Universitatea Transilvania din Brașov

INTERDISCIPLINARY DOCTORAL SCHOOL

Faculty of Economic Sciences and Business Administration

Lai Van TAI

PhD THESIS

Scientific supervisor

Prof.Dr. MONICA RAILEANU SZELES

BRAȘOV, 2026

Lai Van TAI

PhD THESIS

Green economy, Poverty eradication and Sustainable economic development in Developing countries. Mediating role of Green Finance

Economie verde, eradicarea sărăciei și dezvoltare economică durabilă în țările în curs de dezvoltare: Rolul mediator al finanțelor verzi

Doctoral filed : Finance

Defence committee:

Prof.Dr. Raileanu Szeles Monica	Chair, Doctoral supervisor, Transilvania University of Brașov
Prof.Dr. Dincă Gheorghița	Committee member, Transilvania University of Brașov
Prof.Dr. Baba Mirela	Committee member, Transilvania University of Brașov
Prof.Dr. Le Thi Thanh Xuan	Referent official, HCMC University of Technology-VNU HCM
Assoc.Prof.Dr. Andronic Letiția	Referent official, Transilvania University of Brașov

CHAPTER 1: INTRODUCTION

Rationale of the research

In the context of increasing globalization and climate change, developing countries encounter dual problems: maintaining economic growth while ensuring environmental sustainability and social justice. Poverty remains one of the biggest challenges, especially in Low and Lower-middle-income countries, where environmental and economic shocks can exacerbate the vulnerability of the poor. The trade off between economic growth for social development may set back people into the trap of environmental poverty which is known as the Poverty – CO_2 paradox which headaches policymakers in almost all developing countries. In this context, the need to transform the traditional economic model into a new development model, an environmentally friendly economic model, has become more urgent than ever. One of the key pillars of the green transition is the development of green energy, including renewable energy sources. Although the role of renewable energy has been confirmed, the empirical evidence is inconsistent, especially in the context of developing countries, where high investment costs and institutional constraints can degrade the effectiveness of green energy policies.

Green finance has emerged as an important tool to solve the problem of resources for sustainable development. Through the mobilization and allocation of capital for environmentally friendly projects, green finance can promote green energy development, improve environmental quality, and create new livelihood opportunities for people. For developing countries, this issue has become even more urgent because they need to maintain economic growth to reduce both poverty and pressure of environmental degradation.

Many empirical studies have provided evidence of the positive impact of green finance and renewable energy on environmental quality. Although the potential role of green finance and renewable energy in the environment and society has been widely recognized, current research has mixed results, leading to serious debates and exposing many scientific gaps that need to be addressed. Besides, some scholars also warn that green finance can lead to greenwashing, where capital does not actually go into clean production but only serves visual purposes, resulting in poor economic efficiency and not really helping the poor. However, studies that combine the impact of finance and renewable energy on the environment and poverty have not comprehensively analysed the role of renewable energy; most focus on the consumption aspect, pay little attention to the production aspect, and there are no studies that combine both of these aspects. This absence is significant because energy production reflects technological capacity, investment, and industrial structures, while consumption reflects energy use behavior and efficiency. Failure to distinguish between these two aspects can lead to bias in estimation and to missing important mechanisms of action.

In addition, the relationship between environmental degradation and poverty in developing countries is one of the controversial topics in modern ecological economics. The majority of studies use CO_2 emissions as a proxy in research related to environmental degradation, while EF is being paid attention as an indicator that fully reflects the losses of ecosystems. Besides, the Pollution Haven Hypothesis suggests that economic restructuring to reduce EF in developing countries is often hampered by institutional weakness and financial shortfalls, especially green finance.

From the above analysis, it can be seen that renewable energy, green finance, and EF are all closely linked to the problem of poverty, and many studies support and disagree about their impact on the poor. However, these studies are often fragmented, mostly examining the relationship between a few variables discretely rather than being placed in a system of simultaneous interaction. Many studies have focused solely on the impact of green finance or renewable energy on green growth or emission reduction. There has been no study that integrates factors such as renewable energy, green finance, green growth, and ecological footprint into a green ecosystem and simultaneously evaluates their interactions in addressing social/poverty issues within a unified analytical framework.

Moreover, there are debates about contradictory findings and transition risks: There is a common assumption that green investments will automatically create a trickle-down effect, helping to create jobs and reduce poverty. However, recent experimental studies question the universal and effectiveness of this effect. Besides, there is a gap in the mechanism of interaction regarding how green energy, green finance, and EF impact poverty together. Current theory has yet to explain how green finance can simultaneously reduce EF without increasing the input costs to the poor. Studies integrating these impact channels are still very limited, especially in the context of developing economies. This is a weakness in modern science that cannot answer the question: How can we reduce the pressure on the biosphere without increasing the pressure on the incomes of the poor? This study will address that gap by quantifying the optimal threshold of GF and EF in relation to inclusive growth in order to address the problem of poverty towards sustainable development.

Limitations in terms of data and approach are also research gaps that need to be filled. Despite many significant achievements in the development of the green economy, green concepts are still not consistent, especially the concept of green finance, leading to difficulties in data extraction for research. The lack of data on green finance in developing countries has led to limited empirical research related to green finance in this context. In addition, many studies encounter methodological issues in processing endogeneity and heterogeneity. Therefore, modern analytical approaches such as system-GMM, which address endogeneity and heteroskedasticity issues perfectly, are necessary for studying in this field.

Against these research gaps and limitations, this study seeks to advance the literature by developing an integrated framework that conceptualizes the energy–finance–environment–

poverty nexus. By explicitly incorporating both renewable energy production and consumption, and by examining the mediating and moderating roles of green finance, the study aims to provide a more comprehensive understanding of the mechanisms through which energy transitions influence environmental and social outcomes. Focusing on developing countries, the analysis further contributes to ongoing debates on whether green growth pathways can simultaneously achieve ecological sustainability and poverty reduction.

Research questions

From the above gaps, this study raises the core research questions:

1. Does green finance development contribute to preventing environmental degradation and promoting poverty reduction in developing countries, and if so, through what mechanisms?
2. Do green finance and green energy have a complementary effect on improving environmental quality and reducing poverty?
3. How do renewable energy production and consumption have different impacts on environmental quality and poverty reduction?
4. Does the impact of green finance and green energy differ between developing countries due to contextual differences ?

Research objectives

- General objectives: To develop a comprehensive theoretical and empirical framework to measure and evaluate the direct and indirect impacts of green finance on the ecological environment and poverty through renewable energy production and consumption.

- Specific objectives:

1. Determine the impacts of both renewable energy production and renewable energy consumption on environmental degradation and poverty.
2. Simultaneously assess the impact of green transformation factors such as renewable energy production and consumption, green finance, and EF on poverty and sustainable development indicators. Then, determine the effect from green transition to poverty and sustainable development.
3. Determine mediation / moderation role of green finance in solving environment and social issues.
4. Determine heterogeneity between groups of developing countries by context from solving the issues of environmental degradation and poverty toward achieving sustainable development
5. Propose macro policy frameworks that combine environmental sustainability and social protection to optimize the effects of the green transition.

Scope of research

Due to limited data sources, the study selects 74 developing countries for the period 2000-2022 with relatively sufficient data to meet the needs of empirical analysis (The list of countries is mentioned in Appendix A). The study extracts available dataset from well known international sources such as the World Bank (WB), IRENA, IEA, IMF, ADB. The study does not analyse for differences in short-term and long-term impacts impact of explain variables, or verifying the impact by other dynamic panel model than the System GMM.

Novelty and Contributions

By integrating green finance into the energy–environment–poverty framework and examining complex transmission mechanisms in the context of developing countries, this research not only fills important gaps in the literature but also provides a scientific foundation for the design of more effective and inclusive green development policies. It is novelty in term of theory, emperical, and policy implication.

Research contributions

Based on the identification of the research gaps mentioned from the rationale, this research is expected to bring new and insightful contributions in theory by identifing a sequential transmission pathway:

Green Growth → Green Finance → Ecological Footprint → Poverty Reduction

This layered mechanism advances existing models by moving beyond single-channel mediation and offering a more comprehensive representation of causal processes. By integrating the intermediate variable Green Finance into the relationships between Energy-Environment and Energy-Poverty-Sustainability. This helps to expand the theory of sustainable development beyond mere environmental boundaries to touch the aspect of social justice. In addition, by separating Production and Consumption, the study provides a new perspective on the Energy Trap theory, explaining why a country may have a surplus of clean energy but poverty rates remain unabated. Besides, the study will provide clear empirical evidence of how green ecosystems distribute benefits in society, helping policy makers design strategies for ecological protection without leaving disadvantaged groups behind.

Structure of the thesis

This thesis includes 5 chapters including (1) Introduction; (2) Literature review; (3) Research Methodology; (4) Empirical results and discussions; and (5) Conclusion and recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1. CONCEPTS

Based on the foundation of sustainable development, this study envisions the integration of green finance into the relationship of Green Economy – Green finance – Environment – Poverty – Sustainable Development. Therefore, related concepts are considered in turn, including: sustainable development, green economy, green finance, renewable energy, ecological footprints, and poverty.

Sustainable development

In the Brundtland Report from 1987, The World Commission on Environment and Development (WCED) of The United Nations (UNDP) has defined sustainable development as "meet the needs of the present without compromising the ability to meet the needs of future generations themselves" (Asadi et al., 2008; Lavrinenko et al., 2019). Despite receiving a lot of support from scientists and policymakers, the definition has also met some criticism. Most critics argue on the ambiguity and difficulty of measuring goals. As such, it has been modified to adapt for use by international organizations and policymakers (Barbier, 2016). Some adjustments focus on social justice indicators; some rely on sustainable progress in the ecological environment and meeting the essential needs of low-income groups; others are interested in all three pillars of sustainable development: economy, society and environment. However, the goal of every effort to achieve economic development is to try to make people wealthier, healthier, better educated, and have greater access to clean water, safe energy source, good quality housing, a higher standard of living, and a longer life expectancy.

While UNEP and most countries have relied on a lot of indicators integrated in the SDGs to formulating development strategies as well as evaluate the process of achieving sustainable development in the world, there are many scientists trying to synthesize a complex system of indicators into a number of simple development indicators/synthetic indicators to make it easier to evaluate. However, none of the indicators have yet to receive consensus from policymakers due to the existing trade-offs between development goals. Sustainable development has been criticized for its difficulty in measuring synchronously in practice for developing countries, which still faces a grow first, clean up later mentality, in which economic growth and poverty alleviation are often prioritized over ecological protection (Ehigiamusoe et al., 2022). As a result, empirical studies often focus on one or more goals that have complementary relationships to address. This study also focuses on poverty alleviation, which is stated in the first goal of the SDGs, and the declaration on the SDGs from now on mainly refers to the First goal of the SDGs.

Green economy

The green economy is defined as a strategy that delivers human well-being and social justice while significantly reducing the risk of environmental destruction and social scarcity

(Fankhauser et al., 2017), integrating economic growth with three aspects: (1) low greenhouse gas emissions by promoting the use of renewable energy; (2) Efficient and effective use of resources, and (3) Inclusion by ensuring equality in the distribution of benefits. This concept appears in opposition to the brown economy – a traditional growth model that relies heavily on fossil fuels and the depletion of natural resources (UNEP, 2011). The green economy is proposed as an ideal model for achieving sustainable economic development focusing on the three pillars economic, social, and environmental problems. This is critical to achieving social equity, environmental sustainability, and economic well-being as it plays a vital role in addressing crises, fighting poverty, and promoting green investment for a more sustainable future (Mahadi et al., 2024). Besides the significant benefits, the green economy still faces some criticism from academic communities, including (1) failure to demonstrate the feasibility of an absolute separation between GDP growth and resource consumption, which may lead to a rebound effect (Jevons' Paradox), (2) greenwashing; (3) Environmental Kuznets Curve (EKC) debates; (4) conflicting views on the impact of green finance and environmental regulations. and (5) Investment constraints. The criticisms along with the challenge to the green economy and sustainable economic development are complex, especially in measurement when there is limited data for analysis.

Renewable energy (RE)

Renewable energy, or green energy, is a type of energy generated from naturally replenished natural resources and has minimal impact on the environment, including solar, wind, geothermal, biomass, and hydropower. Replacing non-renewable fossil fuels with renewable energy is an important solution to decarbonize the global energy system and combat climate change. Although many empirical researches confirm the benefits of RE to all 3 pillars of sustainable development, it still encounters several criticisms for its drawbacks. First, Renewable energy projects require huge initial infrastructure investment costs, such a large conversion costs makes it not so attractive to private investors, especially from the context of developing countries; Second, energy instability; Third, barriers from finance can restrain small and medium-sized enterprises from implementing technological innovation.

Despite the growing number of empirical studies, there are some significant limitations. Most studies focus on renewable energy consumption as a single variable, while ignoring the role of renewable energy production. This leads to an incomplete perspective. Failure to separate these two aspects can skew estimates and conceal heterogeneous effects, as has been shown in recent studies (Erdogan & Solarin, 2025; Salahuddin et al., 2018). Besides, the use of aggregate proxies for renewable energy, leading to missing out on the transmission mechanism of the difference between supply and demand. Although the current literature has demonstrated the role of renewable energy in mitigating environmental degradation, there is still a significant gap as studies often unilaterally focus on the renewable energy consumption variable (Xu & Wu, 2023) leading to conflicting experimental results (Pata, 2018). Furthermore, according to (Zhang et al., 2022), there is a supply chain paradox: while downstream renewable energy consumption helps reduce fossil fuel emissions, upstream production and infrastructure construction directly generate large

amounts of CO_2 and toxic waste. Therefore, separating these two variables can lead to a misassessment of the overall impact of renewable energy. To fill this gap, our research pioneered the simultaneous integration of both Renewable Energy Production and Consumption into a single model.

Green finance (GF)

The concept of green finance emerged in the context of increasing global environmental challenges, particularly climate change and the degradation of natural resources. This concept is not limited to individual financial instruments, but also encompasses the entire financial system, including banks, capital markets, insurance, and international financial institutions.bGreen investment is the investment of the private and public sectors in energy-saving and environmental protection projects. Investments in environmentally friendly R&D and innovation are also in this group. Because green investment activities have not attracted much to the private sector in the early stages of green transition in developing countries due to the characteristics of risks and capital used, the government's investment activities in this field are considered stimulating and oriented investment activities to shape private investment activities in the direction of greening. Public investment in renewable energy is considered a sign of the government's green development policy orientation, as well as a testament to the long-term benefits that green investment activities bring to stimulate the participation of private investors. This study also uses public investment in renewable energy as a variable that represents green finance due to its popularity and uniformity.

Environmental Degradation and Ecological Footprint

With the orientation to promote the quality of the ecological environment, the green economy is considered a suitable development strategy for a sustainable future. This economic model helps achieve economic growth, ensure social equality, and protect the natural environment. The Ecological Footprint (EF) concept developed by Wackernagel and Rees is presented as a more reliable and comprehensive measure of environmental degradation compared to CO_2 emissions as it reflects multi aspects and actual pressure of human activities on total natural capital. It is an environmental indicator that reflects the extensive use of production surfaces including construction land, cropland, forest area, fisheries, carbon emissions, and grazing land (Wackernagel & Rees, 1998). Therefore, this study uses EF as an important indicator that fully reflects the impact of human consumption of natural resources and green activities of the economy. From development economic perspectives, EF reveals a major paradox known as the Poverty Environmental Trap. Poor communities are directly dependent on natural capital to survive. This leads to overexploitation of natural resources for well being that increases EF. Conversely, when EF exceeds the Earth's biological capacity leading to climate change and biodiversity loss, the poor are the hardest force incurring hit for environmental factor, leaving them trapped deeper into the vicious circle of poverty (Baloch et al., 2020; Rizk & Slimane, 2018).

Poverty and its measurements

The concept of poverty has received vast concern from scientists and policymakers for decades. In the literature, poverty is described as a low-welfare state in which people are unable to adequately meet their needs (Hagenaars, 2014); hence deprivation, in which people or communities lack access to the basic resources and necessities needed to live a healthy and decent life (World Vision, 2023). Different definitions of poverty can be contrasted based on a common assumption that an individual lives in poverty when the resources available to them are less than necessary to meet the minimum standard of living. Previously, poverty was estimated based on income or consumption levels to consider how much the poor could afford. The World Bank has set the threshold of one dollar per day since 1990 to calculate extreme poverty and regularly publishes PPP rates, adjusting this threshold to reflect the purchasing power of different countries. It is now adjusted from a multidimensional poverty perspective to better reflect the extreme poverty used by many international institutions. Therefore, the poverty line is widely used to assess poverty over the world. However, there is a consensus that this poverty level is too low and does not accurately reflect people's real life in wealthy industrial circles because they have a higher basket of consumption values to adapt to their living standards. A higher poverty threshold is proposed to be fair to these economies. The lines used in 2022 are $3.65 per day for middle-income countries and $6.85 per day for high-income countries. The empirical analysis of this research is for developing countries which are listed as middle-income countries, so the poverty line of $3.65 per day was used in this study.

2.2. FOUNDATION THEORIES

Endogenous growth economic model

Endogenous growth theory (EGT) is a body of macroeconomic theories that argue that long-term economic growth is an endogenous result of an economic system, rather than the result of exogenous factors. The emergence of EGT marked a turning point by rejecting the assumption of Solow-Swan's neoclassical theory, explaining that technological progress is an exogenous variable and that the assumption of diminishing returns of capital EGT expresses the view that technological advancement and knowledge are endogenous variables generated by deliberate investment decisions by economic actors seeking to maximize profits and generate knowledge through learning curve theory. The core of EGT lies in protesting the assumption of diminishing returns for accumulated factors such as material capital, human capital, and knowledge. EGT has successfully explained the origins of technological progress, demonstrating that knowledge and ideas can generate increasing profits at a macroeconomic level (Onyimadu, 2015). The integration of environmental factors and poverty reduction in EGT can create a solid foundation for the Green Economy model to achieve the sustainable development goals. While endogenous growth theory provides an optimistic lens on technology and capital, many studies have criticized and highlighted its limitations when applied to the relationship between green finance, environmental degradation, and poverty. At the same time, integrating technological innovation, green economic growth, poverty, income inequality, and ecological degradation into a unified analytical framework

(especially for developing countries) remains very limited and requires more empirical research using integrated econometric models.

Environmental Kurnetz Curve (EKC)

The Environmental Kurnetz Curve (EKC) hypothesis is quite famous for mentioning the non-linear impact of economic growth on environmental degradation and is widely used in environmental economics studies. This theory expresses an inverted U-shaped relationship between economic development and environmental degradation, whereby at the initial stage, growth causes pollution; when an income crosses the threshold, the environment will be improved. The EKC theory has become a well-known theory in environmental economics studies (Abid, 2016; Destek & Sarkodie, 2019; Sarkodie & Strezov, 2019; Ulucak & Bilgili, 2018). The scale, composition, and technique effects have been used to explain this inverted U shape by Grossman and Krueger (1995). Such a relationship is suggested primarily by Simon Kuznets since 1955 regarding the connection between economic growth and income inequality, then applied successfully in the environmental field and became a popular theory in research on the role of economic development in environmental issues. Besides, the study of the EKC when using EF as a proxy for environmental degradation is necessary to thoroughly solve environmental problems in many aspects.

Not just debate over the shape of the EKC, another limitation of the EKC is the assumption that economic growth exceeding the threshold will automatically address pollution, leading to complacency in developing countries. Current research gaps require further empirical studies in developing countries using more comprehensive indicators, such as the Ecological Footprint rather than measuring CO_2 emissions alone. Furthermore, integrating the role of renewable energy and green finance development into the model is essential for accurately assessing the trajectory toward the turning point.

The STIRPAT framework analyses environmental impact factors

Originally extended from the IPAT model, introduced by Erlich and Holdren since the 1970s, the STIRPAT framework is an econometric model that measures the stochastic impact of three main drivers: Population (P), Affluence (A), and Technology (T) on Environmental Impact (I). The STIRPAT is a core quantitative tool for accurately decomposing and measuring the weight of individual macroeconomic dynamics affecting the environment. It is particularly useful in analysing how policies of urbanization, population growth, and poverty alleviation efforts impact climate change and resource consumption in developing countries. Most of the experimental applications of STIRPAT confirm that population growth, urban expansion, and economic growth significantly exacerbate greenhouse gas (GHG) emissions. Meanwhile, the technology variable (T) often exhibits a pollution-reduction effect when it represents green technology. The majority of studies using STIRPAT assume the linear effects of technology and wealth on the environment. A current gap is the scarcity of non-linear STIRPAT models and models that consider the intermediary and regulatory mechanisms of Green Finance and institutional quality, which are game-changers but have not been adequately tested in the context of developing countries. In addition, the

development of renewable energy (RE) has attracted scientists recently thanks to its role in protecting the environment. However, the aspect of renewable energy consumption receives a lot of attention as an important factor contributing to environmental quality, while renewable energy production is not given enough attention. There is a lack of integrated research on both renewable energy production and consumption, accompanied by other macroeconomic indicators, in assessing their impact on EF. This study applies the STIRPAT framework to address this problem by combining the two sides of renewable energy production and consumption in the Environmental Kuznets Curve (EKC) experiment, and the non-monotonous impact of economic growth on environmental outcomes.

Hypothesis of polluted Heaven and pollution Halo effect

Theories about the Heaven and Halo effect emerged from debates about the environmental impact of free trade in the early 1990s. This concept was raised from study of Grossman and Krueger (1991) and later explicitly modeled by Copeland and Taylor.

Pollution Heaven Hypothesis: It argues that multinational corporations in polluting industries relocate factories from developed countries (with strict environmental regulations) to developing countries (with looser regulations) to minimize costs, thereby turning poor countries into havens for pollution.

Pollution Halo Hypothesis: In contrast, this hypothesis holds that foreign direct investment (FDI) brings in advanced, cleaner manufacturing technology and strict environmental management standards from the parent companies, creating a positive spillover effect (halo effect) that improves environmental quality in the host country.

Porter Hypothesis

The Porter hypothesis argues that flexible in design strict environmental regulations create an urge to stimulate ecological innovation and process optimization in business. This hypothesis was proposed by Michael Porter in 1991. This hypothesis challenges the assumption that environmental protection always increases corporate costs, as the traditional neoclassical economic view. The core limitation lies in the implicit assumption that companies always have sufficient financial capacity to invest in R&D and ecological innovation immediately when there is regulatory pressure.

2.3. REVIEW OF PREVIOUS EMPIRICAL STUDIES AND RESEARCH GAPS

Impact of renewable energy in environmental degradation

Even the role of renewable energy in environmental degradation has received widespread attention, with most researchers focusing on using renewable energy consumption as a proxy, while few of them are interested in renewable energy production. Actually, the production of renewable energy infrastructure requires material extraction, construction, and land occupation,

etc., which leads to an increase in EF in the short term. Ignoring renewable energy production can skew policy implications when the upstream costs required for the initial investment in renewable energy production are not accurately observed and evaluated, especially when such investment involves the formation and accumulation of capital to build renewable energy infrastructure. Besides, they are usually only investigated in isolated cases. There is still a lack of studies that combine both aspects of renewable energy production and consumption simultaneously in analysing their impact on environmental degradation in general and EF in particular. Even when using a single proxy, the conclusions for its role on environmental degradation are inconsistent.

Effect of renewable energy on poverty

Renewable energy development plays a key role in the simultaneous implementation of the Sustainable Development Goals of Zero Poverty (SDG 1) and Clean and Affordable Energy (SDG 7). However, to fully understand the transmission mechanism, this study clearly differentiates the impact of renewable energy production and consumption on environmental degradation in developing countries.

Renewable energy production is often associated with large-scale projects, macroeconomic policies, and industrial restructuring. This aspect has a multi-dimensional impact, such as job creation, energy poverty reduction, and green-related business development, etc. In fact, investment and production of clean energy create green jobs and stimulate local economic growth. However, some empirical studies have demonstrated the downside of investing in renewable energy production, leading to social trade-offs. To encourage production, the government often applies feed-in tariffs, which inadvertently push electricity prices up in the short term, creating an additional financial burden and increasing the risk of poverty for disadvantaged groups.

Access and consumption of RE help households replace traditional fuels, thereby reducing indoor air pollution and respiratory diseases. RE consumption not only reduces the headcount ratio, but also directly reduces the Poverty Gap and Poverty Severity by freeing up financial resources from expensive fuel purchases to investments in education and health. However, there are also some studies that reach more cautious conclusions.

High risk and the costs of the new energy system also limit organizations' investment in expanding their operational activities, leading to less chance to find work. While both renewable energy production and consumption are important, combining these two factors simultaneously into the same econometric model to assess their impact on poverty faces major methodological gaps and challenges: (1) endogeneity and reverse causality; (2) ignoring non-linear characteristics; (3) spatial mismatch; and (4) lack of moderating variables

Roles of green finance on environmental degradation and EF

Results from numerous empirical studies show that green finance plays a key role in reducing ecological footprint and environmental degradation by directing capital flows from high-polluting industries to environmentally friendly projects, renewable energy and clean technology projects. However, opposing views argue that green finance does not bring real environmental efficiency, sometimes leading to greenwashing or increasing pollution in some contexts.

Intermediary roles of green finance: Green finance not only has a direct impact but also shapes environmental quality through structural intermediaries. This mechanism stimulates enterprises to carry out technological innovation, acts as an intermediary in reducing CO_2 emissions. Nevertheless, the efficacy of green finance is not uniform across contexts. Studies reveal that, in developing or less developed countries, weak financial infrastructure and limited private sector engagement can constrain the effectiveness of green finance.

Roles of green finance on poverty

The relationship between green finance (GF) and poverty alleviation is a complex, multidimensional topic that is attracting a lot of attention and fierce academic debates. The empirical results indicate that green finance not only has a direct impact but also operates through multiple intermediaries, with different effects depending on space, time, and institutional context. For poverty alleviation roles, the majority of empirical studies support the view that green finance has a direct and positive impact on the reduction of absolute poverty, relative poverty, and energy poverty. However, green finance is not a complete panacea and is not automatically pro-poor. There are many debates on green gentrification and the heterogeneity of GF. Studies are warning about the phenomenon of green gentrification and green grabbing.

Intermediary role of Green Finance: Experimental models demonstrate that GF acts as a catalyst through three core intermediate mechanisms: (1) intermediation through economic growth; (2) intermediation through technological advancement; (3) intermediation through environmental improvement. Despite significant contributions, studies on the role of green finance in the environment still reveal many gaps and empirical limitations that need to be addressed: (1) failure to assess macro risks and consider the environmental impact of green finance in a static policy environment; (2) the lack of a unified social taxonomy framework causes many projects to be labeled green but to ignore social performance metrics; (3) the role of green finance in connecting renewable energy to the environment and poverty has not been fully exploited in empirical studies; (4) the relationship between green finance and poverty reduction has endogeneity and a very strong two-way causal relationship, and an appropriate analytical tool is needed for this relationship.

Ecological footprints and poverty – a dilemma of environment and poverty issues

The paradox of poverty-environment shows the trade-offs when implementing macro policies. In fact, the reduction of environmental pollution and climate risk brings a better quality of life, improved labor health, and productivity. The exploitation of natural resources with care and

responsible ways will give them a chance to be recovered, which could maintain the long-term use and sustain the chance of development for future generations. However, in the short run, climate policies that reduce fossil fuels and use carbon pricing could lead to higher costs for business, as well as to opportunities to invest in energy-intensive activities that increase prices and job losses, affecting potential earnings and the welfare of society, especially the well being of the poor.

Macroeconomic factors for poverty alleviation and sustainable development

Numerous macroeconomic variables are proved to be effective catalysts for the poverty reduction process. This research will focus on the roles of economic growth, remittances, inflation, urbanization, and open trade as control variables for poverty alleviation in the green transition.

2.4. RESEARCH GAPS AT GLANCE

Although the academic literature on green growth and green finance has grown exponentially, there are still major research gaps:

- First, large geographical gap in developing or underdeveloped economies, where poverty and energy shortages are most severe.
- Second, ignoring the complex cointegration mechanisms between green finance, the risk of natural resource depletion, and poverty alleviation efforts in the same empirical model.
- Third, the use of representative indicators leads to inconsistencies in empirical research findings.
- Fourth, the simultaneous integration of green factors and consideration of the mediating role of GF and EF, is essential as the basis for a comprehensive and effective policy combination.
- Finally, most models use static data rather than tracking dynamic parameter variations over time from socio-economic shocks.

2.5. PROPOSED ANALYTICAL FRAMEWORK AND HYPOTHESIS

From theoretical gaps and indications of the intermediary role of GF in the relationship between green economy - environment - poverty, the study will particularly verify the role of the green economy through commonly used green components, such as renewable energy, green finance, and EF in the same model analyse their correlation with poverty and sustainable development. The proposed analytical framework will be empirically validated by econometric investigation.

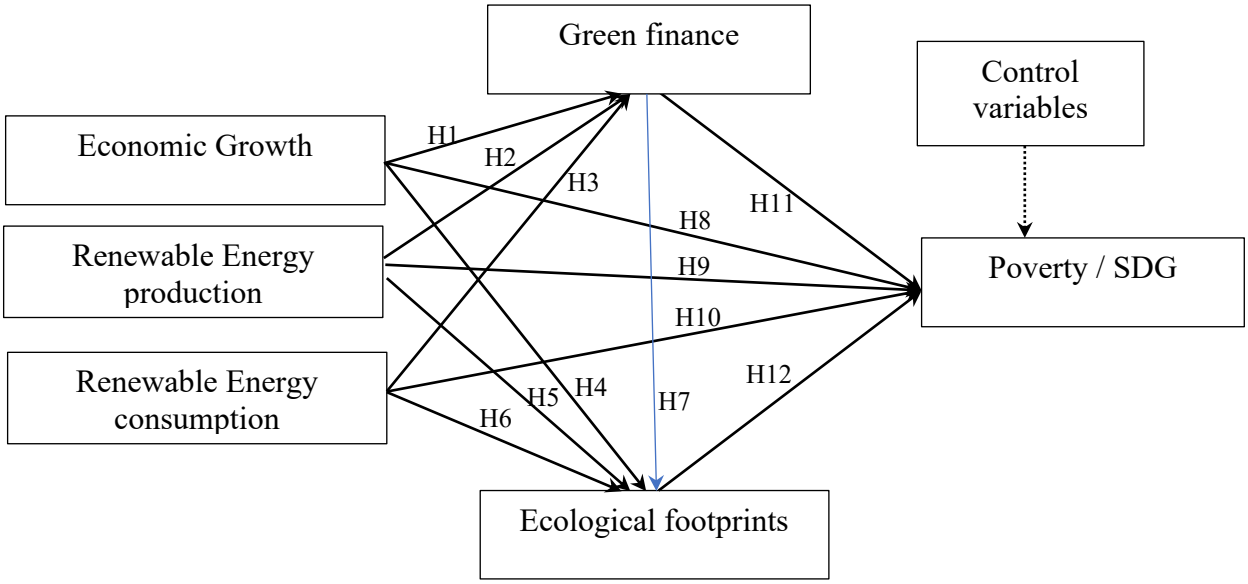

Figure 1: Analytical framework

Core relationships and hypothesis

The study will conduct an analysis in 3 steps: (1) analyze the impact of economic growth and RE on green finance; (2) analyze the combined impact of economic growth and greening factors, then determine the mediation/ moderation roles of green finance on the EF; (3) analyze the combined impact of economic growth, greening factors, and environmental quality on poverty and the Sustainable Development Goals.

From the discussions, the following hypotheses are suggested.

- H1: Economic growth positively impacts green finance
- H2: Renewable energy production negatively impacts green finance
- H3: Renewable energy consumption has a positive impact on green finance
- H4: There exists an inversed U-shaped relationship between economic growth and ecological footprints
- H5: Renewable energy production has a positive impact on Ecological footprints
- H6: Consumption of renewable energy negatively impacts Ecological footprints
- H7: Green finance negatively impacts Ecological footprints
- H7a: Green finance mediates the relationship between renewable energy economic growth, and environmental quality.
- H8: Economic growth contributes to poverty reduction and helps achieve the SDGs
- H9: Renewable energy production contributes to poverty reduction and helps achieve the SDGs in developing countries.
- H10: Consumption of renewables contributes to increasing poverty and reducing access to the SDGs in developing countries.

- H11: Green finance helps reduce poverty and increase the likelihood of achieving the SDGs in developing countries.
- H12: Ecological footprints have the impact of reducing poverty and increasing the likelihood of achieving SDG in developing countries.
- H12a&b: GF and EF play an intermediary/regulatory role in the impact of the green transition on poverty and sustainable development.

2.6. PROPOSED RESEARCH TOPICS

From the complex relationship developed through this analytical framework, this research is extracted into 4 main topics.

(1) Green finance for green growth – Important roles of RE production and consumption
(2) Ecological footprints – the roles of energy transition, green finance, and growth
(3) Poverty alleviation – How the composition of green factors could handle it
(4) SDG achievement – An empirical research for SDG1 and its driven factors

Overall, this study advances the theoretical frontier by moving from a fragmented understanding of sustainability drivers toward an integrated, mechanism-based framework that captures the dynamic interplay between finance, energy, environment, and development. It demonstrates that sustainable development is not driven by isolated factors, but by interconnected systems operating through complex transmission channels.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. RESEARCH DESIGN

The research is conducted through 6 steps, as follows:
Step 1: The study begins by a problem statement, then identifying the research objectives
Step2: Theoretical foundation is analysed.
Step 3: Developing a research model and propose 3 stages of analysis.
Step 4: Data collection for empirical analysis.
Step 5: Data analysis.
Step 6 : The results are interpreted to draw conclusions and implement recommendations.

3.2. RESEARCH METHOD

The study applies a mixed methodology that combines qualitative research and quantitative research. In order to build an integrated framework of Renewable Energy – Green Finance – Environmental Degradation-Poverty, To identify theoretical and empirical gaps, thereby proposing an appropriate analytical framework, the qualitative research method by content analysis is used in the first step. Then, appropriate research topics are identified. Data from 74 countries are collected for quantitative analysis, assessing the impacts of the production and

consumption of renewable energy and green finance on environmental degradation and poverty, and then generating appropriate recommendations for developing countries. Quantitative analysis uses multiple econometric regressions with both static and dynamic panel analysis, in which the static regressions include OLS, FEM, REM, and GLS and the dynamic panel analysis is the twostep system GMM. Dynamic regression is applied to address endogeneity issues that normally exist in macro-level analysis. It also tackles the problems of autocorrelation and heteroskedasticity. Details of the analysis and inspection steps will be presented in the following sections.

3.3. SPECIFICATION OF RESEARCH MODEL

For static analysis by OLS, FEM, REM and GLS, the econometric models to be estimated in according to each topic proposed from chapter 2 as follows:

For Green finance (GF):

$$GF_{it} = a_0 + a.GF_{i(t-1)} + a_1REC_{it} + a_2REP_{it} + a_3GDP_{it} + \sum_k a_k Control_{kit} + \mu_{it} + \varepsilon_{it}$$

For Ecological footprints (EF)

$$EF_{it} = b_0 + b.EF_{i(t-1)} + b_1GF_{it} + b_2REC_{it} + b_3REP_{it} + b_4GDP_{it} + b_5sqGDP_{it} + \sum_l b_l Control_{lit} + \gamma_{it} + \omega_{it}$$

For Poverty (POV)

$$POV_{it} = c_0 + c.POV_{i(t-1)} + c_1GF_{it} + c_2EF_{it} + c_3REC_{it} + c_4REP_{it} + c_5GDP_{it} + \sum_m c_m Control_{mit} + \lambda_{it} + u_{it}$$

For SDG

$$SDG_{it} = d_0 + d.SDG_{i(t-1)} + d_1GF_{it} + d_2EF_{it} + d_3REC_{it} + d_4REP_{it} + d_5GDP_{it} + \sum_n d_n Control_{nit} + \varphi_{it} + v_{it}$$

Where,

- The subscripts i and t denote country and year;
- a_0 b_0 c_0 d_0 are the constant term;
- a_k b_l c_m d_n are coefficients to be estimated;
- $Control_{kit}$ represents control variables;
- μ_{it} γ_{it} λ_{it} φ_{it} : country- specific effect
- ε_{it} ω_{it} u_{it} v_{it} : the idiosyncratic error term.

3.4. DATA SOURCES AND DESCRIPTION

The study used secondary data extracted from reliable international sources such as the World Development Indicators (WDI) of The World Bank (WB), SDGs data of United Nations (UN) and SDSN dashboards, International Energy Agency (IEA), International Renewable Energy Agency (IRENA), Global Footprint Network (GFN), International Monetary Fund (IMF), and Asian Development Bank (ADB).

With the necessary analytical indicators in the research model, prioritizing countries with sufficient data for key variables such as green finance, renewable energy, EF, and SDG, 74 countries with data for the period 2000-2022 were selected. Although data availability varies by indicator,

the final dataset remains strongly balanced from STATA18 and suitable for panel estimations. Details of the data source are presented in Table 1.

Table 1: Data description

Indicators	Variables	Units	Sources
SDG - Goal 1	SDGs	Percent	SDG report of SDSN dashboards.sdgindex.org
Poverty headcount ratio at $3.65/day (2017 PPP, %)	POV	Percent	SDG report of SDSN dashboards.sdgindex.org
Ecological footprint	EF	Gha per capita	Global footprint network
Green finance (Public investment on renewable energies)	GF	in 2021 million USD	IRENA
Renewable energy consumption	REC	percentage of total energy consumption	WDI and IAE
Renewable energy production (Renewable electricity capacity)	REP	MWh	IRENA
Gross capital formation	GCF	Percentage of GDP	WDI
TRADE openness (total TRADE divided by GDP)	TRADE	Percentage of GDP	WDI
Net FDI inflow	FDI	Percentage of GDP	WDI
Population	POP	Person	WDI
Urban growth rate	URBAN	Percent	WDI
GDP growth rate	GDP	Percent	WDI
Remittances	REMIT	Percentage of GDP	WDI
Rule of law	RULE	Index	WDI
Financial development	FD	Index	IMF
Inflation rate (by GDP deflator)	INFL	Percent	WDI
Industrial rate	INDUS	Percentage of GDP	WDI

Except for variables in index and percentage, the remaining continuous variables, especially 4 green factors including green finance, RE production, RE consumption are transformed into natural logarithms to reduce heteroskedasticity, skewness, stabilize variance, and enable elasticity-based interpretation.

3.5. ANALYTICAL PROCEDURE

The empirical procedure follows a multi-stage approach:

1. Descriptive statistics and correlation analysis, to explore variable distributions and potential collinearity.

2. To ensure stationarity and avoid spurious regression, panel unit root tests using the Im–Pesaran–Shin (IPS) technique are conducted.
3. Baseline OLS estimation is supported by diagnostic tests (VIF, the White test for heteroskedasticity, and the Wooldridge test for autocorrelation).
4. FEM and REM estimation, with the Hausman test used for suitable model selection, the Wooldridge test for autocorrelation, and the modified Wald test for heteroskedasticity.
5. GLS estimation to process for regression issues in static estimation.
6. IV–2SLS estimation as a robustness check for endogeneity.
7. Two-step System-GMM estimation, serving as the primary specification (AR(2) for second order autocorrelation, and Hansen tests for overidentification instruments).
8. Delta test for mediating/ moderating effect of GF and EF.

This structured methodology ensures robustness by comparing results across multiple estimators and addressing endogeneity, persistence, and unobserved heterogeneity simultaneously. All variables are specified for stationarity before conducting estimation to ensure reliability and consistency of regressors. This research applies the Im-Pesaran-Shin method (IPS unitroot test) since it allows for unbalanced variables. The result from this test shows that all variables are stationary at level or at the first difference. Therefore, all the variables are qualified to be included in the regression model, and concerns about spurious regressions do not exist.

3.6. ESTIMATION USING GMM SYSTEM

Social factors like poverty and environmental indicators like EF exhibit strong temporal persistence and current values depend partly on their past levels. Furthermore, variables such as GDP, GCF, and renewable energy development may be jointly determined with environmental outcomes, generating endogeneity, simultaneity bias, and omitted-variable concerns. Including lagged EF exacerbates dynamic-panel bias (Nickell bias), making static estimators inconsistent. To address these econometric challenges, the study employs the two-step System Generalized Method of Moments (System-GMM) estimator (Arellano & Bover, 1995; Blundell & Bond, 1998). System-GMM is well suited for panels characterized by many cross-sectional units (large N) and shorter time periods (small T). Diagnostic and validity tests: To ensure the robustness and validity of the estimations, Hansen and Arellano–Bond diagnostic tests are conducted to ensure validity of the instruments, model consistent and reliability.

CHAPTER 4: EMPIRICAL RESULTS AND DISCUSSION

4.1. GREEN FINANCE FOR GREEN GROWTH – IMPORTANT ROLES OF RENEWABLE ENERGY PRODUCTION AND CONSUMPTION

Introduction

In the context of climate change occurring at an uncontrollable pace, the transition from a fossil-based economy to a low-carbon economy has become a top-priority responsibility of every country. In this process, green finance acts as a lifeline, providing the necessary financial resources for environmentally friendly projects. However, the effectiveness of mobilizing and allocating green finance does not exist independently but is strongly influenced by the energy structure and economic growth drivers.

Although the topics of sustainable energy and finance have been much discussed, this research may contribute to the following key knowledge gaps: (1) the separation between renewable energy production and consumption; (2) two-dimensionality and endogenous relationships: Many studies assume a one-way linear relationship; (3) the regulatory role of the level of economic development: The contextual gap is still very large. (4) the transmission channels: there is currently a lack of empirical evidence to explain why the consumption of renewable energy leads to an increase in green finance. Is it through a credit risk mitigation mechanism, or through improving the ESG rating of the enterprise? This research could fill the gap by suggesting theoretical transmission channels between energy production/consumption and financial market readiness. The analytical framework and hypotheses suggested in this topic are from H1 to H3. The methodology follows the process mentioned in Chapter 3.

Descriptive statistics show that the variables with sample sizes ranging between 1490 and 1698 with the GF variable being the least, suggest that despite attempts to select the countries with the most complete data and a preference for the GF variable, GF data is still missing and not up to date in many developing countries. Primary evaluation for possible relation between GF and independent variables, pairwise correlation between variables has been tested by Pearson methods. Overall, the pairwise correlations of all variables are less than 0.6 and most of them are significant at 1%.

Empirical results and discussion

The regression by OLS method shows the impact of the independent variables on GF in the same direction as the correlation signs in the pairwise correlation matrix; however, FDI, TRADE, and FD are statistically insignificant. The determination coefficient is rather low; however, the test for goodness of overall fit is adapted well with sig. at almost zero. Besides, the tests for phenomena of autocorrelation and heteroskedasticity confirm that this estimation encounters both issues, although it does not deal with multicollinearity from the VIF test.

Table 2: Empirical results of GF by multiple estimation methods

	OLS	FEM	REM	GLS	GMM
	GF	GF	GF	GF	GF
REC	0.4606***	1.0384**.	0.7150***	0.5940***	1.0778**.
REP	0.1463***	-0.213	0.1185	0.1150*	-0.9501**.
GDP	0.8096***	0.9842***	1.5178***	0.9099***	1.9120***

GCF	1.4376***	-0.2683	1.1486***	1.2258***	1.4461**.
POP	0.8136***	8.1177***	1.1304***	0.8181***	1.6126***
FDI	0.014	0.0162	0.0071	0.0173	0.0149
INDUS	-0.0707***	0.0118	-0.0588***	-0.0812***	-0.0471*
TRADE	-0.1196	0.9820**.	0.6792*	-0.0042	0.3306
FD	-0.7413	4.2104*	-2.8110*	-0.3919	0.8628
L.GF					0.1501***
_cons	-22.2664***	-148.1201***	-35.8346***	-22.8233***	-41.6574***
N	1266	1266	1266	1266	1112
Rsquare	0.2291	0.3653	0.4526		
Adj-Rsq	0.2236				
Ftest / Wald	.41.48	29.24	219.03	425.58	
Root MSE	2.8961				

Note: * p<.1, ** p<.05, *** p<.01;

Panel regression by FEM and REM also concludes the existence of fixed effects between countries by the Hausman test. The FEM is similar to OLS in finding both autocorrelation and heteroskedasticity issues. Therefore the GLS method applies with suitable options to treat those regression problems. Although the GLS could not solve the issue of endogeneity, it is also admitted to be the best technique in static panel analysis. The test for endogeneity is conducted with IV-2SLS estimation and this phenomenon is found from the first lag variable in several combinations of control variables. The twostep system GMM applies to address this endogeneity issue

In general, the regression results showed that there is slightly different magnitude and the significance of regressors between various techniques, especially the change from REP, TRADE, INDUS and FD. If variable INDUS shows a slight change from negative significance from OLS to positive insignificant in FEM and soon gets back the same result in others methods; the REP demonstrates vital change from positive coefficient on OLS, flexible in others, and becomes negative in the dynamic GMM approaches. The TRADE and FD regressors are in reverse with REP.

For robustness checks, the results show that both REP and REC are significant and consistently show their opposite impact on GF. The rest of the variables reveal consistent results in statistical significance and impact dimensions with GF, as in the GMM estimation. The REC, GDP, GCF, and POP variables affect positively on GF, whereas REP and INDUS exert a negative influence. The lag variable demonstrates a positively and statistically significant impact on GF. This also confirms the suitable use of the system GMM approach in this GF research.

Conclusion and implications

Green finance is an important source of finance for green development. It is also developed through the demand of the green transformation process and green growth for a sustainable future. This section explores the driven factor of GF from various estimation methods, with

necessary tests and comparisons to obtain reliable results. Dynamic assessment indicates that green finance is well adapted to advanced methods such as the two-step system GMM, reflecting its dependence on past values, green factors, and economic growth. Green factors refer to RE development to replace fossil energy sources; however, they need to analyse two sides of production and consumption sides simultaneously to ensure policy implications, since they expose opposite impacts on GF. This session confirms the role of RE and economic growth on GF. That is useful in analyzing the mediation role of GF in the nexus of green transition, poverty reduction, and environmental protection.

4.2. ECOLOGICAL FOOTPRINTS – THE ROLES OF ENERGY TRANSITION, GREEN FINANCE AND GROWTH

Introduction

The accelerating pace of climate change, environmental degradation, and resource depletion poses EF as one of the greatest challenges to sustainable development in the twenty-first century. Despite global commitments such as the Paris Climate Agreement and the UN Sustainable Development Goals (SDGs), many developing economies continue to prioritize rapid industrial expansion and economic growth over environmental protection. The resulting overreliance on fossil fuels has led to rising greenhouse gas emissions, ecosystem deterioration, and biodiversity loss.

Green finance has emerged as a key mechanism to mobilize resources for sustainable investment. Instruments such as green bonds, credit schemes, and public investment funds have been widely recognized for their role in directing capital toward renewable energy and low-carbon technologies. Yet, while the existing literature focuses mainly on private financial mechanisms, the role of public renewable energy investment as a component of green finance remains underexplored.

By examining both production and consumption simultaneously, this study provides a more complete understanding of the renewable energy-environment nexus. At the same time, FDI remains a double-edged sword. While it drives economic growth and employment, the heaven effect alerts for the threats from globalization on exporting energy-intensive and polluting industries to developing countries.

Environmental Kuznets Curve (EKC) reflects the nonlinear impact of development level on environmental degradation, and it is an inverted U-shaped. Numerous empirical studies confirm the validity of EKC; however, it is not the same with different cases, and there are still many studies concluding different shapes of EKC depending on the context and the integrated variables in the analytical model. Moreover, few studies investigate heterogeneity across EF subcomponents, despite their relevance for sector-specific policy design.

This study makes five contributions to the empirical literature on environmental sustainability. Together, these contributions advance understanding of the mechanisms through which green finance and energy transitions can jointly support sustainable development goals. The study offers actionable insights for policymakers, emphasizing the need to align financial, technological, and institutional frameworks to achieve steady growth and meet international climate objectives. The analytical framework and hypotheses suggested in this topic are from H4 to H7. The methodology follows the process mentioned in Chapter 3.

Empirical results and discussion

Baseline estimation and panel estimations with adequate diagnostic tests

The Ordinary Least Square (OLS) regression has been conducted as a baseline investigation for possible explanations independent of Ecological Footprint (EF). The OLS model reveals a good overall fit from the F test, which is significant at nearly zero percent and the adjusted R square is on average 0.5583. The results show that almost all explanatory variables are significant at 1% excepting GDP and GCF. Both renewable energy variables and green finance show a negative impact on EF. The results in OLS regression differed from the results of the correlation analysis above when the REP switched from positive to negative effects in the OLS multivariate regression model. The VIF test confirms for a free from multicollinearity; however, it is detected to encounter heteroskedasticity and autocorrelation, suggesting that the OLS estimation may not be fully efficient and that a more advanced technique, which could address the problems of heteroskedasticity and autocorrelation. Besides, the hidden effects have not been checked from OLS when using panel regression data. The panel data techniques to test for fixed effects and random effects have been employed in this case, with the FEM given as more reliable than REM by the Hausman test. Testing for regression problems, if any, the modified Wald test and Woodridge test confirm groupwise heteroskedasticity and autocorrelation, respectively.

The results of GLS, which addresses those issues in FEM, display slightly different results from FEM in rejecting GF and GCF. This GLS estimation continues to confirm the negative impact of REC, URBAN, and REMIT on EF; it also supports the positive effect of economic growth (GDP), RULE, and FD. The change by contexts and analytical methods implies the complex interaction between variables in research models that need to have further tests for endogeneity and second order correlation.

The results from the system GMM estimation confirm the statistical significance of three explanatory variables at 10% including REC, REP, and GDP. The control variables of URBAN and REMIT are negatively significant at 5% while FD and FDI are positively significant at 10%. Besides, the first lags of EF are positively and statistically significant at 1%, this implies that Ecological Footprint (EF) is affected by its performance from the past.

Table 3: Baseline estimations of EF by multiple approaches

Variable	OLS	FEM	REM	GLS	GMM

	EF	EF	EF	EF	EF
GF	-0.0153***	-0.0018*	-0.0020*	-0.0003	-0.0045*
REC	-0.1371***	-0.2463***	-0.2387***	-0.1864***	-0.0830*
REP	-0.0149**.	-0.0038	-0.0029	0.0047	-0.0227*
GDP	-0.0039	0.0030***	0.0029***	0.0028***	0.0030*
GCF	-0.0374	0.0466***	0.0464***	0.0122	0.0106
REMIT	-0.1007***	-0.0005	-0.0045	-0.0303***	-0.0493**.
URBAN	-0.1102***	-0.0031	-0.0042	-0.0265***	-0.0562**.
RULE	0.1990***	0.0814***	0.0871***	0.0944***	0.0867
FDI	0.0164***	0.0002	0.0004	0.0016	0.0046*
FD	0.4642***	0.4156***	0.4451***	0.7122***	0.3843*
INDUS	0.0051***	0.0012	0.0014	-0.0012	0.0033
L.EF					0.4649***
sqGDP					-0.0002*
_cons	1.4395***	1.1379***	1.1063***	1.0809***	0.7233**.
N	1197	1197	1197	1197	1155
Rsquare	0.5623	0.3784	0.392		
Adj-Rsq	0.5583				
Ftest / Wald	138.42	42.77	518.93	1204.52	
Root MSE	0.35177				

Note: * p<.1, ** p<.05, *** p<.01;

Empirical results confirm a non-linear effect of economic growth (GDP) on ecological footprint (EF) and the relationship is valid in an inverted U shaped. This result is persistence and robustness with various combinations of explanatory and control variables.

By different combinations of control variables, the sign of the coefficients is consistent, although it is slightly changed in magnitude. Therefore, it could be confirmed that the green factors contribute to better environment quality and the EKC is valid in describing inverted U-shaped relation between economic growth and EF. By this robustness, it is reliable to confirm the acceptance of hypothesis H4, H6, and H7 for EKC validity and negative impact EF of REC and GF, respectively. However, the hypothesis H5 should be adjusted to the opposite sign, with a negative impact on environmental degradation.

Mediation/ Moderation of GF

In estimating for EF, both cases of including or excluding GF in the regression model, both REC and GDP are significant at 5%. Especially, for mixed effect GF*GDP and GF*REC, they are both significant and strengthen the significance of REC and GDP. However, for the case of including GF*GDP (GMM3), all variables of GF, GDP, and the mixed GF*GDP are significant confirming for the mediation effect from GF to the impact of GDP on EF. However, the inclusion of the mixed GF*REC in estimation leads to the rejection of GF while REC is still significant at 1%, this could be concluded

that the GF plays a moderating role on catalysing the impact from REC to EF. The presence of GF strengthens the impact from REC to EF increasing the magnitudes of coefficient from 0.0526 to 0.879. Furthermore, the mixed factor GF*REC also shows the indirect effect of REC on EF. The results support for vital role of green finance in solving environmental problems that should be promoted.

Analysing for each Subcomponent footprint

In considering each of 6 footprint sub-components separately, the results show that excepting fishing, the other footprint components adapt well with the tests of the two-step system-GMM. Three sub-components have a statistically significant with its first lag level including Carbon, Builtupland, and Forest footprints, however the impact factors on each footprint sub-component are not similar. There are 3 sub-components including Carbon, Crop, and Forest footprint being influenced by renewable energy consumption, only Built-up-land footprint is affected by renewable energy production, and only Forest land gets benefits from GF. In addition, EKC is not fully valid from subcomponent analysis when only Forest, Fishing, and Grazing exhibit a negative impact from the downside of an inverted U shape, suggesting a better improvement for these footprints when the economy achieves faster economic growth. Besides, Carbon almost mirrors the impact of EF drivers; however, it is significant only for variables of REC, URBAN, FDI, and FD, suggesting that the effectiveness of the policies imposed on Carbon could bring about the same results on EF.

Heterogeneity analysis by Income Groups

To examine differences across income levels, four dummy variables were created based on the World Bank classification: (1) high income (HighInc), (2) upper-middle income (UppMidInc), (3) lower-middle income (LowMidInc), and (4) low income (LowInc). The regression results for the aggregated model of income groups indicate that all dummy variables of income groups are significant at the 5% level, with coefficients increasing from the lower to higher income groups. Other explanatory variables retain the same positive or negative effects on EF as in the original regression model, except the insignificant from GF. Besides, the results suggest that higher economic growth tends to exacerbate EF in the lower and lower-middle income groups, while still unclear about the downside of the inverted U shaped of the EKC in those economies. GF and REC are the main green factors for environmental improvement, while FD and FDI are escalating environmental degradation.

Heterogeneity analysis by Regional Groups

Six regional dummy variables were created to analyze regional differences. All regional dummy variables are significant at 5%. All explanatory variables remain significant, confirming the robustness of the results except GF. It is confirmed that both REC and REP are particularly important for reducing EF and the EKC is valid in aggregate estimation. In comparison of coefficients for these dummies, the highest coefficient is from Latin America and Caribbean, then come orderly with Euro and Central Asia; East Asia and Pacific; Sub-Saharan Africa (SSA); South Asia, and MENA.

Discussion and implication

The empirical results demonstrate that green finance, proxied by public investment in renewable energy, and both renewable energy consumption and production play a significant role in reducing the ecological footprint, confirming their effectiveness as key instruments in mitigating environmental pressure. The valuable drivers for the environment are dissimilar in different components of footprint, in which Carbon footprint is the best in reflecting EF. Similarly, remittances and urbanization are found to reduce EF, implying that this source of finance inflows and sustainable urban planning can promote cleaner consumption and more efficient energy use.. Besides, estimations also confirm for vital role of GF in moderating and strengthening the impact from REC to EF while mediation to reduce the effect of GDP on EF. From a policy perspective, several implications emerge. The research also highlights that income and regional heterogeneity shape the effectiveness of green factors, indicating that environmental strategies must be context-specific.

4.3. POVERTY ALLEVIATION – HOW COMPOSITION OF GREEN FACTORS COULD HANDLE IT

Introduction

The persistence of extreme poverty and escalating environmental crisis are the two most critical challenges to the global community threatening to the process of achieving sustainable development in the 21st century. The UN target of no extreme poverty everywhere by 2030 seems mission impossible while the poverty eradication process has been slowed down (Liu & Ge, 2025), especially when the situation has become worse due to continuous crises from serious diseases and political conflicts. The poor are so sensitive and vulnerable to such incidents and easily fall into the trap of vicious circle. Additionally, the Paris Climate Agreement of net zero by 2050 creates pressure on energy transition and economic transformation in an ecofriendly direction. Adaptation for the poor on such a transition needs to be taken seriously.

Green economy is considered as a suitable strategy to achieve sustainable development, in which energy transition develops the economy in ecofriendly and sustainable ways, solving the problem of fossil energy causing to the environment, ensuring the process of economic growth and poverty alleviation. However, many researches demonstrate that results of green transition did not meet its expectation when promotion of renewable energy consumption exaggerates poverty incidents. Moreover, empirical research on green finance, which could be seen as an effective measure of green transition, does not always contribute to addressing this social issue.

The increasing ecological footprints (EF) from economic activities degrade the natural environment and climate change. This research also combines EF with other the green factors into an economic growth model to address poverty and to identify the structural impact of the three-stage pre–on process–post of green transition on the poor. The interaction between concerned

green indicators in a single model may influence the isolation effect of these factors on poverty alleviation and the finding could contribute to having synergy results for green transformation success.

This research explores the mismatch of green factors, leading to a paradox of the green transition for sustainable development. It is expected to contribute to the literature on green growth and sustainable development in three ways: (1) It documents a green transition paradox in which renewable energy consumption increases poverty; (2) It distinguishes between renewable energy production and consumption by showing opposite effects; and (3) It highlights the role of green finance as a mitigation mechanism. The analytical framework and hypotheses suggested in this topic are from H8 to H12. The methodology follows the process mentioned in Chapter 3.

Testing for possible relation between variables, independent variables show significant correlation with explained variables (POV) at 1%. Among green factors, EF exhibits the strongest correlation with poverty, then comes with REC, REP, and GF; excepting REC show a positive correlation to poverty, the others support for poverty alleviation. For control variables, Urbanization (URBAN), Inflation (INFL), and economic growth (GDP) make poverty worse while remittances (REMIT) and trade openness (TRADE) help escape poor situations.

Empirical results and discussion

The test for data stationary is important in econometric models to ensure the reliability and consistency of estimation results. The Im–Pesaran–Shin (IPS) unit root test allows for not so strict balance and missing observation applies in this case. The test has proved that all concerned variables are stationary at level or at first difference. This confirms that the results from regression are consistent and reliable, and does not deal with spurious correlation analysis.

Primary findings

The OLS regression starts as a baseline estimation indicating that all explanation variables and almost controlled variables are statistically significant impact poverty and SDG1 at 1%, only TRADE is significant at 5%. It demonstrates good overall fit with a high value of F statistic (significant at nearly zero percent) and R square is more than 70%. This implies that more than 70% of poverty variation could be explained by independent variables. Specifically, Ecological footprint (EF), RE production (REP), and Green finance (GF) impact negatively on POV while RE consumption (REC) makes it more severe. The impact of control variables are positive from GDP, INFL, FDI, and URBAN while negative from REMIT and TRADE. This result is also consistent with the analysis from pairwise correlation.

Table 4: Empirical Results from multiple estimation methods for POV

	OLS	FEM	REM	GLS	GMM
	POV	POV	POV	POV	POV
GF	-0.4286***	-0.4000***	-0.4249***	-0.0596**.	-0.0725***

REC	5.9763***	13.1944***	10.9818***	6.6867***	1.0541**.
REP	-2.4663***	-6.0332***	-5.4516***	-3.3645***	-0.4573**.
GDP	0.3594***	0.1278***	0.1491***	-0.0034	-0.1432***
EF	-19.5768***	-16.3022***	-17.3334***	-12.4034***	-3.3889**.
REMIT	-3.8319***	-1.0096***	-1.3973***	-1.7246***	-0.5793**.
INFL	0.1549***	0.0339*	0.0469**.	0.0117	0.0288**.
Urban	4.2341***	0.7506***	0.9239***	2.2998***	0.6595**.
TRADE	-4.1012***	-0.9506	-1.3786	-1.8631***	-0.46
FDI	0.5358***	-0.0667	-0.059	0.022	0.0376
L.POV					0.8312***
_cons	44.3558***	41.9611***	46.4327***	41.4807***	7.0782*
N	1366	1366	1366	1366	1322
Rsquare	0.7121	0.5339	0.5637		
Adj-Rsq	0.7099				
Ftest / Wald	335.09	149.63	1538.73	2706.12	
Root MSE	14.075				

Note: * p<.1, ** p<.05, *** p<.01;

Diagnostic tests for this estimation confirm that this OLS regression is not deal with multicollinearity but encounters the problems of autocorrelation and heteroskedasticity. These issues should be solved to ensure unbiased estimated coefficients. The Fixed effect (FEM) and Random effect (REM) have been applied to test for country-specific and time-specific variations in panel data; the Hausman test reveals that the FEM is favourable. However, further testing for regression issues, the FEM also shows the existence of autocorrelation and heteroskedasticity problems. The results from GLS estimation show that GDP, INFL, and FDI are rejected by the T test at 10%. Moreover, there is a remarkable reduction in the magnitude of the coefficients from the green factors, although it still keeps the impact direction as OLS, FEM, and REM estimations.

Robust tests by System GMM estimations show that the first lag dependent variable exposures a very high positive coefficient (above 0.8). This underscores a strong temporal inertia inherent in poverty and the significance of endogenous treatment to be meaningful and reliable for regression inference. All the tests for instrument validity by Hansen, autocorrelation by Arellano-Bond AR(2), and number of instruments less than number of groups are satisfied, confirming that the instrument set is appropriate and the estimation is reliable for managerial implication. From the T test of each coefficient, all explanation and control variables are significant impact POV excepting TRADE and FDI. Especially, three green factors EF, REC, and REP show significant impact at 5% statistically, when green finance (GF) and economic growth (GDP) confirm stronger significantly at 1%. Surprisingly, if the GDP positively and insignificantly impacts poverty from GLS estimation, the SGMM estimation exhibits a high significance with negatively impact to poverty. It implies that the faster growth of the economy could help in alleviating poverty. The SGMM estimations also confirm the signs of impact from other factors to POV are consistent with the static estimations.

Renewable energy consumption and production impact poverty in reversed direction

The positive result of REC informs that promoting REC increases poverty. Expansion of economic activities could create more chances for the poor getting jobs and earnings to improve their well being, however overexploitation of natural resources for economic activities but not using it in effective ways or having protection and reservation programs could make the environment become worse off affecting long term development. This will affect the sustainable life of people and needs for a comprehensive policy on greener friendly production programs to not impact much on vulnerable and poor people.

In reverse, the negative sign of REP reveals that the investment on production of renewable energy contributes to poverty reduction. Clean and cheap energy could contribute to improve daily life and health of the poor, thereby helping them escape the vicious cycle of poverty. In addition, the set up cost for RE energy production creates opportunities to develop supporting industries, which open up more new green jobs and earning opportunities to the poor.

Besides, the opposite impact of REC and REP on poverty also confirms that it is important to distinguish these 2 aspects in the study and both variables should be to specify the true effect from them. The negative impact of REC on the poor is stronger than that of REP, therefore when combining those impacts in general, it seems that renewable energy creating worsens to the poor.

Mediation/ moderation of GF on POV Drivers

Estimation results show that the inclusion of GF creates a vast change in regressor magnitudes of explanation factors. In more detail, the impact from GDP slightly decreases from 0.1597 to 0.1378 negatively while that of REP increases from 0.2035 to 0.4012 negatively, suggesting mediation role of green finance in the relationship between GDP and POV, meanwhile it strengthens the impact of REC on POV that needs further test for interaction term. Besides, the positive coefficient of REC increased from 0.4282 up to 1.1742 that also requires further testing for the possibility of moderation effect. These coefficient changes suggest that the presence of GF strengthens the impact from green factors, however it is worse off to poverty when REC increases more than REP. The mediation results reveal that green finance does not merely provide financial resources for poverty alleviation; rather, it functions as a catalyst facilitating the impact of economic growth on poverty reduction.

Mediation/ moderation of EF on POV Drivers

Similar to the above case of GF, the EF also strengthens the impact from explanation variables by increasing their magnitudes except the coefficient of REC, suggesting the mediating role of EF in facilitating the impact of REC on poverty reduction. However, the inclusion of the mixed factor from EF*REC is significant at 5%, suggesting that EF also moderates the impact from REC to poverty. Unfortunately, REC demonstrates a positive impact on poverty, therefore this mediation/ moderation roles of EF worsen the poverty incidents. This also highlights the poverty-environment

paradox that should be solved to achieve the dual target of social-environment sustainability. For the remaining explanation factors, they negatively impact poverty as the original estimation, the mixed factor between them and EF are insignificant, though the present mixed factors do not change the significant level of these explanation variables.

The mixed factor of EF*REC is negative and significant, while the presence of EF and its mixed factor strengthen the direct impact from REC on POV, suggesting that the integration of EF in the model may interact to strengthen the direct impact from REC to POV, but it reduces the impact of REC from indirect effect via coefficient of the mixed factor. This means EF neutralizes the impact from REC partly in this case.

Heterogeneous analysis of poverty by different income groups

In analysing the heterogeneity of poverty driven by groups of countries, the results exhibit a slight difference in the statistical significance and magnitude of the regression coefficients between country groups. However, most independent variables retain the same dimension of impact on dependent variables as per the original estimation, in which GF, REP, EF, GDP, and REMIT still show a positive impact on poverty reduction while REC and Urbanization increase poverty. However, in terms of magnitude, REC's regressors are higher than that of GF and REP, while the EF is negative but being the factor that should be reduced. Thus, solving poverty issues is complex, requiring a comprehensive understanding of those links between green factors to ensure the effectiveness of integrated policies implementation.

Heterogeneous analysis by regional groups

In analysing heterogeneity between regional groups, from aggregate estimation, the results show that the dummy variables of SouthAsia, REP and INFL are insignificant, while all other green factors and control variables still keep their consistent impact on the poverty rate, as same as that of original GMM estimation. In comparison between regions, the coefficient from SSA is the highest one, followed by coefficients of EastAsia, EurocenAsi, MENA, and LatinAmer orderly, suggesting the poverty incident in SSA region is higher than that of other regions. However, in estimating separately for each dummy variable along with other explanations on poverty, coefficients from three regions are significant, they are SSA, South Asia, and Latin America and Caribbean. The green transition still brings a better chance for poverty alleviation.

Conclusion and implication

This study explores the impact of ecological footprint, green finance, renewable energy in both consumption and production on poverty rate. The insights analysis from impact of 4 green factors and control variables are conducted from baseline estimation to advanced regression methods. The robustness from results is tested by different groups of control variables. Moreover, heterogeneity of their impact by groups of income and region is analysed to derive implications for different countries in accordance with its status.

In synthesized the impact from green factors, even sum of the coefficients is negative, suggesting that the increasing of these green factor leads to a reduction of poverty, however the EF is negative factor that should be controlled, therefore it creates a trilemma in green transition for solving both environment and social issues. Green energy and green finance contributes in solving environmental issues by cutting off EF, the reduction of EF leads to increase of POV. Besides, the REC affects positively on the POV rate, while REP and GF support poverty alleviation. This makes the issues more sophisticated, which requires a more comprehensive aggregated measure from the government for dual benefit and success. The results also raise some policy implications to address poverty issues.

4.4. SDG ACHIEVEMENT – AN EMPIRICAL RESEARCH FOR SDG1 AND ITS DRIVENS

Introduction

Environmental degradation and climate change threaten future life and sustainable economic activities (Destek & Sarkodie, 2019; Ulucak & Bilgili, 2018). From the 8 Millennium Goals to the 17 Sustainable Development Goals, poverty alleviation is always placed in the No. 1 position – the most important position and the goal that must be achieved as soon as possible. Although there have been many explosives and achievements in eradicating poverty, the progress towards the final stages of no poverty everywhere in 2030 of the UN has been slowed down to spread even though the explosives are more expendable.

Green Economy is considered to be an economic development strategy towards sustainable development when the economy is committed to solve 3 pillars of sustainable development including economic development, environmental protection and promoting social justice at the same time. Although not set as goals like the SDGs, the green economy also aims at poverty alleviation. However, research on the green economy often focuses on solving environmental problems, there has not been much research on the role of green economic activities on social efficiency, or more specifically, on the No. 1 goal of sustainable development which is to eradicate poverty. Besides, combining both factors of renewable energy production and consumption in the same research model to address poverty is still a research gap that needs to be addressed.

The green finance source investing in this green process is also a controversial issue. Inconsistency in terminology leads to inconsistent conclusions. The incorporation of both green finance and renewable energy into the aggregate assessment of poverty is even rarer. Some EF studies also mention poverty but go from the side of poverty as an environmental polluter. There is no research direction to the contrary, exploring how this environmental factor integrating with the production and consumption of renewable energy has an impact on poverty alleviation and achieving the No. 1 goal of sustainable development. This is also the research gap that will be addressed in this study. The analytical framework and hypotheses suggested in this topic are from H8 to H12. The methodology follows the process mentioned in Chapter 3.

For variables that are not logarithmically transformed, including SDG, GDP, RULE, and FDI, due to being in percent/ growth rate units. Their values of mean, standard deviation, min, and max are relatively high, with larger standard deviations. In which, the SDG exhibits the largest figures in the mean and standard deviation. Correlation analysis showed that the SDG variable has a statistically significant correlation with all variables, in which the correlation between the SDGs and greening variables such as EF, REC, REP is superior to the remaining variables in the model. Correlations between the independent variables are low, and the VIF values of the variables are small; thus, it ensures that the multivariate regression model does not encounter multicollinearity phenomena.

Empirical results and discussion

Baseline regressions

The results of multivariate regression according to the OLS method show that excepting for FD, the other variables exert statistically significant impacts on the SDG, in which GF, REP, EF, TRADE, and RULE demonstrate positive impact on achieving the SDG, meanwhile REC, GDP, and FDI is in reversed. This is consistent with correlation analysis above except for the FDI case. Although there is no multicollinearity for this estimation, it is the case of heteroskedasticity and autocorrelation from White test and Wooldridge test, respectively.

FEM and REM estimation has been conducted to test for fixed and random effects from unknown heterogeneity. The Hausman test supports the fixed effect in this case. In comparison between FEM and OLS, there is a slight change in the significant level of FD and GDP, in which FD turns to significant at 1% while GDP becomes insignificant. Testing for heteroskedasticity and autocorrelation to FEM estimation, it shows that the estimation still encounters these problems which may cause bias from regressors. The GLS approach is applied to tackle these issues. The result from GLS reveals the significant impact of GF, REC REP, EF on poverty, and even confirms the insignificance of GDP. Besides, there is also a slight change in control variables. However, it should be tested for whether there is an endogeneity case before coming to a final conclusion for those static regressions.

The estimation by sys-GMM confirms again the significant impact of GDP on SDG in alignment with the driven force from GF, REC, REP, and EF. It also exhibits the positive role of GF, REP, and EF for SDG achievement, while REC is a prevention factor, implying that the research result from REC could not generalize for RE factor in policy application; especially, it could not represent for REP in this case. The other control variables are insignificant in this estimation.

Regarding magnitude of impact, the negative coefficient of REC is larger than positive coefficient of REP, however, the sum of coefficient from EF, GF, and REP is larger than coefficient

of REC, therefore if these green factors is increase in the same rate, the green transition, in general, contributes on SDG success.

Table 5: Empirical results of SDG from multiple estimation methods

Variable	OLS	FEM	REM	GLS	GMM
	SDG1	SDG1	SDG1	SDG1	SDG1
GF	0.7490***	0.4793***	0.5055***	0.0929***	0.0934**.
REC	-8.6291***	-13.1216***	-11.7643***	-8.4235***	-1.6181**.
REP	3.3168***	6.7505***	6.2265***	3.0978***	0.6113**.
GDP	-0.8759***	-0.0576	-0.0884	0.0072	0.0922*
EF	18.3996***	17.6233***	17.7768***	12.5208***	3.5175*
TRADE	9.1247***	-2.6660**.	-2.0298*	2.6533***	1.5298
FD	3.7134	52.8757***	50.0265***	33.4415***	1.3206
FDI	-0.2595*	0.1121*	0.1083*	0.0018	-0.0192
rule	6.4057***	3.9625***	4.2062***	2.0862**.	0.9782
L.SDG1					0.8139***
_cons	24.1113***	47.0409***	45.6137***	43.0561***	4.8394
N	1315	1315	1315	1315	1269
Rsquare	0.5772	0.4935	0.5007		
Adj-Rsq	0.5743				
Ftest / Wald	197.97	163.23	1475.98	2008.06	
Root MSE	20.034				

Note: * p<.1, ** p<.05, *** p<.01;

Robustness test for the impact from those green factors on SDG by changing various combinations of control variables, It shows consistent results for the impact direction of these green factors on SDG, in which negative impact from REC and positive effect from REP, GF, EF, and GDP are reserved.

Mediating/ Moderating roles of GF in achieving SDG

For both cases of with or without GF in estimation, all three factors REC, REP, and GDP are significant at 5% or 10%. In addition, the magnitude of the coefficient of GDP reduces from 0.1810 to 0.1517, demonstrating the mediation role of GF in catalysing the effect of economic growth on achieving SDG. Besides, other coefficients of explanation factors are increasing their values when GF is integrated into the regression model. Therefore, they are considered for a further mixed factor in estimation for the test of moderating role of GF. Among three mixed factors integrated into the model, none of them satisfied the test of significance. Thus, It does not confirm the moderation of GF in this case. However, for all the estimations with contribution of GF and mixed variables, all explanation variables are significant and showing that the inclusion of GF makes change in magnitudes of the other variables, in which it reduces impact from GDP while strengthening the

impact from REC and REP. They all suggest the role of GF in catalysing the impact from RE on achieving the target of SDG1.

Mediation/ Moderation roles of EF on achieving SDG

Similar to GF, all explanation variables are significant when adding or excluding EF from the regression, suggesting the role of EF in transforming / catalysing the impact from explanation variables to SDG. However in adding the mixed variables, it is accepted for three mixed variables between EF and green factors (EF*REC; EF*REP, and EF*GF), confirming moderation roles of GF on the impact of these explanation variables on POV.

Observing the change in coefficient of REC, the impact from REC has increased from 0.6529 to 1.3821; 1.1823; 1.7914 when adding GF, EF, and mixed EF*GF into the model, respectively. At first, GF doubles RE to 1.3821, then EF makes it decline slightly, and the mixed factor rises it up to 1.7914, almost triple the original rate. Similarly, although not creating a huge change like in the REC case, the process is almost the same with REP when it increased from 0.3214 to 0.8113 at the end. The adding of GF increases REP but the EF alone reduces it. The mixed factor shows a big change from this impact. This confirms the vital moderation roles of EF in supporting the achievement of the SDG. In general, both RE production and consumption are catalysed by EF in favor for SDG achievement. The mixed factor of EF*GF is also significant from the aggregate estimation, strengthening the impact from GF increases from 0.0745 to 0.1391 (almost double). Without the mixed factor, the addition of EF just makes a slight rise to this coefficient.

Heterogeneity of countries groups classified by income level

Most of the results are slightly different from the general case when EF and GDP turns to be insignificant at several results. In addition, the aggregate model of all groups shows the rejection of the Upper middle income group. In a separate investigation for each dummy, only the Low income group is significant at 5% and the High income group is accepted at 10%, the other two groups are insignificant however they all still demonstrate the significance at three green factors GF REC and REP.

Heterogeneity of countries groups classified by regional level

GF, EF and GDP still show their consistent roles in SDG as the original estimates; however, both REC and REP are insignificant in the aggregate model. The aggregate estimation reveals that only East Asia Pacific is rejected at 10%, the Middle East and North Africa (MENA) is significant at 10%, while the others are accepted at 5%. South Asia is also the region exerting the strongest influence on SDG achievement; then comes the MENA, Latin America, and European and Central Asia. From separated models, only South Asia, SSA, and Latin America are accepted at 5%, these regions are also being concerned as having high incidents of the poor over the world, especially SSA. The highest positive coefficient is from South Asia, while SSA takes a slightly smaller coefficient but negative one.

Conclusion and implication

This study targets on finding roles of green factors targeting on achieving goal 1 of SDGs. It confirms again the meaningful impact from these four factors in which only REC restricts the accessing to SDG while GF, REP, and EF support for achieving this SDG. Economic growth also exhibits a positive factor to this SDG.

The estimation confirms for direct and indirect roles of GF contributing to poverty alleviation and sustainable development. GF funding to mitigate air and water pollution has acted as an intermediary protecting the health and livelihoods of vulnerable groups. GF integrating with EF in solving poverty issues, in addition, it is confirmed that environmental improvement acts as a mediating channel for green finance to realize its poverty reduction goals. By mitigating pollution, GF helps create ecological jobs and protect public health, thereby improving the livelihoods of vulnerable groups.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

The role of green transformation and green finance in addressing the ecological and poverty crisis simultaneously is investigated in this research. A scientific approach has been conducted to analyse for the suggested framework Green energy – Green finance – Environmental degradation – Poverty alleviation – Sustainable development.

Theoretical research about green economics, sustainable development, and supporting theoretical frameworks such as Endogenous growth theory, EKC, STIRPAT framework, etc. are conducted enclosing with analysing debates, gaps, limitations, hypotheses and findings from previous empirical researches. Based on that, the research proposes an analytical framework and empirical research directions to verify this theoretical one. There are four topics appropriate with this framework to be processed by quantitative analysis with appropriate econometric models for panel data assessment. Multiple regression methods are employed to discover this data, estimation results are compared, evaluated, and tested for any potential regression issue of multicollinearity, heteroskedasticity, or autocorrelation for suitable treatments in order to obtain robust, effective, unbiased, and reliable results.

This study provides new empirical evidence on the interconnected roles of green finance, renewable energy, and environmental sustainability in shaping poverty reduction and sustainable development outcomes in developing countries. By adopting a multi stages analytical framework, the findings highlight that the pathways linking economic transformation to development outcomes are not only direct or linear, but rather mediated through environmental and financial mechanisms.

In general, the success of the green transition is not only measured by the amount of EF reduction, but also by its inclusion. For green finance to truly become a driver of sustainable development, policies need to go beyond purely environmental indicators to integrate values of equity and humanity. The studies with advanced quantitative approaches will serve as a lighthouse to guide policymakers in building a world that is both greener and more equitable for all. The findings emphasize that achieving poverty reduction and sustainable development requires a systemic approach that integrates financial development, energy transition, and environmental sustainability into a coherent policy framework.

5.2. POLICY IMPLICATIONS AND RECOMMENDATIONS

To resolve the paradox of clean energy consumption increasing poverty and achieve a win-win solution, policymakers need to intervene to offset transition costs, specifically through the following strategies: (1) Developing Green Microfinance combined with subsidies; (2) Promoting Green Technology Innovation; (3) Utilizing Public Expenditure as a safety net; (4) Integrating Social KPIs into Green Finance projects

Through a combination of market-based instruments, mandatory regulations, and social policies, the economy can realize the goal of substantially and sustainably shrinking the Ecological Footprint. In supporting these strategies, and following the policies on GF and EF, two key factors mediating the impacts of RE and GDP on development outcomes would be recommended below.

Policies to push up green finance

In aiming at developing GF for a better energy transition results achieving dual effect that are ecological improvement and Poverty eradication: (1) Mandating the application of a social taxonomy in GF; (2) Standardizing Green Finance to combat greenwashing; (3) Perfecting legal framework for green finance; (4) Developing Green microfinance combined with subsidies; (5) Unlocking private capital flows by mitigating economic policy uncertainty; and (6) Optimizing Public Expenditure structure. These policies will rebuild the bridge between the supply (production) and demand (consumption) of renewable energy, ensuring that Green Finance develops sustainably and yields genuine benefits for vulnerable groups.

Policies to improve environmental quality

Toward enhancing environmental quality and reducing ecological footprints, It should have policies that intervene more deeply into the microstructure of the economy. Based on the trade-off among production risks (which restrict GF), consumption pull (which promotes GF), and the common goal of reducing EF, the following policies are recommended to improve environmental quality based on scientific evidence: (1) Enhancing subsidies and tax incentives for renewable energy; (2) Promoting investment in research & development (R&D); (3) Enforcing strict environmental policies; (4) Cut off subsidies for fossil related projects (such as coal-fired power generation…) and redirect this public budget toward subsidies or risk guarantees for renewable energy projects; (5) Establishing Carbon pricing mechanisms; (6) Managing strictly the life cycle of

renewable energy projects; (7) Establishing green guarantee mechanisms and blended finance as de-risking instruments in green investment fields; (8) Information standardization and anti-Greenwashing; (9) Enhancing subsidies for green technology innovation and transfer; and (10) Encouraging small-scale consumption to stimulate stable micro capital flows.

5.3. LIMITATIONS AND FUTURE RESEARCHES

While addressing research gaps and achieving stated research objectives, especially for the findings on contradictory results from REC and REP, that the Renewable Energy Production (REP) impedes green finance, while Renewable Energy Consumption (REC) stimulates it, and both mitigate CO_2 emissions, then they are again contradictory in mitigating poverty and sustainability target, addressing a sharp practical issue, this study still entails certain limitations: (1) Aggregation bias in renewable energy; (2) Limitations of environmental indicators; (3) Omitted Moderating Variables and Risks; (4) Disaggregated green finance components; (5) The research concentrates on the first among 17 SDGs; and (7) This research focus on macro level of 74 developing countries only. Further research directions should focus on exploring other aspects of green indicators, ecological components, types of renewable energy and addressing limitation issues mentioned above.