SUSTAINABLE FINANCE AND ENERGY POVERTY: EMPIRICAL INSIGHTS FROM ASIA PACIFIC COUNTRIES

A Thesis

Submitted to the Master of Finance in Sustainable Finance Study Program at the Faculty of Economics and Business in partial fulfillment of the requirements for the degree of

Master of Finance in Sustainable Finance (M.Fin.SF)

Universitas Islam Internasional Indonesia

by:

Dea Fajria Tatarizqa Japal

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ABSTRACT

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Energy poverty, defined as the proportion of the population without access to electricity, is a multidimensional challenge that hinders sustainable development in the Asia-Pacific region. This study empirically examines how sustainable finance, proxied by renewable energy investment, can contribute to reducing energy poverty levels in 38 countries in the Asia-Pacific region during the period 2016–2025. By combining the Green Finance Transmission Framework (GSPE) and the STIRPAT model, this study applies panel data regression and tests the mediating mechanism of renewable energy consumption, along with control variables such as GDP per capita, foreign direct investment (FDI), and urban population. The results indicate that sustainable finance has a significant direct impact on reducing energy poverty. However, interestingly, the mediating mechanism through renewable energy consumption is statistically significant, suggesting that the impact of sustainable finance on energy is always channeled through increased clean energy consumption, and there may be constraints in terms of adoption, distribution, or energy infrastructure. Additionally, GDP per capita significantly accelerates the reduction of energy poverty, but this finding differs from previous studies as it shows that in Asia-Pacific countries, income growth is more effective when accompanied by good energy governance. Meanwhile, FDI does not show a significant effect, suggesting that foreign capital flows have not been optimally directed toward inclusive energy sectors or remain concentrated in carbon- intensive sectors. Interestingly, urbanization actually exacerbates energy poverty in the short term, highlighting infrastructure disparities in rapidly growing urban areas. These findings are validated through robustness tests using a first-difference approach and clustered standard errors. Overall, this study enriches the literature on the relationship between sustainable finance and energy justice, emphasizing the importance of designing financial policies that target social impacts, not just environmental aspects. This research also provides empirical foundations to support the achievement of SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) in the Asia- Pacific region.

Keywords*: sustainable finance, energy poverty, renewable energy investment, clean energy consumption, , Asia-Pacific, mediation effect*

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ABBREVIATION DIRECTORY

ADB	*: Asian Development Bank*
CO_2	*: Carbon Dioxide*
DMC	*: Developing Member Countries*
ESG	*: Environmental, Social, and Governance*
EP	*: Energy Poverty*
FD	*: First Difference*
FDI	*: Foreign Direct Investment*
GDP	*: Gross Domestic Product*
GSPE	*: Green Finance Transmission Framework*
IEA	*: International Energy Agency*
JFPR	*: Japan's Fund for Poverty Reduction*
LIHEAP	*: Low-Income Home Energy Assistance Program*
NGO	*: Non-Governmental Organization*
RE	*: Renewable Energy*
REC	*: Renewable Energy Consumption*
SDGs	*: Sustainable Development Goals*
SF	*: Sustainable Finance*
SUSPOW	*: Sustainable Power Generation*
TP	*: Transcendent Philosophy*
UP	*: Urban Population*
WDI	*: World Development Indicators*

CHAPTER 1
INTRODUCTION

1.1 Research Background

Poverty has become as the central challenge in the pursuit of sustainable development since long time. While progress has been made to alleviate the traditional poverty, new dimensions have emerged that demand urgent attention, as the most pressing being energy poverty. Meanwhile the income-based poverty alone, energy poverty shows the absence of electricity, inadequate, unreliable, and unaffordable energy services which affect directly to people's health, education, productivity, and overall well-being (Zhao et al., 2022). It has emerged as a critical concern in social and energy economics in recent decades (Rasoulinezhad, 2020; Taghizadeh-Hesary et al., 2023; Belaïd & Massié, 2023).

While many regions worldwide have achieved adequate energy access, millions of households remain energy-poor or energy-insecure. The unequal access to natural energy resources in ethical standpoint that inherently God-given and meant to be shared fairly, develops urgent environmental justice question. The Asian Development Bank (2013), stated that 600 million people in Asia and the Pacific still lack access to electricity, and around 1.8 billion people rely on traditional biomass like wood or charcoal for heating and cooking. Similarly, Schislyaeva and Saychenko (2022), there are 2 billion people in 2021 globally still lacked adequate energy access. The International Energy Agency (IEA, 2023) reported 750 million people still lack access to electricity, and 2.4 billion rely on traditional biomass fuels. These disproportionately affect women and children, which mostly bear the burden of fuel collection, are difficult to get the opportunities for education, health, and employment.

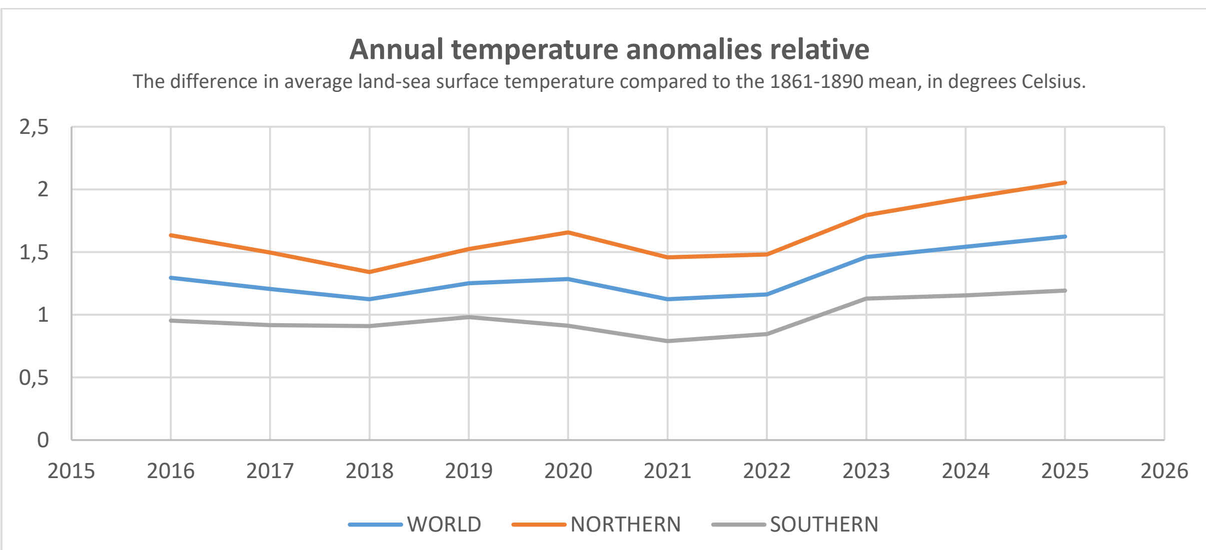
Several countries possess abundant energy resources like fossil fuels in the Middle East, others face challenges related to high extraction costs, poor infrastructure, or the price of energy which renders access unaffordable. The situation is exacerbated by low per capita income, inequitable income distribution, high energy costs, and poor governance quality (Ballesteros-Arjona et al., 2022; Lan et al., 2022).

The international initiatives have been introduced as the response like the EU's Energy Poverty Advisory Hub (EPAH), Japan's Fund for Poverty Reduction (JFPR), China's Solar Energy Poverty Alleviation Program (SEPAP), and the US Low-Income Home Energy Assistance Program (LIHEAP). These programs focusing to improve the household energy efficiency, offer financial aid, and enable access to renewable energy. Meanwhile, energy poverty shows significant, complex, multifaceted problem in nature and the systemic solutions.

At the same time, the energy poverty challenge is inextricably related to the urgent need in climate change, as the largest energy sector, there is greenhouse gas (GHG) emissions with carbon dioxide (CO_2).

According to the International Energy Agency (IEA, 2023), stated there are 70% of global CO_2 emissions stem from the fossil fuels for energy and transportation. These emissions not only accelerate global warming but also disproportionately affect low-income communities, who often reside in environmentally vulnerable areas and lack the adaptive capacity to respond to climate-related disasters.

Figure 1.1. CO2 Emissions Graph



Source: Global Carbon Budget, 2024

As shown in Figure 1.1, global CO_2 emissions have followed a persistent upward trend, indicating that the world remains heavily reliant on fossil fuels despite increased investment in renewables. The figure also highlights the contributions of major economies, such as China, the United States, and India, which remain the largest emitters of CO_2. While emissions from developed countries tend to stabilize or decline due to technological advancements and policy interventions, emissions from developing economies are still rising, driven by industrialization and population growth (Global Carbon Budget, 2024).

The upward emissions trajectory shows transitioning toward clean urgency, low-carbon energy systems. The transition in develop country is a climate imperative and the developmental one. Expanding access to clean, affordable, and reliable energy is crucial to degrage the energy poverty while simultaneously related to international climate commitments like in the Paris Agreement (IEA, 2023).

This dual problem is particularly pronounced in the Asia-Pacific region, where rising energy demands projected to surge by > 20% in the coming caused by population, urbanization, and industrialization (IEA, 2022). This escalation places tremendous pressure on current energy infrastructure and the financial systems that fund energy development. The countries facing more serious socio-economic inequalities and trapped without significant investments in clean, reliable, and affordable energy solutions into carbon-intensive development pathways (Raihan et al., 2021).

However, this growing demand unfolds in a region indicated by stark disparities in energy access. The energy poverty in the Asia-Pacific is spatially uneven, with countries like Myanmar, Papua New Guinea, and several South Asian nations with critical energy access gaps (World Bank, 2021). Women and children are disproportionately impacted because facing the fuel collection burden, which reducing access for education, health, and income generation (Schislyaeva & Saychenko, 2022). Structural barriers, such as low per capita income, inadequate infrastructure, poor governance, high energy prices, and unequal income distribution, further exacerbate this challenge (Ballesteros-Arjona et al., 2022; Lan et al., 2022).

Ironically, many of the most energy-deprived areas are also rich in untapped renewable energy resources. The countries in South and Southeast Asia possess considerable solar, wind, and hydroelectric potential (IRENA, 2023). Meanwhile, there is a gap among renewable supply and actual access causing by financial capacity problems, outdated grids, and policy constraints. This gap requiring technological upgrade, financial flows transformation to be inclusive and sustainable energy infrastructure.

The global financial landscape is witnessing the dynamic rise in investation impact such investment strategies to generate measurable environmental and social impact related to financial returns. It is particularly relevant in energy sector to underserving Asia-Pacific area which the traditional financial neglects marginalized communities. Clean energy investments (decentralized mini-grids and solar home systems) are attracting investors rappidly who are motivated by returns and social benefit (GIIN, 2023). This signals an urgent need in developing financial instruments and frameworks which aligning the private capital with public development goals.

For the solution of these conditions, sustainable finance, as proxied by renewable energy investment, has emerged as a crucial enabler of inclusive energy transitions. Through mechanisms like green bonds, ESG-linked loans, and blended finance instruments, sustainable finance bridging the capital gaps, mitigate investment risks, and accelerate clean energy deployment in underserved regions (Khan et al., 2022; Xu et al., 2022). Government incentives, tax reliefs, and international climate finance initiatives further strengthen these efforts, develop renewable energy to be affordable and scalable among various socio-economic segments.

In actuality, there are already many financial instruments that demonstrate the potential to channel funds toward energy projects, but limited empirical research has explored the pathways through sustainable finance reduces energy poverty. The renewable energy consumption (REC) is an essential mediating role. Since sustainable finance primarily aims to facilitate the clean energy technologies deployment in utility and household levels, while the development REC is the key transmission mechanism through financing efforts lead to improved energy access (Khan et al., 2022; Xu et al., 2022). The lack REC growth causing tangible reduction in energy poverty even significant inflows of green capital. Thus, including REC as a mediating variable not only deepens theoretical understanding (Nguyen & Su, 2023), but also provides empirical insights into the most effective pathways for promoting energy justice and sustainable development in the Asia-Pacific region.

This theoretical linkage gains particular relevance in the Asia-Pacific context, where the dual challenges of energy poverty and climate vulnerability intersect with rapid financial innovation. The region hosts the largest global concentrations of energy-poor populations, while simultaneously becoming a growing hub for green finance initiatives (GIIN, 2023; IEA, 2022). Countries such as India, Indonesia, and the Philippines are rapidly expanding sustainable investment frameworks to attract capital for low-carbon infrastructure (ADB, 2023). However, the empirical exploration of sustainable finance's role in mitigating energy poverty remains limited. Several literatures focuses on high-income or OECD countries (Zhao et al., 2022), neglect the unique institutional and socio-economic conditions which develop energy access result to emerge Asia.

Moreover, the sustainable finance and energy poverty relation must be understood within a broader macroeconomic context. The variables like GDP per capita, foreign direct investment (FDI), and urbanization influence the energy availability and distribution. Higher GDP impact on greater fiscal space for clean energy investments, and FDI can facilitate technological transfers (Dong et al., 2021). Conversely, unplanned urbanization may overburden infrastructure and exacerbate energy access inequality. Institutional factors especially the green governance quality and resource efficiency mediating the financial flows effectiveness toward equitable energy transitions.

According to the background, the study aims to evaluate the sustainable finance role to reduce energy poverty across countries in the Asia-Pacific region. Meanwhile, previous studies concentrates solely on one specific country for example just focus on China or India, while this study adopts a broader regional scope to capture diverse financial and energy dynamics. Country selected according to data availability and shared characteristics, including energy insecurity, environmental vulnerability, and limited access to climate finance. Additionally, the contribution of study to the literature by incorporating underutilized indicators like green governance and natural resource efficiency, which are often excluded from traditional energy poverty analyses. Although energy poverty has been widely investigated (Zhao et al., 2022; Baiwei et al., 2023), its intersection with financial innovation and climate-oriented finance remains underdeveloped. The panel data analysis used to provides empirical insights into how sustainable finance, which mediated by renewable energy consumption to support the SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), advancing a more just and low-carbon future in the Asia-Pacific region.

1.2 Problem Statement

Energy poverty shows a persistent and multidimensional challenge in several developing economies, where significant population still lack access to affordable, reliable, and modern energy services. This issue stems not only from infrastructural and financial constraints but is also exacerbated by high income inequality, weak institutional governance, and a continued reliance on traditional and fossil-based energy sources, factors that collectively contribute to both local energy insecurity and global environmental degradation. While the strategic importance of sustainable and inclusive energy systems has been widely acknowledged in global frameworks such as the Sustainable Development Goals (SDGs), the pace and effectiveness of their implementation in many developing countries remain inadequate. In this context, sustainable finance has emerged as a promising mechanism to mobilize green investments, integrate ESG principles into national development strategies, and accelerate the transition toward low-carbon energy systems. However, despite its growing relevance, the empirical examination of sustainable finance's role in alleviating energy poverty, particularly in the context of Asia-Pacific Countries, remains limited and underexplored. There is a minimun need in understanding the financial mechanisms contributes to expanding clean energy access, especially in regions characterized by complex socio-economic and environmental vulnerabilities. Therefore, this study aims to empirically investigate the impact of sustainable finance on energy poverty across selected Asia-Pacific Countries, using panel data analysis to uncover the economic, environmental, and institutional factors that mediate this relationship.

1.3 Research Question

This study seeks to answer the following questions:

1. To what extent does sustainable finance influence energy poverty in Asia-Pacific Countries?
2. How does renewable energy consumption mediate the relationship between sustainable finance and energy poverty in Asia-Pacific Countries?

1.4 Research Objective

1. This study aims to empirically examine the direct impact of sustainable finance on energy poverty in Asia-Pacific Countries, while controlling for foreign direct investment (FDI), GDP per capita, and urban population.
2. This study also aims to analyze whether renewable energy consumption mediates the relationship between sustainable finance and energy poverty in Asia-Pacific Countries.

1.5 Hypothesis

This study tests the following hypotheses:

1. **H1**: Sustainable finance has a significant effect on energy poverty in Asia-Pacific Countries.
2. **H2** : Renewable energy consumption mediates the relationship between sustainable finance and energy poverty in Asia-Pacific Countries.

1.6 Significance of the study

1.6.1 Academic Contribution

Several prior studies have examined the relationship between green finance and the alleviation of energy poverty, particularly within local and regional contexts. For instance, Zhao et al. (2022) found that green finance significantly reduced energy poverty across 30 provinces in China by promoting industrial restructuring and accelerating green economic recovery. Similarly, Sovacool et al. (2021), in the context of Latin American countries, demonstrated that green finance and renewable energy consumption contributed to reducing energy poverty, with stronger effects observed in countries with moderate levels of energy deprivation. However, most of these studies are geographically limited, focusing on subnational or regional scales, rather than offering a broader, cross-country analysis involving Asia-Pacific Countries. Additionally, the majority of existing research emphasizes the environmental or economic outcomes of green finance, such as carbon emissions reduction or improved energy efficiency, while comparatively fewer studies explicitly investigate access to energy, or energy poverty, as a core social outcome.

Theoretically, the link between sustainable finance and energy poverty can be framed through the STIRPAT model (Stochastic Impacts by Regression on Population, Affluence, and Technology), which underscores the role of structural factors, such as demographic change, economic development, and technological innovation, in shaping environmental and social outcomes. The investment in renewable energy is a technological progress form which enables a cleaner and more inclusive energy transition as broader sustainable finance strategies. In line with Ghisetti et al. (2021) and Zheng et al. (2020) stated that green finance can foster renewable energy adoption across OECD countries. Nonetheless, their focus tends to remain on environmental performance indicators including emission reductions, than energy access as a social development indicator. Even where renewable energy consumption is analyzed, it is often treated as an outcome variable, not as a mediating mechanism between finance and energy poverty.

Unlike many previous studies that adopt the term “green finance,” this research employs the broader concept of “sustainable finance”, which encompasses not only environmental concerns but also social and governance dimensions. In this study, sustainable finance is proxied by renewable energy investment, representing a tangible financial commitment toward achieving an inclusive and clean energy transition. This distinction is crucial, as green finance is often environmentally focused, whereas sustainable finance is designed to balance ecological priorities with social equity, particularly in terms of access to affordable and clean energy. Therefore, the use of renewable energy investment as a proxy for sustainable finance provides a more comprehensive lens than prior studies that tend to limit their scope to environmental effects.

This study contributes to the literature by employing panel data from 38 Asia-Pacific Countries, enabling a cross-national and longitudinal understanding of how sustainable finance affects energy poverty. It advances previous research by investigating the mediating role of renewable energy consumption in the relationship between sustainable finance and energy poverty, rather than limiting the analysis to direct effects. Moreover, this study includes macroeconomic and demographic control variables such as foreign direct investment (FDI), GDP per capita, and urban population to better contextualize the structural dynamics influencing energy access. By bridging the financial and social dimensions of sustainability, this research not only addresses key gaps in the literature but also aligns with global development priorities, particularly Sustainable Development Goal (SDG) 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). As such, the findings of this study offer both theoretical and policy-relevant insights, providing actionable evidence for governments, financial institutions, and international development agencies to design inclusive financial frameworks that foster energy equity.

1.6.2 Public Policy Contribution

From a public policy perspective, this study provides valuable insights for governments and regional organizations in formulating inclusive and effective energy and financial policies. The empirical findings can inform policy design by identifying which aspects of green finance such as ESG investment standards, public-private financing schemes, or international green funding are most effective in improving energy access among underserved populations. As many developing countries struggle to balance economic growth, environmental commitments, and social equity, this study underscores the importance of embedding sustainability principles within national energy and financial policy frameworks. It advocates for the integration of green finance strategies into broader poverty alleviation and energy transition plans, supporting the achievement of SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). Additionally, this research is the policymakers guide to prioritize the investments in green infrastructure and energy access, promote fiscal incentives for private sector participation, and strengthen regulatory environments that support sustainable financial practices. The policy relevance of this study is especially crucial in light of the post-pandemic recovery period, where economic stimulus efforts show a timely opportunity to restructure energy systems towards greener and more equitable outcomes.

1.6.3 Practice Contribution

Practically, this study offers actionable insights for stakeholders like investors, development banks, and non-governmental organizations (NGOs) who are involved in financial and implement clean energy initiatives in Asia. According to crucial role of green finance in overcoming structural barriers to energy access, the findings provide a framework for designing more effective, scalable, and inclusive energy projects. Investors can use these insights to align their portfolios with high-impact energy access interventions that generate both financial returns and social value. Multilateral development institutions use the evidence to tailor their green financing mechanisms to better serve communities in energy poverty with environmental harm degradation. Furthermore, energy project developers and financial institutions can gain clarity on the macroeconomic and governance conditions that facilitate the success of green finance, enabling them to adapt their strategies accordingly. This study also serves as a practical reference for NGOs and community-based organizations working at the grassroots level, helping them to advocate for sustainable and equitable energy solutions that respond to local needs while aligning with global sustainability agendas.

1.7 Research Outline

The writing of this paper is based on a systematic arrangement consisting of several chapters as follows:

Chapter I: Introduction

The introduction contains the research background, research objective, research questions, research hypothesis, research significance and research outline.

Chapter II: Literature Review

The literature review provides an overview of the conceptual framework which includes the theoretical background that discusses each variable utilized in the study, in-depth reviews of relevant previous research.

Chapter III: Methodology

The methodology chapter provides an explanation of the research design, operational definitions of each variable, techniques in collecting data to observe and address research questions, and methods utilized for data analysis.

Chapter IV: Results and Discussion

The findings and their interpretation are presented in this chapter, how the influence of the variables used will be explained while answering the research questions and evaluating the research hypotheses.

Chapter V: Closing

This chapter is a closing that provides conclusions from the research results, research findings, policy implications that can be offered, and also the limitations of the research.

CHAPTER 2
LITERATURE REVIEW

2.1 Theoretical Framework

2.1.1 Green Finance Transmission Framework (GSPE)

In recent years, green finance has become a key instrument in addressing both environmental and social challenges in developing economies. Particularly in the context of energy poverty, green finance operates as a catalyst to enable inclusive access to modern and clean energy services.

This study adopts the Green Finance Transmission Framework (GSPE) as proposed by Cheng and Taghizadeh-Hesary (2023), which explains how green finance contributes to energy poverty alleviation through four main transmission channels:

- G – Green Technological Progress: Green finance supports research, development, and deployment of clean energy technologies such as solar panels, biogas systems, and micro-grids. These technologies, if implemented effectively, can provide affordable energy access to off-grid and underserved populations. However, if innovation is limited to urban or industrial sectors, it may deepen the gap in rural energy access.
- S – Sustainable Power Generation: One of the most direct channels, green finance enables investments in renewable energy infrastructure, hydro, solar, wind, and other sustainable sources. This leads to increased electricity supply and improved grid resilience, especially in energy-poor regions.
- P – Prices (Affordability): By increasing energy supply through renewables, green finance can contribute to lowering the cost of electricity over time. This improves affordability for households and reduces dependence on expensive fossil fuels or traditional biomass. When energy becomes cheaper, energy poverty tends to decline.
- E – Employment Opportunities: Green finance also fosters job creation in renewable energy sectors. These employments engage household incomes, thereby enhance people's ability to pay for energy services. It effects complements the affordability effect, particularly in poor and rural communities.

Empirical evidence supports the GSPE framework. Cheng and Taghizadeh-Hesary (2023) stated a 1% increase in sustainable financing reduces the energy poverty gap in developing Asian countries by 0.02%. Additionally, a 1% increase in sustainable electricity production reduces 0.35% of energy poverty gap. In this study, the GSPE framework shows primary theoretical foundation, guiding the green finance influences energy poverty analysis through technological advancement, sustainable power generation, affordability, and employment.

To enrich the structural socioeconomic factors' analysis and control, this study incorporates insights from the STIRPAT model (Stochastic Impacts by Regression on Population, Affluence, and Technology) by Dietz and Rosa (1994) and later expanded by York et al. (2003). The model is a stochastic reformulation of the IPAT identity.

$$I = a \cdot P^b \cdot A^c \cdot T^d \cdot \varepsilon$$

Where:

- I is the environmental impact,
- P denotes population size,
- A represents affluence (typically GDP per capita),
- T indicates technology (environmental intensity of production),
- a is a constant,
- b, c, d are elasticities,
- and ε is the error term.

This model allows for the empirical estimation on demographic and economic factors affect environmental and energy outcomes. Furthermore, it informs the control variables including urban population, GDP, and foreign direct investment (FDI), factors which influence the supply and demand sides of energy access.

The GSPE and STIRPAT frameworks integration in this study adopts a comprehensive analytical lens to examine the energy poverty determination. The GSPE framework analyzes the financial and policy-oriented channels through green finance impacts energy access, while the STIRPAT model accounts for broader structural factors including population growth, urbanization, affluence, and technology intensity.

The combined framework enables a nuanced energy poverty exploration in Asia-Pacific Countries, highlighting targeted green finance strategies and systemic socioeconomic influences.

Ultimately, this integrative approach enhances the study's explanatory power and policy relevance to understand the complex interplay among sustainable finance and inclusive energy development.

2.1.2. Energy Poverty Trends in Asia-Pacific Countries

Over the past decade, energy poverty trends in the Asia-Pacific Countries have shown significant change, although significant challenges remain until 2025. The region has made significant progress in expanding energy access, driven by strong economic growth, rapid urbanization, and targeted policy interventions and financing support from international institutions. For example, clean energy investment in developing Asia will increase by more than 900% between 2013 and 2023, reaching an estimated USD 729.4 billion in 2023 and accounting for 45% of total global investment in renewable energy (IEA, 2024). However, around 150 million people in the region still do not have access to reliable electricity, indicating that energy inequality remains a serious obstacle to achieving universal energy access (ADB, 2023).

The changing energy mix and infrastructure readiness are key factors shaping the energy poverty landscape in the region. Countries such as China, India, Malaysia, and Thailand have been leaders in adding renewable energy capacity and improving regulation, but the dominance of coal, which will still account for 57% of total electricity generation in 2022, remains a significant environmental and social challenge (IEA, 2024). In addition, aging electricity grids and underinvestment in infrastructure modernization are major barriers to renewable energy integration and expanded access, especially in rural areas and vulnerable communities. The ADB Energy Transition Readiness Assessment 2025 report confirms that without grid modernization and enhanced regional cooperation, the region's clean energy transition ambitions are at risk of being derailed, perpetuating energy poverty for millions (ADB, 2025).

Policy responses in the region are also evolving to meet these challenges. ADB's 2021 Energy Policy marks a significant shift with a commitment to support universal access to reliable, affordable, and clean energy, and an explicit phase-out of financing for new coal-fired power projects. The policy is aligned with global commitments such as the Sustainable Development Goals (SDG 7) and the Paris Agreement, and sets an ambitious target for climate finance, channeling USD 100 billion to ADB's developing member countries over 2019–2030 (ADB, 2023). This approach reflects the recognition that energy is key to inclusive socio-economic development, but that expanding energy access must be done in a sustainable, environmentally sound, and climate-resilient manner.

The novelty of this study lies in its focus on the role of sustainable finance in addressing energy poverty amidst the dynamics occurring in Asia-Pacific countries. Unlike previous studies that have focused more on general progress in energy access, this study fills an important gap by empirically examining how innovative financing instruments, such as green bonds, climate funds, and blended finance, influence the acceleration and equity of energy poverty reduction in the region. Given the enormous financing needs, estimated at USD 282 billion per year by 2050 for electricity grid infrastructure alone, understanding the effectiveness and limitations of sustainable finance is highly policy and scientifically relevant (IEA, 2024; ADB, 2025). Using panel data up to 2025, this study not only makes a novel contribution to the academic literature but also offers practical recommendations for policymakers and development practitioners in accelerating a just and inclusive energy transition in Asia and the Pacific.

2.1.3. Country Classification and Regression

In this study, a country classification approach and panel regression analysis are used to understand the role of sustainable finance, proxied by renewable energy investment, in reducing energy poverty in Asia-Pacific countries. The research sample consists of a number of Asia-Pacific countries selected based on data availability and relevance to the research objectives. Country classification is carried out to ensure that the resulting analysis truly reflects the conditions of developing countries in the Asia and Pacific region, which have diverse economic, social, and energy policy characteristics.

However, unlike some previous studies that separate the analysis into several models based on specific country groups, this study uses a single panel regression model that covers all countries in the sample. This panel regression model is designed to observe the relationship between sustainable finance, renewable energy consumptions for mediating variable, GDP per capita, FDI, Urban Population and energy poverty in aggregate across Asia-Pacific countries. By using panel data, this study can capture the dynamics of the relationship between variables across countries and time periods, and control for unobserved heterogeneity within each country.

This single model approach was chosen because it aims to provide a comprehensive overview of the impact of sustainable finance (proxied by renewable energy investment) on energy poverty in Asia-Pacific countries. The results of this model are expected to show general patterns and the significance of the relationship between key variables, so that they can be the basis for formulating more effective and applicable policies at the regional level. In addition, the use of a single panel regression model also facilitates the interpretation of the results and provides more focused conclusions on the effectiveness of sustainable finance in supporting the energy transition and alleviating energy poverty in Asia-Pacific countries.

2.1.4 Energy Poverty

The crucial aspect to support economic growth and human development. However, the lack of access to electricity in developing countries shows a critical barrier, especially in rural and marginalized regions. Furthermore, the term "energy poverty" encompasses a broad deprivations range like clean cooking, heating, and transport, this study specifically focuses on electricity poverty, which refers to the insufficient or non-existent access to reliable and affordable electricity. This narrower focus is justified by the reality in the majority of Asia-Pacific countries, large-scale energy development projects supported by ADB, have primarily targeted improvements in electricity infrastructure and access (ADB, 2022).

Electricity access is a fundamental enabler of social and economic progress. As highlighted by the International Energy Agency (IEA, 2023), electricity facilitates essential services such as lighting, communication, refrigeration of medicines, access to education through digital technologies, and the functioning of modern businesses. The absence of electricity thus directly impairs opportunities for education, healthcare delivery, productivity, and broader participation in economic and civic life. Therefore, in this research, energy poverty is operationalized specifically as electricity poverty, with electricity access serving as a proxy variable for measuring a country’s level of energy poverty.

While broad definitions of energy poverty, such as that by Reddy (2000), which includes dimensions like affordability, safety, and environmental compatibility, that’s remain relevant conceptually, this study adopts a more measurable and policy-relevant approach by focusing on electricity access as an indicator aligned with SDG 7: “Ensure access to affordable, reliable, sustainable and modern energy for all.” This approach is also consistent with energy development strategies in Asia-Pacific countries, where electricity sector interventions dominate project portfolios (ADB, 2021).

Moreover, disparities in electricity access are profound across regions. In some low-income Asia-Pacific countries such as Nepal, Papua New Guinea, or Myanmar, significant portions of the population still lack access to grid electricity, relying instead on low-quality and expensive energy alternatives such as kerosene, diesel generators, or firewood (IEA, 2023; ADB, 2020). The electricity poverty persistence in these countries shows infrastructure gaps, underscores deeper financial, institutional, and technological challenges that sustainable finance mechanisms are intended to address. To conclude, the study narrows the energy poverty to focus on electricity access due to its critical role to ensure development outcomes, the alignment with ADB's operational focus, and the comparable data across countries. The research aims to contribute empirically to understanding sustainable financial strategies, particularly investment in renewable electricity, may alleviate electricity poverty across Asia-Pacific Countries.

2.1.5 Sustainable Finance

The financial practices which aim for profitability, incorporate environmental, social, and governance (ESG) considerations into investment decisions (OECD, 2020). The sustainable finance in study is operationalized with renewable energy investment as its proxy, and functions as the independent variable that may influence levels of electricity poverty in Asia-Pacific Countries. This approach is grounded to understand the sustainable financial flows, particularly those directed toward clean energy infrastructure as a catalyst to accelerate the energy transition and expand access to electricity in underserved regions (Buchner et al., 2019; IEA & IRENA, 2023).

Numerous studies showed positive relation amongn sustainable finance and energy access. For instance, Weber (2023), financial institutions embedding ESG principles tend to channel investments into environmentally beneficial sectors including solar and wind energy to mitigate environmental degradation and enhance electricity accessibility in off-grid areas. In line with Schoenmaker and Schramade (2019) stated banks with strong sustainability mandates are more likely to hold portfolios favoring renewable energy projects, thereby contributing to low-carbon development and improved energy equity.

Empirical evidence suggests that renewable energy investment, as a core sustainable finance can have direct social and economic benefits. Martínez-Fernández et al. (2012) highlight investments often lead to infrastructure development in rural and remote areas, enhance electricity access and create employment opportunities in the green energy sector. It develops income levels, promote local economic resilience, and alleviate energy poverty, particularly in regions previously reliant on traditional biomass or expensive diesel generators.

Nonetheless, challenges remain, especially in developing contexts. As noted by Zadek (2019), barriers like weak regulatory frameworks, insufficient institutional capacity, and perceived financial risks of green projects continue to deter large-scale renewable investment. This highlights the need for enabling environments like policy, finance, and development priorities are well-aligned to unlock the full potential of sustainable finance. Therefore, the renewable energy investment used as a proxy, this study positions sustainable finance as a strategic driver of electricity poverty alleviation. The ESG principles through such investments not only contributes to climate goals, such as those outlined in SDG 13, but also strengthens progress toward universal energy access under SDG 7, ensuring that financial mechanisms serve both environmental and social equity objectives (UNDP, 2021).

2.1.6 Renewable Energy Consumption

Renewable energy consumption (REC), which refers to the actual use of energy derived from renewable sources such as solar, wind, hydro, geothermal, and bioenergy, plays a crucial mediating role in the nexus between sustainable finance and electricity poverty alleviation. While sustainable finance, proxied in this study by renewable energy investment, serves as a financial enabler of clean energy infrastructure, its effectiveness in reducing electricity poverty depends heavily on whether these investments translate into increased and sustained consumption of renewable energy within communities. In other words, sustainable finance may only significantly impact electricity poverty when it leads to higher adoption and utilization of renewable energy among households, industries, and public facilities in underserved areas (OECD, 2021). Although various sustainable finance instruments have developed significantly in supporting clean energy projects, there is still a gap in understanding the transmission mechanisms that link the availability of such financing to improved energy access for energy-poor communities. In this context, renewable energy consumption (REC) cannot be viewed merely as a technical output of energy projects, but rather as an important pathway bridging financial support and the achievement of energy justice. Without an increase in actual renewable energy consumption at the household, community, or public facility level, the inflow of green capital risks failing to produce tangible impacts on reducing energy poverty. Therefore, treating REC as a mediating variable is not only theoretically relevant but also empirically important for identifying the most effective pathways to convert sustainable financing into inclusive social change. This aligns with a systemic approach that positions energy consumption as an indicator of energy transition success, rather than merely focusing on installed capacity or the number of projects.

Several empirical studies have established the mediating role of renewable energy consumption in the finance-energy development link. For instance, Ali et al. (2021) conducted a panel data analysis on emerging economies and found that green finance does not directly reduce energy poverty unless it effectively facilitates a rise in renewable energy consumption. The study demonstrates that the pathway from green financial flows to improved energy access is mediated by the degree to which renewable energy is actually utilized, rather than just installed or generated. Similarly, Zafar et al. (2022), examining South Asian countries, found that green financial instruments such as green bonds and concessional climate loans enhance energy equity through increased renewable energy consumption, which in turn improves electricity access for marginalized populations.

Thus, the placement of Renewable Energy Consumption (REC) as a mediating variable has a strong conceptual basis. Theoretically, REC is a key element that represents the extent to which sustainable financial instruments actually encourage changes in energy consumption behavior in society. Without this mediating mechanism, the relationship between sustainable financing and energy poverty alleviation becomes weak and indirect. In other words, sustainable financing does not automatically reduce energy poverty unless the investment results in a stable and sustainable increase in clean energy consumption. Therefore, the theory of sustainable energy development emphasizes the importance of measuring not only financial inputs but also how these inputs are converted through RECs into broader and more equitable access to electricity. By using RECs as a mediating variable, this study emphasizes that the influence pathway between sustainable financing and energy justice requires a real functional intermediary, not an assumption of a direct causal relationship.

In the other side, the context of Asia-Pacific Countries, using this mediating mechanism is particularly relevant. These countries often face not only infrastructure challenges but also issues related to affordability and reliability of electricity services. Thus, investment in renewable energy infrastructure, made possible through sustainable finance, must lead to actual uptake and consumption of clean electricity to reduce poverty levels effectively (ADB, 2022). The Asian Development Bank also emphasizes this in its sectoral strategy, noting that the impact of clean energy financing will remain limited unless paired with community-level interventions that drive consumption, such as subsidies for renewable electricity, smart grid implementation, or decentralized off-grid solutions (ADB, 2021). Therefore, renewable energy consumption is a mediator variable which translating financial investments into tangible socio-economic outcomes. It provides the critical link through which sustainable finance affects electricity poverty by ensuring the clean energy made possible by such financing is produced and accessed, used, also sustained across regions with chronic energy deprivation.

2.1.7 Gross Domestic Product per Capita (GDP per Capita)

The GDP per capita used as a control variable, this study aims to decipher complex interactions occur among income, resource abundance and environmental outcomes. It also aims to provide insights intosustainable finance mechanisms can mitigate the adverse resource abundance impact CO2 emissions while shows energy poverty isse. It is expected to contribute to the broader discourse on achieving sustainable development. Generally, higher income levels, as measured by GDP per capita, are associated with energy consumption development. This correlation is driven by intensified industrial activity, rapid urbanization, and evolving consumption patterns. The dynamic interplay among income and energy use is particularly evident in countries heavily reliant on non-renewable energy sources, where economic growth often leads to higher energy demand and associated emissions (Sadorsky, 2011).

The GDP per capita in this study serves as a critical control variable alongside energy poverty, resource abundance, sustainable finance, and greenhouse gas emissions. The GDP per capita incorporation allows to capture a broad spectrum of socioeconomic factors which influencing energy accessibility and consumption behaviors. For resource-rich countries, economic expansion frequently entails the exploitation of natural resources, which can exacerbate greenhouse gas emissions due to continued dependence on carbon-intensive energy sources (Sachs & Warner, 2001).

While economic growth has the potential to alleviate energy poverty by enabling investments in infrastructure and technology, it must be managed carefully to avoid intensifying CO2 emissions. Here, sustainable finance is crucial to channeling investments toward renewable energy projects that are inherently low-carbon, ensuring that economic development does not compromise environmental sustainability (Zhang et al., 2022).

The GDP per capita is a control variable in this study aims to unravel the complex interactions among income levels, resource abundance, and environmental outcomes. Moreover, it seeks to provide empirical insights into sustainable finance mechanisms mitigating the negative environmental impacts of resource-driven growth while simultaneously addressing energy poverty. Such understanding contributes to the broader discourse on sustainable development pathways in Asia-Pacific Countries (ADB, 2023).

2.1.8 Foreign Direct Investment (FDI)

The FDI can have both enabling and limiting effects on energy access related to institutional quality, energy policies, and governance frameworks in the host country. In empirical models, FDI is mostly used as a control variable to capture the external foreign capital inflows influence on domestic energy development. It is also a significant driver of economic growth and development, especially to emerge and develop economies. It facilitates capital inflows, technology transfer, and integration into global value chains that enhancing the productivity and infrastructure development. However, the FDI and energy consumption or environmental sustainability relationship is multifaceted. Meanwhile, FDI can contribute positively by cleaner technologies and renewable energy projects, especially when guided by stringent environmental regulations and sustainable finance frameworks (Yang, Zhang, & Xie, 2024). Furthermore, FDI developed energy consumption and environmental degradation if investments are channeled into energy-intensive industries relying on fossil fuels, that is oftenly in the case in resource-rich developing countries where regulatory oversight may be weaker (Lin & Benjamin, 2018).

In the sustainable finance and energy poverty context, FDI is crucial control variable as influencing the supply and demand sides of energy. The FDI development stimulate industrial growth and urban development, thereby increasing energy demand, but it can also provide the necessary capital to expand energy infrastructure, including renewable energy capacity. Therefore, controlling for FDI helps isolate the specific sustainable finance mechanisms effects on energy poverty and greenhouse gas emissions by accounting for the external influence of foreign investment flows. This is particularly relevant in Asia-Pacific Countries, where FDI patterns vary widely and can significantly impact the energy transitions trajectory and environmental results (Yang et al., 2024).

2.1.9 Urban Population

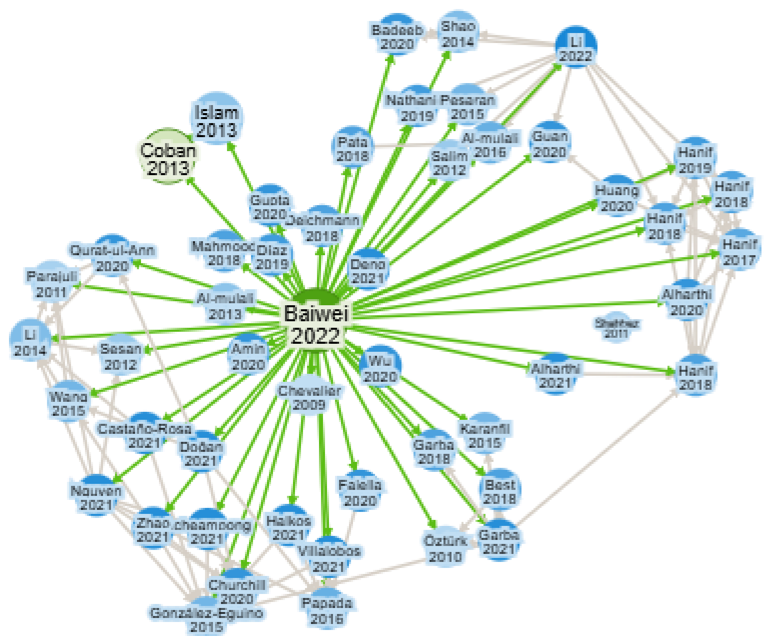
Urban population growth is a critical demographic factor that shapes energy consumption patterns and access to energy services. Urbanization often drives economic development by concentrating labor, capital, and technology, which can improve energy infrastructure and accessibility. However, rapid urban population increases also pose challenges, such as heightened energy demand, increased pollution, and infrastructure strain, particularly in developing countries where urban planning and energy systems may lag behind growth rates (Sadorsky, 2011).

In many Asian developing countries, urban areas typically have higher rates of electricity access compared to rural regions, yet urban energy poverty persists in informal settlements and low-income neighborhoods. Moreover, urbanization tends to increase reliance on electricity and modern fuels, shifting consumption patterns away from traditional biomass but potentially increasing carbon emissions if the energy mix remains fossil fuel-heavy (Lee, Chang, & Chen, 2020). The urban population is control variable to get a more precise understanding on demographic shifts influence the relationship among sustainable finance, renewable energy deployment, and energy poverty alleviation.

The urban population control makes the analysis can differentiate the effects of sustainable finance on energy poverty from those driven by urbanization trends like increased energy demand and infrastructure development. It is crucial to develop targeted policies that address the unique challenges of urban energy poverty while promoting sustainable, low-carbon energy transitions in Asia-Pacific Countries (ADB, 2023).

2.1.10 Previous Study

Figure 2. 1. Bibliometric Network Graph



Source: Author's Compilation from Researchrabbit apps

Based on the above diagram, the large number of studies conducted on the energy sector means that it has become a major focus in the economic literature due to its crucial role in economic development and environmental sustainability. Many studies highlight the importance of understanding energy poverty, which is often a major cause of impeding sustainable development in developing countries. This is supported by several studies, (Qurat-ul-Ann & Mirza, 2020) for example, through their meta-analysis, showed that around 71% of the population in developing countries experienced energy poverty between 2000 and 2019. In addition to the high percentage of energy poverty in developing countries another study, by (Wang, Wang, Li, & Wei, 2015) showed other results, using China as their study case they found that despite the decline in energy poverty (in China between 2000 and 2011), the use of clean energy is still very limited. This fact underscores that improving energy access alone will not be enough so there is still a need to focus on the quality and sustainability of energy sources.

Furthermore, research conducted by Baiwei et al (2022) has the same pattern as this study. In their research, they make CO2 the main variable that is influenced by independent variables, namely energy poverty, sustainable finance, resource abundance. The results show that there is an inverse relation to energy poverty and carbon emission. While a negative relation occurs between sustainable finance and carbon emission. Their research highlights that alleviating energy poverty will intensify environmental pollution. So it is necessary to improve access to clean energy and share of sustainable finance in total investment. Similar results were found in a study by Coban and Topcu (2013) which also highlighted the need for better financial development to increase the spread of energy consumption.

To support the theoretical framework and the selection of variables in this study, a review of previous literature related to sustainable finance and energy poverty has been conducted. These studies provide empirical foundations on how sustainable finance, renewable energy, and other socioeconomic factors contribute to reducing energy poverty, particularly in developing countries. The table below summarizes several key studies that serve as references for this research:

Table 2. 1 Table of Previous Studies on Sustainable Finance and Energy Poverty

Study (Year) & Source	**Country**	**Key Variables Examined**	**Main Findings**
"The Impact of Green Finance on Energy Poverty: A Case Study of China" (2021), Zhang et al.	China	EP (electricity access), GF, SEG, GDP per capita	Higher GF and SEG are associated with increased electricity access; GDP per capita moderates the relationship.
"Innovation and Energy Poverty: Evidence from Developing Countries" (2019), Sharma & Kumar	India	EP (cooking fuel), INNOV, CPI_HE	Innovation in renewable energy technologies can reduce reliance on traditional fuels, but energy prices influence adoption rates.

Study (Year) & Source	Country	Key Variables Examined	Main Findings
"Renewable Energy Deployment and Energy Security in Sub-Saharan Africa" (2022), Ouedraogo	Sub-Saharan Africa	EP (clean cooking fuels), SEG, GDP per capita, POP	Renewable energy sources improve energy security but population growth challenges energy access.
"Green Finance and Sustainable Development Goals: A Global Perspective" (2023), Global Sustainable Investment Alliance (GSIA)	Global	GF, SEG, SDG Indicators including access to energy	Green finance is increasingly directed towards projects supporting renewable energy and improved energy access, contributing to the SDGs.
"Household Energy Expenditures and Poverty in Latin America" (2018), CEPAL	Latin America	CPI_HE, GDP per capita, POP, Energy Poverty Indicators	Energy costs disproportionately impact low-income households.

Source: Author's Compilation

Drawing from the previous studies listed above, several key variables have been identified as influential in determining the level of energy poverty. These include sustainable finance, renewable energy output, income levels, urbanization, and population. The following table outlines the expected direction of influence of each variable on energy poverty within the context of Asia-Pacific Countries, as well as the supporting literature for each.

However, despite the growing body of literature, several limitations in previous studies remain. First, many of the existing works tend to focus on single-country contexts, such as China or India, which limits the generalizability of their findings across other developing countries, particularly within the Asia-Pacific region. For instance, the study by Zhang et al. (2021) primarily centers on China, with limited application to countries with differing governance, financial infrastructure, or energy access conditions. Second, several studies have used energy access as a static outcome, without considering the dynamic interactions like those mediated by renewable energy consumption or output, affect the relationship among finance and poverty alleviation (Ali et al., 2021; Baloch et al., 2022). Third, there is a tendency to treat sustainable finance and green finance as homogeneous concepts, without differentiating among various financial instruments (e.g., green bonds vs. concessional loans), which may vary in their effectiveness (GSIA, 2023; OECD, 2021). Moreover, several studies have emphasized the positive association between green finance and energy access, but failed to examine non-linear or indirect pathways, such as mediating effects of renewable energy infrastructure or regulatory support (Acheampong et al., 2021). Finally, several previos studies do not fully account for institutional or governance constraints, which are often critical to determine sustainable investments are translated into real energy services in rural or marginalized regions.

These limitations highlight the need for a more context-specific, multi-country analysis, especially within Asia-Pacific Countries, that incorporates a mediated framework. such as the role of renewable energy output or consumption as mediators between finance and energy poverty. This study attempts to fill that gap by providing empirical insight into how renewable energy investment (as a proxy for sustainable finance) can reduce electricity poverty, both directly and indirectly, through increased renewable energy utilization.

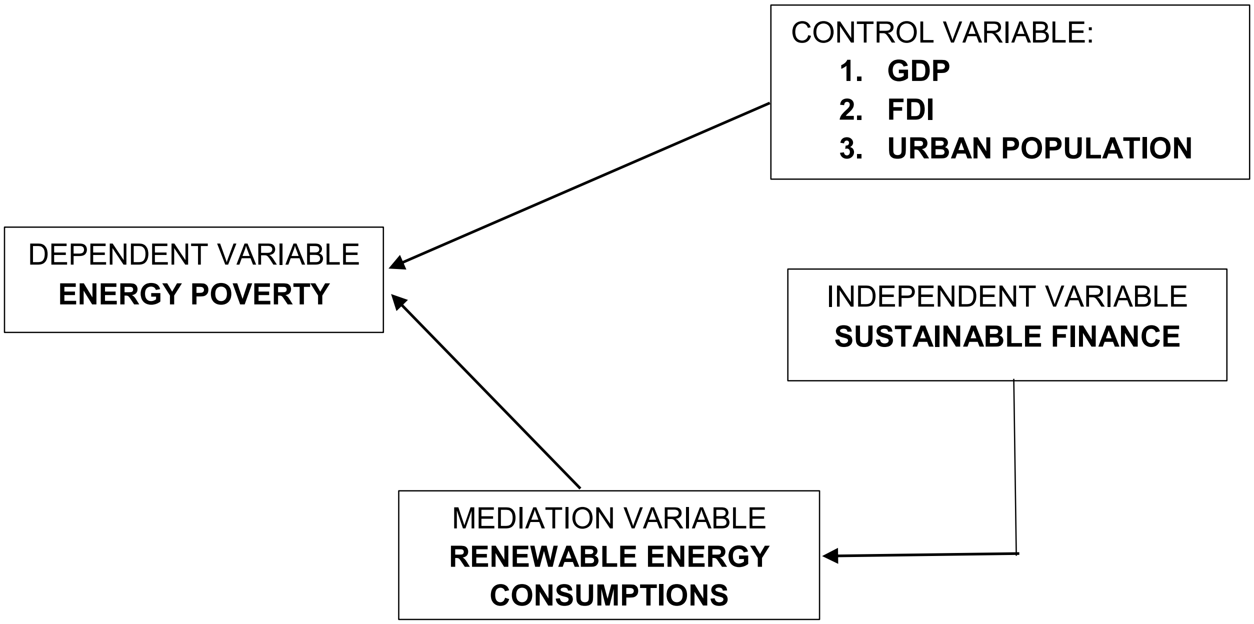
Building upon the reviewed literature and acknowledging its limitations, this study identifies several key variables that are hypothesized to influence the level of electricity poverty in Asia-Pacific Countries. These variables include sustainable finance (proxied by renewable energy investment), renewable energy consumption (REC) as a mediating factor, as well as macro-level controls such as FDI, GDP per capita, urbanization, and urbaniation. Each of these variables plays a distinctive role in shaping access to electricity, either through financial mechanisms, infrastructural capacity, or socioeconomic conditions. The table below outlines the expected direction of influence for each variable on electricity poverty, along with supporting empirical evidence from previous studies. This mapping provides the conceptual basis for the research model tested in this study.

Table 2. 2 Expected Variables and Signs for Research on Sustainable Finance Energy Poverty

Variable	Expected Sign	Explanation	Supporting Studies (Author, Year)
EP (Energy Poverty) as Dependent Variable			
SF (Sustainable Finance)	Negative (–)	Increased GF reduces EP.	Zhang et al. (2021)
REO (Renewable energy output)	Negative (–)	Higher SEG reduces EP.	Ouedraogo (2022)
GDP per capita	Negative (–)	Higher income reduce EP.	Zhang et al. (2021)
FDI (Foreign Direct Investment)	Negative (–)	Higher FDI educes EP.	Khan & Majeed. (2023)
UP (Urbanization)	Negative (–)	Increased urbanization (improving access to energy infrastructure),reduce energy poverty (EP).	Liddle (2020)

Source: Author's Compilation

2.1.9 Conceptual Framework



CHAPTER 3
RESEARCH METHODOLOGY

3. 1 Type of Research

This study uses a quantitative research type that aims to identify and analyze the causal relationship between energy poverty, sustainable finance, renewable energy consumption, GDP per capita, FDI, and urban population in 38 Asia-Pacific Countries with a time span of 2016 to 2025. Quantitative research was chosen because this approach allows researchers to measure variables objectively through numerical data, as well as using statistical methods to find patterns, relationships, and influences between variables.

Table 3 1 Selected Country

Afghanistan	Indonesia	Nauru	Thailand
Armenia	Kiribati	Nepal	Timor-Leste
Azerbaijan	Kazakhstan	New Zealand	Tonga
Bangladesh	Kyrgyz Republic	Palau	Turkmenistan
Bhutan	Lao PDR	Pakistan	Tuvalu
Cambodia	Maldives	Papua New Guinea	Uzbekistan
China	Marshall Islands	Samoa	Vanuatu
Fiji	Micronesia, Fed. Sts.	Solomon Islands	Viet Nam
Georgia	Mongolia	Sri Lanka	
India	Myanmar	Tajikistan	

Source: Author's Compilation

This research is included in the category of explanatory research, which aims to explain the phenomenon or cause-and-effect relationship between the variables studied. The focus of this research is to test the hypothesis related to how sustainable finance can play a role in reducing energy poverty. This approach is relevant for this study because the problem of energy poverty is not only technical, but also illustrates how complex economic, social and environmental systems are at the global level. Thus, this study contributes both in theory and practice, especially by supporting clean energy transition efforts as well as achieving sustainable development in developing countries.

3. 2 Research Approach

A deductive approach is used in this research, which begins with an existing theory then followed by data collection and analysis to then test the formulated hypothesis. This approach is suitable for quantitative research types that have the aim of explaining the relationship between variables assisted by using empirical data. This research also uses models from previous studies conducted by Hanif et al. (2018) and Nguyen and Nasir (2021) to analyze the relationship between the main variables. The model used emphasizes the impact of energy poverty as the dependent variable with independent variables namely sustainable finance (proxied by renewable energy investment), mediating variable namely Renewable energy consumption, GDP per capita, FDI and urban population.

3. 3 Data and Data Source

This study uses secondary data from Asia-Pacific Countries collected from various reliable sources, namely:

- **World Development Indicators (WDI):** provides information on EP, REC, GDP per capita, urban population, and other economic indicators.
- Asian Development Bank (ADB): Provides Information on Sustainable Finance using renewable energy investment as a proxy.

3. 4 Object and Subject of Research

The object of this study is the relationship between sustainable finance, renewable energy consumption, GDP per capita, FDI, and urban population, and their impacts on energy poverty in Asia-Pacific countries. The subjects of the study were 38 Asia-Pacific Countries selected based on on data availability and their shared regional challenges, including energy insecurity, environmental vulnerability, and limited access to climate finance. Asia-Pacific countries are ideal for this investigation because the region is home to some of the world's largest energy-deprived populations, while also being a hotspot for green finance interventions. Moreover, the ADB has emerged as a key actor in climate-related investment, committing over USD 6 billion annually for clean energy and climate adaptation projects in Asia-Pacific countries. The inclusion of 38 representative Asia-Pacific Countries's ensures analytical robustness while maintaining the feasibility of the empirical approach.

The subjects of this study include countries with diverse social and economic characteristics, reflecting the complexity of energy poverty issues and clean energy transition challenges.

Heterogeneity across countries is analyzed using a panel approach to ensure broad generalizability of the results.

3. 5 Data Collection Methods

This study uses a secondary data collection method, obtained from various official and reliable sources. The data collected includes quantitative information on energy poverty, sustainable finance, Renewable energy consumption, GDP per capita, FDI and urban population. Data collection was carried out by considering the availability of data for the period 2016 to 2025 and coverage of 38 Asia-Pacific Countries. This method was chosen because secondary data allows researchers to access a broad and standardized dataset, which is needed for cross-country analysis. In addition, the use of data from international institutions increases the validity of the results because the data has gone through a processing and verification process by the authorities.

Table 3 2 Variable Description

Variables	Measurement	Sources
Dependent Variables		
EP	A proportion of the population has no access to electricity (% of total Population)	WDI
Independent Variables		
SF	Renewable Energy Investment / Project ($ million)	ADB
REC	Renewable Energy Consumption (% of total final energy consumption)	WDI
GDP	GDP per capita (current US$)	WDI
FDI	Foreign Direct Investment net inflows (%)	WDI
UP	Urban Populations (% of total population)	WDI

Source: Author's Compilation

3. 6 Data Analysis

This study utilizes panel data, which is a blend of time-series and cross-sectional data, encompassing observations of several units across various time intervals. The data consists of information from 38 Asia-Pacific Countries from 2016 to 2025, spanning 9 years of research. Gujarati (2004) defines panel data as information collected from people, businesses, states, countries, etc., over a period of time. Panel data has the benefit of providing more informative, diverse, less correlated, and efficient data by integrating time series of cross-sectional observations, resulting in more degrees of freedom. Panel data is considered better in discovering and quantifying impacts that are not discernible in either cross-sectional or time series data alone. The study utilized a balanced panel dataset, where each cross-sectoral unit includes an equal amount of time series observations (Brooks & Wichamann, 2019).

3. 7 Panel Data Regression

This study utilized panel data regression for data analysis. Panel data regression is a statistical method that merges cross-sectional and time-series data, resulting in a larger number of observations than using cross-sectional or time-series data separately (Gujarati, 2004). The panel data regression general model is represented by the equation provided by (Baltagi (2005):

$$Yit = \beta 0+\beta 1X1it+ \beta 2X2it+\ldots \ldots+ \beta nXnit+\epsilon it \quad \textit{(Equation 3. 1)}$$

Where:

Yit	: Dependent variable
β0	: Intercept coefficient
β1, β2, βn	: Coefficients assigned to each
εit	: error term in prediction.

The mathematical model used to analyze the impact of Sustainable finance, Renewable energy output, GDP, FDI and Urbanization is as follows:

Model 1: Direct Effect of Sustainable Finance on Energy Poverty

General Notation:

$$Y_{it} = \beta_0 + \beta_i X_{it} + \sum_{k=2}^{n} \beta_k C_{kit} + \epsilon_{it} \quad \textit{(Equation 3. 2)}$$

Applied Model :

$$EP_{it} = \beta_0 + \beta_1 SF_{it} + \beta_2 d\_ln\_GDPpercapita_{it} + \beta_3 FDI_{it} + \beta_4 d\_UP_{it} + \epsilon_{it} \quad \textit{(Equation 3. 3)}$$

Where :

EP_{it} : Energy poverty in country i at time t

SF_{it} : Sustainable finance in country i at time t

$d\_\ln\_GDPpercapita_{it}$, FDI_{it} , & d_UP_{it} : Control variables

ϵit : Error term

Model 2: Effect of Sustainable Finance on Renewable Energy Consumption (Mediator)

General Notation:

$$M_{it} = a_0 + a_i X_{it} + v_{it} \quad \textit{(Equation 3. 4)}$$

Applied Model :

$$d\_REC_{it} = a_0 + a_1 SF_{it} + v_{it} \quad \textit{(Equation 3. 5)}$$

Where :

d_REC_{it} : Renewable energy consumption in country i at time t

SF_{it} : Sustainable finance in country i at time t

v_{it} : Error term

Model 3: Full Model

General Notation :

$Y_{it} = \gamma_0 + \gamma_i X_{it} + \gamma_i M_{it} + \sum_{k=2}^{n} \gamma_k C_{kit} + n_{it}$ *(Equation 3. 6)*

Applied Model :

$EP_{it} = \gamma_0 + \gamma_1 SF_{it} + \gamma_2 d\_REC_{it} + \gamma_3 d\_ln\_GDPpercapita_{it} + \gamma_4 FDI_{it} + \gamma_5 d\_UP_{it} + n_{it}$

(Equation 3. 7)

Where :

EP_{it} : Energy poverty in country i at time t

SF_{it} : Sustainable finance in country i at time t

d_REC_{it} : Renewable energy consumption (mediator)

$d\_\ln\_GDPpercapita_{it}$, FDI_{it} , & d_UP_{it} : Control variables

n_{it} : Error term

3.7. 1 Common Effect Model

This model utilizes pooled least squares estimation method to merge cross-sectional and time series data into a single entity. The model's parameters are calculated using the least squares approach or ordinary least squares (OLS). The common effect model is the most basic estimate method compared to other panel data regression model estimation strategies. The common effect model ignores variations in individual and temporal dimensions. In the common effect model, it is believed that the data behavior of each individual shows consistent throughout different time periods. Parameter estimation in the common effect model involves merging cross-sectional and time-series data as a unified entity, disregarde variations in time and individual characteristics (Widarjono, 2007).

3.7. 2 Fixed Effect Model

The statistical technique used in panel data analysis to account for individual-specific differences, such as changes in intercepts across different units and helping to control for unobserved variability. It ensures for the distinct qualities management which remaining constant throughout time but various among different units or entities. The model uses fixed effects in examining changes inside each unit over time and determine the independent and dependent variables relationwship within each unit, while considering unitspecific characteristics which remaining constant over time. To address these disparities, one can utilize methods like dummy variables or Least Square Dummy Variables (LSDV) to accommodate.

3.7. 3 Random Effect Model

The random effect model is a statistical method that incorporates error factors to account for disturbances that may occur in the interaction between time and individuals. In the random effect model, it is assumed that there are variations in intercepts among individuals. There are two residual components: general residual and individual residual. The total residual comprises both time-series and crosssectional data, wherea s the individual residual pertains to the residual of each cross-sectional unit.

The random effect model is often referred to as the error component model. The random effect method suggests different intercept terms for each entity that remain constant across time. It assumes that the link between explanatory and explained factors is consistent both cross-sectionally and temporally. In the random effect model, the intercept terms for each cross-sectional unit are assumed to come from a common 'global' intercept α, which is consistent across all units and time periods, along with a random variable ϵi that varies between cross-sectional units but remains constant over time. ϵi quantifies the stochastic variation from the intercept term of each entity to the overall intercept term α (Brooks, 2019).

The random effect model is suitable when entities in the sample are randomly picked from the population, whereas the fixed effect model is more suited when the sample entities properly reflect the complete population. In the Random Effect Model, individual random effects (αi) are assumed to adhere to a normal distribution. The random effects are calculated in conjunction with other model parameters. By including random effects, unobserved unique unit features that might impact the dependent variable can be accounted for.

The Random Effect Model is appropriate when there is considered random and uncorrelated unobserved heterogeneity among units with the independent variables. It offers estimates of the average impact of the independent factors on the dependent variable, considering the heterogeneity among various units. This model does not enable the calculation of unit-specific effects or the analysis of change within units over time.

3.7. 4 Selecting the Appropriate Panel Data Regression Model

From the three methods of panel data regression model; common effect model, fixed effect model, and random effect model. The next stage is to identify the most suitable method for a specific situation among the three options. Widarjono (2007) identifies three particular tests for selecting the optimal panel data regression model: The Chow test, the Hausman test, and the Lagrange Multiplier test.

3.7. 4.1 Chow Test

The Chow test is a statistical method used to assess the equality of coefficients in two distinct regression models. It is commonly used in econometrics to determine if there are significant changes in the structure of the data, especially in time series or panel data analysis. The Chow test evaluates the difference in the sum of squared residuals between a regression using combined data and another utilizing subsets of the data. The test statistic is compared to a critical value obtained from the F distribution. The Chow test is utilized to choose the optimal panel data regression model between models derived from the common effect model method and models derived from the fixed effect model approach, based on specific assumptions (Baltagi, 2005).

The formulation presents two competing hypotheses: H0: Common Effect Model, while H1: Fixed Effect Model. When the p-value is greater than 0.05, the null hypothesis (H0) is accepted, suggesting that the chosen model is the Common effect model. If the p-value is < 5% significance (0.05) then the null hypothesis is rejected and indicates that the most appropriate model used is the fixed effect model.

3.7. 4.2 Hausman Test

It is utilized to choose the best model between the fixed effect model and the random effect model. The specification test in the hausman test follows the chi-square distribution based on the Wald criterion. The two estimated models operate under different assumptions regarding the relationship among the independent variables and the specific impact on unobserved individuals.

The hypotheses used in the Hausman test are H0: Random Effect Model, and H1: Fixed Effect Model. If the test results show a P-value <5% significance level (P-value <0.05) the decision is to reject the null hypothesis and indicate that the fixed effect model is the most appropriate model to use. if the p-value>0.05 indicates the null hypothesis accepted which means that the random effect model is the most appropriate model.

3.7. 4.3 Lagrange Multiplier Test

The statistical test used to evaluate the feasibility of a regression model that assesses whether a set of restrictions on the model variables is in line with the data. This test analyzes the compatibility among the model and the restrictions on the parameters by estimating them independently. The LM test used to choose between two models, including Common Effect Model or the Random Effect Model.

The two hypotheses are, H0: Common Effect Model, while H1: Random Effect Model, with the criterion that if the P-value is under than significance level (P-value<0.05), the decision is to reject the null hypothesis and the random effect model used, otherwise if the p-value>0.05, the decision is to accept the null hypothesis and common effect model used.

3.7. 5 Additional Methodological Approaches

To enhance the reliability and internal validity of the findings, this study incorporates several additional methodological steps beyond the baseline panel data regression. First, a robustness test used to assess the estimated relationships among different model specifications and subsamples. Including alternative estimation techniques like Fixed Effects (FE), Random Effects (RE), and Feasible Generalized Least Squares (FGLS), as well as controlling for potential multicollinearity and heteroskedasticity. Sensitivity analyses applied by excluding outlier countries or years to ensure that the primary results are not driven by a few influential observations. This robustness check is essential in panel data studies to verify the consistency of results under various assumptions (Arellano, 2003; Wooldridge, 2010).

Second, to formally examine the mediating renewable energy consumption (REC) effect on sustainable finance and electricity poverty relation, the Baron and Kenny (1986) mediation analysis framework used. The steps are:

1. Regress the dependent variable (electricity poverty) on the independent variable (sustainable finance),
2. Regress the mediator (REC) on the independent variable, and
3. Regress the dependent variable on independent variable and the mediator.

Mediation is confirmed if the effect of the independent variable on the dependent variable decreases when the mediator is included, and the mediator is statistically significant. To support the robustness of mediation findings, the Sobel test and bootstrapping procedures are also employed to examine the significance of indirect effects, following the improvements suggested in Preacher & Hayes (2008). These additional methodological procedures help ensure that the conclusions drawn from the empirical analysis are both statistically sound and substantively meaningful, particularly in the context of identifying causal pathways through which sustainable finance can alleviate electricity poverty in Asia-Pacific Countries.

CHAPTER 4
RESULT AND ANALYSIS

4.1 Descriptive Statistics

Table 4. 1 Descriptive Statistics

Variable	Obs	Mean	Standard Deviation	Minimum	Maximum
ep	342	82.29	32.55	0.01	100.00
sf	342	207.28	1274.15	0.0122	23406.70
reo	342	21.92	29.75	0.01	100.00
gdp	342	865.48	7101.71	0.01	49624.18
fdi	342	3.30	4.92	0.01	37.17
up	342	39.87	24.15	0.00	100.00

Source: Author's Compilation from Stata

The descriptive analysis in this study provides an initial overview of the characteristics of the data used to examine the role of sustainable finance in addressing energy poverty in Asia-Pacific countries (please go to Appendix 9). The panel data analyzed includes 342 observations over the period 2016 to 2025, which generally show an even distribution of time with an average observation year in 2020. The main variables in this study are the level of energy poverty (ep), sustainable finance (sf), and renewable energy output (reo). The results of descriptive statistics show that the level of energy poverty in Asia-Pacific countries varies greatly, with an average of 82.29 and a standard deviation reaching 32.55. The very extreme minimum and maximum values, namely 0.01 to 100, indicate significant differences in energy access between countries and time.

Meanwhile, sustainable finance as the main variable that is the focus of the study also shows a very large disparity. The average value of sustainable finance is 207.28 with a standard deviation reaching 1274.15, and a very wide range of values from 0.012 to 23,406.7. This indicates that some countries have made great progress in implementing sustainable finance, while other countries are still far behind. Renewable energy output also shows quite large variations, with an average of 21.92 and a standard deviation of 29.75, reflecting the very diverse contribution of renewable energy among member countries.

In addition to the main variables, several control variables such as Gross Domestic Product Per Capita (GDP), foreign direct investment (FDI), and the proportion of urban population (up) also show significant variations. FDI with an average of 3.30 with a standard deviation of 4.92 also shows quite wide variations, as does the proportion of urban population which ranges from 0 to 100, indicating the existence of very rural to very urban countries.

4.2 Unit Root Test

Panel data analysis often requires pre-testing for stationarity in order to ensure valid statistical inferences and avoid spurious regression problems. One of the most prominent methods for such testing is the Levin-Lin-Chu (LLC) unit root test, introduced by Levin, Lin, and Chu (2002), which is specifically designed for panel data structures. The LLC test assumes that all cross-sectional units in the panel share a common unit root process. Although this assumption is somewhat restrictive, the test offers higher statistical power compared to other first-generation unit root tests under certain conditions.

The LLC test is based on the following hypotheses:

- Null hypothesis (H_0): Each individual time series in the panel contains a unit root (i.e., the series is non-stationary).
- Alternative hypothesis (H_1): Each individual time series is stationary (i.e., does not contain a unit root).

If the null hypothesis is rejected, the series is considered stationary, which implies that its statistical properties such as mean, variance, and autocorrelation. Stationarity is a crucial requirement for many econometric models because non-stationary series can lead to inflated R-squared values and unreliable estimators.

Table 4. 2 Root Test Result

Variable	Transformation Level	p-value	Stationarity Status
SF	Level	0.000	Stationary at level
FDI	Level	0.000	Stationary at level
REC	First difference (d_REC)	0.0156	Stationary after 1st differencing
UP	First difference (d_UP)	0.000	Stationary after 1st differencing
EP	Level	0.000	Stationary at level
Ln_GDP	First difference (d_ln_GDP)	0.000	Stationary after 1st differencing

Source: Author's Compilation from Stata

The results of the LLC test show that three variables, namely Sustainable Finance (SF), Foreign Direct Investment (FDI), and Energy Poverty (EP), are stationary at their levels, as indicated by p-values below the 1% significance level. This implies that the null hypothesis of a unit root is rejected for these variables, and therefore, they can be included in econometric models such as fixed effects or random effects regression without requiring transformation.

In contrast**,** Renewable Energy Consumption (REC), Urban Population (UP), and Gross Domestic Product (GDP) are not stationary at the level. However, they become stationary after being differenced once, which is evident from their significant p-values in first-difference form. This implies that these variables follow an integrated order one process, I(1)**.** Including them in level form in a regression model would lead to biased and inconsistent estimators due to non-stationarity. From a methodological standpoint, it is essential to transform all I(1) variables to their first differences before including them in panel regression models, unless a cointegration relationship is present and the estimation method is adjusted accordingly (e.g., Fully Modified OLS or Dynamic Panel Estimation).

Therefore, for the next stages of analysis, particularly for causality testing or regression analysis, it is appropriate to use the level form of SF, FDI, and EP, and the differenced form of REC, UP, and GDP. This approach ensures that all series satisfy the assumption of stationarity, thereby improving the robustness and validity of the empirical findings.

4.2.1 First Difference Model Analysis with Clustered Standard Errors

In this study, a robustness test is conducted to ensure that the main model estimation using the fixed effect method can be empirically accounted for and free from bias that may arise due to the characteristics of the panel data used. One of the robustness methods applied is the first difference (FD) model approach, in which the variables analyzed in the model are converted into the form of changes between periods (differencing), so that the focus of the analysis is on the dynamics of variable changes, not their absolute values.

The first difference model was chosen for several methodological reasons. First, this model is effective in eliminating fixed effects that are constant across time in each cross-section unit (country). By subtracting the value of the variable at time t from the value of the variable at time t-1, constant unobserved factors can be eliminated automatically without the need for additional parameter estimation. Second, the FD model can also overcome the problem of non-stationarity in variables that are often encountered in cross-time panel data, thus minimizing the risk of biased and inconsistent estimates. Furthermore, in order to accommodate the possibility of heteroscedasticity and autocorrelation in residual errors that are common in panel data with repeated observations in the same unit, this model also uses the clustered standard errors calculation method at the panel unit (country) level. The use of clustered standard errors provides a more valid standard error estimate because it allows the correlation of residual errors to occur between observations in the same cluster, so that statistical inference becomes more accurate and credible. This suggests that in the context of the first difference model, foreign direct investment does not have a clear influence on changes in energy poverty over the observed time period. This factor could be due to the fact that the investment allocation is not directly directed at the energy sector or also because the effect of the investment takes a longer time to affect socioeconomic conditions at the community level. Meanwhile, the change in urbanization variable (d_up) has a positive and highly significant coefficient (coefficient = 1.9379, $p < 0.001$). This result indicates that urbanization in the short term is associated with an increase in energy poverty. A possible explanation is that urbanization often puts enormous pressure on energy infrastructure in cities, so that adequate energy access cannot immediately meet rapidly increasing demand, leading to energy poverty conditions even though urban economies are growing in aggregate.

4.2.2 Implications of Findings of Robustness Test

Overall, the robustness test results reinforce the main findings of the study using the fixed effects model, particularly regarding the important role of sustainable financing and economic growth in reducing energy poverty. The use of the first difference model provides additional validation by eliminating unobserved fixed effects and focusing on changes between periods, so that the results obtained are more focused on the temporal dynamics of these variables.

The insignificance of the renewable energy output and foreign direct investment variables in the first difference model provides an important signal that the effect of these variables on reducing energy poverty may be long-term and require a longer adaptation process, such as infrastructure development, regulatory improvements, and strengthening institutional capacity. This opens up opportunities for future research to examine the lag effects and long-term effects of renewable energy investment and FDI.

The significant positive urbanization efect on energy poverty adds important insights into the rapid urbanization in developing countries. Rapid urban development has to be matched by sufficient energy infrastructure investment in reducing the negative impact on energy poverty. This calls for an integrated policy among urban development and equitable and sustainable energy provision.

4.2.3 Robustness Test Conclusion

The first difference model used with clustered standard errors show the sustainable finance and GDP per capita variables consistently significantly negative effect on changes in energy poverty, confirms the essential role to alleviating energy poverty. Meanwhile, renewable energy output and foreign direct investment variables do significantly affects on short-term changes, while urbanization contributes to increasing energy poverty. These findings create an important contribution to the sustainable energy literature and provide policy inputs for countries in energy and urban development challenges.

4.2.4 Data and Variables Used

The dependent variable analyzed is energy poverty (EP), which is the energy poverty in the level among years. The independent variables which focusing on analysis include sustainable finance (SF), changed in renewable energy consumption (d_REC), changed in economic growth according to GDP per capita (d_ln_GDPPercapita), foreign direct investment (FDI), and changed in urbanization levels (d_UP). There are 38 countries in panel data consists which observed for 9 years, from 2015 to 2023, resulting in a total of 304 observations.

These variables were selected according to theoretical studies and empirical literature that shows aspects of sustainable financing, renewable energy capacity, economic strength, foreign investment, and urbanization are the main factors which significantly affect the energy poverty level.

4.2.5 Estimation Results and Interpretation

Table 4. 3 Robustness Test

Statistik	Fixed Effects	Random Effects
R-squared (within)	0.8674	0.8656
R-squared (between)	0.2199	0.2227
R-squared (overall)	0.5125	0.5221
rho	0.8449761	0.5254675
sigma_u	26.952233	12.147714
sigma_e	11.544435	11.544435
Prob > F / chi2	0.0000	0.0000

Source: Author's Compilation from Stata

The estimation first difference model result with clustered standard errors shown in Table 6 and Appendix 4. From the regression results, it can be seen that the model is able to explain about 85% of the variation in changes in energy poverty (R-squared = 0.8535), which is quite high and indicates that the independent variables used simultaneously are able to capture the dynamics of changes in energy poverty well.

The coefficient of the variable change in sustainable finance (SF) is negatively significant at the 5% significance level (coefficient = -0.000104, p = 0.025). It means that increase in sustainable finance from year to year contributes significantly in reducing the energy poverty level in the observed countries. It is in line with expectations, as an increase in sustainable finance opens up opportunities for investment and clean energy infrastructure development which improving people's access to affordable and environmentally friendly energy.

Meanwhile, the variable change in renewable energy consumption (d_REC) shows a negatively non-significant coefficient ($p = 0.415$). It implies in the short term, changes in renewable energy output have not directly had a significant impact to reduce energy poverty. Most likely, renewable energy development takes longer to have a real impact on people's energy access, especially in developing countries with limited infrastructure and regulations.

The variable change in GDP per capita (d_ln_GDPPercapita) has a statistically significant negative effect (coefficient = -0.001472, $p < 0.001$), showing that economic growth has a real role in reducing energy poverty. This is consistent with economic theory which states that an increase in per capita income increases people's purchasing power, and led easier access to decent and modern energy. The variable change in foreign direct investment (FDI), a positively insignificant coefficient was found ($p = 0.605$).

4.3 Classical Assumption Test

The impact of sustainable finance on energy poverty in Asia-Pacific Countries analysus, it is important in ensuring that the model used fit with basic statistical requirements through classical assumption tests. Classical assumption tests are a series of tests applied on a regression model in ensuring the estimation is BLUE (Best, Linear, Unbiased, Estimator), namely a regression model which producing an estimator that is unbiased, consistent, normally distributed, and efficient. Classical assumption testing is crucial in regression models that use the Ordinary Least Square (OLS) approach, where the linear variables relationship is a fundamental assumption. In the "The Sustainable Finance and Energy Poverty: Empirical Insights from Asia-Pacific Countries", the classical assumption testing is implemented in ensuring the results of the panel data regression analysis provide an accurate and reliable picture of the sustainable finance and energy poverty relationship in the selected countries.

In panel data analysis, right estimation model is a crucial first step before proceeding to classical assumption testing. The three main approaches used in panel data regression model estimation: Common Effect Model, Fixed Effect Model, and Random Effect Model. When the Fixed Effect (FE) or Pooled Least Square (PLS) model is the best choice based on the model specification test, then classical assumption testing must be carried out comprehensively. Conversely, if the Random Effect

(RE) model is the optimal choice, some literature states that classical assumption testing does not need to be carried out comprehensively. Classical assumption testing that is generally carried out on panel data regression models includes normality, linearity, multicollinearity, heteroscedasticity, and autocorrelation tests, where each test has an important role in ensuring the validity of the model used.

4.3.1 Multicollinearity Test

Table 4. 4 Correlation Matrix of Variables

Variable	ep	sf	rec	ln_gdp	fdi	up
ep	1.0000					
sf	0.0137	1.0000				
d_rec	0.1166	0.0156	1.0000			
d_ln_gdp	0.8724	0.0218	0.2312	1.0000		
fdi	0.1746	-0.0037	-0.0093	0.2078	1.0000	
d_up	0.6852	0.0130	-0.1463	0.6720	0.2508	1.0000

Source: Author's Compilation from Stata

Before conducting the Variance Inflation Factor (VIF) test, this study examined the correlation matrix among independent variables to identify potential multicollinearity issues. Generally, a correlation coefficient above 0.70 is considered an early indication of possible multicollinearity (Gujarati, 2004). In this study, several variable pairs showed moderate-to-high correlation coefficients slightly exceeding 0.70. However, to confirm whether these correlations pose a serious threat to the regression model, the VIF test was applied. The results showed that all VIF values were well below the critical threshold of 10, indicating that although some variables are moderately correlated, there is no severe multicollinearity affecting the model. Therefore, the variables included in the regression can be considered sufficiently independent for reliable estimation.

Table 4. 5 Multicollinearity Result

Variable	VIF	1/VIF
d_up	1.64	0.609
d_ln_gdp	1.56	0.640
fdi	1.07	0.936
d_rec	1.02	0.976
sf	1.00	0.998
Mean	**1.26**	

Source: Author's Compilation from Stata

Multicollinearity test in research is employed to see the high correlation between independent variables. According to Kennedy (2008), the variance inflation factor (VIF) value is commonly used as a general measure to investigate multicollinearity symptoms with an acceptable threshold of 10. When the VIF value exceeds 10, it indicates the presence of multicollinearity or high correlation between predictor variables in the study.

Based on the results of the multicollinearity test (please go to Appendix 1) that has been carried out, it can be seen that the VIF values for all independent variables used in the model are far below the critical value of 10. Specifically, the variable d_up (Urban Population) has a VIF value of 1.64 , which is the highest value among all variables, but still far below the threshold indicating a multicollinearity problem. The variable d_ln_gdp (GDP per capita) has a VIF value of 1.56, followed by fdi (foreign direct investment) with a VIF value of 1.07, d_rec (renewable energy consumption) with a VIF value of 1.02, and sf (sustainable finance) with the lowest VIF value of 1.00. The average VIF value of all variables is 1.26, which is very low and confirms that the model as a whole is free from serious multicollinearity problems.

The 1/VIF value, which is the inverse of VIF and is also called tolerance, also supports this conclusion. The tolerance ranges value for all variables are 0.609 (> 0.998 (for sf), where the closer to 1, the lower the level of multicollinearity. These results show the sustainable finance (sf) variable as the main focus of the study has a very high level of independence from other independent variables, as showed in the lowest VIF value (1.00) and the highest tolerance (0.998). This is very beneficial for the analysis to isolate the effect of sustainable finance on energy poverty without any significant intervention or overlap from other independent variables. By fulfilling this non-multicollinearity assumption, researchers can obtain more stable regression coefficient estimates and more accurate relationships between variables interpretations, thereby credibility of research findings development on the sustainable finance role to address energy poverty in ADB's developing member countries.

Kalnins (2022), multicollinearity in a model does not introduce bias in the estimated coefficients. However, it does lead to variance of the estimates development, resulting in larger standard errors and consequently reducing the statistical significance (p-value) of the model. According to the literature, if a variable with collinearity is a control variable and is not collinear with the variable of interest, then it does not pose an issue (Allison, 2012). Awan & Azam (2022) and Jin et al. (2017) stated the variables GDP and GDP2 to provide evidence for the EKC theory.

4.3.2 Heteroscedasticity Test

Table 4. 6 Heteroscedasticity Result

Test Statistics	**Value**
Chi² (df = 38)	58445.44
p-value	0.0000
Decision	Reject H_0 (Heteroskedasticity detected)

Source: Author's Compilation from Stata

Heteroscedasticity is the presence of different amounts of residual variability in a regression model, where this variability varies across different data sets. The examination of heteroscedasticity in these three research models indicates the presence of signs of heteroscedasticity. This is corroborated by the results of the heteroscedasticity test with p-value<0.05 indicating the rejection of the null hypothesis and the presence of heteroscedasticity (please go to Appendix 2).

4.3.3 Autocorrelation Test

Table 4. 7 **Autocorrelation Result**

Test Statistics	Value
F	7.156
p-value	0.0111
Decision	Reject H_0 (Autocorrelation detected)

Source: Author's Compilation from Stata

An autocorrelation test, also known as a serial correlation test, examines the connection between errors or residuals from a regression model at different time intervals or data points. This phenomenon occurs when errors in a time series or panel data display a consistent pattern of correlation. Autocorrelation challenges the concept of independence in classic linear regression, which posits that errors are unrelated. When there is autocorrelation, the calculated coefficients may remain unbiased, but the standard errors and hypothesis tests may become inaccurate (Kennedy, 2008).

This study used the Wooldridge's test, described by Drukker (2003), to examine the autocorrelation test. The null hypothesis being tested is the absence of serial correlation. The results of the Wooldridge's test for the three models in this study indicate a P-value of less than 0.05. Based on these results, it rejects the null hypothesis (H0) and concludes that there is a presence of serial correlation in this study (please go to Appendix 3).

The classical assumption tests in this study reveal the presence of heteroskedasticity and first-order autocorrelation. To ensure the validity and reliability of the regression estimates, this study adopts a fixed effect panel data model with robust standard errors. While Driscoll-Kraay standard errors are commonly used to handle cross-sectional dependence, this study applies robust standard error adjustments to correct for heteroskedasticity and autocorrelation, ensuring consistent and unbiased estimates. Robust standard errors, as implemented in the fixed effects model, are widely recognized for addressing heteroskedasticity and autocorrelation in panel data settings (Arellano, 1987). Although this study does not incorporate Driscoll-Kraay standard errors, the robust adjustment used here ensures the consistency of standard errors and the reliability of inference.

4.4 Choosing Best Regression

When selecting the most suitable regression model for analyzing panel data, it is necessary to perform three testing steps: 1) Chow test; 2) Hausman Test; and 3) Lagrange Multiplier Test. These three tests are used to ascertain the most suitable model to employ among the three models, specifically the common effects model, fixed effects model, or the random effects model.

Table 4. 8 Model Specification Test Result

Chow Test	**Hausman Test**	**Lagrangian Multiplier Test**	**Best Model**
(Prob >F)	(Prob > chi2	(Prob > chibar2)	
0.000	0.8671	0.0000	Random Effect Model
Data processed by Author			

Source: Author's Compilation from Stata

The table above presents the results of several tests conducted to determine the most appropriate model for analyzing the first test performed is the Chow test (please go to Appendix 5), which compares the common effect model and the fixed effect model. The Chow test yields a p-value less than 0.05, indicating that the null hypothesis, which assumes the common effect model is adequate, is rejected. This suggests that the fixed effect model is more suitable for the data.

Following this, the Lagrangian Multiplier (LM) test is used to decide between the common effect model and the random effect model. The LM test produces a p-value of 0.0000, which is well below the 0.05 significance level (please go to Appendix 7). This result implies that the random effect model fits the data better than the common effect model.

Finally, the Hausman test is conducted to choose between the fixed effect model and the random effect model. The test results in a p-value of 0.8671, also above 0.05 leading to a failure to reject the null hypothesis that the random effect model is consistent and efficient (please refer to Appendix 6). This indicates that the random effects model is preferred, as it provides consistent and efficient estimates for this dataset.

Considering the outcomes of the Chow test, Lagrangian multiplier test, and Hausman test together, it can be concluded that the random effect model is the most appropriate and reliable model to use for analyzing the data involving all countries in this study.

4.5 Outcomes Derived from Random Effect Model

4.5.1 Analysis Strategy and Model Selection

This study aims to analyze the effect of Sustainable Finance (SF) on Energy Poverty (EP) by taking Asia-Pacific countries as its object, also by considering the role of Renewable Energy Consumption (REC) as a mediating variable. To be able to answer these objectives thoroughly, researchers use two analytical approaches, namely using panel regression with the Random Effect Model and path analysis based on the Baron and Kenny (1986) framework, which is then also complemented by the Sobel test.

In this study, the panel regression approach is used first to identify the direct effect of SF on EP and also to evaluate the extent of SF's influence on REC, as well as whether REC contributes directly to EP. This model allows researchers to reveal variations between countries (cross-section units) that cannot be observed directly but are assumed to be random.

Furthermore, to deepen understanding of the indirect relationship mechanism, researchers use a path analysis approach. This approach allows us to assess whether REC can act as an intermediary variable in the relationship between SF and EP, using statistical procedures that are more focused on testing mediation effects, including through the Sobel test. These two approaches were ultimately chosen in a complementary manner. Panel regression provides an overview and direct effects in a longitudinal data structure, while path analysis provides a more specific understanding of the transition mechanisms or flow of effects between variables, which is particularly important in the study of sustainable development policies and energy transition.

4.5.2 Panel Regression Analysis: Direct Effect of Sustainable Finance on Energy Poverty

The first step in this analysis is to use a Random Effect panel regression approach with the aim of testing the direct effect of Sustainable Finance on Energy Poverty. Estimation was done in three different models viz:

Model 1: Tests the direct effect of SF on EP without including the mediating variable REC

Table 4. 9 SF on EP Regression Result

Variable	Coefficient	Robust Std. Error	p-value
sf	-0.0001503***	0.0000407	0.000
fdi	0.0694368	0.085398	0.416
d_ln_gdp	5.029244***	0.9472343	0.000
d_up	0.5265789**	0.2346543	0.025
cons	25.00553***	3.425694	0.000

Standard errors in parentheses

p < 0.01 : *, p < 0.10 : **, p < 0.05 : ***.

Source: Author's Compilation from Stata

Model 2: Testing the effect of SF on REC to identify whether SF has potential indirect effects through renewable energy consumption

Table 4. 10 SF on REC Regression Result

Variable	Coefficient	Robust Std. Error	p-value
sf	0.0004364***	0.0001045	0.000
cons	28.22454***	4.927816	0.000

Standard errors in parentheses

p < 0.01 : *, p < 0.10 : **, p < 0.05 : ***.

Source: Author's Compilation from Stata

Model 3: Combining SF and REC simultaneously to see if there is any change in the significance or strength of the effect

Table 4. 11 Full Model Regression

Variable	Coefficient	Robust Std. Error	p-value
sf	-0.0001265**	0.0000413	0.004
d_rec	0.211904***	0.0510867	0.000
fdi	0.0536851	0.2132091	0.803
d_ln_gdp	-0.0011657**	0.0003766	0.004
d_up	1.853141***	0.1497468	0.000
cons	10.00425	4.258041	0.024

Standard errors in parentheses

$p < 0.01$: *, $p < 0.10$: **, $p < 0.05$: ***.

Source: Author's Compilation from Stata

The results listed in Model 1 show that SF has a negative and significant effect on EP with a coefficient of -0.0001503 and p-value <0.01. This means that an increase in sustainable financing can significantly contribute to reducing energy poverty. This is in line with theory and previous findings which show that environmentally and socially oriented financial flows (such as green bonds, ESG investment, blended finance and impact investment) are able to support the development of clean energy infrastructure and more inclusive access (Asbahi et al., 2019; Huang et al., 2022).

Then in Model 2, the results show that SF has a positive and significant effect on REC with a coefficient value of 0.0004364 and a p-value <0.01. This means that an increase in sustainable financing can encourage an increase in renewable energy consumption, so it can indicate that there is a flow of SF funds into clean energy projects. However, when both variables are included together in the full model as shown in Model 3, the results show that while SF remains significant on EP, REC becomes statistically significant on EP with a p-value of 0.004. In other words, although renewable energy consumption increases due to financing with the adoption of sustainable systems, the increase has shown a strong enough direct effect to reduce Electricity Poverty.

4.5.3 Mediation Analysis: Renewable Energy Consumption as a Mediating Mechanism

To further explore the role of REC as a mediating variable, researchers used a path analysis approach with three steps as proposed by Baron and Kenny (1986). These steps include three steps. First, testing the relationship between SF and EP (total effect). Second, testing the relationship between SF and REC. And third, testing the relationship between SF and EP by including REC as a mediator.

In the first step, which is also evident in the results of Model 1 regression, SF was again proven to have a negative and significant effect on EP with a p-value < 0.01. This indicates that an increase in sustainable finance can directly reduce energy poverty. The second step, also seen in the results of Model 2 regression, shows that SF has a positive and significant effect on REC with a p-value < 0.01. This indicates that green funds are indeed channeled to the renewable energy sector. Interestingly, in the third step, which is also evident in the results of Model 3 regression, when REC is included together with SF in the regression model for EP, the results show that REC becomes statistically significant and has a positive effect on EP with a coefficient value of 0.2119 and a p-value < 0.01. This indicates that an increase in REC is associated with an increase in energy poverty in this model. Meanwhile, the effect of SF on EP remains significant, though with a slightly lower coefficient compared to the initial model. The interpretation of these findings suggests partial mediation. While sustainable finance has a direct impact on reducing energy poverty, part of that impact also occurs and is reflected through an increase in REC. The positive effect of REC on EP in this model likely reflects an imbalance in distribution or an energy transition that is not yet inclusive, where renewable energy is indeed increasing but has not yet optimally reached populations experiencing energy poverty.

To confirm the presence of this mediating effect, the researchers conducted a Sobel test. The formula for the Sobel test statistic is as follows:

The calculated test statistics are:

$$z = \frac{a \times b}{\sqrt{b^2 \times s_a^2 + a^2 \times s_b^2}}$$

Table 4. 12 Sobel Test Result

Input	Test Statistic	*p*-value
t_a = 4.18	Sobel test = 2.9450	0.0032
t_b = 4.15	Aroian test = 2.9034	0.0037
	Goodman test = 2.9884	0.0028

Source: Calculation for the Sobel test (Preacher and Hayes (2004, 2008)

The Sobel test results showed significant results at the 1% level (with a p-value of 0.0032). These results were reinforced by the Aroian and Goodman tests, all of which showed that the indirect effect of SF on EP through REC was indeed statistically significant. Thus, the path analysis approach showed that REC acted as a transitional mechanism that bridged some of the influence of SF on EP.

4.5.4 The Impact of Sustainable Finance (SF) on Energy Poverty

The coefficient of sustainable finance (SF), proxied by renewable energy investment, is estimated at -0.0001265 and is statistically significant at the 1% level (p-value = 0.004). This indicates that a one-unit increase in SF is associated with a 0.0001265 unit reduction in the energy poverty index, holding all other variables constant. While the numerical value of the coefficient may appear small, its statistical robustness suggests a meaningful structural relationship in which increasing financial flows into sustainable investments tangibly contributes to alleviating energy deprivation. This result empirically supports the central hypothesis of this study, as well as the Global Sustainable Power Equation (GSPE) framework, which posits that financial flows embedded with environmental and social safeguards such as green bonds, ESG-linked funds, and climate finance can be effective tools for accelerating access to inclusive energy systems. In the Asia-Pacific context, where many communities still lack reliable electricity, such investments can help overcome both infrastructure and affordability barriers. Therefore, this finding underscores that sustainable finance is not only a climate mitigation mechanism but also a vehicle for achieving social equity and development goals. Moreover, the fact that SF remains statistically significant even in the full model (Model 3), where renewable energy consumption is also included, highlights its direct impact on reducing energy poverty, independent of its indirect pathways. Moreover, the coefficient offers a broader policy insight that sustainable finance is not merely a climate instrument, but also a tool of social equity. The finding aligns with studies by Carvajal et al. (2021) and IEA (2022), which argue that well-directed green finance can deliver co-benefits for poverty alleviation when focused on decentralized renewables, mini-grids, and rural electrification. Thus, expanding sustainable finance should be seen not only as an environmental imperative but also as a strategic policy for achieving SDG 7 and SDG 10 concurrently.

4.5.5 The Influence of Renewable Energy Consumption (REC) as a Mediating Variable

To investigate whether Renewable Energy Consumption (REC) mediates the relationship between Sustainable Finance (SF) and Energy Poverty (EP), the Author employed the classical mediation framework introduced by Baron and Kenny (1986) called Path Analysis, consisting of three regression steps, along with a formal Sobel test to assess the significance of the indirect pathway.

The results of the two analytical approaches used in this study (namely, panel regression with random effects and path analysis) provide a complementary picture of the relationship between sustainable finance (SF), renewable energy consumption (REC), and energy poverty (EP) in Asia-Pacific countries. The main findings confirm that SF has a significant direct impact on reducing energy poverty, with indications that part of this impact also flows through increased renewable energy consumption. Although in the panel regression model (particularly Model 3) the REC variable does not show strong statistical significance for EP, the path analysis approach reveals a statistically significant mediating effect, as evidenced by the results of the Sobel, Aroian, and Goodman tests. These results indicate that, although the direct effect of REC on EP is not clearly visible in the model, there is an indirect pathway that operates systematically, namely through the flow SF → REC → EP. This finding is also consistent with the concept of transition mechanisms in sustainable development policies, where changes at the structural level (e.g., in funding allocation) do not immediately produce direct impacts on energy welfare but must go through a series of intermediate processes, one of which is through increased capacity and access to clean energy.

In this context, REC acts as an intermediary linking sustainable finance policies with energy welfare outcomes. Sustainable finance, through various instruments such as green bonds, ESG investment, blended finance, and impact investment, can drive the growth of the renewable energy sector. However, the final outcome of reducing energy poverty depends heavily on whether the energy actually reaches energy-poor communities or not. Therefore, REC's role as a mediator is conditional, meaning it will effectively act as a channel only if distribution and access are inclusive for all members of the population. This finding also reinforces the literature on the importance of energy justice in the energy transition. As stated by Sovacool and Dworkin (2015), an energy transition that focuses solely on technology and investment without considering social justice aspects has the potential to create new inequalities.

Furthermore, in this study, even though renewable energy consumption has increased, it does not necessarily mean that vulnerable groups will automatically feel the benefits. Therefore, the indirect impact of SF through RECs will only be optimal if clean energy is developed and distributed equitably and affordably across all levels of society. Furthermore, this finding also has important policy implications. Governments and financial institutions must recognize that expanding access to clean energy is not sufficient through increased allocation of sustainable funds alone but requires projects or investments that genuinely impact social equity, particularly for all levels of society.

Additionally, affirmative policies and governance mechanisms are needed to ensure that renewable energy truly reaches those experiencing energy poverty, such as through targeted subsidies, micro-grid infrastructure development, or incentives for community-scale energy projects. Otherwise, sustainable finance risks creating only "statistical progress" without real change for the poorest communities. Finally, the integration of panel regression and path analysis approaches in this study emphasizes the importance of using more than one analytical model to understand complex issues. The panel regression approach helps detect direct relationships and general trends, while path analysis provides a deeper understanding of the causal mechanisms that occur indirectly. Therefore, although in the conventional model the effect of REC on EP is not significant, the findings from path analysis confirm that there is a mediating mechanism that works statistically and substantively, which is highly relevant for the design of more holistic and equitable energy development policies.

4.5.6 The Impact of GDP Per Capita on Energy Poverty

The coefficient for GDP per capita in this study is -0.0011657 and statistically significant at the 5% level (p-value = 0.004), indicating that a one-unit increase in GDP per capita is associated with a 0.0011657 unit reduction in the energy poverty index, holding other variables constant. This negative relationship supports the conventional understanding that higher levels of economic development generally contribute to broader access to essential services, including energy. The underlying mechanism is that as income per capita rises, both public institutions and households are better positioned to invest in energy infrastructure and access. Governments in wealthier countries are more capable of financing electrification projects, implementing renewable energy solutions, and offering subsidies, while households are more likely to afford connection costs, appliances, and ongoing electricity expenses. These factors collectively help reduce barriers to modern energy access. Nonetheless, the relatively small magnitude of the coefficient suggests that economic growth, while helpful, is not a panacea for energy poverty. This finding is consistent with the arguments of Lee and Kim (2023), who emphasize that in the absence of strong redistributive and inclusive policies, rising GDP can actually widen the energy access gap, particularly in rural and marginalized areas. In many Asia-Pacific countries, persistent income inequality, governance challenges, and geographic isolation hinder the equitable distribution of energy infrastructure. Economic growth in such contexts often leads to urban-centered development and energy-intensive industries without necessarily improving access for the poor. In addition, scholars such as Buttle et al. (2016) and Zhao et al. (2022) have stressed that GDP growth must be accompanied by improvements in access to modern and clean energy in order to reduce energy poverty meaningfully. They also highlight the crucial role of government in directing economic growth toward inclusive and sustainable outcomes. Without targeted policies such as pro-poor energy subsidies, rural electrification programs, and infrastructure investments in underserved communities benefits of economic development may not reach vulnerable populations. Therefore, while the results of this study confirm the beneficial impact of GDP per capita on reducing energy poverty, they also underline the importance of integrating economic growth strategies with inclusive and energy-specific policies to achieve equitable and sustainable development outcomes.

4.5.7 The Impact of Foreign Direct Investment (FDI) on Energy Poverty

The coefficient for foreign direct investment (FDI) in this study is 0.0536851 and statistically insignificant (p-value = 0.803), indicating that changes in FDI are not associated with significant changes in the energy poverty index across Asia-Pacific countries. This suggests that, within the context of this model, FDI inflows do not have a measurable impact on reducing energy poverty. This finding challenges the assumption that foreign investment automatically supports development outcomes and underscores the complex relationship between capital flows and access to energy. One explanation for this insignificant relationship may lie in the way FDI is allocated across sectors. In many developing countries, foreign investment is commonly directed toward capital-intensive and export-oriented industries such as mining, manufacturing, or financial services. These sectors often offer limited benefits to rural or energy-poor populations. As noted by Aluko and colleagues (2024), this misalignment between investment focus and inclusive energy objectives reduces the potential of FDI to support access to modern energy services. Moreover, the absence of clear regulatory incentives or national energy frameworks that integrate foreign investment into social development priorities further limits its impact. While FDI can potentially bring valuable resources such as capital, technology, and expertise (which particularly in the renewable energy sector), its success depends heavily on the governance quality and strategic planning of host countries. According to the study by Khan and Majeed (2023), the effectiveness of FDI in expanding energy access is strongly influenced by the ability of governments to direct investment into sustainable sectors and ensure coordination between investment authorities and energy development institutions. Additionally, FDI may contribute to overall economic growth, which in turn could help improve household income levels. Higher incomes theoretically enable households to afford modern energy services. However, Nguyen and Su (2022) emphasize that without proper redistribution policies, the benefits of economic growth driven by foreign investment may fail to reach the poorest and most vulnerable segments of the population. As a result, inequalities in energy access can persist or even worsen despite increasing investment flows. In summary, the findings of this study indicate that FDI alone is not sufficient to alleviate energy poverty. To fully leverage the potential of foreign capital, governments need to adopt inclusive investment strategies, promote FDI in green energy sectors, and enforce environmental, social, and governance (ESG) standards. Only through policies that actively direct investment toward marginalized communities and prioritize long-term sustainability can FDI become a meaningful contributor to the reduction of energy poverty.

4.5.8 The Influence of Urban Population Proportion (UP) on Energy Poverty

The coefficient for urban population in this study is 1.853141 and is statistically significant at the 1 percent level, which means that a one-unit increase in the proportion of the urban population is associated with a 1.853141 unit increase in the energy poverty index. This positive and significant relationship may seem unexpected, considering that urbanization is often associated with improved access to public infrastructure, including electricity. However, this result reveals a more nuanced reality, especially in many developing countries where urban growth tends to occur rapidly and without proper planning. In various parts of the Asia-Pacific region, urban population growth has not been matched by the expansion of adequate energy infrastructure. Many informal settlements and peri-urban areas still face limited access to electricity, despite being geographically close to the main power grid. According to Chen and colleagues, rapid urbanization without efforts to ensure equitable energy access often leads to an increase in urban energy poverty. Inadequate infrastructure, limited funding, and weak coordination among energy service providers have made it difficult for many urban residents, particularly those living in slums or overcrowded areas, to benefit from the city's development. Urban energy poverty is not only caused by lack of infrastructure but also by affordability issues. Low-income households in urban areas often rely on prepaid electricity systems or informal sources of energy that cost more per unit. This creates a situation where people in cities, although physically closer to energy supply, experience greater difficulty in accessing reliable and affordable electricity compared to some rural populations. A case study in Mozambique by Matinga and Annegarn supports this view by showing that while urbanization may improve access to modern fuels, it can also increase the financial burden of energy, especially for poor households. Moreover, unplanned urbanization often exacerbates existing social and economic inequalities. Torasa and colleagues emphasize that vulnerable groups in urban settings are frequently left behind in terms of energy access due to structural barriers. This highlights the need for energy access strategies that go beyond infrastructure provision and include inclusive urban planning, targeted subsidy programs, and public education about energy use. In conclusion, the findings of this study point to the importance of developing energy policies that are tailored specifically to urban contexts. Governments should prioritize initiatives such as subsidized electricity connection fees, urban electrification programs for informal settlements, and upgrades to outdated or overloaded infrastructure. Without such targeted measures, continued urban growth may deepen rather than reduce energy poverty. To ensure that urbanization contributes positively to inclusive and sustainable development, energy planning must address both the physical and socioeconomic dimensions of urban life.

4.5.9 Theoretical Reflections on Energy Poverty

The preceding empirical findings (Sections 4.5.4 to 4.5.8) provide a strong foundation for theoretical reflection regarding the mechanisms through which sustainable finance affects energy poverty across Asia-Pacific countries. Sustainable finance is instrumental in supporting a just energy transition by addressing affordability, accessibility, and environmental sustainability. Within the Global Sustainable Power Equation (GSPE) framework, energy justice is conceptualized as a function of these three components, wherein financial instruments operate as structural levers for achieving greater inclusivity in energy systems. When combined with equitable governance, sustainable finance contributes not only to infrastructure development but also to expanding access and lowering costs.

Nevertheless, the empirical evidence suggests that such optimism requires a more critical perspective. As shown in Section 4.5.4, sustainable finance has a statistically significant negative effect on energy poverty, which supports GSPE's core hypothesis. However, the mediation analysis in Section 4.5.5 reveals that renewable energy consumption (REC), although positively influenced by sustainable finance, is associated with an increase in energy poverty when included in the full model. This result indicates that increases in REC do not necessarily lead to equitable outcomes unless institutional and distributional challenges are addressed. In this context, GSPE's input–output logic is limited, as it overlooks the social and political factors that shape the implementation and accessibility of clean energy solutions. This limitation becomes more apparent when applied to real-world cases. For instance, although countries such as India and Indonesia have made substantial progress in expanding renewable energy infrastructure, institutional inertia and elite capture often hinder equitable distribution. Therefore, as evidenced in the findings, REC alone is insufficient to reduce energy poverty unless embedded within inclusive policy frameworks.

The STIRPAT framework offers a useful alternative perspective by exploring how population, affluence, and technology interact with structural inequalities. The results presented in Section 4.5.6 demonstrate that GDP per capita negatively affects energy poverty. However, the relatively small coefficient suggests that economic growth alone is not a sufficient condition. This finding is consistent with the situation in Central Asian countries, such as Uzbekistan and Tajikistan, where rising incomes coexist with persistent regional disparities in access to modern energy. These observations emphasize the need for redistributive mechanisms to accompany economic development.

Furthermore, Section 4.5.8 shows that a higher urban population share correlates positively with energy poverty. This counterintuitive finding highlights the challenges of unplanned urbanization, particularly in countries like Bangladesh and the Philippines, where informal settlements often lack adequate energy infrastructure. Urban proximity to the grid does not guarantee affordability or access, and as such, spatial exclusion continues to shape energy inequality in cities. The findings in Section 4.5.7, which reveal the statistically insignificant impact of foreign direct investment (FDI) on energy poverty, also support this broader reflection. Although FDI is often assumed to stimulate economic development, its effectiveness depends on how it is allocated. In many cases, foreign capital is directed towards sectors that do not benefit energy-poor communities. Without strategic guidance and strong governance, FDI is unlikely to support inclusive energy transitions. The significant mediating role of REC in the relationship between sustainable finance and energy poverty, as confirmed by the Sobel test, further illustrates that financial flows can contribute indirectly to energy access improvements. However, this effect is most apparent when financial resources are accompanied by institutional capacity, regulatory clarity, and social inclusion. In countries such as Lao PDR, Myanmar, and Papua New Guinea, governance constraints and fiscal limitations reduce the effectiveness of clean energy projects. In conclusion, while the GSPE framework provides a normative foundation for sustainable energy systems, it does not fully capture the implementation challenges in diverse institutional and political environments. The STIRPAT framework contributes to this analysis by highlighting the uneven outcomes of energy transitions, especially in relation to urbanization, economic inequality, and demographic pressure. Therefore, addressing energy poverty in the Asia-Pacific region requires more than increased financial and technological inputs. It calls for comprehensive governance reforms, spatial equity in infrastructure distribution, and a deliberate effort to ensure that sustainable finance reaches marginalized populations.

CHAPTER 5
CLOSING

5.1 Conclusion

This study aimed to address two central research questions: (1) To what extent does sustainable finance influence energy poverty in Asia-Pacific countries? and (2) Does renewable energy consumption mediate the relationship between sustainable finance and energy poverty in these countries? By analyzing panel data from 38 Asia-Pacific countries covering the period from 2016 to 2025 and applying random effects panel regression, the findings provide strong empirical evidence that sustainable finance contributes significantly to the reduction of energy poverty. This impact is particularly evident when financial investments in renewable energy result in increased renewable energy consumption at the community level. The results confirm that sustainable finance serves not only as a tool for promoting clean energy development but also as an important driver of equitable energy access. The regression analysis shows that sustainable finance, measured through renewable energy investment, has a statistically significant negative effect on energy poverty. This finding supports the first hypothesis, which states that sustainable finance plays an important role in alleviating energy deprivation in the Asia-Pacific region. In addition, the mediation analysis using the Baron and Kenny framework and supported by the Sobel test confirms that renewable energy consumption acts as a significant mediating variable. This supports the second hypothesis, which suggests that the effect of sustainable finance on energy poverty largely occurs through increased use of renewable energy by households, businesses, and public institutions in areas with limited access. Several control variables also provide relevant insights. GDP per capita is significantly negatively associated with energy poverty, indicating that higher levels of economic development tend to improve energy access and infrastructure. On the other hand, urbanization is positively associated with energy poverty in the short term, especially in rapidly growing urban areas where energy infrastructure has not kept up with population increases. Foreign direct investment and renewable energy output do not show statistically significant effects in the first-difference model, suggesting that their influence may be more visible in the long term or under different institutional settings. These findings align with the Green Sustainable Power Equation (GSPE) framework used in this study, which explains that green financial flows can reduce energy poverty through various pathways such as technological innovation, sustainable energy generation, affordability improvements, and job creation. In the context of developing countries in the Asia-Pacific region, the most effective mechanism appears to be the increase in renewable energy consumption. This confirms that financial investments are only impactful when they lead to actual use of clean energy by populations that were previously underserved. Nonetheless, the results reveal substantial differences across countries. The success of sustainable finance in reducing energy poverty is influenced by factors such as regulatory frameworks, the strength of institutions, and infrastructure quality. Countries like India, Vietnam, and Bangladesh have achieved better results thanks to consistent policies, regulatory clarity, and strong financial incentives. In contrast, countries with fragile institutions or inadequate infrastructure, including small island developing states and post-conflict nations, have faced greater challenges in translating sustainable finance into improved energy access. The study also emphasizes the importance of international cooperation. Many developing countries in Asia do not have sufficient technology, institutions, or funding to independently scale up renewable energy systems. Therefore, collaboration with developed countries and multilateral institutions is crucial, not only to provide financial support but also to facilitate technology transfer, institutional capacity-building, and harmonization of standards. Successful examples include China's Solar Energy Poverty Alleviation Program, Germany's Energiewende, and the Just Energy Transition Partnership (JETP) between the G7 and Indonesia. These initiatives show that well-structured public-private cooperation, combined with clear policy direction, can accelerate renewable energy adoption and promote inclusive energy access. Despite the progress achieved (particularly in phasing out coal financing and increasing climate-related funding) around 150 million people in the Asia-Pacific region still lacked access to reliable electricity as of 2025. This indicates a persistent gap between policy commitments and actual implementation, especially in remote and marginalized communities. The findings highlight the need to integrate sustainable finance strategies with energy infrastructure development, such as smart grids and decentralized energy systems that can serve off-grid populations. In conclusion, the study finds that sustainable finance plays a key role in reducing energy poverty in the Asia-Pacific region, especially when it leads to increased consumption of renewable energy. However, the effectiveness of sustainable finance depends heavily on the presence of supportive regulatory frameworks, strong institutions, adequate infrastructure, and international support. Addressing energy poverty is not only a financial or technical matter; it requires a comprehensive approach that combines inclusive governance, local engagement, and cross-border collaboration. Only through such an integrated strategy can universal energy access and a just energy transition be achieved in a sustainable and equitable manner throughout the region.

5.2 Policy Recommendation

This section provides a set of policy recommendations that are fully grounded in the empirical results of the regression and mediation analyses conducted in this study. Rather than drawing from general literature or commonly held policy norms, each recommendation corresponds directly to the variables tested in the model. The objective is to provide actionable guidance for governments, financial institutions, and regional bodies across the Asia-Pacific region to design targeted strategies that effectively reduce energy poverty in ways that are both data-driven and socially responsive.

1. **Strengthen the Role of Sustainable Finance in Expanding Equitable Energy Access**

   The study finds that sustainable finance is significantly associated with lower levels of energy poverty. This underlines the importance of enhancing the availability and accessibility of financial mechanisms that support clean energy investments in marginalized areas. However, to maximize its impact, sustainable finance should be deployed not only for projects with high commercial returns but also for those with strong social outcomes. Governments and financial institutions must ensure that capital is directed toward projects that address energy deficits among underserved populations, including those in remote rural regions and informal urban settlements.

   Concrete actions may include scaling up green bonds and sustainability-linked loans that are earmarked for rural electrification, community-based solar systems, and decentralized clean cooking technologies. Public institutions can also introduce risk mitigation instruments such as guarantees or first-loss capital to attract private investors into less bankable but socially critical projects. Furthermore, national development plans should explicitly link sustainable finance flows to energy access indicators, ensuring that the growth of ESG finance leads to measurable social outcomes, not just environmental or financial ones.

2. **Promote Not Only Renewable Energy Supply, but Also Its Effective Use Among Vulnerable Groups**

The mediation analysis highlights that renewable energy consumption acts as a key channel through which sustainable finance reduces energy poverty. This finding suggests that efforts to boost renewable energy should move beyond simply expanding supply and instead emphasize increasing its actual adoption among energy-poor communities. Many clean energy projects remain inaccessible to low-income populations due to high upfront costs, lack of information, or absence of consumer-oriented policy support.

Governments should design targeted interventions that lower barriers to renewable energy usage in everyday life, particularly for households located off-grid or in informal urban areas. These could include voucher schemes for solar kits, community ownership models for mini-grids, and financing schemes with flexible repayment tailored to household cash flows. Policy instruments should also account for the cultural and gender dynamics of energy use, ensuring that solutions are relevant and sustainable within local contexts. Technical support and after-sales maintenance are equally crucial to ensure that renewable energy systems remain functional over time. Ultimately, the transition must prioritize the needs of end-users and support lasting behavioral change.

3. **Recognize and Address the Hidden Vulnerabilities of Urban Energy Poverty**

Contrary to expectations, the study finds a statistically significant positive relationship between urban population and energy poverty, which reveals that urbanization does not automatically translate into better access. Many growing cities across the Asia-Pacific region contain expanding pockets of energy deprivation, particularly in slums, informal housing, and peri-urban areas where grid infrastructure is either weak or nonexistent.

This calls for an urgent policy shift to recognize energy poverty as a multidimensional urban issue. Authorities should embed energy access considerations within housing policy, spatial planning, and slum upgrading programs. Investment in low-voltage grid upgrades, energy-efficient street lighting, and household-level electrification should be prioritized in urban areas where informal status has previously excluded communities from formal services. Additionally, governments can leverage digital tools such as geospatial mapping and remote monitoring to identify urban energy-poor households and design targeted subsidy programs. By mainstreaming energy access into the urban development agenda, countries can address a major blind spot in their energy poverty strategies and reduce the risk of deepening urban inequality.

4. **Enhance the Social Impact Potential of Foreign Direct Investment (FDI)**

Although the analysis does not find a statistically significant direct effect of FDI on energy poverty, this does not negate the strategic relevance of FDI in shaping energy systems across the region. Many infrastructure and utility projects continue to rely on foreign capital, and with appropriate policy direction, FDI can be leveraged to generate broader social benefits.

Governments should embed social and energy access criteria into their FDI frameworks, particularly in sectors such as energy, infrastructure, and manufacturing. For example, investment licensing and project approval mechanisms could require companies to demonstrate their contributions to community electrification, local employment in renewable energy, or inclusive technology transfer. Incentives could also be tied to performance indicators related to energy access improvements, especially in areas with high levels of deprivation. Such alignment does not merely enhance the social license of investors but also ensures that capital inflows deliver shared prosperity. Rather than viewing FDI purely through the lens of macroeconomic growth, policy should reframe it as a tool to advance national development priorities, including the reduction of energy poverty.

5. **Translate Economic Growth into Inclusive and Measurable Energy Access Outcomes**

While GDP per capita was found to have a negative relationship with energy poverty, the effect size was relatively modest. This reinforces the idea that economic growth, although important, is not sufficient on its own to guarantee reductions in energy deprivation. Growth benefits often bypass marginalized populations, particularly when governance systems lack strong mechanisms to ensure equitable distribution.

To correct this, policymakers must integrate energy access considerations into the architecture of economic development planning. Public budgets should allocate specific resources to expand electrification in remote and poor regions. Performance-based transfers to local governments could be introduced, linking fiscal incentives to progress in achieving household-level energy access. Development programs aimed at poverty alleviation should also incorporate energy access as a core outcome, recognizing its role in enhancing productivity, health, and educational attainment. Only by embedding energy access within the broader logic of economic governance can countries ensure that growth leads to meaningful and widespread social gains.

Overall, the findings of this study underscore that energy poverty is not merely an infrastructure gap, but a complex challenge that intersects with financial systems, governance choices, and social inequality. The policy responses must therefore be as multifaceted as the problem itself. By using empirically validated variables (such as sustainable finance, renewable energy use, and urban demographic pressures) governments and development actors can design more effective and targeted interventions. A data-informed policy approach ensures that investments in clean energy not only expand supply but also reach and empower those who have been historically excluded. In doing so, the Asia-Pacific region can build an energy transition that is both environmentally sustainable and socially just.

5.3 Research Limitation

While this study contributes important empirical insights into the role of sustainable finance in addressing energy poverty across Asia-Pacific countries, several limitations should be acknowledged that may affect the interpretation and generalizability of the findings.

First, the study is constrained by limitations in data availability and consistency. Although the panel dataset covers a wide time span from 2016 to 2025 and includes 38 countries, a number of Asia-Pacific countries were excluded due to missing or inconsistent data across key variables. This exclusion may lead to sample bias and limits the representativeness of the results across the entire Asia-Pacific region. Additionally, inconsistencies in how countries report energy and finance-related data may introduce measurement errors that are difficult to control in secondary datasets.

Second, the variable representing sustainable finance in this study is proxied by renewable energy investment due to the lack of disaggregated, country-level data on specific instruments such as green bonds, climate funds, or green sukuk. While renewable energy investment is a credible proxy, it does not capture the full spectrum or diversity of sustainable finance mechanisms in practice. Consequently, the study cannot distinguish between the effects of different financing instruments, which may have varying impacts on energy poverty depending on their structure, source, and governance.

Third, the analytical framework is based on a fixed-effects panel regression and mediation model, which are designed to identify general relationships across countries and over time. However, this approach does not fully account for within-country heterogeneity or context-specific nuances such as political stability, institutional quality, or subnational disparities in energy access. Future research could benefit from country-level case studies or subnational panel data to capture localized dynamics more effectively.

Fourth, the model does not explicitly include external shocks or global factors that may significantly influence both energy poverty and financing trends such as global fossil fuel price fluctuations, international interest rate changes, or the macroeconomic impact of COVID-19. These exogenous variables, if included, could provide a more comprehensive understanding of the volatility and sensitivity of energy access outcomes in the face of global crises.

Fifth, while several relevant control variables were included such as GDP per capita, foreign direct investment (FDI), urbanization, and renewable energy output, other potentially influential variables were omitted due to data constraints. These include education levels, institutional governance quality, ease of doing business, and corruption indices, all of which may play critical roles in shaping the implementation and impact of sustainable finance on energy poverty.

Sixth, this study adopts a purely quantitative approach. While statistical models can reveal significant correlations and causal pathways, they cannot fully capture the perspectives, lived experiences, and behavioral responses of affected communities or implementing institutions. A future mixed-methods approach combining quantitative modeling with interviews, surveys, or focus group discussions would enrich the findings by providing a more nuanced understanding of implementation challenges and policy effectiveness.

Seventh, the study does not address the broader social and environmental co-benefits of sustainable finance such as job creation, community empowerment, health improvements, or emissions reduction. While the focus is deliberately placed on energy poverty, future research could evaluate how clean energy projects funded through sustainable finance impact a wider range of social development indicators, particularly in vulnerable or marginalized populations.

Eighth, the time frame of the study ending in 2025 may be too short to capture the full effects of long-term investment in sustainable energy infrastructure. The impact of such projects may manifest only over a longer horizon, especially when considering policy incubation periods, construction timelines, and behavioral adoption patterns. Longer-term longitudinal studies are needed to assess whether current trends in sustainable finance can produce lasting reductions in energy poverty.

Ninth, there may be potential biases resulting from reliance on secondary data and estimation methods. Although standard econometric techniques were applied to ensure robustness, some measurement errors or endogeneity issues may persist. To improve the accuracy and credibility of future findings, researchers should consider triangulating secondary data with primary sources, conducting panel diagnostics more extensively, and using advanced methods such as instrumental variables or structural equation modeling.

Lastly, while this study offers cross-country generalizations, it does not test the practical applicability of its findings in real-world policymaking contexts. Pilot programs, policy trials, or comparative case studies across regions could further validate the theoretical model and offer more specific, actionable lessons for governments and development partners. In particular, exploring how national energy and finance agencies operationalize sustainable finance tools on the ground could enhance the relevance and utility of future research for practitioners.

Despite these limitations, this study provides a valuable empirical foundation for understanding how sustainable finance can be strategically leveraged to address energy poverty in developing Asia. The findings can serve as a springboard for further research that is both broader in scope and deeper in focus, ultimately contributing to more inclusive, effective, and sustainable energy transitions across the Global South.

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APPENDIX

Appendix 1. Multicollinearity Test

Variable	VIF	1/VIF
up	1.64	0.609680
gdp	1.56	0.640606
fdi	1.07	0.936246
rec	1.02	0.976200
sf	1.00	0.998977
Mean VIF	1.26	

Appendix 2. Heteroskedasticity Test

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (38)  =   58445.44
Prob>chi2 =      0.0000
```

Appendix 3. Autocorrelation Test

```
Wooldridge test for autocorrelation in panel data
H0: no first order autocorrelation
    F(  1,      37) =      7.156
           Prob > F =      0.0111
```

(obs=342)

	ep	sf	rec	ln_gdp	fdi	up
ep	1.0000					
sf	0.0137	1.0000				
rec	0.1166	0.0156	1.0000			
ln_gdp	0.8724	0.0218	0.2312	1.0000		
fdi	0.1746	-0.0037	-0.0093	0.2078	1.0000	
up	0.6852	0.0130	-0.1463	0.6720	0.2508	1.0000

Appendix 4. Robustness Test

```
Fixed-effects (within) regression               Number of obs     =        342
Group variable: id                              Number of groups  =         38

R-sq:                                           Obs per group:
     within  = 0.9351                                         min =          9
     between = 0.1727                                         avg =        9.0
     overall = 0.7483                                         max =          9

                                                F(4,37)           =     332.60
corr(u_i, Xb)  = -0.2620                        Prob > F          =     0.0000

                                    (Std. Err. adjusted for 38 clusters in id)
```

ep	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
sf	-.000153	.000037	-4.13	0.000	-.000228	-.000078
ln_gdp	4.803657	1.005294	4.78	0.000	2.766738	6.840577
fdi	.0921229	.0738302	1.25	0.220	-.0574713	.2417171
up	.609114	.2589042	2.35	0.024	.0845242	1.133704
_cons	25.65592	3.92262	6.54	0.000	17.70794	33.60391
sigma_u	15.175733					
sigma_e	8.0638099					
rho	.7798209	(fraction of variance due to u_i)				

```
Fixed-effects (within) regression               Number of obs      =        342
Group variable: id                              Number of groups   =         38

R-sq:                                           Obs per group:
     within  = 0.2597                                         min =          9
     between = 0.1874                                         avg =        9.0
     overall = 0.2191                                         max =          9

                                                F(4,37)            =      16.11
corr(u_i, Xb)  = -0.0953                        Prob > F           =     0.0000

                                    (Std. Err. adjusted for 38 clusters in id)
```

rec	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
sf	.0003385	.0000956	3.54	0.001	.0001448	.0005323
ln_gdp	3.575427	.8100324	4.41	0.000	1.934146	5.216708
fdi	.0978373	.1484445	0.66	0.514	-.2029397	.3986144
up	-.5723094	.1717616	-3.33	0.002	-.9203313	-.2242874
_cons	17.27267	2.122215	8.14	0.000	12.97265	21.57268
sigma_u	14.652011					
sigma_e	14.083448					
rho	.51977838	(fraction of variance due to u_i)				

```
Fixed-effects (within) regression               Number of obs     =        342
Group variable: id                              Number of groups  =         38

R-sq:                                           Obs per group:
     within  = 0.9354                                         min =          9
     between = 0.1769                                         avg =        9.0
     overall = 0.7497                                         max =          9

                                                F(5,37)           =     279.24
corr(u_i, Xb)  = -0.2623                        Prob > F          =     0.0000

                                    (Std. Err. adjusted for 38 clusters in id)
------------------------------------------------------------------------------
             |               Robust
          ep |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          sf |  -.0001399   .0000371    -3.77   0.001     -.000215   -.0000648
         rec |  -.0387296   .0433748    -0.89   0.378    -.1266153    .0491561
      ln_gdp |   4.942132   1.042774     4.74   0.000     2.829271    7.054994
         fdi |   .0959121   .0735776     1.30   0.200    -.0531703    .2449944
          up |   .5869487   .2651282     2.21   0.033     .0497479    1.124149
       _cons |   26.32489   4.157811     6.33   0.000     17.90036    34.74941
-------------+----------------------------------------------------------------
     sigma_u |  15.131591
     sigma_e |   8.058784
         rho |  .77903368   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Appendix 5. Chow test

```
. testparm i.ep sf reo ln_gdp fdi up

 ( 1)  sf = 0
 ( 2)  ln_gdp = 0
 ( 3)  fdi = 0
 ( 4)  up = 0

       F(  4,   299) =  920.98
            Prob > F =    0.0000
```

Appendix 6. Hausman Test

```
. hausman fixed random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
          sf |   -.0001399    -.0001426        2.71e-06               .
         rec |   -.0387296    -.0416043        .0028747        .0030526
      ln_gdp |    4.942132     5.265578       -.3234458         .091859
         fdi |    .0959121     .0763894        .0195227               .
          up |    .5869487     .4890009        .0979478        .0282034
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        1.87
                Prob>chi2 =      0.8671
                (V b-V B is not positive definite)
```

Appendix7. Lagrange Multiplier Test.

```
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

        ep[id,t] = Xb + u[id] + e[id,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                      ep |   1059.486       32.54975
                       e |     64.944       8.058784
                       u |   143.0978       11.96235

        Test:   Var(u) = 0
                             chibar2(01) =   637.92
                          Prob > chibar2 =   0.0000
```

Appendix8. Random Effect Model

```
. xtreg ep sf rec ln_gdp fdi up, re

Random-effects GLS regression                   Number of obs     =        342
Group variable: id                              Number of groups  =         38

R-sq:                                           Obs per group:
     within  = 0.9349                                         min =          9
     between = 0.1698                                         avg =        9.0
     overall = 0.7629                                         max =          9

                                                Wald chi2(5)      =    4118.82
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000

------------------------------------------------------------------------------
          ep |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          sf |  -.0001426   .0003772    -0.38   0.705     -.000882    .0005967
         rec |  -.0416043   .0328956    -1.26   0.206    -.1060785    .0228699
      ln_gdp |   5.265578   .2541438    20.72   0.000     4.767465    5.763691
         fdi |   .0763894   .1164395     0.66   0.512    -.1518278    .3046066
          up |   .4890009   .0611146     8.00   0.000     .3692184    .6087834
       _cons |   28.16899   2.440489    11.54   0.000     23.38571    32.95226
-------------+----------------------------------------------------------------
     sigma_u |   11.96235
     sigma_e |   8.058784
         rho |  .68783198   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Appendix9. Descriptive Statistic

```
. summarize ep sf rec fdi ln_gdp up

    Variable |        Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
          ep |        342    82.28883    32.54975        .01        100
          sf |        342    207.2813    1274.148    .012168    23406.7
         rec |        342    18.69883     22.1249          0       83.9
         fdi |        342    2.518684    5.363326     -37.17      28.18
      ln_gdp |        342     6.69223    4.197813   -4.60517   10.81223
-------------+---------------------------------------------------------
          up |        342    39.87007     24.1519          0        100
```

Appendix 10. Root Test

```
. xtunitroot llc sf

Levin-Lin-Chu unit-root test for sf
-----------------------------------
Ho: Panels contain unit roots              Number of panels  =     38
Ha: Panels are stationary                  Number of periods =      9

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 6.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -21.6609
 Adjusted t*        -15.3040        0.0000
------------------------------------------------------------------------------


. xtunitroot llc fdi

Levin-Lin-Chu unit-root test for fdi
------------------------------------
Ho: Panels contain unit roots              Number of panels  =     38
Ha: Panels are stationary                  Number of periods =      9

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 6.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -10.0052
 Adjusted t*         -2.2007        0.0139
------------------------------------------------------------------------------
```

```
. xtunitroot llc d.rec

Levin-Lin-Chu unit-root test for D.rec
--------------------------------------
Ho: Panels contain unit roots              Number of panels  =     38
Ha: Panels are stationary                  Number of periods =      8

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 6.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -11.4208
 Adjusted t*         -2.1543        0.0156
------------------------------------------------------------------------------


. xtunitroot llc d.up, lag (0)

Levin-Lin-Chu unit-root test for D.up
-------------------------------------
Ho: Panels contain unit roots              Number of panels  =     38
Ha: Panels are stationary                  Number of periods =      8

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 0 lags
LR variance:     Bartlett kernel, 6.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -49.1079
 Adjusted t*        -50.2284        0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot llc ep

Levin-Lin-Chu unit-root test for ep
-----------------------------------
Ho: Panels contain unit roots              Number of panels  =     38
Ha: Panels are stationary                  Number of periods =      9

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 6.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -24.3583
 Adjusted t*        -19.4496        0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot llc d.gdp

Levin-Lin-Chu unit-root test for D.gdp
--------------------------------------
Ho: Panels contain unit roots              Number of panels  =     38
Ha: Panels are stationary                  Number of periods =      8

AR parameter: Common                       Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 6.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -24.8755
 Adjusted t*        -18.6328        0.0000
------------------------------------------------------------------------------
```

Appendix 11. Baron & Kenny

```
. xtreg ep sf fdi gdp up, fe vce(robust)

Fixed-effects (within) regression               Number of obs     =        342
Group variable: id                              Number of groups  =         38

R-sq:                                           Obs per group:
     within  = 0.8590                                         min =          9
     between = 0.2112                                         avg =        9.0
     overall = 0.4867                                         max =          9

                                                F(4,37)           =      92.34
corr(u_i, Xb)  = -0.6829                        Prob > F          =     0.0000

                                     (Std. Err. adjusted for 38 clusters in id)
------------------------------------------------------------------------------
             |               Robust
          ep |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          sf |  -.0000341   .0000348    -0.98   0.335    -.0001047    .0000365
         fdi |   .0723187   .2234304     0.32   0.748    -.3803942    .5250317
         gdp |   -.001284   .0003674    -3.49   0.001    -.0020284   -.0005395
          up |   1.928327    .151663    12.71   0.000     1.621028    2.235625
       _cons |   11.47846   4.746074     2.42   0.021     1.862002    21.09492
-------------+----------------------------------------------------------------
     sigma_u |  28.373889
     sigma_e |  11.883776
         rho |  .85076205   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
. xtreg rec sf fdi gdp up, fe vce(robust)

Fixed-effects (within) regression               Number of obs     =        342
Group variable: id                              Number of groups  =         38

R-sq:                                           Obs per group:
     within  = 0.0908                                         min =          9
     between = 0.2033                                         avg =        9.0
     overall = 0.0123                                         max =          9

                                                F(4,37)           =      10.45
corr(u_i, Xb)  = -0.5036                        Prob > F          =     0.0000

                                    (Std. Err. adjusted for 38 clusters in id)
------------------------------------------------------------------------------
             |               Robust
         rec |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          sf |   .0004364   .0001045     4.18   0.000     .0002246    .0006481
         fdi |   .0879341   .1404648     0.63   0.535    -.1966747     .372543
         gdp |  -.0005583   .0002916    -1.91   0.063    -.0011491    .0000324
          up |   .3548117   .0720801     4.92   0.000     .2087634    .5008599
       _cons |   6.956953   2.466951     2.82   0.008     1.958435    11.95547
-------------+----------------------------------------------------------------
     sigma_u |  19.218199
     sigma_e |  15.607977
         rho |   .6025619   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
. xtreg ep sf rec fdi gdp up, fe vce(robust)

Fixed-effects (within) regression               Number of obs     =        342
Group variable: id                              Number of groups  =         38

R-sq:                                           Obs per group:
     within  = 0.8699                                         min =          9
     between = 0.1914                                         avg =        9.0
     overall = 0.5152                                         max =          9

                                                F(5,37)           =      88.56
corr(u_i, Xb)  = -0.6409                        Prob > F          =     0.0000

                                    (Std. Err. adjusted for 38 clusters in id)
------------------------------------------------------------------------------
             |               Robust
          ep |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          sf |  -.0001265   .0000413    -3.07   0.004    -.0002101   -.0000429
         rec |    .211904   .0510867     4.15   0.000     .1083925    .3154155
         fdi |   .0536851   .2132091     0.25   0.803    -.3783176    .4856879
         gdp |  -.0011657   .0003766    -3.10   0.004    -.0019287   -.0004027
          up |   1.853141   .1497468    12.38   0.000     1.549725    2.156557
       _cons |   10.00425   4.258041     2.35   0.024     1.376645    18.63186
-------------+----------------------------------------------------------------
     sigma_u |  26.335748
     sigma_e |  11.433329
         rho |  .84141431   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Appendix 12. Sobel Test

Input:			Test statistic:	Std. Error:	*p*-value:
a	0.0004364	Sobel test:	0.41276181	0.00022404	0.67978113
b	0.211904	Aroian test:	0.40151993	0.00023031	0.68803737
s_a	0.0001045	Goodman test:	0.42500411	0.00021759	0.67083368
s_b	0.510867	Reset all	Calculate		

Alternatively, you can insert t_a and t_b into the cells below, where t_a and t_b are the *t*-test statistics for the difference between the *a* and *b* coefficients and zero. Results should be identical to the first test, except for error due to rounding.

Input:			Test statistic:	*p*-value:
t_a	4.18	Sobel test:	2.94504245	0.0032291
t_b	4.15	Aroian test:	2.90349641	0.00369021
		Goodman test:	2.98842453	0.0028042
		Reset all	Calculate	