THE ROLE OF INSTITUTIONAL QUALITY IN SOLAR ENERGY DEVELOPMENT: THE CASE OF SOUTHEAST ASIA

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DECLARATION

We hereby declare that:

1. This undergraduate research project is the end result of our own work, and that due acknowledgement has been given in the references to ALL sources of information be they printed, electronic, or personal.

2. No portion of this research project has been submitted in support of any application for any other degree or qualification of this or any other university, or other institutes of learning.

3. Equal contribution has been made by each group member in completing the research project.

4. The word count of this research report is 17,464.

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LIST OF ABBREVIATIONS

SD	Solar Development
IQ	Institutional Quality
ISC	Installed Solar Capacity
GDP	Gross Domestic Product
FDI	Foreign Direct Investment
POP	Population
ATE	Access to Electricity
RE	Renewable Energy
SEA	Southeast Asia
CO2	Carbon Dioxide
TWH	Tera Watt Hour(s)
FiT	Feed-in Tariff
PV	Photovoltaic
TNB	Tenaga Nasional Berhad
NEM	Net Energy Metering
R&D	Research and Development
ASEAN	Association of Southeast Asian Nations
GW	Gigawatt
MW	Megawatt
kW	Kilowatt
SAR	Special Administrative Region
JETP	Just Energy Transition Partnership
PDP	Power Development Plan
PPA	Power Purchase Agreements
OP	Outright Purchase

EMT	Ecological Modernization Theory
IEA	International Energy Agency
CSP	Concentrated Solar Power
AHP	Analytic Hierarchy Process
TOPSIS	Technique for the Order of Preference by Similarity to the Ideal Solution
OECD	Organisation for Economic Co-operation and Development
FMOLS	Fully Modified Pooled Ordinary Least Square
DOLS	Dynamic Ordinary Least Square
OLS	Ordinary Least Squares
POLS	Pooled Ordinary Least Square
FEM	Fixed Effect Model
REM	Random Effect Model
GMM	Generalized Method of Moments
BRI	The Belt and Road Initiative
PLS-SEM	Partial Least Square Structural Equation Modelling
ARDL	Autoregressive Distributed Lag Model
PMG	Pooled Mean Group Models
VECM	Vector Error Correction Model
BPLM	Breusch-Pagan Lagrange Multiplier Test
LM	Lagrange Multiplier
GCI	Global Competitiveness Index
VAR	Vector Autoregression
PPML	Poisson Pseudo Maximum Likelihood
BRICS	Brazil, Russia, India, China, South Africa
UAE	United Arab Emirates
MCDM	Multi-Criteria Decision-Making model
UNCTAD	United Nations Conference on Trade and Development
WGI	Worldwide Governance Indicator

USD	United States Dollar
LLC	The Levin, Lin and Chu Test
IPSW	The Im, Pesaran, Shin W-stat test
ADF-Fisher	Augmented Dickey-Fuller Fisher-type Test
PP-Fisher	Phillips-Perron Fisher-type Test
LR	Likelihood Ratio
H_0	Null Hypothesis
H_1	Alternative Hypothesis
P-value	Calculated Probability
α	Alpha value
R^2	Coefficient of Determination

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PREFACE

This research project was submitted to meet the undergraduate requirement of the Bachelor of Economics (Hons) Financial Economics. Dr. Chen Fanyu (PhD) was the supervisor of this undergraduate research. The topic of this study is "The Role of Institutional Quality in Solar Energy Development: The Case of Southeast Asia". This research was written by Chen Hou Yao, Low Jun Bong and Wong Ken Fai with the support of multiple cases of studies referred by other researchers.

The research topic was chosen as there is absence of research on solar energy development in Southeast Asia. As the rapid growth of Southeast Asian solar economy sees the region emerge as the fourth largest solar market in Asia, there sparks the interest of studying the role of institutional quality in governing solar energy development. This research hopes to assist the government, policymakers, researchers and household individuals to understand the influence of institutional quality on solar energy development in Southeast Asia.

In this research, control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law, voice and accountability were used as proxies to measure institutional quality. On the other hand, solar development is measured by installed solar capacity. Other independent variables namely Gross Domestic Product (GDP). Access to Electricity (ATE), Foreign Direct Investment (FDI) and Population (POP) are included to ensure soundness and accuracy of the estimation. With that, this empirical analysis hopes to help readers to have a better comprehension of solar development in Southeast Asia.

ABSTRACT

This paper investigates the role of institutional quality (IQ) in the development of solar energy in Southeast Asia, using a panel data analysis of 11 countries from 2000 to 2022. Controlling for variables such as GDP, FDI, population, and access to electricity (ATE), the study identifies institutional quality as a key driver of solar energy development. Results indicate that strong institutions—characterized by low corruption, high regulatory quality, and political stability—attract investments in solar infrastructure. GDP and FDI positively influence solar development, while population growth also fosters demand. However, ATE shows a negative impact, as regions with reliable access to conventional electricity may resist adopting solar energy. The findings suggest policy recommendations for Southeast Asian governments to capitalize on population growth by investing in solar energy, offering incentives and subsidies to encourage the transition to sustainable energy.

CHAPTER 1: INTRODUCTION

1.0 Research Background

Energy has a fundamental and strategic role in the social, economic, cultural, and political spheres, driving civilization forward by meeting all societal needs (Mamat et al, 2019). It is an important factor of production as all production processes rely on the usage of energy. According to Park (2017), energy can be used for operations like heating, cooling, and producing power. Various domestic needs, industry, business, and commercial trade are all supported by energy use. Large-scale energy consumption is also promoted by its ability to meet the needs of enterprises, industries, and households. As a result, an enormous and limitless supply of energy is needed to meet the growing needs of society. International Energy Agency (2024) data shows that energy consumption has been increasing at an annual rate of approximately 1% to 2% in recent years.

Initially, renewable energy (RE) such as biomass, wind, and hydropower have been the only available source of energy. However, after the discovery of fossil fuels such as coal, crude oil, and gas, the usage of renewable energy has decreased significantly in most industrialized nations within the 19^{th} and 20th centuries which are mainly used for transportation and electricity. It is not until the late 20th century when renewable energy has grown in popularity due to the depletion of fossil fuels, high volatility of energy price, energy supply shocks, and serious negative environmental impact (Bulut & Menegaki, 2020). Renewable energy is key in reducing greenhouse gas emissions, which is vital for slowing global warming and promoting sustainable development. Therefore, there is a need to transform the current energy structure into low-carbon and environmentally friendly sources according to the Paris Agreement. (Zhang et al, 2019) Solar energy has emerged as a crucial alternative to traditional fossil fuels, playing a pivotal role in addressing climate change and achieving sustainable development goals.

The successful development and implementation of solar energy projects are heavily influenced by the quality of institutions in a country or region (Hernandez et al., 2020). Good institutional quality is characterized by transparent and predictable regulations, effective governance structures, secure property rights, and a supportive policy environment (Shahsavari & Akbari, 2018). These institutional factors shape the investment climate and determine the attractiveness of solar energy projects to both domestic and international investors. Moreover, institutional quality impacts various aspects of solar energy development. For example, in countries with strong institutional quality, there is usually a clear and streamlined process for obtaining permits and licenses for solar projects. Additionally, strong institutions ensure the protection of intellectual property rights related to solar technologies, which encourages innovation and technology transfer.

Southeast Asia (SEA) comprises eleven diverse countries with rich histories, cultures, and geographical features. These countries include Brunei, Myanmar, Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. The high average sunlight exposure hours and suitable geographical landscapes across Southeast Asia have motivated the governments to integrate solar energy for an optimized energy mix in respective nation. For Malaysia, it stands as a notable player in the global palm oil industry and ranks among the top producers. However, this prominence comes with environmental challenges, as deforestation for palm oil plantations contributes significantly to carbon emissions. Other than that, Malaysia has a significant reliance on fossil fuels, particularly natural gas and oil, for energy production. Fossil fuels accounted for 94.10% of Malaysia's energy supply in 2021. Malaysia's energy consumption has been steadily increasing, with the volume of energy produced reaching 1528TWh in 2021. As a result, Malaysia's CO2 emissions have also been on the rise, escalating from 4.40 metric tons per capita in 1990 to 8.70 metric tons per capita in 2021. To address these concerns, Malaysia has initiated efforts to transition towards sustainable energy. The government aims to increase the share of renewable energy in the national energy mix to 20% by 2025, as outlined in the Eleventh Malaysia Plan. Additionally, Malaysia has committed to reducing its carbon intensity by 45% by 2030 compared to 2005 levels under the Paris Agreement.

For micro-generation level, Feed-in Tariff (FiT) has become an effective policy implemented by SEA governments to promote residential and industrial use of solar photovoltaic (PV). FiT is an electricity scheme that enables solar consumers to sell excess electricity to the domestic power authority in a bilaterally agreed rate. The procedures and parties involved in FiT require the government to play the role as a moderator to facilitate multilateral partnerships among the power authority, the solar companies, and the solar consumers. Therefore, institutional quality is a key factor in determining the success of RE policy implementation.

Good governance on energy sector is required to balance market contradictions between traditional fossil fuel power authorities and RE sources represented by solar energy in the context of this study. The Malaysian electricity utility (TNB) would face intense challenges from solar investors because they can offer lower tariff rates in relative to fossil-generated power. If a large number of its existing consumers shift to solar energy, TNB would experience a heavy loss in profit. Therefore, governmental schemes like Net Energy Metering (NEM) in Malaysia can help neutralize the negative impact of profit loss of TNB. Under NEM, solar consumers can sell excess electricity generated by solar PV to TNB with a designated rate. From the perspective of solar consumers, they are able to reduce wastage of solar energy generation by selling unused electricity to TNB. On the other hand, TNB can reduce its fossil power generation by buying excess solar energy from solar companies. Solar investors play the role of intermediary party in this exchange. In that way, solar investors are encouraged to collaborate with traditional fossil-generated power authority by achieving a mutual beneficial relationship in the energy market.

Figure 1.0 illustrates the solar development, proxied by installed solar capacity in Gigawatts (GW), in Southeast Asia. As seen in Figure 1.0, the emergence of solar development in Southeast Asia begins around 2011. Over time, solar development gradually gained momentum across various countries in the region, with Thailand leading during the initial period. A significant milestone occurred in 2018 when solar development in Vietnam began to accelerate rapidly. By 2020, Vietnam's installed solar capacity had surpassed that of all other Southeast Asian countries by a considerable margin, establishing and maintaining its dominance in the region's solar market.

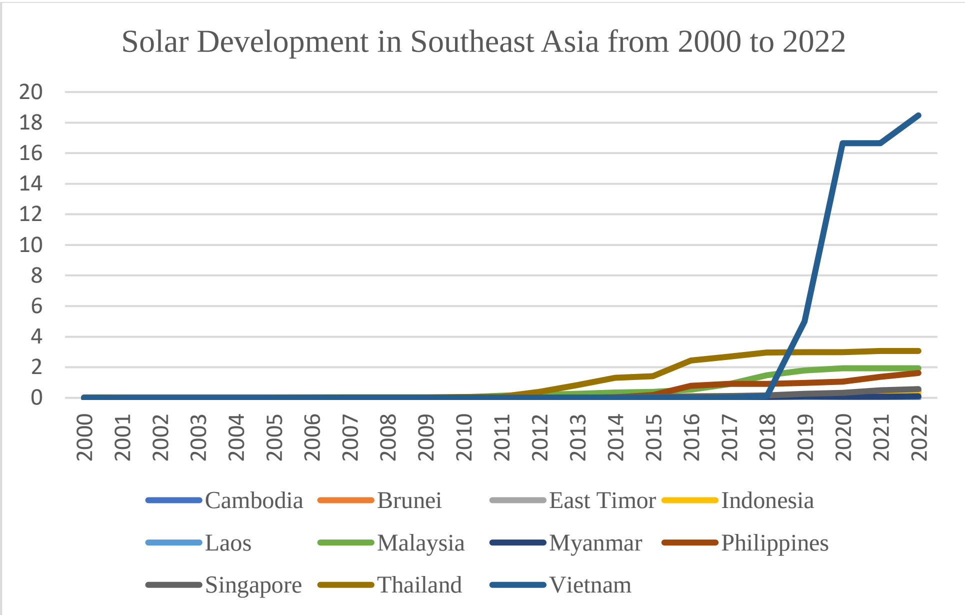

Figure 1.0. Solar Development in Southeast Asia from 2000 to 2022. Note. The data is from *Our World in Data.*

There is indeed huge potential for solar energy in SEA due to the favourable solar landscape in that region. Due to the unique geographical location, most Southeast Asian countries exist near the equator and receive significant amounts of irradiation from the sun throughout the year. Besides, high demand for electricity and CO_2 emission targets also presents opportunities for solar growth within that region (Siala et al., 2021). Due to rapid urbanization and industrialization, many countries in the region of SEA have adopted the use of solar energy to meet the growing demand of energy. Moreover, the sustainable ASEAN Socio-Cultural Community Blueprint 2025 has promoted the use of renewable energy to help ease the energy supply burden and minimize environmental damage caused by urban expansion (Dalapati et al., 2023).

The SEA region is abundantly endowed with a diverse array of renewable energy resources. Among these, solar energy is regarded as the most reliable and promising form of renewable energy due to its inexhaustible nature, sustainability, and virtually unlimited potential. Table 1.0 shows the on-grid and off-grid solar capacity in SEA. On-grid solar capacity refers to solar power systems connected to the main electricity grid. These systems supply power directly to the grid and are typically larger installations, like utility-scale solar farms or residential or commercial rooftop systems connected to the grid. On the other hand, off-grid solar capacity involves solar power systems not connected to the main electricity grid. These are often used in remote or rural areas and can include standalone solar home systems, mini-grids, and solar lanterns. As shown in Figure 1, SEA accounts for a total of 26190 MW on-grid and off-grid solar capacity, signifying a huge solar potential in that region. The total solar capacity of SEA is ranked 4th in Asia after China, Japan, and India, while surpassing Korea, Chinese Taipei, and Chinese HK SAR (IRENA, 2024). Within SEA, Vietnam contributes the most in total solar capacity amounting to 17077 MW, followed by 3186 MW by Thailand, 1933 by Malaysia, and 1729 by Philippines.

Table 1.1:

On-Grid and Off-Grid Solar Capacity (MW) in Southeast Asia

Country	On-Grid and Off-Grid Solar Capacity (MW)
Vietnam	17077
Thailand	3186
Malaysia	1933
Philippines	1729
Singapore	901
Indonesia	637
Cambodia	482
Myanmar	181
Lao PDR	59
Brunei	5
Timor-Leste	0
Total	26190

Note. The data is from International Renewable Energy Agency (2024)

The solar photovoltaic (PV) market in the ASEAN region has seen rapid expansion, with significant installations expected across the region. As depicted in Figure 1.1, by 2023, Vietnam has emerged as the market leader with the highest cumulative PV capacity among ASEAN countries, driven primarily by attractive feed-in tariffs (FITs) that have spurred significant solar investments. The total cumulative solar PV capacity in the ASEAN region is projected to continue its substantial growth, with large-scale projects being the primary contributors, followed by smaller distributed solar installations as their economic viability improves.

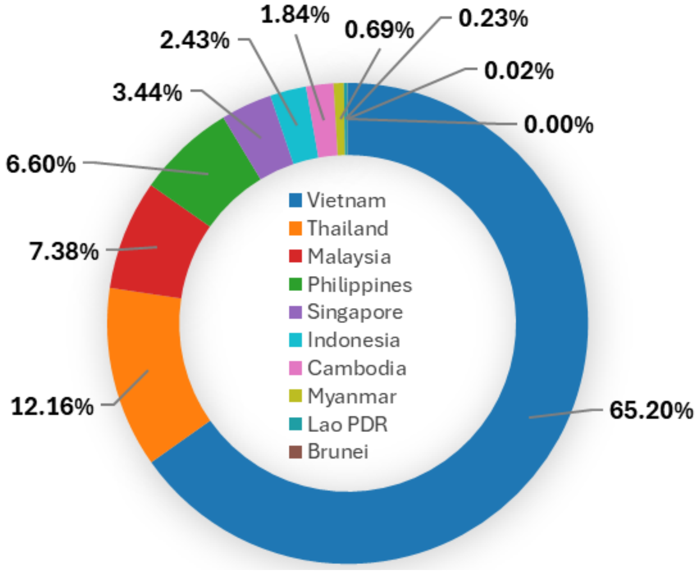

Figure 1.1. ASEAN market cumulative PV system installation in 2023. Note. The data is from *International Renewable Energy Agency (2024).*

1.1 Problem Statement

Despite the notable potential for solar energy in SEA, weak governance hinders the development of solar energy in a country. The adoption of solar energy is dependent on governmental action in grid integration, policy implementation and solar financing to shape a solar-friendly landscape. Political instability in several SEA countries may cause a change in government in the respective country, leading to inconsistent policies regarding Renewable Energy (RE) policies. Besides, an effective solar scheme requires robust support from the government. The effective implementation of solar energy projects requires coordinated efforts among various stakeholders, including government entities, electricity authorities, grid operators, solar investors, and landowners. Successful execution of solar schemes necessitates a comprehensive approach to managing these interactions and ensuring alignment between the involved parties.

RE policies require high government effectiveness, one of the important estimators of institutional quality, to be implemented and executed. Govindarajan et al. (2023) states that the effectiveness of RE policies implementation specifically Net Energy Metering (NEM) policy is instrumental in boosting solar developments in several Southeast Asian countries. In the absence of effective governance, the successful realization of promising solar development projects may be compromised. Poor governance can lead to a range of adverse consequences, including delays, inefficiencies, and potential conflicts among stakeholders, which may ultimately hinder the achievement of the project's objectives. This highlights the importance of examining the role of institutional quality in the development of solar energy projects in SEA.

The inconsistency in solar policies has imposed substantial challenges for solar development in Southeast Asia. Consistency in solar policies is associated with political stability which is another important estimator of institutional quality. For example, the government of Indonesia has shown inconsistent policy support, as evidenced in the regulatory restriction of residential rooftop solar exports to the grid, contradicting the renewable target of 44% by 2023 in the nation's Just Energy Transition Partnership (JETP). In Thailand, Power Development Plan (PDP) promotes renewable energy through auctions and green tariffs, but simultaneously grants approval to additional gas power plants (Hung, 2024). These governmental actions discourage the development of solar in Southeast Asia.

Besides, regulatory hurdles, strong fossil fuel interests, and rigid commercial deals have kept fossil fuels favoured over renewable energy. Institutional quality plays a role in ensuring good control of corruption and upholding regulatory quality. In the context of Malaysia, lacking adequate incentives and subsidies for residential solar adoption leads to long payback periods of up to 10 years for households (Lau et al., 2022). If there is absence of transparent and reliable legal framework regulating incentives and subsidies for solar adoption, a shudder on solar development in Southeast Asia is foreseeable.

From the financial aspect, solar schemes like Power Purchase Agreements (PPA) and Outright Purchase (OP) indeed help individual household and commercial consumers in financing a solar PV system. However, the high upfront investment required for the installation of utility-scale solar PV systems contributes to a high barrier of owning a solar PV. Although solar financing is available in various commercial banks in Malaysia, it remains a debate for micro-scale electricity consumers to acquire a solar loan when the savings made from a solar PV do not exceed the total payables. Due to economies of scale, individuals that utilize higher electricity consumption will enjoy more savings in relative to micro-scale solar PV consumers, generally household individuals, under the same loan scheme. In addition to the high upfront installation cost, the insignificant savings of low-power consumers has kept ordinary household individuals from owning a solar PV. On the other hand, those who are able to afford the installation cost of a solar PV get another boost when the savings on electricity bills offset the interest payment of the solar loan. If the situation persists, income inequality may be worsened as ones with greater financial capability enjoy even more benefits while financing a solar PV, in contrast with individual households that have not obtained any financial benefits in solar financing. A government with good institutional quality shall display government effectiveness in launching effective solar policies that defend the income inequality gap.

Finally, good institutional quality of Southeast Asian governments is instrumental in establishing necessary infrastructure for solar development. Southeast Asian solar development is constrained by technical capability in that region. Cambodia, Myanmar and Vietnam have the lowest grid reliability, the ability to supply electricity and meet demands, in Southeast Asia (Huang et al., 2019). Low grid ability implies low grid flexibility which is an indication of unsatisfactory grid integration with renewable energy sources. Moreover, grid integration with renewable energy such as solar energy also hampers solar development in Southeast Asia. According to Huang et al. (2019), most of Southeast Asian countries have low grid flexibilities to integrate renewable energy sources, hence leading to an increase in grid transaction costs.

1.2 Research Objectives

General Objective:

To analyse how Institutional Quality (IQ), Gross Domestic Product (GDP), Access to Electricity (ATE), Foreign Direct Investment (FDI), and Population (POP) influence the Solar Development in Southeast Asia.

Specific Objective:

To examine the effects of institutional quality on the solar development in Southeast Asia.

1.3 Research Questions

Is there a relationship between institutional quality and the solar development in Southeast Asia?

1.4 Significance of Study

This study aims to examine the relationship between institutional quality and the development of solar energy in Southeast Asian countries, a topic that has received limited attention in existing research. While there is extensive literature on renewable energy adoption and policy frameworks, the connection between institutional quality and solar energy development remains underexplored. This research seeks to bridge that gap by analysing the impact of institutional quality, foreign direct investment (FDI), population, gross domestic product (GDP), and access to electricity on the expansion of solar energy in Southeast Asia. By addressing this underrepresented area, the study provides fresh insights into the complex factors driving solar energy growth and sustainability, offering guidance for both policymakers and industry stakeholders.

Solar energy, as a scalable and environmentally sustainable energy source, plays a key role in reducing the environmental impact of traditional energy sources. Southeast Asia's geographic advantage, with abundant sunlight, makes solar energy a viable and reliable option for the region. The increased adoption of solar power can lower energy costs for businesses, attract foreign and domestic investments, and stimulate economic activity. This development also brings job creation and technological advancements that can drive down the costs of solar installation and maintenance. By making energy more affordable, solar development has the potential to reduce income inequality, lower energy bills for households, and promote inclusive economic growth across the region. Furthermore, it helps countries transition toward a low-carbon economy, reducing their dependence on fossil fuels and contributing to their international commitments toward sustainable development and greenhouse gas emission reduction.

From an investor's perspective, the maturation of solar energy in Southeast Asia presents significant opportunities for technological exchange and cross-border investments. As the solar industry develops, it can lower operational costs for businesses, reduce consumer prices, and enhance market competitiveness by breaking monopolies in the energy sector. This creates a favourable environment for economic liquidity, increases investor confidence, and strengthens fiscal stability by reducing government subsidy burdens. For governments, solar energy development can play a critical role in managing energy security and reducing reliance on fossil fuel imports. It also supports public services like healthcare and education by ensuring broader and more affordable energy access for the population.

Policymakers can benefit from this research as it offers insights into how improving institutional quality can accelerate solar energy deployment. By ensuring a stable regulatory environment, transparent governance, and supportive policies, governments can attract greater investments in renewable energy. In turn, this enhances national energy security, mitigates environmental impacts, and fosters long-term economic development. Additionally, the study’s findings can help governments design policies that reduce the fiscal strain of energy subsidies, create green jobs, and promote regional cooperation on clean energy technologies.

The significance of this study extends beyond practical applications. The results will serve as a valuable reference for future academic research, offering comparative analyses among Southeast Asian countries. While geographical similarities exist among these nations, differences in policies, investment climates, and socio-economic conditions will provide critical insights into the factors that most influence solar energy development. This research will contribute to the broader academic discourse on sustainable energy, enriching the literature with findings that can guide future studies and inform sustainable technology deployment in SEA.

1.5 Chapter Layout

Chapter 1 studies on the introductory information of the research. The chapter firstly provides the research background on the history development of solar energy and the details of implementing solar policies in Malaysia and Southeast Asian countries. Next, the problem statement is stated. The research objectives, questions and hypothesis are formed. The significance of conducting this study is also stated.

Chapter 2 emphasizes the literature review of the study. The chapter consist of a review of previous research on the dependent variable and the independent variables. Following that, the chapter studies the theoretical perspective, and the proposed conceptual framework model based on the research topic while providing the study's hypothesis development on the dependent and independent variables. The research gaps are also discussed in this section.

Chapter 3 focuses on the methodology in this study. This section provides a logical and detail way to conduct the research process. The research design, sampling size, sampling technique and research instrument are given. Other than that, the methodologies in data processing and analysis are also explained.

Chapter 4 will present the research results. For diagnosis testing, Unit Root Test, Heteroscedasticity Test, and Normality Test are conducted. We will be using Pooled Ordinary Least Square (POLS), Fixed Effect Model (FEM), and Random Effect Model (REM) for regression analysis. Lastly, Poolibility Test, Hausman Test, and Breusch-Pagan Lagrange Multiplier (BPLM) Test are run to select the best model.

Chapter 5 will provide an overview of the study's major conclusions based on the data that were examined in Chapter 4. We will discuss about how this research affects individuals, educational institutions, employers, and policy makers. This chapter will also cover the limitations that were encountered during the research process and offer suggestions for future researchers that are studying related or similar topics.

1.6 Conclusion

In conclusion, this research aims to investigate the relationship between the dependent variables which is the solar development and the main independent variable, which is institutional quality, alongside with control variables including Gross Domestic Product (GDP), Foreign Direct Investment (FDI), Population (POP) and Access to Electricity (ATE). Besides, this research will use Malaysia as base country to compare with other Southeast Asian countries in terms of the role of institutional quality in solar energy development.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

This chapter offers a thorough exploration that includes a literature review, an analysis of relevant theoretical models, a theoretical perspective, and a proposed theoretical framework. Prior research studies have been referenced to provide literature reviews on both the dependent and independent variables. The dependent variable of this study is solar energy development, which is represented by Installed Solar Capacity (ISC), while its independent variables include Institutional Quality (IQ) as the primary variable, and Gross Domestic Product (GDP), Foreign Direct Investment (FDI), Population (POP), and Access to Electricity (ATE) as control variables. The synopses of academic journals and previous research endeavours furnish insights and elucidate the relationships among the dependent variable and its determinants, thereby facilitating a deeper understanding of this research for external audiences.

2.1 Theoretical Review

Theoretical review provides a critical examination of relevant theories to establish a conceptual framework for the research study. By synthesizing key theoretical perspectives, this review highlights the connections between theoretical constructs and empirical findings while identifying gaps in the literature that necessitate further investigation. This section contextualizes the study within the broader academic discourse, demonstrating how it contributes to the existing body of knowledge and addresses unresolved issues in the RE field, ultimately laying a solid foundation for the research methodology and subsequent findings.

2.1.1 Metabolic Rift

The Metabolic Rift Theory, as proposed by John Bellamy Foster, is a concept that has gained significant interest in the Spanish-speaking linguistic area and particularly in Iberian America (Sacher, 2022). The theory suggests that there is a need to rethink the materials and mechanisms involved in metabolic rifting, integrating historical and epistemological dimensions beyond a purely material conception. This includes considering the potential for a "rift in the production and reproduction of knowledge", a loss of knowledge in the sphere of agricultural practices and local ecosystems, and even an epistemic rift due to changes in conceptions of value.

In this research, the Metabolic Rift Theory is a concept that can be applied to the analysis of the relationship between Foreign Direct Investment (FDI), Gross Domestic Product (GDP), and institutional quality with solar development. This theory suggests that the natural metabolic relationship between humans and nature has been fractured through modernization. In the context of solar development, the Metabolic Rift Theory can be used to analyse the relationship between FDI, GDP, and institutional quality with solar development by considering the socio-ecological contradictions inherent in the transition to solar energy technologies (Stuart et al., 2020). FDI, GDP, and institutional quality can impact the transition to solar energy technologies in various ways. For instance, FDI can provide the necessary capital for the development and implementation of solar energy technologies, while institutional quality can influence the regulatory frameworks and policies that govern the adoption of these technologies.

Besides, this theory also can be used to explain the relationship between population and solar development by highlighting the impact of human activities on the natural cycles of the earth. The theory suggests that industrialization and the expansion of capitalist production have led to the disruption of the natural metabolic relationship between humans and nature, resulting in the depletion of natural resources and the accumulation of waste. As the global population continues to grow, the demand for energy and resources increases, leading to further exploitation of the earth's natural resources and the exacerbation of environmental problems.

2.1.2 Ecological Modernization Theory (EMT)

Ecological Modernization Theory (EMT) is a school of thought that argues that both the state and the market can work together to protect the environment. This theory assumes that environmental readaptation of economic growth and industrial processes can be a source of future growth and development. This includes increases in energy and resource efficiency, product, and process innovations such as environmental clean technologies, benign substitution of hazardous substances, and product design for the environment.

Ecological modernization gives humans an active role to play in upgrading the environment's carrying capacity, which may entail conflicts with nature conservation. The scope of ecological modernization varies, with some scholars focusing on techno-industrial aspects and others including cultural aspects such as the ecological modernization of mind, value orientations, attitudes, behaviour, and lifestyles.

The relationship between ecological modernization and solar development involves various factors such as Foreign Direct Investment (FDI), Gross Domestic Product (GDP), and institutional quality. Ecological modernization theory emphasizes the integration of environmental concerns into economic activities and institutions to promote sustainable development. In the context of solar development, this theory suggests that FDI, GDP, and institutional quality play crucial roles in advancing renewable energy technologies like solar power.

Foreign Direct Investment (FDI) can influence the adoption and expansion of solar energy technologies by providing financial resources, technology transfer, and expertise. Countries with higher FDI inflows in renewable energy sectors, including solar, are likely to experience accelerated development and deployment of solar technologies. While for the Gross Domestic Product (GDP), it can reflect the economic performance of a country and can impact its ability to invest in and promote solar development. Higher GDP levels often correlate with increased investments in renewable energy, including solar, as countries strive to achieve energy security, reduce carbon emissions, and foster sustainable economic growth. In addition, with a strong institutional quality, including regulatory frameworks, governance structures, and policy support, is essential for creating an enabling environment for solar development. Countries with robust institutions that support renewable energy initiatives, provide incentives for solar investments, and ensure regulatory stability are more likely to experience successful solar energy deployment.

The relationship between population growth and solar development can be explained by the theory by emphasizing the need for sustainable practices that balance environmental protection with economic development. In the context of solar development, population growth can impact energy demand and resource consumption, highlighting the importance of transitioning to renewable energy sources like solar power to meet the needs of a growing population without compromising the environment (Dauda, 2019). By integrating solar energy technologies into the energy mix, societies can reduce their reliance on fossil fuels, mitigate environmental impacts, and contribute to a more sustainable future for both current and future generations.

2.2 Review of Literature

The review of literature offers a concise synthesis of existing research pertinent to the study, highlighting significant findings, methodologies, and theoretical frameworks. By critically analysing relevant studies, this section identifies patterns, contradictions, and gaps in the current body of knowledge, thereby underscoring the necessity for further research. Additionally, it contextualizes the study within the broader academic landscape, illustrating how the proposed research builds on previous work and addresses unresolved issues, ultimately reinforcing the study's relevance and contribution to the field.

2.2.1 Solar Development

Solar energy is the energy of solar radiation, which is known as heat and light and is obtained from the Sun, Earth's primary energy source (Prvulovic et al. 2018). It is undeniable the greatest renewable energy source found on Earth. Solar energy dates to the seventh century, when solar-powered mirrors were used. Scientists discovered the photovoltaic (PV) effect in 1893, and decades later they developed this technology to generate electricity (Frass et al, 2014). On the basis of this, solar energy technology is categorized into two main applications: solar thermal and solar PV. Solar

PV has emerged as a critical component in the low-carbon sustainable energy system required to provide affordable and reliable electricity, contributing to the Paris climate agreement and the 2030 SDG targets (Gahrens et al., 2021). It has various advantages over fossil energy sources such as does not release greenhouse gases, raise the quality of water and land resources, expands energy supply, and offer energy independence and security (Solangi et al. 2011). Hence, solar energy developments have increased exceeding during the last decade, and the solar energy's share in total RE generation have also increased. Based on the data of IEA (2024), the solar energy's share in total RE generation is 5.3% in 2016, 8.7% in 2019, and 13.7% in 2022.

In the context of this study, solar development is measured by installed solar capacity. In order to meet global energy demands, solar energy installed capacity has rapidly increased. Between 2010 and 2020, the installed capacity of photovoltaic technology increased from 40 334 to 709 674 MW, while the installed capacity of concentrated solar power (CSP) applications increased from 1266 MW in 2010 to 6479 MW after a decade. As a result, there are more installed installations of solar PV technology than CSP applications. (IRENA, 2022) Therefore, large-scale grid-connected PV plants and standalone solar PV systems are widely used in space applications and throughout the world.

2.2.2 Institutional Quality

Institutional quality refers to the effectiveness and dependability of a country's economic, political, and social institutions. It includes aspects such as governance, rule of law, corruption control, democratic processes, and political rights. High institutional quality is linked to improved economic and social outcomes, such as attracting debt portfolio investments between nations, generating economic and social advantages, enhancing the efficiency of innovation inputs, and shaping the quality and suitability of healthcare services. Institutional quality can be assessed based on various indicators such as static efficiency, dynamic efficiency, credibility, and adaptability. It plays a crucial role in shaping the performance and outcomes of various sectors within a country (Samadi & Alipourian, 2021).

In the context of solar development, institutional quality is crucial for creating an enabling environment for the adoption and deployment of solar energy technologies. Several studies have highlighted the importance of institutional quality in promoting solar development. High-quality institutions can provide a stable and predictable regulatory framework that promotes investment in solar energy, supports the development of solar energy infrastructure, and fosters innovation and technological advancements in the sector (Maka & Alabid, 2022). Moreover, institutional quality plays a critical role in the effective implementation and enforcement of policies and regulations that promote sustainable solar energy use, as demonstrated through the application of the Fuzzy Analytic Hierarchy Process (AHP) and the Fuzzy Technique for the Order of Preference by Similarity to the Ideal Solution (TOPSIS) method (Sadat et al., 2021). These methods highlight the importance of institutional strength in supporting renewable energy targets, feed-in tariffs, and net metering policies.

Rafiq et al. (2024) investigated the influence of institutional quality on renewable energy promotion in OECD economies using Fully Modified Pooled Ordinary Least Square (FMOLS), Dynamic Ordinary Least Square (DOLS), and Generalized Method of Moments (GMM) techniques with data spanning from 1980 to 2014. Their findings indicate that institutional quality exerts a positive and significant impact on renewable energy consumption. Similarly, Sheng et al. (2023) conducted a study exploring the relationship between institutional quality and energy production in BRI countries, using Panel Quantile Regression analysis on data from 2000 to 2020. The study found that producing energy from renewable sources, such as wind and solar, reduces CO2 emissions, with institutional quality playing a significant role in promoting the adoption of renewable energy sources. Furthermore, Ali et al. (2022), utilizing Partial Least Square Structural Equation Modelling (PLS-SEM) on data collected from 78 participants in 2021, concluded that effective governance and financial support significantly moderate the relationship between renewable energy policy instruments and the influx of green FDI, particularly in the solar energy sector.

Additionally, Saadaoui and Chtourou (2022) found that institutional quality positively influences renewable energy consumption, reflecting an increased demand for renewable energy. This conclusion is based on their analysis of historical data from 1984 to 2017 in Tunisia using the autoregressive distributed lags (ARDL) model. Moliterni (2017), using a Difference-in-Difference analysis of 76 provinces, revealed that Italy's 2005 public subsidies for the solar energy sector resulted in increased corruption. This was driven by rent-seeking opportunities in areas with weak institutional quality and complex administrative procedures, with solar radiation serving as an exogenous variable.

Uzar (2020) examines the relationship between solar energy consumption and institutional quality from 1990 to 2015, incorporating economic growth and CO2 emissions as control variables, using ARDL and Pooled Mean Group (PMG) models. The findings indicate that institutional quality has a positive long-term effect on solar energy consumption, shaping market demand for solar energy. Qureshi et al. (2017), through Likert scale analysis, identified the lack of sufficient government financial support for the installation of small solar PV systems at the household level as the primary factor discouraging adoption decisions in Lahore, Pakistan. Kabir et al.

(2017) find that a strong regulatory framework, along with incentives and rebates—important aspects of institutional quality—is essential for the growth of the solar energy market. The study underscores the need for innovative strategies to alleviate the fiscal burden associated with these policy measures. Dagnachew et al. (2020) support this conclusion by demonstrating that scaling up off-grid systems and achieving universal electricity access rely significantly on strong institutional quality. Effective institutions provide stable policy frameworks, clear technical standards, and efficient management of financial incentives, which are crucial for mitigating corruption risks in low-interest loan schemes and promoting the sustainable development of decentralized electricity systems.

Overall, institutional quality is a critical factor in promoting solar development and achieving sustainable energy transitions. By creating an enabling environment for investment, innovation, and technological advancements, high-quality institutions can help drive the adoption and deployment of solar energy technologies, promote the sustainable use of solar energy, and contribute to the achievement of sustainable development goals.

2.2.3 Gross Domestic Product

According to Van Den Bergh (2009), Gross Domestic Product (GDP), is a tool used to measure the monetary value of all final goods and services produced in a country over a period of time. As such, GDP is often used as a broad indicator of the health of a country's economy and provides direction for the government's next economic policy direction. While GDP is considered an economic advancement, it does not directly represent the quality of life of the country's people; in other words, GDP growth does not include broader social benefits such as health and hygiene, educational attainment, environmental quality, and life satisfaction. An increase in GDP means that a country's economy is growing and driving up energy demand, and with it, the demand for solar energy, making GDP critical to the development of solar energy.

Previous studies have extensively examined the development and deployment of solar energy by such as efficiency, conditions, socio-economic impacts, and applications and analysis. Sahlian et al. (2021) use panel regression analysis with data from 2000 to 2019 to show that economic growth stimulates the demand, consumption, and development of solar energy. Simionescu et al. (2020), using FMOLS analysis from 2007 to 2019, demonstrate that progress in solar energy consumption positively affects GDP and GCI growth, and that economic growth also positively influences solar energy consumption. In addition, Sadorsky (2009) found a positive correlation between GDP and solar energy consumption through panel data analysis covering the period from 1994 to 2003. Ohler and Fetters (2014), using FMOLS and DOLS analyses with data from 1990 to 2008, demonstrate a significant positive bidirectional relationship between GDP and solar energy development.

Li (2024), employing simple linear regression analysis, finds that increases in GDP and employment opportunities are consistently associated with higher solar energy utilization. Mature solar technology will also provide better energy options for businesses and investors, the reliability and predictability of solar energy can gain the confidence of businesses to expand and drive economic activity in the region. Using multiple linear regression analysis covering from 2018 to 2021, Szustak et al. (2021) found that strong GDP performance leads to increased electricity production, while during economic crises, declining GDP results in significantly reduced voltage ratings of power plants, negatively impacting solar energy consumption.

Although Khobai et al. (2020), using the ARDL model, observed that South Africa's renewable energy consumption from 1990 to 2014 has a positive long-term impact on the economy, the relationship is not significant in the short term. Rahman et al. (2023), using the ARDL cointegration method and Granger Causality (Toda Yamamoto) test within the VAR framework, examined the relationship between renewable energy use, unemployment, and GDP growth in emerging South Asian countries from 1990 to 2019. The results differed for Sri Lanka and Bangladesh: Sri Lanka showed a significant positive relationship between the variables, while Bangladesh experienced a significant negative impact between GDP growth and renewable energy use. The study concludes that policymakers should diversify strategies to stimulate economic growth and develop renewable energy sources to reduce reliance on conventional energy, minimize environmental pollution, and lower CO_2 emissions.

2.2.4 Access to Electricity

Electricity is one of the forms of energy that is produced because of the presence of charged particles (Truffer et al., 2001). Almost all of today's mechanical and electrical work relies heavily on the supply of electricity, including the use of electronics, electric lighting, and the enhancement of a variety of services, thus the energy supply from electricity has significantly improved people's lives (Winther et al., 2017). As mentioned by Kirsten Ulsrud (2020), sub-Saharan Africa has a poor access to healthcare due to the lack of electricity supply and the difficulty of accessing energy. This lack of energy is also known as energy poverty, which has a very high impact on health and causes even more deaths than malaria or tuberculosis (González-Eguino, 2015).

Saim and Khan (2021) highlight in their study on Bangladesh and its remote islands that grid expansion is often unfeasible for energy-poor regions due to the high environmental requirements and the prohibitive costs associated with laying and maintaining grid infrastructure, making it challenging for economically disadvantaged countries to pursue grid expansion. Whereas Lemaire (2011) found that the high costs associated with diesel generators, including the need for continuous diesel supply, maintenance, and mechanical parts, make home solar systems a more reliable and cleaner alternative, with photovoltaic (PV) systems being particularly efficient. These studies suggest that as electricity costs rise, countries often turn to local solar energy development as a viable alternative.

Timilsina et al. (2012) noted that solar energy has grown significantly, reaching over 179 GW by 2023, largely due to government interventions such as subsidized feed-in tariffs, tax credits, and direct subsidies aimed at reducing barriers to solar energy adoption. This rise in solar energy is closely linked to addressing energy shortages, which, as Bhide and Monroy (2011) highlighted, have exacerbated national poverty. India's 10th Five-Year Plan, which sought to reduce poverty by 15 percentage points by 2012, illustrates how expanding access to renewable energy sources like solar power can play a crucial role in alleviating poverty and improving living standards, especially in regions with significant electricity deficits.

2.2.5 Foreign Direct Investment

Foreign direct investment (FDI) has increasing significance in RE sector. Fan and Hao (2020) proposed that FDI plays a crucial role in fostering the growth of renewable energy. After employing Vector Error Correction Model (VECM) covering dataset from 2000 to 2015, they argue that FDI can have a beneficial influence on the technological progress of firms in host nations by facilitating technology transfer and spillovers. Additionally, given the substantial financial and technological requirements for renewable energy development, FDI offers a means to supply funding and technical assistance to the industry effectively. To attract FDI, the institutional environment holds the greatest significance, surpassing both macroeconomic factors and natural conditions. Within the macroeconomic realm, factors such as economic growth and access to local finance play crucial roles in enticing FDI. Conversely, land availability emerges as the most significant factor for attracting FDI within the dimension of natural conditions (Mahbub et. al., 2022).

The nexus between FDI and solar energy development varies among various academic research. According to Samour et al. (2022), using ARDL analysis on RE consumption and FDI of United Arab Emirates (UAE) from 1989 to 2019, FDI can significantly enhance solar energy development. Moreover, a study conducted across 33 African economies using Poisson Pseudo Maximum Likelihood (PPML) analysis from 2003 to 2019 revealed a positive correlation between FDI inflows and the rising share of renewable energy in total energy consumption. This suggests that attracting FDI into India's economy could similarly strengthen its renewable electricity sector, helping to reduce its heavy reliance on coal for energy production (Rashed et al., 2021).

On the other hand, another study revealed that FDI inflows linked with renewable energy adoption can mitigate environmental deterioration and enhance public health in areas of China characterized by extensive utilization of renewable energy sources (Kilicarslan, 2019). Kilicarslan (2019) further added that FDI inflows have a detrimental impact on renewable energy output in Brazil, indicating that FDIs are not primarily directed towards the renewable energy sector. In the context of BRICS countries, Yilanci et al. (2019) discovered that FDI positively impacts clean energy use in Russia, but not significantly in China and South Africa employing Fourier ADL (Autoregressive Distributed Lag) covering dataset from 1985 to 2017.

In general, the influence of FDI on the advancement of solar energy hinges on a range of factors, including the nature of the FDI, existing policies, and the unique circumstances of the country or locality involved. Implementing suitable incentive policies alongside a conducive regulatory framework can effectively draw FDI into the renewable energy sector, thus fostering the growth of solar energy.

2.2.6 Population

Population is the total number of people or residents in a given area, including the number of people and other living things occupying a particular room (Fakrulloh and Wismuyani, 2019). It is a collection of individuals who live in a region, are subject to various laws that govern them, and regularly communicate with one another (Said, 2019).

Population growth will result in a high demand for commodities, which will raise the need for capital and enable the establishment of a successful market based on Keynes. Optimists such as Arthur Lewis (1954) and Jorgenson (1961) claim that population growth will accelerate economic development.

As the world's population grows, energy consumption rises due to advancements in technology and globalization. With an increase in total population, an increase in total energy consumption should occur (Christenson, 2013). If more people are using more energy, then it could be that renewable energy increases to keep pace with demand from a larger state population. Vladislav et al. (2018) highlighted that the rapid growth in global population, along with accelerated energy consumption and economic industrialization, underscores the need for expanding solar energy development as a sustainable solution to meet rising energy demands while mitigating the environmental impact of traditional energy sources.

According to the study of Hang and Phuong (2021), there is a significant relationship between population and solar energy development as renewable energy usage responds positively to population growth, leading to increased adoption and development of solar energy sources. This can be supported by the study of Shao et al. (2020) as population is one of the important criteria to determine solar energy development based on Multi-Criteria Decision Making (MCDM) methods. Other than that, the study by Nepal and Paija (2021) examines the inter-relationship between energy security, electricity consumption, population, and economic growth for Nepal, a developing resource-rich country. The authors, using data from 1978 to 2016 and applying the ARDL bounds testing approach to cointegration, find that population growth positively influences electricity consumption, thereby accelerating the adoption of solar technologies as a sustainable solution to meet increasing energy demand.

2.3 Proposed Theoretical Framework

2.3.1 Conceptual Framework

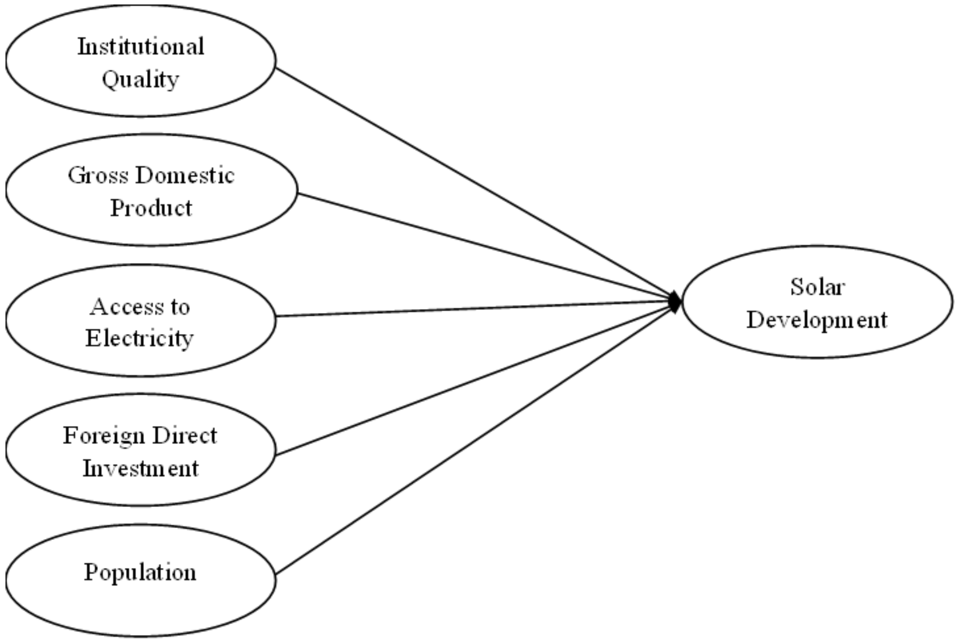

Figure 2.3. Conceptual Framework

Figure 2.3. presents the conceptual framework for this study, which explores the relationship between solar development and five independent variables: institutional quality, gross domestic product, access to electricity, foreign direct investment, and population. Additionally, the study examines the impact of these variables on the dependent variable, solar development.

2.4 Hypotheses Development

This section involves creating testable predictions based on theoretical foundations and prior research. These hypotheses outline expected relationships between variables and serve as a guide for data collection and analysis. Rooted in existing literature, they aim to address research gaps and provide a framework for validating the study's assumptions through empirical testing.

2.4.1 Institutional Quality

H_{01}: There is no significant relationship between institutional quality and solar development.

H_{a1}: There is a significant relationship between institutional quality and solar development.

2.4.2 Gross Domestic Product (GDP)

H_{02}: There is no significant relationship between GDP and solar development.

H_{a2}: There is a significant relationship between GDP and solar development.

2.4.3 Access to Electricity (ATE)

H_{03}: There is no significant relationship between access to electricity and solar development.

H_{a3}: There is a significant relationship between access to electricity and solar development.

2.4.5 Foreign Direct Investment (FDI)

H_{05}: There is no significant relationship between FDI and solar development.

H_{a5}: There is a significant relationship between FDI and solar development.

2.4.6 Population

H_{06}: There is no significant relationship between population and solar development.

H_{a6}: There is a significant relationship between population and solar development.

2.5 Gaps of Literature Review

Research gap shows the area where previous research is lacking or missing compared to our study. Based on the literature review, we found out that there is more to discover about the role of institutional quality in solar energy development. We observed out that the previous literature mostly focuses on how economic indicators such as FDI, GDP, and economic growth will affect the renewable energy consumption (Samour et al., 2022), and some of the literature treat institutional quality and solar energy development as controlled variable together to observe other variable, but there is no literature that shows how institutional quality can influence the solar energy development. Institutional quality is a political factor that is rarely discussed by other researchers regarding this topic. Our emphasis on institutional quality shows a clear gap on this topic as it is an unexplored topic that have not been studied before.

Next, there is a significant research gap in the field of solar development research, especially within the Southeast Asia context. Most of the studies founded are from Western countries and rarely based on Southeast Asian countries. For example, Rafiq et al. (2024), Said (2019) focus on groups of countries like OECD countries and G-20 countries respectively, while other researchers' studies on a particular country such as Bakali et al. (2022) focus on America; Sahlian et al. (2021), Sunuibescu et al (2020), Stustak et al (2021) focus on Europe countries, and Ulsrud (2020) focus on Africa. Since there are huge differences between the economy, policies and culture of Southeast Asian countries and other countries, the previous research results from other countries may not be applicable or tally the context of our research. The data and research on solar energy development is extremely scarce, which our studies can be used as an indicator for Southeast Asian countries.

2.6 Summary

This section presents a summary of prior literature on the relevant variables and outlines the anticipated relationships between solar development and several independent variables. Based on a review of previous studies, we expect a significant and positive relationship between SD and IQ, the key independent variable in this study.

For the relationship between SD and GDP, the literature reveals mixed findings, with outcomes ranging from positive and significant to positive but insignificant, and even negative and significant. Similarly, mixed results are observed for the relationship between ATE and SD, where some studies report a positive and significant relationship, while others find a negative and significant one.

The relationship between FDI and SD is also inconsistent in the literature. There are instances of positive and significant effects, positive but insignificant results, as well as negative and significant outcomes. Finally, the literature suggests that POP has a consistently positive and significant relationship with SD.

2.7 Conclusion

This research includes five independent variables to assess SD. After reviewing prior studies, the researchers have recognized these variables as key factors impacting SD. As a result, they will gather data for the research methodology to carry out data analysis and ensure the reliability of the findings.

CHAPTER 3: METHODOLOGY

3.0 Introduction

This chapter discusses data collection methods, research designs, study framework, variable specifications and the diagnostic tests used. Hence, various techniques in empirical analysis, including econometrics methods and the choice of the appropriate diagnostic tests are investigated in this chapter.

3.1 Research Design

The general objective of this research is to examine the relationships among solar energy development, proxied by Installed Solar Capacity (ISC) and its main independent variable, Institutional Quality (IQ), as well as other control variables such as Gross Domestic Product (GDP), Foreign Direct Investment (FDI), Population (POP), and Access to Electricity (ATE). The scope of this study is Southeast Asian countries between the years 2000 and 2022.

In this study, panel data analysis is used. We study 11 Southeast Asian countries that have recorded solar development within the period of 23 years from 2000 to 2022 for this empirical study.

3.2 Data Collection Method

The data sources used in conducting this research are secondary data sources. Typically, secondary data is data retrieved from public sources. This study analyses secondary data to conduct panel data analysis. The independent variables are IQ, GDP, FDI, POP and ATE. Data used in this study is retrieved from World Bank Databank, Our World in Data, and UNCTAD.

3.3 Sampling Design

This study begins with choosing the Southeast Asian countries that have recorded solar energy development. Firstly, a total of 11 Southeast Asian countries is chosen. Then, the researchers conduct elimination process that selects the time period for 23 years, which is from 2000 to 2022, after considering the availability of data recorded from open sources.

3.4 Variable Specification

Variable specification involves identifying and defining both the dependent and independent variables for the model. In model specification, the dependent variable represents the outcome of interest, which in this study is [insert dependent variable]. The independent variables, including [list independent variables], are the predictors hypothesized to influence the dependent variable. The model is structured to test the relationships between these variables, ensuring that the specified variables align with the research objectives and theoretical framework. Proper specification is crucial to accurately capture the effects and interactions between the variables in the analysis.

3.4.1 Model Specification

$$\ln SD_{it} = \beta_0 + \beta_1 IQ_{it} + \boldsymbol{\beta_2} \ln GDP_{it} + \boldsymbol{\beta_3} \ln ATE_{it} + \boldsymbol{\beta_4} \ln FDI_{it} + \boldsymbol{\beta_5} \ln POP_{it} + \boldsymbol{\mu_{it}}$$

where $SD_{it} = \boldsymbol{Solar\ Development}$

$IQ_{it} = \boldsymbol{Institutional\ Quality}$

$GDP_{it} = \boldsymbol{Gross\ Domestic\ Product}$

$ATE_{it} = \boldsymbol{Access\ to\ Electricity}$

$FDI_{it} = \boldsymbol{Foreign\ Direct\ Investment}$

$POP_{it} = \boldsymbol{Population}$

$\mu_{it} = \boldsymbol{Error\ Term}$

$\boldsymbol{i} = \boldsymbol{Individual\ cross - sectional\ unit}$

$\boldsymbol{t} = \boldsymbol{Time\ period}$

3.4.2 Dependent Variable

The dependent variable is affected by independent variables in an empirical analysis. In this research, installed solar capacity is used as the proxy to measure solar development.

3.4.2.1 Solar Development

In this study, solar development is used as the dependant variable in which installed solar capacity is used as the proxy. Installed solar capacity is used to determine the overall market shares of solar energy in a country’s energy generation. The higher the installed solar capacity is in a country; the more significance solar energy is in the energy combination of a country.

Installed solar capacity refers to the total amount of solar power generation infrastructure installed within a specific region, typically measured in kilowatts (kW) or megawatts (MW). It is a crucial indicator for understanding a country's progress towards adopting renewable energy sources and reducing reliance on fossil fuels. The level of installed solar capacity in a country reflects its commitment to renewable energy adoption and environmental sustainability. Higher levels of solar capacity indicate progress towards achieving energy independence, reducing greenhouse gas emissions, and promoting economic growth through investments in clean energy infrastructure.

3.4.3 Independent Variable

In an empirical analysis, independent variable influences the dependent variable. In this research, IQ is set as the main independent variable, alongside four control variables namely GDP, FDI, POP, and ATE.

3.4.3.1 Institutional Quality (IQ)

Institutional quality is characterized by transparent and predictable regulations, effective governance structures, secure property rights, and a supportive policy environment. These institutional factors shape the investment climate and determine the attractiveness of investment projects to both domestic and international investors. Moreover, institutional quality impacts various aspects of national development.

3.4.3.2 Gross Domestic Product (GDP)

GDP refers to the monetary value of goods and services produced in a country in a quarter or a year. GDP is often used to measure the health of a country's economy. However, as a tool to measure the economic situation of a country, GDP does not represent income equality or social well-being. A higher GDP can only indicate that the country's economy is performing well over a period of time, but not whether there are inequalities within the country, such as the gap between the rich and the poor. However, at the same time, GDP can be used as one of the guidelines for the policies adopted by the governors, and an excessively high GDP also means that the country may face a high inflation rate. Conversely, a weak GDP also signals that the country may have economic problems. The GDP of a country also affects the investment strategies of many investors or entrepreneurs.

3.4.3.3 Foreign Direct Investment (FDI)

Foreign Direct Investment (FDI) involves an investment by an entity in one country into a business or corporation in another country, with the aim of establishing a long-term interest. This lasting interest sets FDI apart from foreign portfolio investments, where investors hold foreign securities in a more passive manner. FDI plays a crucial role in fostering the growth of renewable energy. Rashed et al. (2021) conducted studies across 21 African economies and revealed a correlation between FDI inflows and increased proportions of renewable energy in the overall energy consumption statistics. The study suggested that attracting FDI into the Indian economy could bolster the nation's renewable electricity sector, thus reducing its heavy dependence on coal for energy.

3.4.3.4 Population (POP)

Population is the total number of individuals living within a specific geographical area, typically measured over a given period, such as a year or a decade. It serves as a fundamental indicator for learning the demographic landscape and social dynamics of a country. A growing population can signify vitality and dynamism within a society, which lead to increased innovation and productivity. Moreover, a larger population can support various industries and services, contributing to economic and technological growth of a country.

3.4.3.5 Access to Electricity (ATE)

Electric power is a type of energy, it is one of the basic requirements of modern society and can be converted into other types of energies with the help of electrical appliances, such as refrigerators, induction cookers, fans, etc. Many services work on electricity, such as medical facilities, communication services, and appliances for mobility. By the popularization of electricity, it means the development of society along with technology. The more people in a country have access to electricity, the more developed the country usually is. On the other hand, less than 35% of the people having electricity would, therefore, mean that the gap between the haves and the have-nots is wide, and the country is economically backward.

3.5 Data Sources

Table 3.5 outlines the key variables used in the research on solar development and institutional quality. Solar development is measured by installed solar capacity, while institutional quality is represented through six governance indicators, including control of corruption, government effectiveness, and regulatory quality, among others. The institutional quality in this study is computed by averaging these six governance indicators, which sets this research apart. Other variables include GDP, access to electricity, foreign direct investment, and population, with data sourced from reputable organizations like the World Bank and UNCTAD.

Table 3.5:

Data Sources of Variables

Variable	Proxy	Unit of Measurement	Source
Solar Development	Installed Solar Capacity	Gigawatts (GW)	Our World in Data
Institutional Quality	Control of Corruption: Estimate	Estimates, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5	Worldwide Governance Indicator (WGI)
	Government Effectiveness: Estimate		
	Political Stability and Absence of Violence/Terrorism: Estimate		
	Regulatory Quality: Estimate		
	Rule of Law: Estimate		
	Voice and Accountability: Estimate		
Gross Domestic Product	Real GDP	Constant USD	World Bank
Access To Electricity	Electrification Rate by Region or Sector	Percentage to population	World Bank
Foreign Direct Investment	Balance of Payment	Constant USD	United Nations Conference on Trade and Development (UNCTAD)

Population	Total Number of Households	Absolute Number	World Bank

3.6 Data Processing

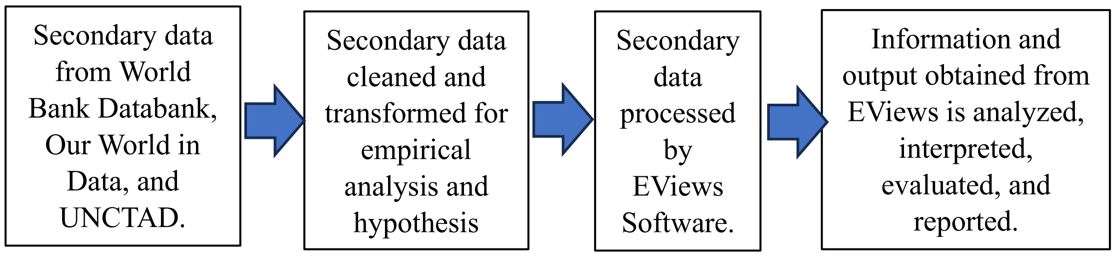

Figure 3.6: The flow of data processing

Figure 3.6 illustrates the data processing flow of the study. Initially, secondary data is sourced from reputable open databases, including the World Bank Databank, Our World in Data, and UNCTAD. Following the data collection, the raw secondary data undergoes a rigorous cleaning and transformation process to prepare it for empirical analysis and hypothesis testing. Once the data is cleaned and transformed, EViews software is utilized to facilitate the processing and analysis. Finally, the researchers analyse, interpret, evaluate, and report the findings and outputs generated from the EViews software, ensuring a comprehensive examination of the data.

3.7 Diagnosis Testing

Diagnosis testing is conducted to ensure the accuracy and reliability of the model by identifying potential issues that could lead to misspecification, bias, or inefficiency in the estimates. By conducting these tests, the study aims to avoid model misspecification, ensure the unbiasedness and consistency of estimates, and improve the overall validity of the findings. This step is crucial in ensuring that the model's results are both accurate and interpretable.

3.7.1 Unit Root Test

The unit root test, also known as a stationarity test, is conducted to assess whether variables exhibit a unit root. The null hypothesis indicates non-stationarity, while the alternative hypothesis suggests stationarity. This test is employed in the study due to the extensive time period relevant to the cross-sectional data. A key distinction between panel unit root tests and series unit root tests lies in the asymptotic behaviour of the cross-sectional and time-series dimensions. The Augmented Dickey-Fuller Fisher-type test, Phillips-Perron Fisher-type test, Levin, Lin, and Chu test, along with the Im, Pesaran, and Shin W-statistic test, were utilized in this research.

3.7.1.1 Levin, Lin, and Chu (LLC) Test

The Levin, Lin and Chu test is a method of panel data analysis that tests for unit roots. Panel data usually involves observations of multiple entities over time. The LLC test extends the analysis to panel datasets by assuming that all cross-sections share a common unit root process. This approach allows for incorporating cross-sectional dependencies and individual deterministic trends, which are essential for accurately assessing the stationarity. The LLC test provides a framework for determining whether the variables in a panel dataset exhibit unit-root behaviour, thereby indicating that the dataset is non-stationary.

3.7.1.2 Im, Pesaran, and Shin W-stat Test

The Im, Pesaran, Shin W-stat test (IPSW), introduced in 2003, tests for a unit root process across cross-sections in a panel dataset. Unlike some other panel unit root tests, the IPSW does not assume that all cross-sections have a common unit root process. Instead, it aggregates individual unit root tests, takes into account potential heterogeneity between cross-sections, and captures the different behaviours between entities over time, thus flexibly enhancing the analysis of panel data.

3.7.1.3 Augmented Dickey-Fuller (ADF) Fisher-type Test

For panel data, the ADF-Fisher test uses Fisher's chi-square method to combine the results of individual ADF tests for each cross-section. This test handles serial correlation of disturbed terms. By including a lagged dependent variable, this disturbance can be mitigated for a more comprehensive analysis. This method aggregates the p-values for each cross-section and allows for a robust and comprehensive analysis of unit roots in panel data sets.

3.7.1.4 Phillips-Perron (PP) Fisher-type Test

The Phillips-Perron test, developed in 1988, this test is to examine for the presence of a unit root in a variable that would suggest a random walk behaviour. The Phillips-Perron test does not include lag difference terms, unlike the Dickey-Fuller test, which takes a serial correlation and heteroscedasticity in the error terms into consideration. The Fisher-PP test for panel data integrates individual PP test findings across cross-sections to provide a thorough examination of unit roots in panel datasets.

3.7.2 Normality Test

In panel data analysis, normality tests are employed to determine whether the residuals of a model follow a normal distribution across multiple cross-sectional units over time. These tests are crucial for validating the assumptions underlying many econometric models, particularly those relying on maximum likelihood estimation or hypothesis testing, which assume normally distributed errors. By checking the normality of residuals, these tests help ensure that inference results, such as p-values and confidence intervals, are accurate and reliable. Commonly used normality tests in panel data include the Jarque-Bera test, Shapiro-Wilk test, and Lilliefors test. These tests evaluate skewness and kurtosis, allowing for an assessment of deviations from normality, which, if detected, may necessitate model adjustments or transformations to improve model fit and performance.

3.7.3 Heteroscedasticity Test

In panel data analysis, heteroscedasticity tests are used to assess whether the variance of residuals remains constant across cross-sectional units and over time. Ensuring homoscedasticity is critical for many econometric models, particularly those relying on ordinary least squares (OLS) estimation. Violations of this assumption can result in inefficient and biased estimates, as well as inaccurate inferences, including p-values and confidence intervals. These tests help detect unequal variances in residuals, which can compromise the reliability of the model's results. Common heteroscedasticity tests in panel data include the Breusch-Pagan test, White test, and Likelihood Ratio test. If heteroscedasticity is present, adjustments, such as applying robust standard errors, are necessary to correct for its effects and improve the model's validity.

3.8 Estimation Technique

The researchers conduct regression analysis to interpret and report the valuable insights within the data. The secondary data is analysed using the EViews Software in which a panel data analysis is conducted. The focus of the analysis is whether the independent variables significantly influence the dependent variable. Besides, the researchers conduct tests on the relationships among the independent variables.

3.8.1 Pooled Ordinary Least Square (POLS) Regression

A pooled model merges data from different individuals without considering variations between them, resulting in uniform coefficients across observations (Hill et al., 2011). In the Pooled OLS model, intercepts and slopes are assumed to be constant throughout the observation period, ignoring any heterogeneity. The model also presumes time-invariance and uniformity across the sample. The Ordinary Least Squares (OLS) method is critical for estimating pooled data, as it assumes no heteroscedasticity and no correlation among individual effects over time.

3.8.2 Fixed Effect Model (FEM)

The Fixed Effect Model assumes that certain variables remain constant across individuals. However, a concern with this model is its tendency to ignore many degrees of freedom, potentially leading to unstable estimates. Furthermore, this approach may introduce time invariance, preventing the study of changes over time in the dependent variable. An important assumption of the FEM is that these time-invariant features differ among individuals. Each entity is considered unique, so the constant and error terms for each entity should be uncorrelated. If this condition is not met, the fixed effect may not be appropriately recognized, impacting the model's validity.

3.8.3 Random Effect Model (REM)

The Random Effect Model is a statistical method used to analyze panel or longitudinal data, allowing for both within-group and between-group variations. REM considers individual-specific effects as random variables. This model assumes that the individual-specific effects are uncorrelated with the independent variables and have a constant variance. Additionally, it assumes that the individual-specific effects are uncorrelated with the error term. These assumptions enable the REM to capture both individual-level and group-level variations, offering a flexible approach for analysing complex data structures.

3.9 Model Selection

Model selection in panel data analysis is a crucial step in identifying the most appropriate model among POLS, FEM, and REM. The choice of model depends on the underlying data structure and the assumptions regarding unobserved heterogeneity across cross-sectional units. POLS assumes that there are no individual effects, treating all units uniformly, while FEM accounts for time-invariant characteristics by allowing individual-specific intercepts. REM, on the other hand, treats individual effects as random and uncorrelated with the independent variables. To determine the best model, statistical tests such as the F-test, Breusch-Pagan Lagrange Multiplier test, and Hausman test are typically employed. These tests help identify whether fixed or random effects are more appropriate, ensuring that the selected model provides unbiased, efficient, and consistent estimates for the analysis.

3.9.1 Poolability Test

A poolability test is used in panel data analysis to determine whether it is appropriate to pool data from different cross-sectional units and estimate a common regression model for all units. The test checks if the relationships between the independent and dependent variables are the same across all cross-sectional units. If the test indicates that the data can be pooled, it suggests that a common regression model can be applied, simplifying the analysis. If the test suggests that pooling is not appropriate, it means that separate models should be estimated for each unit, or a more complex model should be used.

3.9.2 Breusch-Pagan Lagrange Multiplier (BPLM) Test

The Breusch-Pagan LM test, developed by Breusch and Pagan in 1979, evaluates heteroscedasticity within a linear model (Breusch & Pagan, 1979). It also examines the random effects of linear models based on pooled OLS residuals. Breusch and Pagan (1980) further describe its application in alternative models, using least squares to estimate whether they depend on maximum likelihood or a two-step procedure. Typically, this test employs maximum likelihood to compute LM statistics, simplifying comparison between restricted and unrestricted models.

3.9.3 Hausman Test

This test is utilized to uncover endogenous regressors within the model. Endogenous variables' values are determined by other factors. When endogenous regression arises, it can undermine the effectiveness of ordinary least square estimators. This occurs because one assumption of ordinary least squares is that there is no correlation between the error term and the predictor variables. As a result, instrumental variables estimation is employed as an alternative. Consequently, this test is employed to examine the issue of FEM versus REM (Stephanie, 2017).

3.10 Conclusion

This chapter studies several research methodologies to investigate the respective relationship between solar development and its independent variables which are IQ, FDI, GDP, POP and ATE. This chapter describes the methods used in hypothesis testing. The methods of hypothesis testing discussed in Chapter 3 will be performed and the outputs will be displayed in the following chapter.

CHAPTER 4: DATA ANALYSIS

4.0 Introduction

As sources of data and explanation for the empirical model are discussed in the previous chapter, further analysis and interpretation of the test results will be explained in this chapter. Diagnosis testing is firstly conducted to ensure soundness of the panel data analysis. Then, the researcher conducts regression analyses to examine the relationship between the dependent variable, Solar Development (SD) and the independent variables, including Institutional Quality (IQ), Gross Domestic Product (GDP), Access to Electricity (ATE), Foreign Direct Investment (FDI), and Population (POP). The method for determining the most appropriate model from Pooled Ordinary Least Squares (POLS), Fixed Effects Model (FEM), and Random Effects Model (REM) will be comprehensively discussed in the next section. Finally, this chapter is ended with a comparison between the results obtained in our analysis and the literature review discussed in Chapter 2.

4.1 Preliminary Results

The preliminary results in this regression analysis are derived from descriptive statistics and a correlation analysis. Descriptive analysis provides an initial overview of the data, highlighting key trends, distributions, and relationships among variables. The cointegration test further examines the long-term equilibrium relationships between variables, ensuring that non-stationary variables move together over time. These preliminary results offer valuable insights into the data's structure and potential long-run associations, laying the foundation for more detailed econometric analysis.

4.1.1 Descriptive Analysis

A descriptive analysis on the model is conducted by using EViews. From the analysis, the mean, median, standard deviation, maximum and minimum values, skewness as well as the Kurtosis and Jarque-Bera of the model is computed.

Table 4.1.1 shows the results of the descriptive analysis from 233 observations. First of all, the dependent variable, Solar Development (SD), has a mean of -5.2161 and a median of -5.6770 while owning the highest standard deviation in the model which is 3.5590. Furthermore, the key independent variable of this model is Institutional Quality (IQ). IQ has the lowest mean and median in the model which are -0.2125 and -0.3789. The standard deviation of IQ is 0.7788. A mean of 24.7970 and a median of 25.2772 are obtained for Gross Domestic Product (GDP), along with a standard deviation of 1.9710. Next, Access to Electricity (ATE) computes a mean of 4.3580, a median of 4.5521, and the lowest standard deviation of the model which is 0.4200. Moreover, Foreign Direct Investment (FDI) has a mean of 7.5886, a median of 8.0524 and a standard deviation of 2.2936. The last independent variable in the model, Population (POP), obtains a mean of 16.6967, the highest median in the model which is 17.1730 and a standard deviation of 1.8892.

In terms of maximum values, the highest maximum value in the model is 27.9080 of GDP. The second variable with the highest maximum value is

POP with 19.4341, followed by FDI with 11.8580, ATE with 4.6052, and SD with 2.9164. The smallest maximum value is obtained by IQ which is 1.6232.

For minimum values, GDP has the largest minimum value in the model which is 19.9332. Moreover, POP obtains the second highest minimum value which is 12.7187, followed by 2.2543 by ATE, -0.0965 by FDI, and -1.7534 by IQ. The smallest minimum value in the model is -13.1224 which is obtained by the dependent variable, SD.

Table 4.1.1:

Summary of Descriptive Analysis

Variable	**SD**	**IQ**	**GDP**	**ATE**	**FDI**	**POP**
Mean	-5.2161	-0.2125	24.7970	4.3580	7.5886	16.6967
Median	-5.6770	-0.3789	25.2772	4.5521	8.0524	17.1730
Maximum	2.9164	1.6232	27.9080	4.6052	11.8580	19.4341
Minimum	-13.1224	-1.7534	19.9332	2.2543	-0.0965	12.7187
Std. Deviation	3.5590	0.7788	1.9710	0.4200	2.2936	1.8892
Skewness	-0.0774	0.8272	-0.6349	-2.4099	-0.9113	-0.6167
Kurtosis	2.7703	3.2155	2.4522	9.1025	3.7862	2.3789
Jarque-Bera	0.7452	27.0233	18.5645	587.0655	38.2521	18.5147
Observation	233	233	233	233	233	233

4.1.2 Correlation Analysis

A correlation analysis is run to detect the correlation between each of the variables. A preliminary result of the relationship between the variables can be shown before the regression analysis in the following section.

As seen from Table 4.1.2, GDP and FDI share the highest correlation of 0.8737 in the model. Regarding the correlation with the key independent variable, IQ, FDI has the highest correlation of 0.5062, indicating a potential autocorrelation problem. The lowest correlation between a variable and the key independent variable is -0.3232 between the pair of POP and IQ.

Table 4.1.2:

Summary of Correlation Analysis

Correlation						
Variable	SD	IQ	GDP	ATE	FDI	POP
SD	1					
IQ	0.1931	1				
GDP	0.7042	0.3433	1			
ATE	0.4495	0.4890	0.6074	1		
FDI	0.6752	0.5062	0.8737	0.5817	1	
POP	0.4540	-0.3232	0.7224	0.1564	0.4930	1

4.2 Diagnosis Testing

4.2.1 Unit Root Test

Table 4.2.1 reports the results of Levin, Lin and Chu (LLC) test, Im, Pesaran and Shin W-stat (IPSW) test, Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) test at level and first differenced form, by taking into account both the case of constant with trend and constant without trend. The optimal number of lag length is determined by using the Newey-West Bandwidth selection and Bartlett Kernel. Based on the result in Table 4.4.1, the test statistics of variables with intercept is significant to reject the null hypothesis in LLC test at level, contradicting with the results in which the test statistics are insignificant to reject the null hypothesis in IPSW test, ADF test, and PP test at 1% significance level. This shows that the variables are non-stationary at level form, and it might contain one or more unit root. Therefore, we proceed to the first differenced form. In this case, the test statistics for all the tests indicate that the null hypothesis the series contains unit root should be rejected as all test statistics are statistically significant to reject null hypothesis and we concluded that the series is integrated of order one I(1).

While for the case of constant with trend, a similar observation is found when most of the variables are statistically insignificant to reject the null hypothesis in LLC, IPSW, ADF and PP tests at 10% level of significance. This shows that the variables contain one or more unit root at level. After executing first differencing, we observe that most of the variables are statistically significant to reject the null hypothesis at 10% level of significance except Population. Therefore, a second differencing is practiced.

After executing second differencing, all variables are statistically significant to reject the null hypothesis at 10% level of significance. This indicates that the variables with trend are stationary and do not contain autocorrelation with its past values. Therefore, the validity in hypothesis testing is safeguard.

Table 4.2.1:

Summary of Unit Root Test

	Constant				**Constant with Trend**			
	Levin, Lin and Chu	Im, Pesaran and Shin	ADF	PP	Levin, Lin and Chu	Im, Pesaran and Shin	ADF	PP
In Level								
ln_SD	-0.6583***	2.0884	13.4968	6.5874	0.1832	-0.0650***	24.762	9.0099
IQ	-0.2865	0.6718	17.0295	18.255	-0.1888	-0.6464	25.1432	34.5668***
ln_GDP	-5.6647***	-1.4446***	33.0298***	15.1500	3.0249	4.2475	4.5570	3.0924
ln_ATE	-2.6195***	0.6050	12.3345	40.1147***	-0.3776	0.2095	17.8428	75.4762***
ln_FDI	-1.972***	-1.4325***	29.1035	62.6534***	-0.4760	-1.5611***	33.0881***	89.9343***
ln_POP	-3.5303***	-0.1166	25.3305	729.980***	-0.7383	4.4512	14.1716	13.4223
First Difference								
ln_SD	-2.5741***	-5.845***	79.8876***	82.7717***	-1.8176***	-4.4915***	61.5317***	80.3249***

IQ	-2.8455***	-5.1162***	69.5370***	157.587***	-1.3168***	-3.7165***	53.1917***	137.122***
ln_GDP	-1.2285	-2.7509***	43.2317***	95.5775***	-3.6676***	-3.7921***	51.4803***	113.043***
ln_ATE	-8.4273***	-10.2092***	120.343***	622.884***	-8.2778***	-9.8536***	107.742***	999.255***
ln_FDI	-7.484***	-9.1418***	119.466***	679.127***	-7.1011***	-7.3344***	93.0504***	319.979***
ln_POP	-0.5845	1.7297	23.3045	18.4830	-0.3719	-0.3483	30.4448	13.5270
Second Difference								
ln_SD	-5.5059***	-9.8480***	127.937***	625.584***	-3.6867***	-7.3849***	92.722***	451.431***
IQ	-7.33204***	11.6242***	150.251***	1394.12***	-4.0835***	-9.5956***	115.595***	1160.01***
ln_GDP	-9.2648***	-11.131***	144.086***	522.907***	-6.8809***	-9.2641***	111.556***	424.505***
ln_ATE	-16.2026***	-17.669***	317.693***	2165.83***	-12.9581***	-15.589***	138.364***	2051.42***
ln_FDI	-12.5146***	-14.5381***	191.05***	1618.09***	-9.7958***	-12.0335***	146.603***	1125.36***
ln_POP	-6.9725***	-6.0368***	79.4876***	53.9401***	-7.2320***	-5.3132***	67.6136***	38.0028***

Note. The null hypothesis for Levin, Lin, and Chu test is that the series is not stationary, or contains a unit root, while assuming common unit root process. The null hypothesis for Im, Pesaran and Shin test is that the series is not stationary, or contains a unit root, while assuming individual unit root process. The rejection of null hypothesis for Levin, Lin and Chu test is based on Levin, Lin, and Chu (2002) critical values, while for Im, Pesaran and Shin test is based on Im, Pesaran and Shin (2003). The null hypothesis for Fisher Type test using ADF and PP tests is that the series is not stationary, or contains a unit root, while assuming individual unit root process. The rejection of null hypothesis for ADF test is based on Madalla and Wu (1999) critical values, while for PP test is based on Choi (2001).

***, **, * indicates rejection of null hypothesis at 1%, 5% and 10% levels of significance. Standard Errors are in parentheses.

4.2.2 Normality Test

To ensure that the residual of the model is normally distributed, a normality test is conducted. As seen from Figure 4.2.2, the null hypothesis is the error term of the model is normally distributed. The alternative hypothesis is the error term of the model is not normally distributed. Furthermore, the significance level is at 5% which is 0.05. We reject the null hypothesis if the Jarque-Bera test statistic is large and/or the p-value is less than or equal to level of significance at 5%. On the other hand, we do reject the null hypothesis if the Jarque-Bera test statistic is small and/or the p-value is greater than level of significance at 5%.

Since the Jarque-Bera test statistic is small (2.5887) and the p-value (0.2741) is greater than the level of significance at 5%. We do not reject the null hypothesis and can conclude that the error term of the model is normally distributed at level of significance 5%.

Figure 4.2.2. Summary of Normality Test

Normality Test
H_0: The residuals follow a normal distribution. H_1: The residuals do not follow a normal distribution. Significance Level, α: 0.05 Decision Rule: If the Jarque-Bera test statistic is large and/or the p-value ≤ α, reject the null hypothesis. If the Jarque-Bera test statistic is small and/or the p-value > α, do not reject the null hypothesis.

Test Statistics:
Jarque-Bera = 2.5887
p-value = 0.2741

Decision Making:
Do not reject null hypothesis as p-value (0.2741) is greater than significance level at 5%.

Conclusion: The residual of the model is normally distributed at significance level 5%.

4.2.3 Heteroscedasticity Test

To assess whether the model exhibits heteroscedasticity, a Likelihood Ratio (LR) test is conducted. As illustrated in Figure 4.2.3, the null hypothesis posits that the residuals of the model have constant variance, while the alternative hypothesis suggests that the residuals exhibit non-constant variance. The significance level is set at 5% (0.05). The null hypothesis is rejected if the LR test statistic exceeds a certain threshold and/or if the p-value is less than or equal to the significance level. Conversely, the null hypothesis is not rejected if the test statistic is below the threshold and/or the p-value is greater than the significance level.

In this analysis, the LR test statistic is 19.2166 and the p-value is 0.0573. Since the p-value is greater than the significance level of 5%, we do not reject the null hypothesis. Therefore, we can conclude that the residuals of the model do not exhibit heteroscedasticity at the 5% significance level.

Figure 4.2.3. Summary of Heteroscedasticity Test

Heteroscedasticity Test
H_0: The residuals have constant variable. H_1: The residuals do not have constant variable Significance Level, α: 0.05 Decision Rule: If the LR test statistic is large and/or the p-value ≤ α, reject the null hypothesis. If the LR test statistic is small and/or the p-value > α, do not reject the null hypothesis. Test Statistics: Likelihood Ratio = 19.2166 p-value = 0.0573 Decision Making: Do not reject null hypothesis as p-value (0.0573) is greater than significance level at 5%. Conclusion: The residual of the model is homoscedastic at significance level 5%.

4.3 Regression Analysis

4.3.1 Pooled Ordinary Least Square (POLS)

A Pooled Ordinary Least Square (POLS) analysis is conducted to study the relationship between the dependent variable, SD, and the independent variables, IQ, GDP, ATE, FDI, and POP. In overall, the regression model is significant to explain the variation in the dependent variable with at least one of the independent variables in the model has a non-zero coefficient. The high value of F-statistic which is 66.4964 and the low level of probability from F-statistic which is 0.0000 suggest that the model is statistically significant and that the independent variables, as a group, explain a significant portion of the variation in the dependent variable. The Durbin-Watson statistic of 0.1655 indicates that there may be presence of positive autocorrelation among the residuals. The R^2 of the model is 0.5943, showing that 59.43% of the variation in SD can be explained by the variations in IQ, GDP, ATE, FDI, and POP.

The key independent variable, IQ, has a p-value of zero which is less than the level of significance at 1%. This indicates that there is a significant relationship between IQ and SD. The slope of coefficient of -3.0389 indicates that there for every one unit increase in IQ results in 3.04% decrease in SD. Furthermore, IQ exerts the strongest influence on SD among the independent variables, as indicated by the highest absolute value of its coefficient. This suggests that IQ has a more substantial impact on SD compared to other factors. This finding of a negative yet significant relationship between IQ) and SD contrasts with previous research by Sheng et al. (2023), Maka & Alabid (2022), and Rafiq et al. (2024), which suggests that high-quality institutions typically create a stable and predictable regulatory environment. Such frameworks encourage investment in solar energy, support the development of solar infrastructure, and drive innovation and technological progress in the sector. This may indicate that the contribution of a stable legal framework is minimal to solar energy development in the emerging markets of Southeast Asia. According to Alam et al. (2019), an overly stable legal framework may fail to adapt to changing market conditions or emerging technologies. Investors may seek environments that allow for innovation and flexibility. Overly rigid laws can stifle entrepreneurial activity and discourage investment in sectors that demand flexibility, such as technology and renewable energy, particularly in the case of solar energy. A highly regulated environment may limit innovation and slow the pace of adoption, as businesses and investors may find it challenging to adapt to evolving market conditions or emerging technologies. The inconsistency in findings may be attributed to the varying countries examined in the literature. For instance, Sheng et al. (2023) focused on BRI countries, while Rafiq et al. (2024) investigated OECD nations. In contrast, this study explores 11 Southeast Asian countries, where differences in institutional frameworks, economic structures, and solar energy development stages may lead to divergent results.

In addition, GDP is significant in explaining the variation in SD as the p-value of zero is less than 10% level of significance. The slope of coefficient of 2.3323 indicates that there is a positively significant relationship between GDP and SD. This indicates that every one percent increase in GDP results in 2.33% increase in SD. This finding is consistent with the findings of Shalian et al. (2021), Simionescu et al. (2020) and Li (2024) that economic growth helps in stimulating the demand, consumption, and development of solar energy.

Moreover, ATE is insignificant to influence IQ as the p-value of 0.2041 is greater than the 10% level of significance. The slope of coefficient of -0.6829 proves that there is a negative correlation between ATE and SD. This indicates a negative and insignificant relationship between ATE and SD. This finding is inconsistent with the results of previous studies, whether it is the positive and significant relationship reported by Bhide and Rodriguez (2011) or the negative and significant relationship found by Saim and Khan (2021). The inconsistency is likely attributed to the differences in the time periods analysed, with Bhide and Rodriguez (2011) focusing on the period from 1983 to 2005, while Saim and Khan (2021) concentrate on data from 2020.

For FDI, the p-value is 0.0004 which indicates its significance in influencing SD as the p-value is less than the level of significance at 10%. The slope of coefficient of 0.5455 shows that there is a positive relationship between FDI and SD. For every 1% increase in FDI results in 0.55% increase in SD. This finding aligns with the research of Fan & Hao (2020), Samour et al. (2020), and Rashed et al. (2021), among others, but contradicts Kilicarslan (2019), who identified a negative and significant relationship. The inconsistency is likely due to differences in methodology and time periods, as Kilicarslan (2019) utilized ARDL analysis from 1996 to 2015, while this study applies POLS regression analysis covering the period from 2000 to 2022.

Finally, POP obtains a p-value of 0.0000 which is less the 10% level of significance, presenting a significant relationship with SD. A slope of coefficient of -1.61 shows that there is a negative relationship between POP and SD. This means that for every 1% increase in POP results in 1.61% decrease in SD. This finding is inconsistent with the findings in the literature in which Christenson (2013), Hang and Phuong (2021), Nepal and Paija (2021) reported a positive and significant relationship between POP and SD. We believe this inconsistency arises from the different methodologies used in the respective analyses. Nepal and Pajia (2021) applied ARDL to detect cointegration between population and solar development, proxied by solar energy demand, while Christenson (2013) employed Linear Regression Analysis, and Hang and Phuong (2021) used descriptive analysis. This study, however, utilizes POLS regression analysis.

Table 4.3.1:

Summary of Pooled Ordinary Least Square (POLS) Analysis

Variable	Coefficient	t-Statistic	Probability
Constant	-37.9779	-11.0551	0.0000***
		(3.4353)	
IQ	-3.0389	-6.7813	0.0000***
		(0.4481)	
LN_GDP	2.3323	7.2369	0.0000***
		(0.3223)	
LN_ATE	-0.6829	-1.2737	0.2041
		(0.5362)	
LN_FDI	0.5455	3.6005	0.0004***
		(0.1515)	
LN_POP	-1.6100	-6.0443	0.0000***
		(0.2664)	
R^2	0.5943		
Adjusted R^2	0.5853		
F-statistic	66.4964		
Probability (F-stat)	0.0000		
Durbin-Watson Stat	0.1655		

***, **, * indicates rejection of null hypothesis at 1%, 5% and 10% levels of significance. Standard Errors are in parentheses.

4.3.2 Fixed Effect Model (FEM)

A Fixed Effect Model (FEM) regression analysis was conducted to examine the relationship between the dependent variable, SD, and the independent variables—IQ, GDP, ATE, FDI, and POP—with separate intercepts for each entity, accounting for unique time-invariant characteristics. Overall, the model is significant in explaining the variation in SD, as indicated by at least one independent variable having a non-zero coefficient. The high F-statistic value of 76.3610 and the corresponding low p-value of 0.0000 suggest that the model is statistically significant, meaning the independent variables collectively explain a considerable portion of the variation in SD. However, the Durbin-Watson statistic of 0.2486 suggests potential positive autocorrelation in the residuals. The model explains 84.07% of the variation in SD, as reflected by the R^2 value of 0.8407, indicating a strong fit.

The key independent variable, IQ, has a p-value of 0.0762 which is less than the level of significance at 10%. This indicates that there is a significant relationship between IQ and SD. The slope of coefficient of 1.1761 tells us that there is a positive relationship between IQ and SD. For every one unit increase in IQ results in 1.18% increase in SD. This finding is in consistency with the findings of Maka and Alabid (2022), Sadat et al. (2021), Rafiq et al. (2024) and more in the literature review. We believe that this finding indicates a positive solar development in terms of energy infrastructure, investment, R&D can be achieved through a stable and predictable legal framework. Besides, good IQ ensures effective implementation and enforcement of solar-friendly policies such as feed-in tariffs and net metering policies. Moreover, effective governance plays an important role as a policy instrument for solar energy development and stimulate influx of green financing in solar energy sector.

In addition, GDP is significant in explaining the variation in SD as the p-value of zero is less than 10% level of significance. The slope of coefficient of 1.9090 indicates that there is a positive and significant relationship between GDP and SD. For every 1% increase in GDP results in 1.91% increase in SD. This finding is consistent with the findings of Shalian et al. (2021), Simionescu et al. (2020), and Sadorsky (2009) that GDP growth contribute to stimulating the demand, consumption, and development of solar energy.

Additionally, ATE is found to have an insignificant effect on SD, with a p-value of 0.2461, exceeding the 10% significance level. The negative coefficient of -0.5518 implies that a 1% increase in ATE leads to 0.55% decrease in SD. This result contrasts with the findings of Timillsina et al. (2012) and Bhide and Rodrigues (2011), who documented a significant positive relationship, as well as Saim and Khan (2021), who reported a significant negative relationship. The discrepancy may arise from methodological differences, as Saim and Khan (2021) employed Descriptive Analysis for data from 2020, while this study applies FEM analysis using data spanning from 2000 to 2022, potentially leading to variations in outcomes.

For FDI, the p-value of 0.1226 indicates that it is statistically insignificant in influencing SD, as it exceeds the 10% significance threshold. The coefficient of 0.2063 suggests a positive relationship, meaning that a 1% increase in FDI corresponds to a 0.21% increase in SD. This result deviates from the anticipated findings in the literature, which report either a positive and significant relationship, as found by Fan and Hao (2020) and Samour et al. (2022), or a negative and significant relationship, as noted by Kilicarslan (2019). The divergence in results may be attributed to differences in the geographical focus of these studies, with Fan and Hao (2020) concentrating on China and Samour et al. (2022) on the UAE, whereas this research examines 11 Southeast Asian countries, which may present unique economic and institutional contexts.

Finally, POP exhibits a p-value of 0.0000, which is well below the 10% significance threshold, indicating a significant relationship with SD. The coefficient of 12.4645 suggests a strong positive relationship, where a 1%

increase in POP leads to a 12.46% rise in SD. This result aligns with the expected positive and significant relationship between POP and SD, as documented in the literature by Vladislav et al. (2018), Shao et al. (2020), and Nepal and Paija (2021), supporting the notion that population growth drives the demand for renewable energy sources like solar development.

Table 4.3.2:

Summary of Fixed Effect Model (FEM) Analysis

Variable	**Coefficient**	**t-Statistic**	**Probability**
Constant	-259.5800	-8.4009 (30.8992)	0.0000*
IQ	1.1761	1.7814 (0.6602)	0.0762*
LN_GDP	1.9090	4.5924 (0.4157)	0.0000*
LN_ATE	-0.5518	-1.1630 (0.4745)	0.2461
LN_FDI	0.2063	1.5499 (0.1331)	0.1226
LN_POP	12.4645	5.4183 (2.3004)	0.0000*
R^2	0.8407		
Adjusted R^2	0.8297		
F-statistic	76.3610		
Probability (F-stat)	0.0000		
Durbin-Watson Stat	0.2486		

***, **, * indicates rejection of null hypothesis at 1%, 5% and 10% levels of significance. Standard Errors are in parentheses.

4.3.3 Random Effect Model (REM)

A Random Effect Model (REM) regression analysis is run to study the relationship between the dependent variable, SD, and the independent variables, IQ, GDP, ATE, FDI, and POP while assuming that the unobserved individual-specific effects are uncorrelated with the independent variables. In overall, the regression model is significant to explain the variation in the dependent variable with at least one of the independent variables in the model has a non-zero coefficient. The high value of F-statistic which is 74.8422 and the low level of probability from F-statistic which is 0.0000 suggest that the model is statistically significant and that the independent variables, as a group, explain a significant portion of the variation in the dependent variable. The Durbin-Watson statistic of 0.2066 indicates that there may be presence of positive autocorrelation among the residuals. The R^2 of 0.6224 suggests that 62.24% of the variation in SD can be explained by the variations in IQ, GDP, ATE, FDI, and POP.

The key independent variable, IQ, exhibits a p-value of 0.0168, which falls below the 10% significance threshold, indicating a statistically significant relationship with SD. The negative slope coefficient of -1.2312 suggests that for each one-unit increase in IQ, SD decreases by 1.23%. This outcome contradicts the expected positive relationship between IQ and SD, as observed in studies by Sadat et al. (2021), Sheng et al. (2023), and Rafiq et al. (2024). The discrepancy in findings may be attributed to differences in time periods, countries studied, and the methodologies employed in these analyses. For example, Rafiq et al. (2024) employed FMOLS, DOLS, and GMM methodologies to analyse OECD countries, while Sheng et al. (2023) utilized Panel Quantile Regression to study BRI countries. In contrast, this research adopts a REM approach focused on 11 Southeast Asian nations.

The findings suggest that an excessively rigid regulatory framework could hinder the flexibility needed in dynamic markets, particularly in sectors such as renewable energy, where innovation and adaptability are crucial. Investors may prefer markets with regulatory environments that can evolve in response to technological advancements (Alam et al., 2019).

In addition, GDP significantly explains the variation in SD, with a p-value of zero, which is below the 10% significance level. The slope coefficient of 3.2383 indicates a positive and significant relationship between GDP and SD, suggesting that for every 1% increase in GDP, SD increases by 3.24%. Notably, this coefficient is the highest among the independent variables in the model, highlighting that GDP exerts the greatest influence on SD. This result aligns with the findings of Szustak et al. (2021), Khobai et al. (2020), and Ohler and Fetters (2014), who indicate that economic growth fosters the demand, consumption, and development of solar energy.

Moreover, ATE is found to be insignificant in influencing IQ, as the p-value of 0.9365 significantly exceeds the 10% significance level. The slope coefficient of -0.0365 indicates a negative correlation between ATE and SD. This finding diverges from previous literature, which reports both positive and significant relationships, as seen in Lemaire (2011) and Bhide and Rodriguez (2011), as well as a negative and significant relationship identified by Saim and Khan (2021). This inconsistency may arise from differing time periods and methodologies employed in these studies. For instance, Bhide and Rodriguez (2011) utilized Life Cycle Analysis from 1983 to 2005, while Saim and Khan (2021) conducted a Descriptive Analysis based on data from 2020. The results presented here stem from REM analysis covering the period from 2000 to 2022.

For FDI, the p-value of 0.0116 indicates a significant influence on the variation in SD, as it falls below the 10% significance level. The slope coefficient of 0.3240 demonstrates a positive relationship between FDI and SD, suggesting that a 1% increase in FDI corresponds to a 0.32% increase in SD. This finding aligns with the expected relationships identified in the literature, as reported by Fan & Hao (2020), Samour et al. (2022), and Rashed et al. (2021). Specifically, FDI inflows facilitate the development of large-scale solar projects and contribute to technological spillover effects.

Finally, the variable POP exhibits a p-value of 0.0000, indicating a significant relationship with SD, as it is below the 10% significance level. The slope coefficient of -1.7371 suggests a negative relationship between POP and SD. Every 1% increase in POP results in 1.74% decrease in SD. This finding contrasts with the expected positive relationships reported in the literature by Nepal and Paija (2021), Hang and Phuong (2021), and Shao et al. (2020). We posit that the discrepancy may be primarily due to the different methodologies employed in these analyses. For instance, Nepal and Paija (2021) utilized an ARDL approach, whereas this study employs REM analysis.

Table 4.3.3:

Summary of Random Effect Model (REM) Analysis

Variable	**Coefficient**	**t-Statistic**	**Probability**
Constant	-58.9646	-12.6238 (4.6709)	0.0000**
IQ	-1.2312	-2.4092 (0.5110)	0.0168**
LN_GDP	3.2383	11.5241 (0.2810)	0.0000**
LN_ATE	-0.0365	-0.0798 (0.4579)	0.9365

LN_FDI	0.3240	2.5438 (0.1274)	0.0116**
LN_POP	-1.7371	-5.3663 (0.3237)	0.0000**
R^2	0.6224		
Adjusted R^2	0.6141		
F-statistic	74.8422		
Probability (F-stat)	0.0000		
Durbin-Watson Stat	0.2066		

***, **, * indicates rejection of null hypothesis at 1%, 5% and 10% levels of significance. Standard Errors are in parentheses.

4.4 Model Selection

4.4.1 Poolability Test

The Poolability Test is employed to choose the best-fit model among the Pooled OLS and FEM models. The null hypothesis and alternative hypothesis are posited as:

H_0: POLS is preferred.

H_1: FEM is preferred.

Table 4.4.1 displays the output summary of the Poolability Test. Since the p-value (0.0000) is lesser than the 10% significance level, this showed that the Poolability test is significant. In other words, we will reject H_0. Hence, the FEM model is preferred.

Table 4.4.1:

Summary of Poolability Test

	F-statistic	**Probability (F-statistic)**
Poolability Test	66.4964	0.0000

4.4.2 Breusch-Pagan Lagrange Multiplier Test (BPLM)

The Breusch-Pagan Lagrange Multiplier (BPLM) Test is used to determine whether the REM or the POLS model is more appropriate for the data. The null hypothesis and alternative hypothesis are posited as:

H_0: POLS is preferred.

H_1: REM is preferred.

Table 4.4.2 displays the output summary of the BPLM Test. Since the p-values for the cross-sectional, time, and combined effects are significantly less than the 10% significance level, we reject the null hypothesis in each case. Therefore, REM is more suitable for this analysis.

Table 4.4.2:

Summary of BPLM Test

	Cross-Section	**Time**	**Both**
Breusch-Pagan Lagrange Multiplier	130.6241 (0.0000)	120.6356 (0.0000)	251.2597 (0.0000)

Note. Probability is in Parenthesis.

4.4.3 Hausman Test

The Hausman Test is conducted to determine whether the FEM or the REM better fits the data. The null hypothesis and alternative hypothesis are posited as:

H_0: REM is preferred.

H_1: FEM is preferred.

Table 4.4.3 displays the output summary of the Hausman Test. The test results show a Chi-Square statistic of 112.1106 with a p-value of 0.0000. Since the p-value is significantly less than the 10% significance level, we reject the null hypothesis. Hence, the FEM model is preferred.

Table 4.6.3:

Summary of Hausman Test

	Chi-Sq. Statistic	**Chi-Sq. d.f.**	**Probability**
Hausman Test	112.1106	5	0.0000

4.5 Comparison with Literature Review

This section offers a detailed comparison of findings between the literature review and the FEM regression analysis, as FEM is identified as the most suitable method following the hypothesis testing conducted to determine the optimal model for this study.

The findings of the FEM regression analysis largely align with the expected relationships from the literature. In particular, IQ consistently shows a positive and significant relationship with SD, matching the results of numerous studies such as those by Sadat et al. (2021), Rafiq et al. (2024), and Ali et al. (2022). This consistency reinforces the idea that stronger institutions play a vital role in fostering renewable energy development.

GDP also exhibits a positive and significant effect on solar energy development, which is consistent with most of the reviewed literature, including Sahlian et al. (2021) and Ohler and Fetters (2014). However, there are some inconsistencies, such as the finding by Rahman et al. (2023), who reported a negative and significant relationship between GDP and solar energy development.

ATE, on the other hand, presents a significant negative relationship with solar energy development in the FEM analysis, which is inconsistent with many of the reviewed studies that expected a positive relationship, such as those by Lemaire (2011) and Bhide and Rodriguez (2011). The findings on FDI and POP are generally in line with the literature, confirming that these factors positively influence SD, though a few studies presented different findings for FDI.

Nevertheless, some inconsistencies between the literature and the FEM regression findings warrant consideration. These discrepancies are likely attributable to several factors, including variations in the countries included in the sample, differences in the time periods studied, and the methodologies employed in the respective analyses. For instance, while the literature may focus on different geographic contexts or utilize distinct datasets, the FEM approach in this study emphasizes the unique characteristics of the 11 Southeast Asian countries examined. Such differences underscore the complexity of establishing universal relationships in research and highlight the importance of context-specific analysis.

CHAPTER 5: CONCLUSION

5.1 Summary and Policy Implications

The present paper focuses on the role of institutional quality (IQ) in the development of solar energy in Southeast Asia. Control variables such as Gross Domestic Product (GDP), Foreign Direct Investment (FDI), Population (POP), and Access to Electricity (ATE), are included to enable an in-depth analysis of its significance and provide subtle insights into factors influencing solar development within the region.

Fixed Effects Model (FEM) is the most appropriate model for the panel data analysis of Southeast Asian countries comprising Brunei, Myanmar, Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam, for the period 2000 to 2022. Institutional quality has come out in this paper as one of the essential drivers of solar energy development in the Southeast Asian countries. The results indicate that there is a positive relationship between institutional quality and solar development. This emphasizes the role of strong and efficient institutions. Indeed, nations with high institutional backgrounds, characterized by low levels of corruption, high government efficiency, political stability, high regulatory quality, and respect for the rule of law, are better placed to attract investment in solar infrastructure. It will ensure that investment and innovation potentials in the renewable energy sector, especially in the development of solar energy, are properly harnessed. The results also provide additional empirical evidence that countries in Southeast Asia need to increase their institutional structures, transparency of institutions, reduce red tape, and institute regulations enhancing the use of sustainable energy. This will enhance the ability adapt and meet the changing needs of the solar market more efficiently. Indeed, enhancing the quality of institutions is about creating an enabling environment that would foster active support for the growth of solar energy, so these countries can benefit from this global shift to renewable energy.

The findings of this study are consistent with a portion of the literature that suggests that GDP plays a positive and important role in solar energy development. It is hypothesized that investors are more interested in investing in solar energy in larger economies because these large economies are always able to reduce the cost of solar energy development and increase efficiency and returns through economies of scale. Since most of the countries in Southeast Asia are not uniform in terms of economic size and resource distribution, regional cooperation among Southeast Asian countries can be reached through the exchange of resources to address the constraints posed by the small revenue base within the country, and to jointly develop projects to gain a foothold in the international arena and to attract investors. Gross domestic product (GDP) appreciation can attract foreign direct investment, build foreign confidence through GDP-enhanced exchange rates, and allow Southeast Asian countries to use GDP growth as a powerful catalyst for advancing their solar energy programs, ensuring that economic progress is closely aligned with sustainable energy goals. The findings of the study indicate that FDI also has a positive and significant impact on solar energy development, which is like the findings of some studies. Southeast Asian countries' exchange rates are susceptible to large-scale economies, therefore maintaining a stable and strong exchange rate is now an important issue in attracting and consolidating investor confidence. By having a strong exchange rate, investors can obtain a higher return on their investment from it. FDI can bring new technology and expertise to solar energy development in Southeast Asia, making it more efficient and reducing the cost of technology for solar energy development, which leads to cost-effective solutions for innovation in the industry.

In the case of Southeast Asia, both population growth and access to electricity have significant impacts on solar energy development, with population growth having a positive impact on solar energy development in line with other studies, while access to electricity has a negative impact on solar energy development. Population growth is also increasing the demand for sustainable and scalable energy solutions, allowing for accelerated investment and progress in solar infrastructure. Whereas electricity penetration determines overall electricity usage, some lagging regions do not have the technology to develop solar energy and are more reliant on the convenience of technologically mature conventional energy sources, but the increased demand for such conventional energy sources will have a negative impact on solar energy development, especially in South East Asian countries where the population already has stable and reliable access to conventional electricity, and therefore generally will not adopt solar energy in the short term. The adoption of solar energy is generally not expected in the short term. The lack of demand for solar energy has led to a slowdown in the adoption of solar technologies and a reduction in investment.

The policy implications of the findings suggest that, since most countries in Southeast Asia are developing countries and one of the characteristics of developing countries is that their populations are growing faster than those of developed countries, Governments in Southeast Asia should invest in solar energy to take advantage of the energy demand generated by population growth. Through the implementation of incentives and subsidies, among other things, businesses and people should be encouraged to make the transition to solar energy to reduce energy pollution, achieve energy sustainability, and offset the negative impacts of the existing conventional power supply.

5.2 Limitation and Recommendation

There are several recommendations for future research based on our study. Firstly, we would recommend future researchers to include a broader range of countries across different regions to improve the generalizability of findings. By comparing Southeast Asian countries with those from Europe, Africa, or other regions, researchers can identify regional differences and similarities in solar energy development. This approach will allow for a more comprehensive understanding of the global trends and factors influencing solar energy adoption.

Next, future researchers are advisable to consider including more macroeconomic determinants, such as inflation rates, unemployment rates, and interest rates to enhance the robustness of the analysis. As the variables chosen for the study are Institutional Quality, GDP, Population, FDI, and Access to Electricity, the addition of these factors may influence the variables chosen in the study and help avoid bias in estimation and analysis. Incorporating more instrumental variables that are correlated with the independent variables could also help mitigate bias and improve the validity of the findings as it will avoid the possibility of bidirectional results where the increase of development in solar energy will lead to a lower FDI or IQ which is neglected.

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Appendices

Appendix 2.1. *Summary Table of Literature Review*

Variables	**Author & Year**	**Methodology**	**Time Period of Study**	**Result**	**Sign**
Institutional Quality	Maka and Alabid (2022)	Non-empirical Research	-	Significant	+
	Sadat et al. (2021)	Fuzzy ATP-TOPSIS	-	Significant	+
	Rafiq et al. (2024)	FMOLS, DOLS & GMM	1980-2014	Significant	+
	Sheng et al. (2023)	Panel Quantile Regression	2000- 2020	Significant	+
	Ali et al. (2022)	PLS-SME	2021	Significant	+
	Saadaoui and Chtourou (2022)	ARDL Model	1984-2017	Significant	+
	Moliterni (2017)	Difference-in-Difference Analysis	2005	Significant	+
	Uzar (2020)	ARDL-PMG	1990-2015	Significant	+
	Qureshi et al. (2017)	Likert Scale Analysis	2017	Significant	+
	Kabir et al. (2017)	Non-empirical Research	-	Significant	+

	Dagnachew et al. (2020)	Workshops and Interviews	-	Significant	+
Gross Domestic Product	Sahlian et al. (2021)	Panel Regression Analysis	2000-2019	Significant	+
	Simionescu et al. (2020)	FMOLS	2007-2019	Significant	+
	Sadorsky (2009)	FMOLS, DOLS & OLS	1994-2003	Significant	+
	Ohler and Fetters (2014)	FMOLS & DOLS	1998- 2008	Significant	+
	Li (2024)	Simple Linear Regression Analysis	-	Significant	+
	Szustak et al. (2021)	Multiple Linear Regression Analysis	2018-2021	Significant	+
	Khobai at al. (2020)	ARDL	1990-2014	Insignificant	+
	Rahman et al. (2023)	ARDL	1990-2019	Significant	-
Access to Electricity	Lemaire (2011)	Non-empirical Research	-	Significant	+
	Timilsina et al. (2012)	Levelized Cost Analysis	-	Significant	+

	Bhide and Rodriguez (2011)	Life Cycle Analysis	1983-2005	Significant	+
	Saim and Khan (2021)	Descriptive Analysis	2020	Significant	-
Foreign Direct Investment	Fan and Hao (2020)	VECM	2000-2015	Significant	+
	Samour et al. (2022)	ARDL	1989-2019	Significant	+
	Rashed et al. (2021)	PPML	2003-2019	Significant	+
	Yilanci et al. (2019)	Fourier ADL	1985-2017	Significant	+
	Yilanci et al. (2019)	Fourier ADL	1985-2017	Insignificant	+
	Kilicarslan (2019)	ARDL	1996-2015	Significant	-
Population	Christenson (2013)	Linear Regression Analysis	2013	Significant	+
	Vladislav et al. (2018)	Non-empirical Research	1980-2020	Significant	+
	Hang and Phuong (2021)	Descriptive Analysis	2019	Significant	+
	Shao et al. (2020)	MCDM	2001-2018	Significant	+
	Nepal and Paija (2021)	ARDL	1978-2016	Significant	+

Appendix 4.1.1. *Descriptive Analysis*

	LN_SD	C	IQ	LN_GDP	LN_ATE	LN_FDI	LN_POP
Mean	-5.216124	1.000000	-0.212450	24.79699	4.358031	7.588604	16.69665
Median	-5.676946	1.000000	-0.378923	25.27716	4.552086	8.052417	17.17303
Maximum	2.916391	1.000000	1.623155	27.90797	4.605170	11.85801	19.43410
Minimum	-13.12236	1.000000	-1.753384	19.93315	2.254295	-0.096511	12.71867
Std. Dev.	3.559013	0.000000	0.778831	1.970965	0.420021	2.293591	1.889156
Skewness	-0.077431	NA	0.827204	-0.634859	-2.409889	-0.911320	-0.616705
Kurtosis	2.770277	NA	3.215518	2.452242	9.102460	3.786205	2.378873
Jarque-Bera	0.745164	NA	27.02331	18.56449	587.0655	38.25213	18.51473
Probability	0.688953	NA	0.000001	0.000093	0.000000	0.000000	0.000095
Sum	-1215.357	233.0000	-49.50083	5777.699	1015.421	1768.145	3890.320
Sum Sq. Dev.	2938.645	0.000000	140.7262	901.2508	40.92888	1220.450	827.9868
Observations	233	233	233	233	233	233	233

Appendix 4.1.2 *Correlation Coefficient*

	LN_SD	C	IQ	LN_GDP	LN_ATE	LN_FDI	LN_POP
LN_SD	1.000000	NA	0.193051	0.704188	0.449545	0.675197	0.454041
C	NA	NA	NA	NA	NA	NA	NA
IQ	0.193051	NA	1.000000	0.343260	0.488984	0.506174	-0.323174
LN_GDP	0.704188	NA	0.343260	1.000000	0.607400	0.873661	0.722368
LN_ATE	0.449545	NA	0.488984	0.607400	1.000000	0.581699	0.156442
LN_FDI	0.675197	NA	0.506174	0.873661	0.581699	1.000000	0.492962
LN_POP	0.454041	NA	-0.323174	0.722368	0.156442	0.492962	1.000000

Appendix 4.2.1. *Unit Root Test*

1. Solar Development

Null Hypothesis: Unit root (common unit root process)
Series: LN_SD
Date: 08/21/24 Time: 22:21
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Total number of observations: 221
Cross-sections included: 11

Method	Statistic	Prob.**
Levin, Lin & Chu t*	-0.65830	0.2552

** Probabilities are computed assuming asympotic normality

Intermediate results on LN_SD

Cross section	2nd Stage Coefficient	Variance of Reg	HAC of Dep.	Lag	Max Lag	Band-width	Obs
Malaysia	-0.06405	0.7901	0.8086	1	1	0.0	18
Indonesia	-0.03751	0.0813	0.0527	1	1	3.0	21
Singapore	0.00401	0.1423	0.2333	1	1	2.0	21
Thailand	-0.03054	0.0924	0.2630	1	1	2.0	21
Timor-Leste	-0.06391	0.1365	0.3074	1	1	2.0	21
Vietnam	0.00468	0.6836	1.8817	1	1	1.0	21
Cambodia	0.02935	0.1100	0.0788	1	1	4.0	21
Philippines	-0.04117	0.2105	0.8279	1	1	2.0	21
Brunei Darus...	-21.8044	0.0482	0.0640	1	1	0.0	21
Lao PDR	-0.01128	0.6320	0.7713	1	1	1.0	21
Myanmar	-0.11095	0.0813	0.1885	1	1	1.0	14

	Coefficient	t-Stat	SE Reg	mu*	sig*	Obs
Pooled	-0.03150	-2.486	1.042	-0.554	0.919	221

Null Hypothesis: Unit root (common unit root process)
Series: LN_SD
Date: 08/21/24 Time: 22:29
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Total number of observations: 221
Cross-sections included: 11

Method	Statistic	Prob.**
Levin, Lin & Chu t*	0.18324	0.5727

** Probabilities are computed assuming asympotic normality

Intermediate results on LN_SD

Cross section	2nd Stage Coefficient	Variance of Reg	HAC of Dep.	Lag	Max Lag	Band-width	Obs
Malaysia	-0.38134	0.6428	0.8082	1	1	0.0	18
Indonesia	-0.43340	0.0677	0.0290	1	1	4.0	21
Singapore	-0.28519	0.1016	0.1722	1	1	1.0	21
Thailand	-0.20491	0.0744	0.2568	1	1	2.0	21
Timor-Leste	-0.10409	0.1348	0.2582	1	1	2.0	21
Vietnam	-0.20680	0.5218	1.8933	1	1	1.0	21
Cambodia	-0.32928	0.0918	0.0462	1	1	7.0	21
Philippines	-0.18863	0.1544	0.7231	1	1	2.0	21
Brunei Darus...	-32.8537	0.0220	0.0510	1	1	1.0	21
Lao PDR	-0.31641	0.4769	0.5825	1	1	3.0	21
Myanmar	-0.10173	0.0813	0.0798	1	1	3.0	14

	Coefficient	t-Stat	SE Reg	mu*	sig*		Obs
Pooled	-0.21762	-6.096	1.085	-0.703	1.003		221

Null Hypothesis: Unit root (common unit root process)
Series: D(LN_SD)
Date: 08/21/24 Time: 22:30
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Total number of observations: 209
Cross-sections included: 11

Method	Statistic	Prob.**
Levin, Lin & Chu t*	-2.57409	0.0050

** Probabilities are computed assuming asympotic normality

Intermediate results on D(LN_SD)

Cross section	2nd Stage Coefficient	Variance of Reg	HAC of Dep.	Lag	Max Lag	Band-width	Obs
Malaysia	-0.92109	0.9022	0.1118	1	1	17.0	16
Indonesia	-1.22185	0.0873	0.0227	1	1	6.0	20
Singapore	-0.67321	0.1449	0.0217	1	1	20.0	20
Thailand	-0.44186	0.1003	0.0848	1	1	2.0	20
Timor-Leste	-0.53131	0.1578	0.0533	1	1	9.0	20
Vietnam	-0.54743	0.5124	1.0225	1	1	3.0	20
Cambodia	-1.21925	0.1135	0.0151	1	1	20.0	20
Philippines	-0.43884	0.2034	0.2656	1	1	0.0	20
Brunei Darus...	-34.5202	0.0132	0.0067	1	1	20.0	20
Lao PDR	-1.02382	0.6110	0.1349	1	1	12.0	20
Myanmar	-0.69318	0.1422	0.0978	1	1	4.0	13

	Coefficient	t-Stat	SE Reg	mu*	sig*		Obs
Pooled	-0.67892	-7.402	1.214	-0.554	0.919		209

Null Hypothesis: Unit root (common unit root process)
Series: D(LN_SD)
Date: 08/21/24 Time: 22:51
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Total number of observations: 209
Cross-sections included: 11

Method	Statistic	Prob.**
Levin, Lin & Chu t*	-1.81762	0.0346

** Probabilities are computed assuming asympotic normality

Intermediate results on D(LN_SD)

Cross section	2nd Stage Coefficient	Variance of Reg	HAC of Dep.	Lag	Max Lag	Band-width	Obs
Malaysia	-0.94862	0.8619	0.0885	1	1	17.0	16
Indonesia	-1.29011	0.0845	0.0228	1	1	6.0	20
Singapore	-0.73162	0.1434	0.0112	1	1	20.0	20
Thailand	-0.43016	0.1000	0.0574	1	1	3.0	20
Timor-Leste	-0.66472	0.1437	0.0485	1	1	9.0	20
Vietnam	-0.56392	0.5088	0.9292	1	1	3.0	20
Cambodia	-1.47850	0.0962	0.0147	1	1	20.0	20
Philippines	-0.48065	0.1993	0.2642	1	1	0.0	20
Brunei Darus...	-33.0030	0.0107	0.0070	1	1	20.0	20
Lao PDR	-1.10410	0.5928	0.0988	1	1	11.0	20
Myanmar	-1.42098	0.0758	0.0506	1	1	7.0	13
	Coefficient	t-Stat	SE Reg	mu*	sig*		Obs
Pooled	-0.78132	-8.048	1.240	-0.703	1.003		209

Null Hypothesis: Unit root (individual unit root process)
Series: LN_SD
Date: 08/21/24 Time: 22:55
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Total number of observations: 221
Cross-sections included: 11

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	2.08844	0.9816

** Probabilities are computed assuming asympotic normality

Intermediate ADF test results

Cross section	t-Stat	Prob.	E(t)	E(Var)	Lag	Max Lag	Obs
Malaysia	-0.9713	0.7400	-1.511	0.953	1	1	18
Indonesia	-1.0318	0.7220	-1.516	0.904	1	1	21
Singapore	0.1167	0.9593	-1.516	0.904	1	1	21
Thailand	-0.8411	0.7862	-1.516	0.904	1	1	21
Timor-Leste	-1.4834	0.5221	-1.516	0.904	1	1	21
Vietnam	0.0761	0.9557	-1.516	0.904	1	1	21
Cambodia	0.7821	0.9911	-1.516	0.904	1	1	21
Philippines	-0.9959	0.7351	-1.516	0.904	1	1	21
Brunei Darus...	-2.6046	0.1078	-1.516	0.904	1	1	21
Lao PDR	-0.2249	0.9209	-1.516	0.904	1	1	21
Myanmar	-2.8190	0.0807	-1.500	1.060	1	1	14
Average	-0.9088		-1.514	0.923			

Null Hypothesis: Unit root (individual unit root process)
Series: LN_SD
Date: 08/21/24 Time: 22:57
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Total number of observations: 221
Cross-sections included: 11

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	-0.06503	0.4741

** Probabilities are computed assuming asympotic normality

Intermediate ADF test results

Cross section	t-Stat	Prob.	E(t)	E(Var)	Lag	Max Lag	Obs
Malaysia	-2.0334	0.5453	-2.171	0.897	1	1	18
Indonesia	-2.0005	0.5675	-2.172	0.830	1	1	21
Singapore	-2.4822	0.3322	-2.172	0.830	1	1	21
Thailand	-2.2165	0.4571	-2.172	0.830	1	1	21
Timor-Leste	-1.0716	0.9102	-2.172	0.830	1	1	21
Vietnam	-1.9249	0.6063	-2.172	0.830	1	1	21
Cambodia	-1.6583	0.7335	-2.172	0.830	1	1	21
Philippines	-2.7102	0.2425	-2.172	0.830	1	1	21
Brunei Darus...	-5.1985	0.0023	-2.172	0.830	1	1	21
Lao PDR	-2.3049	0.4136	-2.172	0.830	1	1	21
Myanmar	-0.4874	0.9695	-2.170	1.071	1	1	14
Average	-2.1899		-2.172	0.858			

Null Hypothesis: Unit root (individual unit root process)
Series: D(LN_SD)
Date: 08/21/24 Time: 23:01
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Total number of observations: 209
Cross-sections included: 11

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	-5.84474	0.0000

** Probabilities are computed assuming asympotic normality

Intermediate ADF test results

Cross section	t-Stat	Prob.	E(t)	E(Var)	Lag	Max Lag	Obs
Malaysia	-2.6551	0.1032	-1.506	0.992	1	1	16
Indonesia	-3.5672	0.0166	-1.516	0.915	1	1	20
Singapore	-2.4013	0.1538	-1.516	0.915	1	1	20
Thailand	-1.9269	0.3141	-1.516	0.915	1	1	20
Timor-Leste	-2.0460	0.2665	-1.516	0.915	1	1	20
Vietnam	-2.8558	0.0685	-1.516	0.915	1	1	20
Cambodia	-3.6203	0.0149	-1.516	0.915	1	1	20
Philippines	-2.4248	0.1479	-1.516	0.915	1	1	20
Brunei Darus...	-8.7402	0.0000	-1.516	0.915	1	1	20
Lao PDR	-3.4476	0.0213	-1.516	0.915	1	1	20
Myanmar	-1.7515	0.3852	-1.497	1.109	1	1	13
Average	-3.2215		-1.513	0.940			

Null Hypothesis: Unit root (individual unit root process)
Series: D(LN_SD)
Date: 08/21/24 Time: 23:02
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Total number of observations: 209
Cross-sections included: 11

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	-4.49145	0.0000

** Probabilities are computed assuming asympotic normality

Intermediate ADF test results

Cross section	t-Stat	Prob.	E(t)	E(Var)	Lag	Max Lag	Obs
Malaysia	-2.6734	0.2579	-2.170	0.949	1	1	16
Indonesia	-3.5867	0.0570	-2.172	0.845	1	1	20
Singapore	-2.2793	0.4251	-2.172	0.845	1	1	20
Thailand	-1.7810	0.6755	-2.172	0.845	1	1	20
Timor-Leste	-2.4008	0.3679	-2.172	0.845	1	1	20
Vietnam	-2.7802	0.2193	-2.172	0.845	1	1	20
Cambodia	-4.1718	0.0189	-2.172	0.845	1	1	20
Philippines	-2.4191	0.3597	-2.172	0.845	1	1	20
Brunei Darus...	-8.8240	0.0000	-2.172	0.845	1	1	20
Lao PDR	-3.4241	0.0763	-2.172	0.845	1	1	20
Myanmar	-3.5509	0.0761	-2.171	1.166	1	1	13
Average	-3.4447		-2.172	0.884			

Null Hypothesis: Unit root (individual unit root process)
Series: LN_SD
Date: 08/21/24 Time: 23:06
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Total number of observations: 221
Cross-sections included: 11

Method	Statistic	Prob.**
ADF - Fisher Chi-square	13.4968	0.9184
ADF - Choi Z-stat	2.19945	0.9861

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results LN_SD

Cross section	Prob.	Lag	Max Lag	Obs
Malaysia	0.7400	1	1	18
Indonesia	0.7220	1	1	21
Singapore	0.9593	1	1	21
Thailand	0.7862	1	1	21
Timor-Leste	0.5221	1	1	21
Vietnam	0.9557	1	1	21
Cambodia	0.9911	1	1	21
Philippines	0.7351	1	1	21
Brunei Darussa...	0.1078	1	1	21
Lao PDR	0.9209	1	1	21
Myanmar	0.0807	1	1	14

Null Hypothesis: Unit root (individual unit root process)
Series: LN_SD
Date: 08/21/24 Time: 23:09
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Total number of observations: 221
Cross-sections included: 11

Method	Statistic	Prob.**
ADF - Fisher Chi-square	24.7620	0.3086
ADF - Choi Z-stat	0.02898	0.5116

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results LN_SD

Cross section	Prob.	Lag	Max Lag	Obs
Malaysia	0.5453	1	1	18
Indonesia	0.5675	1	1	21
Singapore	0.3322	1	1	21
Thailand	0.4571	1	1	21
Timor-Leste	0.9102	1	1	21
Vietnam	0.6063	1	1	21
Cambodia	0.7335	1	1	21
Philippines	0.2425	1	1	21
Brunei Darussa...	0.0023	1	1	21
Lao PDR	0.4136	1	1	21
Myanmar	0.9695	1	1	14

Null Hypothesis: Unit root (individual unit root process)
Series: D(LN_SD)
Date: 08/21/24 Time: 23:10
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Total number of observations: 209
Cross-sections included: 11

Method	Statistic	Prob.**
ADF - Fisher Chi-square	79.8876	0.0000
ADF - Choi Z-stat	-5.32235	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results D(LN_SD)

Cross section	Prob.	Lag	Max Lag	Obs
Malaysia	0.1032	1	1	16
Indonesia	0.0166	1	1	20
Singapore	0.1538	1	1	20
Thailand	0.3141	1	1	20
Timor-Leste	0.2665	1	1	20
Vietnam	0.0685	1	1	20
Cambodia	0.0149	1	1	20
Philippines	0.1479	1	1	20
Brunei Darussa...	0.0000	1	1	20
Lao PDR	0.0213	1	1	20
Myanmar	0.3852	1	1	13

Null Hypothesis: Unit root (individual unit root process)
Series: D(LN_SD)
Date: 08/21/24 Time: 23:11
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Total number of observations: 209
Cross-sections included: 11

Method	Statistic	Prob.**
ADF - Fisher Chi-square	61.5317	0.0000
ADF - Choi Z-stat	-3.88476	0.0001

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results D(LN_SD)

Cross section	Prob.	Lag	Max Lag	Obs
Malaysia	0.2579	1	1	16
Indonesia	0.0570	1	1	20
Singapore	0.4251	1	1	20
Thailand	0.6755	1	1	20
Timor-Leste	0.3679	1	1	20
Vietnam	0.2193	1	1	20
Cambodia	0.0189	1	1	20
Philippines	0.3597	1	1	20
Brunei Darussa...	0.0000	1	1	20
Lao PDR	0.0763	1	1	20
Myanmar	0.0761	1	1	13

Null Hypothesis: Unit root (individual unit root process)
Series: LN_SD
Date: 08/21/24 Time: 23:15
Sample: 2000 2022
Exogenous variables: Individual effects
Newey-West automatic bandwidth selection and Bartlett ...
Total number of observations: 233
Cross-sections included: 11

Method	Statistic	Prob.**
PP - Fisher Chi-square	6.58736	0.9994
PP - Choi Z-stat	3.67881	0.9999

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results LN_SD

Cross section	Prob.	Bandwidth	Obs
Malaysia	0.8491	0.0	20
Indonesia	0.3594	4.0	22
Singapore	0.9841	2.0	22
Thailand	0.9044	2.0	22
Timor-Leste	0.6347	2.0	22
Vietnam	0.6546	2.0	22
Cambodia	0.9920	6.0	22
Philippines	0.9361	2.0	22
Brunei Darussa...	0.9766	0.0	22
Lao PDR	0.9575	2.0	22
Myanmar	0.3789	2.0	15

Null Hypothesis: Unit root (individual unit root process)
Series: LN_SD
Date: 08/21/24 Time: 23:16
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
Newey-West automatic bandwidth selection and Bartlett ...
Total number of observations: 233
Cross-sections included: 11

Method	Statistic	Prob.**
PP - Fisher Chi-square	9.00990	0.9933
PP - Choi Z-stat	2.37242	0.9912

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results LN_SD

Cross section	Prob.	Bandwidth	Obs
Malaysia	0.6701	1.0	20
Indonesia	0.4833	0.0	22
Singapore	0.3830	1.0	22
Thailand	0.6668	2.0	22
Timor-Leste	0.9529	2.0	22
Vietnam	0.5201	2.0	22
Cambodia	0.7558	1.0	22
Philippines	0.7069	2.0	22
Brunei Darussa...	0.9819	0.0	22
Lao PDR	0.5209	2.0	22
Myanmar	0.9870	2.0	15

Null Hypothesis: Unit root (individual unit root process)
Series: D(LN_SD)
Date: 08/21/24 Time: 23:20
Sample: 2000 2022
Exogenous variables: Individual effects
Newey-West automatic bandwidth selection and Bartlett ...
Total number of observations: 221
Cross-sections included: 11

Method	Statistic	Prob.**
PP - Fisher Chi-square	82.7717	0.0000
PP - Choi Z-stat	-6.27992	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results D(LN_SD)

Cross section	Prob.	Bandwidth	Obs
Malaysia	0.0419	2.0	18
Indonesia	0.0010	3.0	21
Singapore	0.0314	0.0	21
Thailand	0.1795	1.0	21
Timor-Leste	0.0826	2.0	21
Vietnam	0.0094	0.0	21
Cambodia	0.0028	3.0	21
Philippines	0.2497	1.0	21
Brunei Darussa...	0.0065	0.0	21
Lao PDR	0.0186	5.0	21
Myanmar	0.0707	1.0	14

Null Hypothesis: Unit root (individual unit root process)
Series: D(LN_SD)
Date: 08/21/24 Time: 23:19
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
Newey-West automatic bandwidth selection and Bartlett ...
Total number of observations: 221
Cross-sections included: 11

Method	Statistic	Prob.**
PP - Fisher Chi-square	80.3249	0.0000
PP - Choi Z-stat	-5.57997	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results D(LN_SD)

Cross section	Prob.	Bandwidth	Obs
Malaysia	0.1511	2.0	18
Indonesia	0.0023	4.0	21
Singapore	0.1040	0.0	21
Thailand	0.4723	1.0	21
Timor-Leste	0.1501	3.0	21
Vietnam	0.0386	2.0	21
Cambodia	0.0011	9.0	21
Philippines	0.5340	1.0	21
Brunei Darussa...	0.0090	1.0	21
Lao PDR	0.0777	5.0	21
Myanmar	0.0001	9.0	14

Panel unit root test: Summary
Series: D(LN_SD,2)
Date: 08/29/24 Time: 23:41
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-5.50591	0.0000	11	197
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-9.84801	0.0000	11	197
ADF - Fisher Chi-square	127.937	0.0000	11	197
PP - Fisher Chi-square	625.584	0.0000	11	209

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_SD,2)
Date: 08/29/24 Time: 23:44
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.68668	0.0001	11	197
Breitung t-stat	-1.87142	0.0306	11	186
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-7.38487	0.0000	11	197
ADF - Fisher Chi-square	92.7220	0.0000	11	197
PP - Fisher Chi-square	451.431	0.0000	11	209

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(IQ,2)
Date: 08/30/24 Time: 06:49
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-7.33204	0.0000	11	209
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-11.6242	0.0000	11	209
ADF - Fisher Chi-square	150.251	0.0000	11	209
PP - Fisher Chi-square	1394.12	0.0000	11	220

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(IQ,2)
Date: 08/30/24 Time: 06:51
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-4.08352	0.0000	11	209
Breitung t-stat	-6.46818	0.0000	11	198
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-9.59557	0.0000	11	209
ADF - Fisher Chi-square	115.595	0.0000	11	209
PP - Fisher Chi-square	1160.01	0.0000	11	220

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

2. Institutional Quality

Panel unit root test: Summary
Series: IQ
Date: 08/21/24 Time: 23:38
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.28652	0.3872	11	231
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	0.67183	0.7492	11	231
ADF - Fisher Chi-square	17.0295	0.7617	11	231
PP - Fisher Chi-square	18.2554	0.6907	11	242

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: IQ
Date: 08/21/24 Time: 23:40
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.18876	0.4251	11	231
Breitung t-stat	1.40676	0.9203	11	220
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-0.64639	0.2590	11	231
ADF - Fisher Chi-square	25.1432	0.2903	11	231
PP - Fisher Chi-square	34.5668	0.0430	11	242

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(IQ)
Date: 08/21/24 Time: 23:44
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-2.84553	0.0022	11	220
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-5.11616	0.0000	11	220
ADF - Fisher Chi-square	69.5370	0.0000	11	220
PP - Fisher Chi-square	157.587	0.0000	11	231

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(IQ)
Date: 08/21/24 Time: 23:46
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-1.31683	0.0939	11	220
Breitung t-stat	-3.22391	0.0006	11	209
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-3.71646	0.0001	11	220
ADF - Fisher Chi-square	53.1917	0.0002	11	220
PP - Fisher Chi-square	137.122	0.0000	11	231

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

3. Gross Domestic Product

Panel unit root test: Summary
Series: LN_GDP
Date: 08/21/24 Time: 23:54
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-5.66472	0.0000	11	231
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-1.44459	0.0743	11	231
ADF - Fisher Chi-square	33.0298	0.0615	11	231
PP - Fisher Chi-square	15.1500	0.8557	11	242

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: LN_GDP
Date: 08/21/24 Time: 23:56
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	3.02491	0.9988	11	231
Breitung t-stat	3.42585	0.9997	11	220
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	4.24753	1.0000	11	231
ADF - Fisher Chi-square	4.55697	1.0000	11	231
PP - Fisher Chi-square	3.09239	1.0000	11	242

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_GDP)
Date: 08/21/24 Time: 23:58
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-1.22853	0.1096	11	220
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-2.75093	0.0030	11	220
ADF - Fisher Chi-square	43.2317	0.0044	11	220
PP - Fisher Chi-square	95.5775	0.0000	11	231

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_GDP)
Date: 08/21/24 Time: 23:59
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.66757	0.0001	11	220
Breitung t-stat	0.01263	0.5050	11	209
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-3.79214	0.0001	11	220
ADF - Fisher Chi-square	51.4803	0.0004	11	220
PP - Fisher Chi-square	113.043	0.0000	11	231

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_GDP,2)
Date: 08/30/24 Time: 06:53
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-9.26480	0.0000	11	209
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-11.1310	0.0000	11	209
ADF - Fisher Chi-square	144.086	0.0000	11	209
PP - Fisher Chi-square	522.907	0.0000	11	220

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_GDP,2)
Date: 08/30/24 Time: 06:58
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-6.88094	0.0000	11	209
Breitung t-stat	-3.54550	0.0002	11	198
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-9.26411	0.0000	11	209
ADF - Fisher Chi-square	111.556	0.0000	11	209
PP - Fisher Chi-square	424.505	0.0000	11	220

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

4. Access to Electricity

Panel unit root test: Summary
Series: LN_ATE
Date: 08/22/24 Time: 00:03
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-2.61947	0.0044	9	189
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	0.60500	0.7274	9	189
ADF - Fisher Chi-square	12.3345	0.8295	9	189
PP - Fisher Chi-square	40.1147	0.0020	9	198

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: LN_ATE
Date: 08/22/24 Time: 00:05
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.37759	0.3529	9	189
Breitung t-stat	-2.65501	0.0040	9	180
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	0.20948	0.5830	9	189
ADF - Fisher Chi-square	17.8428	0.4661	9	189
PP - Fisher Chi-square	75.4762	0.0000	9	198

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_ATE)
Date: 08/22/24 Time: 00:10
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-8.42734	0.0000	9	180
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-10.2092	0.0000	9	180
ADF - Fisher Chi-square	120.343	0.0000	9	180
PP - Fisher Chi-square	622.884	0.0000	9	189

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_ATE)
Date: 08/22/24 Time: 00:10
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-8.27779	0.0000	9	180
Breitung t-stat	-7.35720	0.0000	9	171
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-9.85358	0.0000	9	180
ADF - Fisher Chi-square	107.742	0.0000	9	180
PP - Fisher Chi-square	999.255	0.0000	9	189

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_ATE,2)
Date: 08/30/24 Time: 07:02
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-16.2026	0.0000	9	171
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-17.6690	0.0000	9	171
ADF - Fisher Chi-square	317.693	0.0000	9	171
PP - Fisher Chi-square	2165.83	0.0000	9	180

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_ATE,2)
Date: 08/30/24 Time: 07:04
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-12.9581	0.0000	9	171
Breitung t-stat	-10.6891	0.0000	9	162
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-15.5890	0.0000	9	171
ADF - Fisher Chi-square	138.364	0.0000	9	171
PP - Fisher Chi-square	2051.42	0.0000	9	180

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

5. Foreign Direct Investment

Panel unit root test: Summary
Series: LN_FDI
Date: 08/22/24 Time: 00:14
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-1.97188	0.0243	11	211
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-1.43253	0.0760	11	211
ADF - Fisher Chi-square	29.1035	0.1419	11	211
PP - Fisher Chi-square	62.6534	0.0000	11	225

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: LN_FDI
Date: 08/22/24 Time: 00:16
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.47602	0.3170	11	211
Breitung t-stat	-1.77043	0.0383	11	200
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-1.56113	0.0592	11	211
ADF - Fisher Chi-square	33.0881	0.0606	11	211
PP - Fisher Chi-square	89.9343	0.0000	11	225

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_FDI)
Date: 08/22/24 Time: 00:26
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-7.48400	0.0000	11	199
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-9.14182	0.0000	11	199
ADF - Fisher Chi-square	119.466	0.0000	11	199
PP - Fisher Chi-square	679.127	0.0000	11	211

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_FDI)
Date: 08/22/24 Time: 00:28
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-7.10110	0.0000	11	199
Breitung t-stat	-3.59491	0.0002	11	188
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-7.33443	0.0000	11	199
ADF - Fisher Chi-square	93.0504	0.0000	11	199
PP - Fisher Chi-square	319.979	0.0000	11	211

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_FDI,2)
Date: 08/30/24 Time: 07:09
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-12.5146	0.0000	11	187
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-14.5381	0.0000	11	187
ADF - Fisher Chi-square	191.050	0.0000	11	187
PP - Fisher Chi-square	1618.09	0.0000	11	199

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_FDI,2)
Date: 08/30/24 Time: 07:10
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-9.79575	0.0000	11	187
Breitung t-stat	-5.17977	0.0000	11	176
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-12.0335	0.0000	11	187
ADF - Fisher Chi-square	146.603	0.0000	11	187
PP - Fisher Chi-square	1125.36	0.0000	11	199

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

6. Population

Panel unit root test: Summary
Series: LN_POP
Date: 08/22/24 Time: 00:18
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.53028	0.0002	11	231
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-0.11656	0.4536	11	231
ADF - Fisher Chi-square	25.3305	0.2815	11	231
PP - Fisher Chi-square	729.980	0.0000	11	242

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: LN_POP
Date: 08/22/24 Time: 00:20
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.73827	0.2302	11	231
Breitung t-stat	5.17199	1.0000	11	220
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	4.45117	1.0000	11	231
ADF - Fisher Chi-square	14.1716	0.8953	11	231
PP - Fisher Chi-square	13.4223	0.9207	11	242

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_POP)
Date: 08/22/24 Time: 00:22
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.58454	0.2794	11	220
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	1.72972	0.9582	11	220
ADF - Fisher Chi-square	23.3045	0.3847	11	220
PP - Fisher Chi-square	18.4830	0.6770	11	231

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_POP)
Date: 08/22/24 Time: 00:24
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.37189	0.3550	11	220
Breitung t-stat	1.10452	0.8653	11	209
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-0.34825	0.3638	11	220
ADF - Fisher Chi-square	30.4448	0.1080	11	220
PP - Fisher Chi-square	13.5270	0.9174	11	231

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_POP,2)
Date: 08/29/24 Time: 23:12
Sample: 2000 2022
Exogenous variables: Individual effects
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-6.97245	0.0000	11	209
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-6.03680	0.0000	11	209
ADF - Fisher Chi-square	79.4846	0.0000	11	209
PP - Fisher Chi-square	53.9401	0.0002	11	220

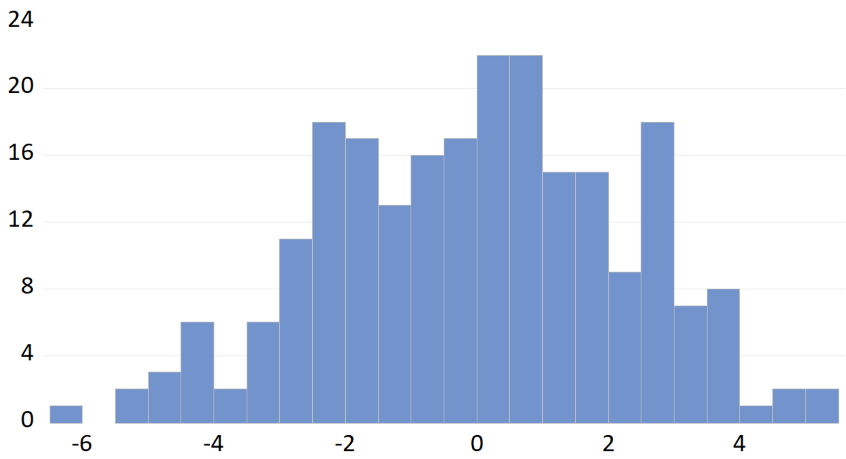
** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: D(LN_POP,2)
Date: 08/29/24 Time: 23:35
Sample: 2000 2022
Exogenous variables: Individual effects, individual linear trends
User-specified lags: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-7.23203	0.0000	11	209
Breitung t-stat	-3.05809	0.0011	11	198
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-5.31315	0.0000	11	209
ADF - Fisher Chi-square	67.6136	0.0000	11	209
PP - Fisher Chi-square	38.0028	0.0183	11	220

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Appendix 4.2.2. *Normality Test*



Series: Standardized Residuals	
Sample 2000 2022	
Observations 233	
Mean	1.68e-14
Median	0.257932
Maximum	5.266039
Minimum	-6.201181
Std. Dev.	2.266989
Skewness	-0.120241
Kurtosis	2.543034
Jarque-Bera	2.588724
Probability	0.274073

Appendix 4.2.3. *Heteroscedasticity Test*

Panel Period Heteroskedasticity LR Test
Equation: UNTITLED
Specification: LN_SD C IQ LN_GDP LN_ATE LN_FDI LN_POP
Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	19.21663	11	0.0573

LR test summary:

	Value	df
Restricted LogL	-520.8110	227
Unrestricted LogL	-511.2027	227

Appendix 4.3.1 *Pooled Ordinary Least Square*

Dependent Variable: LN_SD
Method: Panel Least Squares
Date: 08/19/24 Time: 13:21
Sample: 2000 2022
Periods included: 23
Cross-sections included: 11
Total panel (unbalanced) observations: 233

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-37.97789	3.435335	-11.05508	0.0000
IQ	-3.038922	0.448136	-6.781253	0.0000
LN_GDP	2.332288	0.322276	7.236924	0.0000
LN_ATE	-0.682914	0.536161	-1.273711	0.2041
LN_FDI	0.545494	0.151504	3.600536	0.0004
LN_POP	-1.609961	0.266359	-6.044324	0.0000

R-squared	0.594268	Mean dependent var	-5.216124
Adjusted R-squared	0.585331	S.D. dependent var	3.559013
S.E. of regression	2.291820	Akaike info criterion	4.521983
Sum squared resid	1192.303	Schwarz criterion	4.610851
Log likelihood	-520.8110	Hannan-Quinn criter.	4.557819
F-statistic	66.49642	Durbin-Watson stat	0.165486
Prob(F-statistic)	0.000000		

Appendix 4.3.2 *Fixed Effect Model*

Dependent Variable: LN_SD
Method: Panel Least Squares
Date: 08/19/24 Time: 13:58
Sample: 2000 2022
Periods included: 23
Cross-sections included: 11
Total panel (unbalanced) observations: 233

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-259.5800	30.89924	-8.400855	0.0000
IQ	1.176051	0.660168	1.781441	0.0762
LN_GDP	1.908987	0.415681	4.592434	0.0000
LN_ATE	-0.551778	0.474456	-1.162970	0.2461
LN_FDI	0.206259	0.133076	1.549929	0.1226
LN_POP	12.46454	2.300449	5.418306	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.840724	Mean dependent var	-5.216124
Adjusted R-squared	0.829714	S.D. dependent var	3.559013
S.E. of regression	1.468652	Akaike info criterion	3.672765
Sum squared resid	468.0557	Schwarz criterion	3.909746
Log likelihood	-411.8771	Hannan-Quinn criter.	3.768326
F-statistic	76.36098	Durbin-Watson stat	0.248576
Prob(F-statistic)	0.000000		

Appendix 4.3.3 *Random Effect Model*

Dependent Variable: LN_SD
Method: Panel EGLS (Cross-section random effects)
Date: 08/19/24 Time: 14:00
Sample: 2000 2022
Periods included: 23
Cross-sections included: 11
Total panel (unbalanced) observations: 233
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-58.96462	4.670902	-12.62382	0.0000
IQ	-1.231230	0.511044	-2.409244	0.0168
LN_GDP	3.238304	0.281002	11.52414	0.0000
LN_ATE	-0.036519	0.457870	-0.079758	0.9365
LN_FDI	0.323993	0.127367	2.543782	0.0116
LN_POP	-1.737138	0.323713	-5.366282	0.0000

Effects Specification

	S.D.	Rho
Cross-section random	1.365260	0.4636
Idiosyncratic random	1.468652	0.5364

Weighted Statistics

R-squared	0.622429	Mean dependent var	-1.190937
Adjusted R-squared	0.614112	S.D. dependent var	2.871537
S.E. of regression	1.781563	Sum squared resid	720.4903
F-statistic	74.84215	Durbin-Watson stat	0.206626
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.160839	Mean dependent var	-5.216124
Sum squared resid	2465.995	Durbin-Watson stat	0.060370

Appendix 4.4.1 *Breush-Pagan Lagrange Multiplier Test*

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided
(all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	130.6241 (0.0000)	120.6356 (0.0000)	251.2597 (0.0000)
Honda	11.42909 (0.0000)	10.98342 (0.0000)	15.84804 (0.0000)
King-Wu	11.42909 (0.0000)	10.98342 (0.0000)	15.61222 (0.0000)
Standardized Honda	15.96886 (0.0000)	11.35370 (0.0000)	14.32563 (0.0000)
Standardized King-Wu	15.96886 (0.0000)	11.35370 (0.0000)	15.12446 (0.0000)
Gourieroux, et al.	--	--	251.2597 (0.0000)

Appendix 4.4.2 *Hausman Test*

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	112.110550	5	0.0000

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
IQ	1.176051	-1.231230	0.174656	0.0000
LN_GDP	1.908987	3.238304	0.093829	0.0000
LN_ATE	-0.551778	-0.036519	0.015464	0.0000
LN_FDI	0.206259	0.323993	0.001487	0.0023
LN_POP	12.464539	-1.737138	5.187277	0.0000

Appendix 4.5 *Comparison with Literature Review*

Variables	**Author and Year**	**Expected Relationship(s) from Literature Review**	**Findings from FEM Regression Analysis**	**Consistency**
Institutional Quality	Maka and Alabid (2022)	Positive and Significant	Positive and Significant	Consistent
	Sadat et al. (2021)	Positive and Significant	Positive and Significant	Consistent
	Rafiq et al. (2024)	Positive and Significant	Positive and Significant	Consistent
	Sheng et al. (2023)	Positive and Significant	Positive and Significant	Consistent
	Ali et al. (2022)	Positive and Significant	Positive and Significant	Consistent
	Saadaoui and Chtourou (2022)	Positive and Significant	Positive and Significant	Consistent
	Moliterni (2017)	Positive and Significant	Positive and Significant	Consistent

	Uzar (2020)	Positive and Significant	Positive and Significant	Consistent
	Qureshi et al. (2017)	Positive and Significant	Positive and Significant	Consistent
	Kabir et al. (2017)	Positive and Significant	Positive and Significant	Consistent
	Dagnachew et al. (2020)	Positive and Significant	Positive and Significant	Consistent
Gross Domestic Product	Sahlian et al. (2021)	Positive and Significant	Positive and Significant	Consistent
	Simionescu et al. (2020)	Positive and Significant	Positive and Significant	Consistent

	Sadorsky (2009)	Positive and Significant	Positive and Significant	Consistent
	Ohler and Fetters (2014)	Positive and Significant	Positive and Significant	Consistent
	Li (2024)	Positive and Significant	Positive and Significant	Consistent
	Szustak et al. (2021)	Positive and Significant	Positive and Significant	Consistent
	Khobai at al. (2020)	Positive and Insignificant	Positive and Significant	Inconsistent

	Rahman et al. (2023)	Negative and Significant	Positive and Significant	Inconsistent
Access to Electricity	Lemaire (2011)	Positive and Significant	Negative and Significant	Inconsistent
	Timilsina et al. (2012)	Positive and Significant	Negative and Significant	Inconsistent
	Bhide and Rodriguez (2011)	Positive and Significant	Negative and Significant	Inconsistent
	Saim and Khan (2021)	Negative and Significant	Negative and Significant	Consistent
Foreign Direct Investment	Fan and Hao (2020)	Positive and Significant	Positive and Significant	Consistent
	Samour et al. (2022)	Positive and Significant	Positive and Significant	Consistent

	Rashed et al. (2021)	Positive and Significant	Positive and Significant	Consistent
	Yilanci et al. (2019)	Positive and Significant	Positive and Significant	Consistent
	Yilanci et al. (2019)	Positive and Insignificant	Positive and Significant	Inconsistent
	Kilicarslan (2019)	Negative and Significant	Positive and Significant	Inconsistent
Population	Christenson (2013)	Positive and Significant	Positive and Significant	Consistent
	Vladislav et al. (2018)	Positive and Significant	Positive and Significant	Consistent
	Hang and Phuong (2021)	Positive and Significant	Positive and Significant	Consistent
	Shao et al. (2020)	Positive and Significant	Positive and Significant	Consistent

	Nepal and Paija (2021)	Positive and Significant	Positive and Significant	Consistent