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Energy Transition and Economic Growth in Asia Region: Evidence with Panel Quantile Regression

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ABSTRACT

Countries in the Asia region are increasingly aware of the importance of realising the Sustainable Development Goals (SDGs), The energy transition policy that has been carried out will affect their economic growth, so this research is focused on an in-depth study of the effect of energy transition on the economic growth of countries in Asia region. The results show that this study reveals that the energy transition plays an important role in driving economic growth in the Asia region. Variables such as sustainability and regulation as well as political commitment are shown to have a significant influence on increasing economic growth, highlighting the importance of policies that support clean energy. However, other results also suggest a potential trade-off between sustainability and economic growth for Asia countries in the short term, emphasising the need for a cautious approach in designing energy transition policies in the region.

Keywords: Asia Region, Economic Growth, Energy Transition, Panel Quantile Regression
JEL Classification: O13, Q54, Q56, R11

1. INTRODUCTION

Energy plays a very important role in modern economies in this era of globalisation. This is due to several factors, including: (1) the global energy framework is the result of decades of investment in scientific advances, innovative technologies, human resources, infrastructure and energy regulation; (2) energy is essential to power industry and other sectors of the economy, as well as modern social life; and (3) per capita energy consumption is increasing and has become an important indicator of a country's economic development and a key factor influencing the quality of life of its population (Stern and Cleveland, 2004; Martinez and Ebenhack, 2008). Therefore, the United Nations (UN) considers access to affordable, reliable, sustainable and modern energy for all as one of the sustainable development goals (SDGs) interlinked with the achievement of other SDGs (Bazilian et al., 2013). It is impossible to overstate how much environmental sustainability has affected economic sectors as it has become a central topic of discussion worldwide (Nohong et al., 2024).

The global energy system is currently undergoing a major transformation driven by technological advancements, climate change mitigation strategies and geopolitical reasons. The ongoing changes in the energy system are influenced by the rapid advancement of modern technologies, the global nature of energy trade, the huge investments that have been made, as well as the pressing urgency of climate change. These variables have contributed to the complexity, scale and speed of the current energy transition. The factors fuelling this transformation of the energy system are considered to be more powerful than they were fifty years ago. Therefore, in general, countries around the world, both large emitters and developing countries, want to transform their energy systems to ensure the sustainability of reliable, affordable energy supply, as it is essential to support economic activity, social development and poverty alleviation (Bouzarovski, 2017; Nerini et al., 2018).

This research questions the government's ability to implement the necessary reforms to achieve their specific goals. This is important given that the energy transition has become a major policy concern and corporate risk, requiring greater transparency and fact-based understanding of the progress of the energy transition (Singh et al., 2019). Consequently, the energy transition has become a key objective of all decarbonisation strategies that can be substantially achieved through accelerated adoption of renewable energy technologies and energy efficiency measures (Li and Strachan, 2019; Sovacool et al., 2018; Tagliapietra et al., 2019). In addition, the World Economic Forum has also developed the Energy Transition Index (ETI) framework to systematically assess the global energy transition. The Index is a useful analytical framework for evaluating the transition as a movement towards an energy system that supports sustainability, security and accessibility, and the institutions that facilitate this performance.

Countries around the world are currently working to establish a workable agreement to switch from fossil fuels to renewable energy sources and improve energy efficiency to achieve the goal of carbon neutrality (Wiseman, 2018). The Shell Energy Transition Report, 2019 states that although demand for fossil fuels is expected to increase until 2030 compared to its current amount, its proportion in the global energy mix is projected to decrease. The World Economic Forum (2018) emphasises the need for an "Effective Energy Transition" - a rapid transformation to meet global energy challenges while creating value for business and society. Implementing such a transformation is a complex task and requires in-depth research to explore its various dimensions and impacts on macroeconomic performance outcomes, such as economic growth, in each country (World Economic Forum, 2018).

The Asia Region has an important position on the global stage, especially in relation to the need to accelerate the energy transition. The region's significant industrial production and large population make the energy transition in Asia Region crucial to fostering a cleaner planet in the future (Mohammad, 2019). Declining clean energy costs and advances in green energy efficiency offer great opportunities for Southeast Asia Region countries to implement their energy transition policies (Qiao, 2019). The UN Economic and Social Council (2018) emphasised the importance of energy transition in Asia Region, given the region's growing fossil fuel consumption and large industrial production capacity (UN Economic and Social Council, 2018). Some countries in Asia Region, such as China and India, have dominated global renewable energy production by pursuing energy transition and economic transformation simultaneously (Mamat et al., 2019). Many studies emphasise the importance of studying the dynamics of the energy transition in the Asia Region, given its implications for sustainability goals, both regional and global (Jairah and Kumar, 2019); (Al-Shamma's et al., 2020).

Energy transition and economic growth in Asia Region countries have a complex and interdependent relationship. Asia Region, as a fast-growing region, faces the challenge of balancing increasing energy demand with the demand to reduce carbon emissions and adopt sustainable energy. The Word Economic Forum, has established 8 indicators that make up the Energy Transition Index, including Equitable; Secure; Sustainable; Regulation and Political Commitment; Infrastructure; Education and Human Capital; Innovation; Finance and Investments.

The Asia Region is critical to decarbonising the global energy sector and transitioning to net-zero emissions worldwide. Energy-related emissions in the region have increased by 151 percent from 2000 to 2023, driven by high economic growth rates, population increase and industrialisation. These emissions must peak and rapidly decline to meet the Paris Agreement goals (Bloomberg NEF, 2024). The region needs to significantly increase its spending in the energy sector, especially in renewable energy development. Governments should reallocate funds to renewable energy infrastructure and provide financial incentives to encourage the advancement of energy storage technologies, thereby accelerating the transition to a green economy in the region (Lin et al., 2024).

There is a need for more in-depth research on the economic growth performance of countries in Asia region and their future prospects at a time when these countries have pursued policies to implement comprehensive energy transition policies through strong efforts to reduce the exploitation and use of non-renewable energy, mainly fossil fuels, to renewable energy in accordance with the potential availability of abundant renewable energy-producing natural resources in the region. It is interesting to take an in-depth look at the economic growth performance of countries in Asia region as they implement their current energy transition policies. Through this research, it is hoped that results can be obtained regarding the effect of economic transition policies that have been implemented by countries in this region on their economic growth performance and their potential in the future in order to realise sustainable development in these countries. The analysis of the economic growth potential of the countries in this region will be studied in more depth by utilising the grouping of countries in the Asia region based on established criteria and by using the Panel Quantile Regression method.

To date, there is no research that examines economic growth potential through energy transition readiness indicators in Asia countries. Therefore, this study focuses on assessing the economic growth enhancement of Asia countries with the aim of strengthening their economic growth, improving energy security, promoting green economic development, and supporting the economic recovery of countries in Asia region by considering environmental factors. This analysis uses the energy transition readiness indicators of countries in the Asia region by utilising Panel Quantile Regression. This study aims to examine the effect of energy transition indicators on the economic growth of countries in Asia region. In addition, it also aims to formulate a plan that can be developed to enhance the economic growth potential and stabilise environmental factors in Asia countries based on this perspective.

2. LITERATURE REVIEW

The relevant literature can be classified into issues related to the Energy Transition Index and economic growth, with all indicators applied to countries in the Asia region.

Diverse fuel sources, market regulations, governance frameworks, supply chains, and integrated trade result in various definitions and metrics for energy transition. Some studies define the energy transition as a change in the primary fuel or dominant technology, although there is growing consensus on the broader socio-economic and political aspects of the energy transition.

Energy transitions are ongoing events, suggesting that energy systems are always evolving. However, the earlier change from simple energy sources (animals, water, wind and firewood) to coal, and then from coal to liquid and gaseous hydrocarbons (as well as, to a lesser extent, nuclear fission) was a gradual process that took place over decades or even hundreds of years. The current energy transition has unique and unprecedented characteristics, characterised by an urgent need for rapid change to effectively meet contemporary global challenges. Today's energy transition has socio-economic, ecological and geopolitical components that are deeply intertwined with poverty alleviation, inequality, climate change mitigation, national security, economic development and global energy trade. As a result, the relationship between finance and growth remains ambiguous, especially for high-income countries (Razak and Soedarmono, 2023). This challenge is further complicated by the dynamic equilibrium as energy demand continues to increase and varies among countries and economic sectors, requiring adjustment with better supply.

The energy transition, which highlights the shift from fossil fuels to more sustainable energy sources, remains an important topic of discussion in academia. A key question that arises is how macroeconomic variables affect the pace of energy transition in different locations, which may result in uniform transition patterns. This study aims to analyse the relationship between energy transition patterns and economic variables in Asia countries, categorised by income level. This study examines data from 45 Asia countries in the period 1993-2018, using the Generalised Method of Moments (GMM) method. The results show that economic growth drives the energy transition, while CO2 emissions hinder it. In addition, population growth also hinders the energy transition in high-income, upper-middle, low-income, and lower-middle-income country groups. This paper recommends that Asia countries adopt customised policies based on their income levels to enhance and accelerate energy transition efforts. Governments in developing countries and countries with rapid economic growth and increasing energy demand should implement policies that support access to green energy sources, in line with the sustainable development goals (SDGs). This is all the more important given the current low oil price environment (Taghizadeh-Hesary and Rasoulinezhad, 2020).

Various studies have examined the impact of the energy transition by studying the relationship between renewable and non-renewable energy sources and various economic variables. Some researchers argue that there is a relationship between economic growth and energy consumption, both in the short and long term (Carfora et al., 2019; Pandey and Rastogi, 2019; Saud et al., 2018; Kyophilavong et al., 2017; Hossein et al., 2012). This suggests that energy consumption is critical in industrial operations and acts as a driver or maintainer of economic growth (Ram et al., 2020). Moreover, additional research shows a reciprocal relationship between renewable energy use and economic growth (Dogan, 2015; Al-Mulali and Sab, 2012). Further research highlights the positive impact of industrial output on energy consumption (Keho, 2016; Ubani, 2013; Adom et al., 2012; Shahbaz et al., 2013; Shahbaz and Lean, 2012).

A recent assessment of the energy transition is the World Economic Forum's Energy Transitions Index (ETI), which evaluates the performance of 120 countries based on their energy system efficiency and transition readiness, in line with the focus of this research. The ETI is based on the standardisation of various indicators on economic (growth and development, capital and investment), environmental (sustainability), energy (access, security, energy mix), political (commitment and regulation), institutional (governance, infrastructure, innovation), and human (capital and participation) dimensions (Singh et al., 2019).

All indicators used in building the ETI monitor certain aspects of the energy transition, such as sustainability, accessibility, and energy security. The energy transition goes beyond the mere amalgamation of its components. More and more information is highlighting the broad impacts of the energy transition, beyond the boundaries of the energy system itself. Energy policy does not operate in isolation; it responds to or influences macroeconomic, institutional, social and geopolitical factors. Policy development and corporate decisions can be enhanced by a deeper understanding of the variables that facilitate an effective energy transition. To effectively benchmark the progress of the energy transition amidst these challenges, it is important to integrate information from reliable data sources covering topics such as pollution, affordability, supply chains, system inertia, political institutions, financial systems and human capital.

The other research seeks to experimentally examine the correlation between energy transition, economic growth, and CO_2 emissions in Algeria from 1980 to 2018, utilizing a simultaneous equations model. The empirical findings indicate that human capital, per capita physical capital stock, energy transition, and oil prices enhance real GDP per capita. Similarly, real GDP per capita has a positive correlation with CO_2 emissions; conversely, the latter are inversely associated with energy transition and exports. Therefore, increasing the share of renewable energy to fossil fuels consumption is one of the suitable strategies to stimulate economic growth and improve environmental sustainability (Bouznit, 2022).

3. DATA AND METHODOLOGY

3.1. Data

This study uses panel data from countries in the Asia Region, focusing on each country's national level data from 2014 to 2023 to analyse the relationship between the energy transition index and economic growth in Asia Region countries. Data sources include the Word Bank for economic growth and the World Economic Forum for the variables of the Energy Transition Index. Panel data was chosen because it can provide more varied information with greater variability, more degrees of freedom, lower collinearity between variables and higher efficiency in estimating parameters (Fajar et al., 2024).

The selection of the research period and the countries studied is based on the completeness of the data and the availability of data in each country based on the variables used. Due to the lack of data on several countries in Asia that are difficult to interpolate, this study only focuses on 28 countries in the Asia Region. This part of the paper states its aim, detailed methodology and data used. The title of the paper must be compatible with its aim and its content.

As a representation of economic growth, Gross Domestic Product per capita is used, reflecting the economic performance of a country, with data sourced from the World Bank. Economic growth is quantified by the rise in gross domestic product (GDP) per capita. This is a metric of total revenue concerning the annual rate of change in real GDP (Jones, 2002). Economic growth signifies an increase in a nation's production as reflected in real national income. Defines economic growth as an increase in the inflated market value of commodities and services within an economy over a specified period (Thaddeus et al., 2020).

The independent variables used include various indicators used in building the Energy Transition Index based on data from the World Economic Forum. These variables include Equitable; Secure; Sustainable; Regulation and Political Commitment; Infrastructure; Education and Human Capital; Innovation; Finance and Investments. Each of these variables is measured by various indicators, which in turn builds on these indicators.

Table 1 presents a comprehensive overview of the information's details, sources and units of measurement associated with the variables.

3.2. Methodology

The STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model serves as the framework to elucidate the impact of economic activities on environmental pollution, encompassing carbon emissions (Dietz and Eugene, 1997; Pattak et al., 2023). This model has been frequently employed to assess the influence of specific factors or policies by utilizing them as proxies for a component in STIRPAT or as emissions, such as: industrial activity, energy efficiency, and Kyoto Protocol ratification as proxies for technological change (Bargaoui et al., 2014); Industrial waste, SO_2, soot, and domestic refuse as proxies for carbon emissions (Xu et al., 2020); And carbon intensity alongside fixed asset investments (Wang et al., 2017), among others. The fundamental structure of the model is as follows:

$$I_t = P^b_{it} A^c_{it} T^d_{it} e_{it} \quad (1)$$

In this context, I denotes environmental pollution, P signifies population number, A represents economic prosperity, T indicates technology level, and e is the error term.

We utilize an expanded STIRPAT model based on the fundamental form to incorporate our variable of interest and the control variable for analysis. The model employs the natural logarithmic transformation of the variables to address issues of nonlinearity and skewed distribution in the data (Wang et al., 2021).

$$Ln(GDP)_{it} = \beta_{oi} + \beta_1 Equi_{it} + \beta_2 Sec_{it} + \beta_3 Sus_{it} + \beta_4 RPC_{it} + \beta_5 IN\_F_{it} + \beta_6 EHC_{it} + \beta_7 Inv_{it} + \beta_8 FI_{it} + e_{it} \quad (2)$$

Each variable corresponds to Table 1 in the previous section. *i* represents the country and *t* represents the predefined period. Ln(GDP) is used as the dependent variable. While the independent variables are indicators for Energy Transition Index. Finally, e_{it} represents the stochastic error for time and country. This study aims to assess the significance of β_7-β_8 as the coefficient associated with the Energy Transition Index, along with other explanatory variables, on Ln(GDP) which represents economic growth. The study seeks to determine whether these variables have a significant impact on economic growth and whether this impact is positive or negative.

In this study, we adopt the Quantile regression (QR) method to examine the distributional effects of Energy Transition Index on economic growth. Unlike Ordinary Least Squares (OLS) that only estimates the mean relationship, quantile regression allows for the estimation of the effects at different points of the conditional distribution of the dependent variable, providing a more comprehensive view of the relationship between the variables across the entire distribution of economic growth (Paddu et al., 2024). Considering the general panel data model, the expression is as follows

$$y_{it} = x_{it}\beta + \alpha_i + u_{it}, \; i = 1,2,\ldots,N; \; t = 1,2,\ldots,T \quad (3)$$

Where, *i* represents different sample individuls, *t* represent the random error term, β represents the coefficient vector of the explanatory variable and α_i repesents the unobservable random effect of the i sample.

Table 1: The list of variable used in the model

Variable	Sign	Measurement	Source
Dependent Variable Economic Growth	Ln (GDP)	The level of economic growth, measured of real Gross Domestic Product (GDP) per capita (USD)	World Bank
Independent Variable			
Equitable	Equi	Scale (1-100)	World Economic Forum
Secure	Sec	Scale (1-100)	World Economic Forum
Sustainable	Sus	Scale (1-100)	World Economic Forum
Regulation and Political Commitment	RPC	Scale (1-100)	World Economic Forum
Infrastructure	IN_F	Scale (1-100)	World Economic Forum
Education and Human Capital	EHC	Scale (1-100)	World Economic Forum
Innovation	Inv	Scale (1-100)	World Economic Forum
Finance and Invesments	FI	Scale (1-100)	World Economic Forum

Source: Own Source, 2025

Quantile regression method can also be used to estimate the parameters of the panel data model. For that. The quantile equation under the following conditions is established:

$$Q_{yit}\left(\tau_j \mid x_{it},\alpha_i\right) = x_{it}^{'}\beta\left(\tau_j\right) + \alpha_i, i = 1,2,\ldots,N; t = 1,2,\ldots,T \quad (4)$$

The quantile equation above assumes that the individual effects are fixed. For this equation, Koenker (2004) pointed out that when the number of individuals N is large and the number of observations contained by each individual is relatively small, appropriate contraction control of the individual effect can effectively reduce the variance α_i due to estimation. For the linear quantile loss function ρ_T (μ), in order to maintain the linear characteristics of the objective function, 1_i linear penalty term can be considered, that is (Koenker, 2004).

$$P(\alpha) = \sum_{i=1}^{n} |\alpha_i| \quad (5)$$

Therefore, based on the variables used, the quantile regression model is given by:

$$Q_\tau (Ln(GDP)|X_{it}) = \beta_0 (\tau) + \beta_1 (\tau) Equi_{it} + \beta_2 (\tau) Sec_{it} + \beta_3 (\tau) Sus_{it} + \beta_4 (\tau) RPC_{it} + \beta_5 (\tau) IN\_F_{it} + \beta_6 (\tau) EHC_{it} + \beta_7 (\tau) Inv_{it} + \beta_8 (\tau) FI_{it} + \varepsilon_{it} (\tau) \quad (6)$$

Where:

$Q_\tau (Ln(GDP)_{it} |X_{it})$ is the conditional τ-quantile of the dependent variable, which represents a p oint in the distribution of $Ln(GDP)_{it}$ for the country i at time t. The β coefficients are quantile-specific, meaning they represent the effect of each independent variable at different quantiles of the dependent variable's distribution.

Quantile regression is particularly useful for this study as it provides insights into how the impact of Energy Transition Index might vary across countries with different levels of economic growth. This approach allows for a more nuanced understanding of how these variables influence economic growth in countries with low, middle, and high GDP levels.

To estimate the quantile regression model, the Koenker and Bassett Method (1978) is used, which minimises the weighted sum of the absolute residuals for different quantiles. The procedures used in this study with reference to the Koenker and Basset method include: (1) collecting and preprocessing panel data from Asian countries over the period 2014-2023; (2) ensuring the data has been logged to stabilise variance and overcome non-linearity; (3) handling missing values using appropriate techniques as required, such as interpolation or imputation; (4) estimating quantile regression models for different quantiles from 0.1 to 0.9 to test the variation in the impact of independent variables at different points of the GDP distribution; (5) performing quantile regression estimation using statistical software; (6) performing diagnostic tests, such as checking for multicollinearity between independent variables, heteroscedasticity, and cross-sectional dependence to ensure the robustness of the results; (7) bootstrapping method was used to obtain robust standard errors and improve the reliability of the quantile regression estimates; (8) results were analysed at various quantiles to identify differences in the impact of the Energy Transition Index on economic growth across countries with different levels of economic performance; (9) comparing the impact of the independent variables at the lower (poor countries), median, and upper quantiles (rich countries) to understand how these factors may contribute differently to the economic growth of each group of countries in Asia based on the economic growth rates of countries in the region.

4. RESULTS AND DISCUSSION

4.1. Statistic Analysis

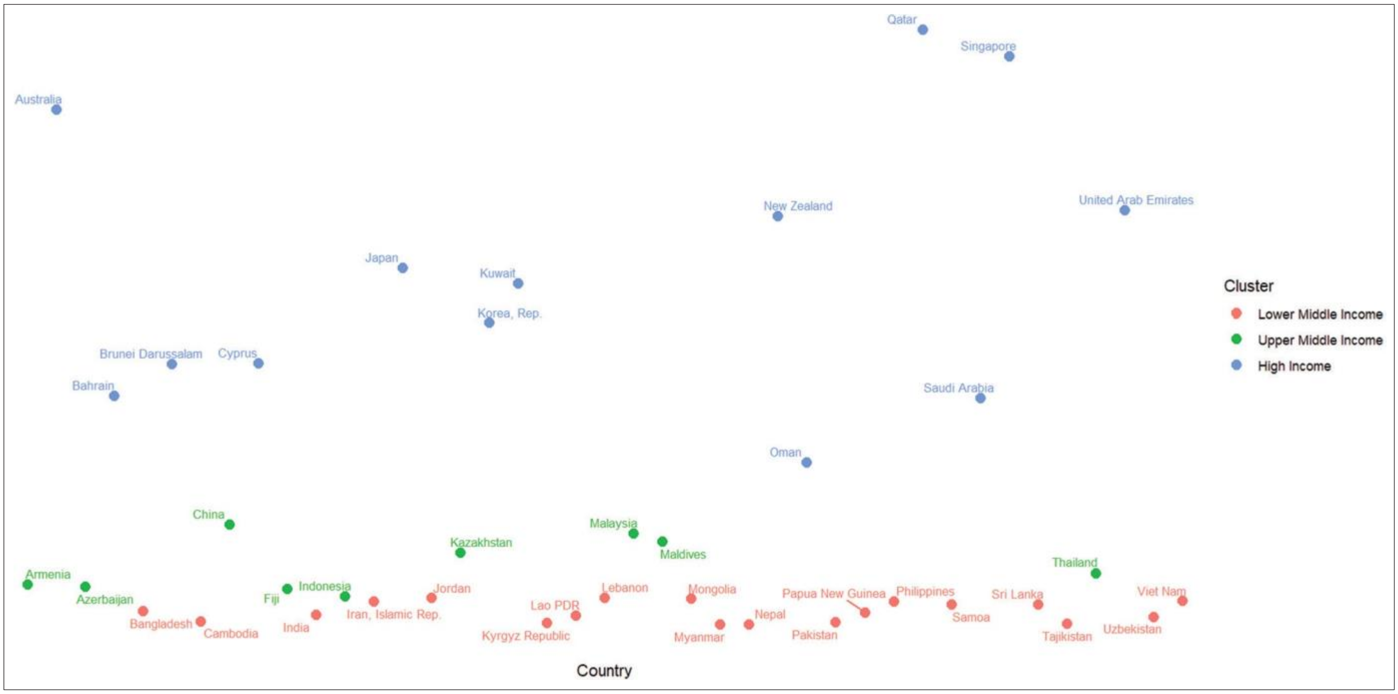
Based on the World Bank Group Country Classifications by Income, countries in the world can be classified into 4 income groups, including Low Income, Lower Middle Income, Upper Middle Income and High Income. This classification is based on GNI per Capita, measured in US Dollars using conversion factors derived based on the Atlas Method, which was introduced in 1989. The World Bank's income classification aims to reflect a country's level of development using the GNI per capita Atlas as a widely available indicator of economic capacity (Hamadeh et al., 2024). As shown in Figure 1, the 28 countries in the Asia Region selected fall into three categories: Lower Middle Income, Upper Middle Income and High Income.

Table 2 shows the descriptive statistics for the variables used, namely GDP per capita (as the dependent variable) and a number of indicators that make up the energy transition index (as independent variables). GDP per capita shows the level of inequality and income distribution between countries, with high mean values and large standard deviations, indicating significant variations between countries in terms of economic well-being. In addition, most of the independent indicators have high mean values, with modest variations, indicating that despite the differences, most countries have fairly similar levels of indicators in the energy transition.

It is important to note that the data also shows distributional imbalances for some indicators, such as in Skewness and Kurtosis, which show the asymmetry of the data distribution. Some variables such as Equitable, Secure and Sustainable have skewness and kurtosis values close to 0, indicating a relatively normal distribution. Meanwhile, variables such as Regulation and Political Commitment, Infrastructure and Finance and Investments show distributions that are more skewed in one direction, which may indicate large differences between countries in terms of energy policy, infrastructure and financing. As such, this analysis provides a snapshot of how consistent or varied the elements of the energy transition influenced by economic and policy factors are across Asia Region.

A Scatter Plot with adjusted value lines can be seen in Figure 2, which illustrates the relationship between economic growth (Ln(GDP)) and various independent variables used in the Asia Region countries. The Scatter plot shows how strong the linear relationship is between the variables. A positive correlation indicates a unidirectional relationship, while a negative correlation indicates an opposite relationship. It can be seen that Ln(GDP) has significant positive correlations with Equitable, Secure, Regulatory

Figure 1: Country classification in Asia region by income level



Source: Data analysis results, 2025

Table 2: Summary statistics

Variable	Mean	Standard deviation	Skewness	Kurtosis	Minimum	Maximum
GDP	26733899.47	134428529.6	9.151340	95.15134	2839.05792	1632326887
Equi	69.08821	11.38459	−0.39766	−0.86487	35.2	88
Sec	65.86036	9.846243	−0.00142	−0.82078	42.2	86.7
Sus	47.025	16.6145	−0.30757	−1.06745	15	81.4
RPC	50.35786	13.23669	0.081979	−0.55653	17.1	84
IN_F	41.26979	13.21017	0.271902	−0.59373	14.9	71.1
EHC	33.39929	12.75081	0.563975	−0.40524	13.8	75.4
Inv	37.73286	13.70121	1.069802	1.439519	14.9	85.3
FI	39.6825	16.25611	0.725586	−0.15704	14.6	85.3

Source: Data Analysis Results, 2025

and Political Commitment and Finance and Investments, indicating that improvements in these indicators tend to be associated with increases in GDP per capita.

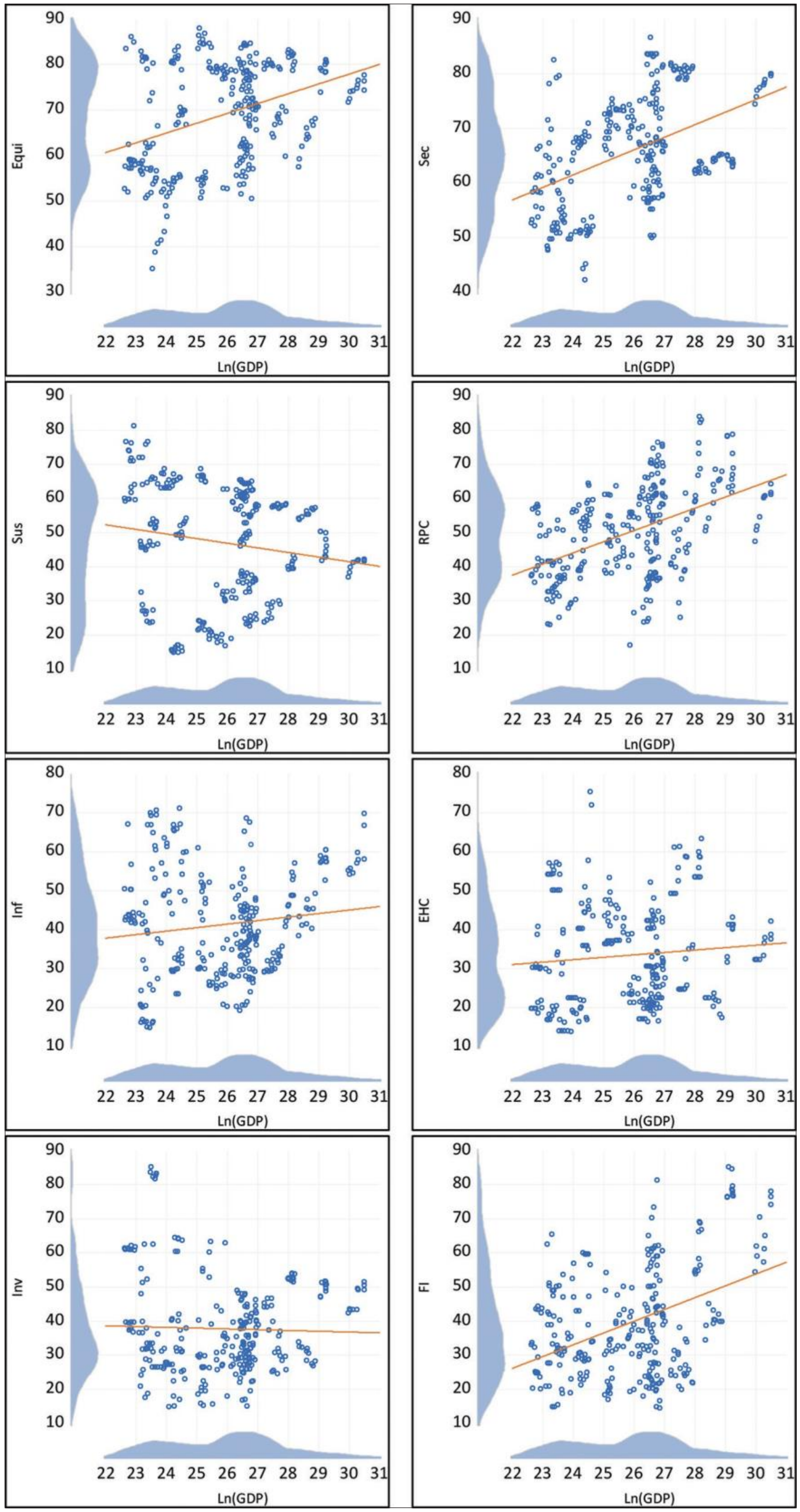
On the other hand, some indicators show a negative correlation with Ln(GDP). Sustainable and Innovation have a negative correlation with GDP, indicating that increases in sustainability and innovation indicators do not necessarily correspond with increases in GDP per capita. This could be due to various structural factors or policies that lead to a trade-off between economic growth and these indicators in certain countries.

4.2. Pre-Estimation Diagnostics

Before conducting the analysis using the panel quantile regression model, the estimation diagnostics test is conducted first. The first step of this estimation diagnosis is to select the best model. In this study, several analysis models are used, namely Pooled OLS, Fixed Effects and Random Effects. In estimating panel quantile regression, the best model selection between Pooled OLS, Fixed Effects, and Random Effects must be done to ensure that the model used is in accordance with the characteristics of panel data, such as individual heterogeneity and combination structure across time and individuals. Tests, such as Chow, Hausman, and Lagrange Multiplier help determine the most efficient and consistent model, resulting in accurate estimates across different quantiles of the data distribution (Ceesay and Moussa, 2020).

Based on the test results presented in Table 3, it can be seen that the most appropriate model to use in this analysis is Fixed Effects. The Breush Pagan test shows that Random Effects is more appropriate than Pooled OLS, while the F test for individual effects and the Hausman test show that Fixed Effects is more appropriate than both Pooled OLS and Random Effects. Although the Breush Pagan test provides results that favour Random Effects, the F and Hausman tests favour the use of Fixed Effects. Overall, these results confirm that the Fixed Effects model is the best choice for analysing the data, given the sustainability and accuracy of the model's adjustment to variation between individuals.

Figure 2: Scatter plots for independent towards dependent variables



Source: Data analysis results, 2025

The next step in diagnosing the estimation is to conduct an assumption test. To see the effect of heteroscedasticity and cross-sector dependence, Modified Wald Test and Pesaran Test are used. The Modified Wald Test is used to detect heteroscedasticity in the Fixed Effects model, especially when the number of cross-section units is large (N is large) and the time period is small (T is small), thus ensuring that the error variance between individuals remains constant. Meanwhile, the Pesaran Test is used to identify cross-sectional dependence due to correlation between cross-section units, which often arises due to external factors that affect all units simultaneously (Yakubua and Jalil, 2016; Moon et al., 2006).

The test results shown in Table 4 indicate the presence of both problems. Therefore, cluster robust standard errors on fixed effects are used to address the presence of heteroskedasticity and cross-sectoral dependence.

Finally, Fixed-Effect Model Estimation with Robust Standard Errors is conducted to overcome the heteroscedasticity and autocorrelation problems in panel data, so that the non-constant error variance does not affect the accuracy of the estimation results. By using robust standard errors, parameter estimation results become more consistent and efficient, ensuring valid inference even though the classical assumption of homoscedasticity is not met (Stock and Watson, 2008).

Table 5 shows the results of robust standard errors for the effect of each independent variable on the dependent variable, GDP per capita, as well as the statistical significance of the effect based on the P-value. The coefficient value indicates the direction and strength of the relationship between the independent variable and the dependent variable, while the P-value determines whether the relationship is statistically significant at a certain confidence level.

The results show that Sustainable and Regulation and Political Commitment have a statistically significant influence on GDP per capita with a P-value below 0.05. This means that sustainability and political regulation play an important role in driving economic growth per capita. The positive relationship of the Regulation and Political Commitment variable indicates that an increase in regulation and political commitment is associated with an increase in GDP per capita, while the negative coefficient on Sustainable indicates a potential trade-off between sustainability and economic growth in the short term.

In contrast, Equitable, Secure, Infrastructure, Education and Human Capital, Innovation and Finance and Investments show no statistically significant effect on GDP per capita. This means that the influence of these variables on economic growth per capita is not strong enough to be statistically proven in this model, although some of them have a small positive or negative relationship.

The *R*-Adjusted value of 0.3748 indicates that about 37.48% of the variation in GDP per capita can be explained by this model, while the rest is due to other factors not included in the model. This indicates that although some independent variables have a significant relationship with GDP per capita, there is still room to improve the model by adding other variables that are more relevant or better able to explain variations in GDP per capita.

4.3. Main Estimating Results

Due to the disparity between countries in terms of GDP per capita, as shown in Figure 3, this study will proceed using quantile regression with fixed effects to test whether the effect of financial technology and digital infrastructure on economic growth varies between Low Income, Low Middle Income, Upper Middle Income and High Income countries in the selected Asia region. This approach follows Machado and Silva (2019) which

Table 3: Test for model selection

Test	P-valuze	
Breush Pagan LM Test	$2.2e^{-16}$	
F Test for Individual Effects	$2.2e^{-16}$	
Hausman Test	0.8837	
	Prob	**Interpretation**
Pooled OLS versus random effects	<0.05	Random effects is appropriate
Pooled OLS versus fixed effects	<0.05	Fixed effects is appropriate
Fixed effects versus random effects	>0.05	Fixed effects is appropriate
Overall	Fixed effects is appropriate	

Source: Data Analysis Results, 2025

Table 4: Testing assumption

	Test	P-value	Prob	Interpretation
Homoscedasticity	Modified Wald Test	$1.277e^{-05}$	<0.05	There is problem of heteroskedasticity
Cross-sectional dependence	Pesaran Test	$2.2e^{-16}$	<0.05	There is cross-sectional dependent

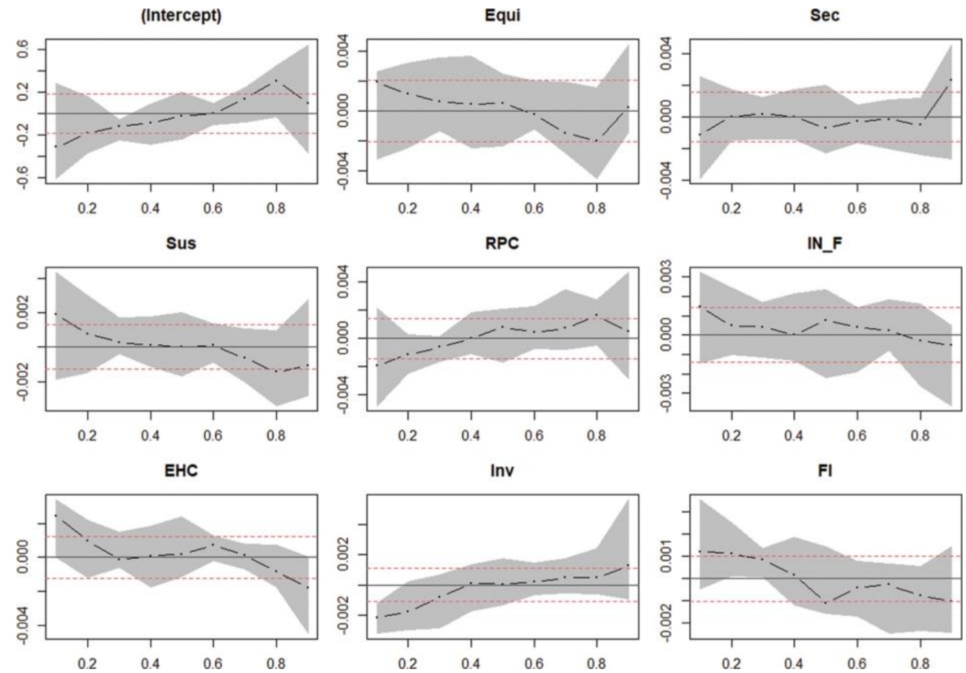
Source: Data Analysis Results, 2025

Table 5: Robust standard error estimations

	Coefficient	P-value	Prob.	Interpretation
EQUI	0.00303	0.27208	>0.05	Statistically not significant impact
SEC	0.010087	0.07326	>0.05	Statistically not significant impact
SUS	−0.010906	0.03712*	<0.05	Statistically significant positive impact
RPC	0.013797	$1.104e^{-11}$***	<0.05	Statistically significant positive impact
INF	−0.0001056	0.94452	>0.05	Statistically not significant impact
EHC	0.0002649	0.91749	>0.05	Statistically not significant impact
INV	−0.0023551	0.09616	>0.05	Statistically not significant impact
FI	0.0016341	0.33535	>0.05	Statistically not significant impact
R-Adjusted				0.3748547

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1
Source: Data Analysis Results, 2025

Figure 3: Coefficient across different quantiles in dependent variable and independent variable for Quantile 0.1 until 0.9



Source: Data analysis results, 2025

has utility for panel data models with individual effects, as per the data used in this study.

The results illustrated in a visual representation of the economic growth coefficients at various quantiles in Figure 3 show that quantiles 0.1-0.3 are interpreted as low economic growth, quantiles 0.4-0.5 as medium economic growth and 0.6-0.9 as high economic growth. The low, medium and high economic growth states will be in different countries during different years. The estimated value of the intercept (Ln(GDP)) decreases up to quantile 0.3. However, it continues to increase from quantile 0.4 to quantile 0.9. Similarly, the independent variables used, there are fluctuations that vary at certain quantiles. This indicates that the independent variables used can increase or decrease economic growth at certain quantiles.

Parameter testing on the panel quantile regression is conducted to determine whether the independent variables used and contained in the model have a significant relationship with economic growth during conditions of low economic growth, medium economic growth and high economic growth, shown in Table 6. The test is conducted using the following hypothesis.

$H_0: \beta_1 (\tau) = \beta_2 (\tau) = \cdots = \beta_k (\tau)$

H_1: *At least one* $\beta_k (\tau) \neq 0$

Table 6 shows the results of the quantitative model analysis with economic growth as the dependent variable, while the indicators that make up the Energy Transition Index are the independent variables. This study uses a quantile regression (QR) approach, which aims to analyse the effect of each independent variable on economic growth at various quantiles of the distribution. This approach provides a more complete picture than ordinary regression, as it considers the dynamics of variable relationships at different parts of the data distribution.

Each row in the table shows the estimation results for a particular quantile, starting from the 10th quantile (0.1QR) to the 90th quantile (0.9QR). The "Coeff" column indicates how much influence each indicator has on economic growth at that quantile. A positive coefficient indicates a direct relationship, while a negative coefficient indicates an inverse relationship. Meanwhile, the "P>z" column shows the statistical significance (P-value) of each coefficient. A P-value smaller than 0.05 indicates that the effect of the variable is statistically significant at the corresponding quantile.

From the table results, it can be seen that some indicators such as Education and Human Capital (EHC) and Finance and Investments (FI) tend to have significant effects in certain quantiles, indicated by low P-values. For example, in the 0.1QR quantile, EHC has a significant positive coefficient, suggesting that improved education and human capital development has a large contribution to economic growth at the bottom of the distribution. On the other hand, some variables such as Equitable (EQUI) and Secure (SEC) show more varied and inconsistent effects across quantiles.

In addition, the different signs of the coefficients across quantiles suggest that the effect of the indicators on economic growth is not uniform across the distribution. For example, the Innovation (INV) indicator has a significant negative effect in the 0.1QR quantile, but this effect reverses to positive in the other quantiles, reflecting the different need or potential for innovation in countries with low versus high economic growth rates.

Table 6: Estimating results from panel quantile regression framework

Quantile	Equi	Sec	Sus	RPC	IN_F	EHC	Inv	FI
0.1QR								
Coefficient	1.924585	−1.12047	1.917091	−1.898413	1.458563	2.44244	−2.187975	1.210739
P>z	0.550284	0.77354	0.299917	0.690697	0.315406	0.00000	0.496424	0.0068173
0.2QR								
Coefficient	1.144071	1.737001	7.814923	−1.156315	4.810519	9.796542	−1.769611	1.123637
P>z	0.645594	0.9905968	0.600692	0.6433813	0.6347019	0.4109987	0.5491772	0.000000
0.3QR								
Coefficient	1.924585	−1.120478	1.917091	−1.898413	1.458563	2.44244	−2.187075	1.210739
P>z	0.550284	0.77354	0.2999173	0.6906978	0.3154068	0.00000	0.4964247	0.0068739
0.4QR								
Coefficient	4.399953	1.784616	1.329001	1.010679	1.890071	7.667211	6.924067	1.751525
P>z	0.8566908	0.9990008	0.9036441	0.9924695	0.9886309	0.9654601	0.9674481	0.881715
0.5QR								
Coefficient	5.447979	−6.92274	1.539058	7.954721	7.608672	1.690091	6.017283	−1.089061
P>z	0.8154381	0.7635127	0.9927519	0.638503	0.726084	0.8820921	0.96447733	0.4874444
0.6QR								
Coefficient	−2.257641	−3.044217	1.084179	4.663901	4.294652	7.018777	2.132228	−4.016621
P>z	0.852873	0.854291	0.9011702	0.5207571	0.8208519	0.0005158	0.737467	0.809941
0.7QR								
Coefficient	−1.470283	−1.448003	−6.344879	7.127493	2.186825	1.371537	4.615468	−2.738402
P>z	0.59811554	0.9424427	0.7543121	0.3657728	0.7728057	0.840084	0.3622596	0.91120417
0.8QR								
Coefficient	−2.023771	−5.089722	−1.444076	1.633744	−2.835403	−8.35821	4.729857	−7.721334
P>z	0.65310419	0.8308389	0.6722606	0.0004604	0.9142222	0.6392138	0.425743	0.73822625
0.9QR								
Coefficient	2.064103	2.307126	−1.071311	4.812871	−5.340460	−1.782227	1.252841	−1.022762
P>z	0.8866191	0.390589	0.7041167	0.866023	0.691797	0.1852583	0.6704843	0.5245194

Source: Data Analysis Results, 2025

Overall, these results suggest that energy transition analyses need to take into account the different dynamics at each level of economic growth, so that policy strategies can be designed more specifically to suit countries at different levels of the economic growth distribution. It also underlines the importance of a quantile-based approach in understanding the complexity of the relationship between the energy transition index and economic growth.

4.4. Discussion and Practical Implications

The findings of this study highlight the important role of energy transition in shaping the economic growth of countries in the Asia region. The significance of variables such as sustainability, regulation and political commitment suggests that countries that prioritise these elements can effectively drive GDP growth. The interaction between sustainable practices and economic performance highlights the complexity of pursuing a green transition in both developing and developed economies. Although sustainability initiatives may result in short-term trade-offs, as indicated by the negative coefficient, these efforts are likely to yield long-term benefits, aligning economic progress with environmental preservation.

The positive effect of regulation and political commitment emphasises the importance of strong governance structures and policy frameworks. A clear regulatory environment, along with political will, is critical in creating an ecosystem where investments in clean energy technologies and infrastructure can flourish. This highlights the need for Asia countries to strengthen their institutional capacity to effectively guide and manage the energy transition process, ensuring that policies are not only well designed but also consistently implemented.

The presence of several insignificant variables, including equitable energy access and secure energy systems, requires a deeper exploration of structural and regional disparities. While these variables may not appear statistically significant in the broader model, their importance should not be overlooked, especially in less developed economies where equitable energy distribution and reliability are critical to addressing socioeconomic inequalities. Ensuring safe and equitable energy access can be the basis for broader economic development by enabling marginalised communities to contribute to and benefit from growth.

Education and human capital, along with finance and investment, are emerging as significant contributors to economic growth in certain segments of the GDP distribution. This suggests that customised strategies targeting these areas can have a substantial impact on low-income countries. By investing in education systems and workforce development, Asia countries can increase their capacity to innovate and adapt to the demands of a transitioning energy landscape. Similarly, financial mechanisms, such as green bonds and incentives for clean energy investments, can accelerate progress in countries with lower GDP per capita.

Innovation plays a more profound role in the relationship between energy transition and economic growth. Its varying impact across income levels suggests that innovation strategies should be tailored to the unique needs of countries at different stages of development. In low-income countries, innovation may need to focus on cost-effective and scalable solutions for clean energy deployment. In contrast, high-income countries may benefit from high-tech advances and breakthroughs that push the boundaries of energy efficiency and sustainability.

Quantile regression analyses reveal the varying impacts of energy transition indicators across the economic spectrum. Policymakers should recognise that a one-size-fits-all approach to energy transition is not sufficient. Countries with low GDP per capita may require basic investments in education, infrastructure and secure energy systems to enable growth. In contrast, rich countries may prioritise improving regulatory frameworks and promoting leading-edge innovation to maintain their competitive advantage.

To achieve a balanced and sustainable economic path, regional collaboration is essential. Given economic interconnectedness, initiatives that share knowledge, technology and financial resources can amplify the positive impacts of the energy transition. Regional organisations and agreements, such as ASEAN and The Belt and Road Initiative, should prioritise energy transition projects that align with shared goals for economic and environmental resilience.

In practice, the findings suggest that governments and development planning agencies in each Asian country should adopt holistic strategies that integrate economic, environmental and social dimensions in driving their countries' economic growth to realise sustainable and equitable development. Energy transition policies should be included in broader national development plans to ensure that initiatives address both short-term needs and long-term goals. For example, infrastructure projects that combine renewable energy with job creation can simultaneously address unemployment and reduce dependence on non-renewable energy, primarily fossil fuels.

Ultimately, the transition to a sustainable energy system is not just a technological challenge, but must be coupled with socio-economic transformation. Understanding the complex relationship between energy transition indicators and economic growth across the economic spectrum, countries in Asian can design customised strategies that have the impact of improving their macroeconomic performance. This will be key to ensuring that the region can become a global leader in sustainable development while achieving inclusive economic prosperity.

5. CONCLUSION

This research reveals that the energy transition plays an important role in driving economic growth in the Asian region. Variables such as sustainability and regulation as well as political commitment are shown to have a significant influence on boosting economic growth, highlighting the importance of policies that favour clean energy. However, other results also suggest a potential trade-off between sustainability and economic growth for Asian countries in the short term, emphasizing the need for a cautious approach in designing energy transition policies in the region.

The results of the quantile regression analysis show that the impact of the energy transition is not uniform across clusters of economic growth rates of countries in Asian region. Some indicators, such as education and human capital, have significant effects in lower economic growth quantiles, while others, such as innovation and investment, show larger impacts in higher economic growth quantiles. These findings highlight the importance of an energy transition strategy that is tailored to the specific needs of each country in Asian based on its income level and economic structure.

Overall, this study provides an in-depth look at the effect of energy transition on economic growth, while offering insights for evidence-based policy formulation. It underscores the need for an integrated approach that focuses on long-term sustainability to create a balance between economic development and environmental protection in the Asia region.

Governments in the region should strengthen regulations and political commitments to promote the energy transition. This could include implementing fiscal incentives for renewable energy, removing fossil fuel subsidies, and strengthening the legal framework and oversight of green energy projects. A strong regulatory framework will create confidence for investors and encourage private sector participation in supporting the energy transition in the region.

Countries in Asia with low economic growth rates need to focus on education and human capital development as part of their energy transition strategy. Clean energy-oriented training and education programmes can increase the capacity of the local workforce, thereby promoting the development of renewable energy technologies and supporting economic growth.

Greater investment in energy infrastructure is needed, especially in less developed regions. Building efficient electricity grids, increasing access to renewable energy and modernising energy systems will be key to accelerating the energy transition. Funding for these projects can be obtained through partnerships between governments, the private sector and international organisations.

Regional co-operation should be strengthened to share knowledge, technology and resources to accelerate the energy transition. For example, Asia countries could establish joint research centres to develop innovative solutions in energy, while creating common standards for clean energy implementation across the region. This collective effort will enable greater efficiency and accelerate the achievement of sustainability goals.

This study has several limitations, one of which is the limited scope of the independent variables used to construct the Energy Transition Index. While the selected variables cover the main dimensions of the energy transition, it is possible that other factors, such as specific technology levels or consumer behaviour, also play an important role but are not represented in the analytical model used in this study. In addition, the panel-based quantile regression analysis does not fully capture the long-term dynamics between energy transition and economic growth, which requires a more detailed time-series approach. The author evaluates whether the aim of the paper was fulfilled and presents the main findings of the research. Limitations of the research/results and a direction for further research should be explained.

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