectively explained by the SEM, as indicated by the significant chi-square values. The RMSEA value of 0.019 indicates that the model exhibits a strong fit, as it is below the widely accepted threshold of 0.06 (Steiger 1990). The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values of 0.952 and 0.943, respectively, suggest a strong fit, surpassing the threshold of 0.90 (Bentler, 1990; Bentler and Bonett, 1980; Tucker and Lewis 1973).

The high Coefficient of Determination (CD) of 0.916 indicates that a significant portion, approximately 91.6%, of the variance in the model's outcome variables can be attributed to the predictors used in the model. This finding demonstrates a strong level of explanatory power. The results of the Wald test for lnII and lnEFP demonstrate the significance of the structural equations. The chi-square value of 30.7 with 1 degree of freedom and a p-value of 0.000 indicates a high level of significance for the structural equation of lnII. In a similar vein, the chi-square value of 4076.81 with 5 degrees of freedom and a p-value of 0.000 demonstrates the high significance of the structural equation for lnEFP.

Based on the fitness statistics, it can be concluded that the structural equation model is a suitable fit for the data and effectively represents the relationships between the variables in the model.

Table No 7: Equation-Level Goodness

Dependent Variables	Fitted	Variance Predicted	Residual	R-squared	mc	mc2
Observed						
lnII	0.042287	0.000751	0.041536	0.01776	0.133265	0.01776
lnEFP	0.549016	0.384242	0.164775	0.699873	0.836584	0.699873
Overall				0.703522		

The statistics presented in Table 7 offer valuable insights into the ability of the Structural Equation Model (SEM) to explain the variance in Income Inequality (lnII) and Ecological Footprint (lnEFP). In the research publication, the model demonstrates a moderate level of explanation for lnII, as indicated by a low predicted variance that highlights differences between the predicted and observed values. On the other hand, the model proposed by lnEFP provides a comprehensive explanation for a significant amount of variability, accurately predicting observed values and demonstrating a high level of explanatory capability. The Wald tests provide strong evidence of the significance of both equations, demonstrating the significant impact of the predictors in explaining lnII and lnEFP.

Table No 8: Hypotheses Validation

Hypotheses	Conclusion
H_1: Green Finance is negatively related to Ecological Footprint.	Sustained
H_2: Green Finance is negatively related to Income Inequality.	Sustained
H_3: Income Inequality is positively related to Ecological Footprint.	Rejected
H_4: Income Inequality mediates the relationship between Green Finance and Ecological Footprint.	Sustained

The explanations in Table 8 provide support for three out of four hypotheses, with the exception of Hypothesis 3 which was not supported. H_1 is supported that green finance affect the ecological footprint negatively. It means that investing in green finance lowers the ecological degradation. This result aligns with the findings of (Brandi et al., 2020; Li et al., 2019). H_2 is verified which is unique contribution of this study. This relationship is not comprehensively investigated in the extant literature. However, the findings align with the study results of by Topcu and Tugcu (2020). H_4 is also supported and this finding is also a significant contribution of the study because the mediating role of income inequality between the relationship of green finance and ecological footprint has never been investigated according to the knowledge of the authors of this study.

5. Conclusion

Using the structural equation modeling approach, this study has explored that green finance has significant impact on ecological footprint. It means that investment in green finance lowers the degradation of the environment. Income inequality has also impact on ecological footprint. The results show that income inequality has also the mediating role in the relationship between green finance and ecological footprint. Economic development as a control variable has also positive significant impact on ecological footprint. Added as a control variable in the study, urbanization has insignificant impact on ecological footprint.

The links between environmental sustainability and socioeconomic inequities reinforce the need for a holistic, systems-level approach to addressing this complex challenge. Recently, the link between economic development and its influence on the environment as well as income inequality has attracted greater attention. This underlines the pivotal role of economic policies and measures in determining both environmental and social conditions. Moreover, the research identified the possibility of green finance to alleviate ecological footprint; thus, it is essential for policymakers to encourage sustainable financial activities that reduce its impact on the environment. The in-depth analysis revealed the complicated links between variables like renewable energy consumption (REC) and urbanization (URB), observing that they have various effects on ecological footprint and income inequality dynamics. Comprehending these intricate dynamics is essential in order to create focused interventions that tackle particular issues concerning environmental sustainability and socioeconomic equity.

5.1 Policy Recommendations

Policy efforts should focus on initiatives that support environmentally sustainable investments and practices, especially in the field of green finance. These can include tax incentives for green investments, the issuance of green bonds or other innovative financing mechanisms to fund renewable energy initiatives, and cooperation between financial institutions and environmental organizations in directing funds towards sustainable development projects.

Policymakers need to embrace an integrated concept of outcomes with the inseparability of environmental and social issues. This involves environmental concerns being embedded in social policy, and conversely emancipatory policies to address income inequality also advancing environmental sustainability, which brings us back to the concept of socio-ecological transformation.

Given the critical role of renewable energy consumption in reducing their ecological footprint, it is essential that policy planners prioritize investments in the development of renewable energy infrastructure and technologies. These will include boosting the share of renewables, promoting the deployment of clean energy technologies, and phasing out present incentives for fossil fuels to aid in speeding up the transition to a carbon-neutral economy.

Urbanization presents a number of challenges and opportunities to meet environmental sustainability along with fostering social equity. It is, therefore, essential for policies acting as stimuli to promote strategies for sustainable urban growth through which compact and walkable communities facilitated by accessible green spaces, and public transport infrastructure are prioritized. Additionally, the prevention of further income inequality and more devastating effects on our ecosystems through urbanization also arises from creating plans addressing housing affordability and accessibility.

Education and awareness campaigns are essential in promoting a culture of environmental stewardship and social responsibility. Efforts to engage the public should focus on increasing understanding of the interdependence of environmental and social concerns, empowering individuals and communities to make sustainable choices, and encouraging the adoption of environmentally and socially conscious behaviors.

5.2 Limitations and Future Research Recommendations

The study's data is derived from a comprehensive analysis of 126 countries worldwide. The countries have been selected based on the availability of the data. In order to enhance the overall applicability of the findings, future researchers may consider utilizing a more extensive and diverse range of data. In addition, it is possible to conduct comparative studies on the same model using various classifications such as income level, geographical regions, economic groups, democracy level, and more. In addition, the most recent dataset can be utilized to examine the identical model, as the data utilized in this study encompasses up until 2022.

Upon careful examination, the modification indices have revealed promising opportunities for enhancement by exploring supplementary paths or relationships. Based on the modification indices, it is recommended to explore the potential relationships between Renewable Energy Consumption (lnREC), Economic Development (lnED), Urbanization (lnURB), and Income Inequality. The presence of moderate to high modification indices suggests that incorporating direct effects from these variables to lnII could enhance the overall model fit. In future research, addressing these suggestions could lead to a more comprehensive and nuanced understanding of the intricate relationship between income inequality, ecological footprint, renewable energy consumption, economic development, and urbanization within the same research context. The following recommendations can provide valuable guidance for further enhancing the accuracy and depth of SEM analysis, resulting in more comprehensive and enlightening findings regarding the various factors that impact income distribution and environmental consequences.

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