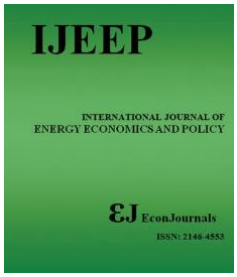

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# The Nexus of Energy Consumption and Economic Growth: A Case Study of the East Asia and Pacific Region

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**ABSTRACT**

Energy plays a vital role in the economic development of most countries. However, the relationship between energy consumption and economic growth remains a subject of ongoing debate within academia. Some studies suggest that energy consumption drives economic growth, while others indicate an inverse effect or no clear correlation. This study aims to assess the impact of energy consumption on economic growth in countries within the East Asia and Pacific region. Research data was collected from the World Development Indicators and the International Energy Agency for the period 2001–2024. The estimation method employed is Feasible Generalized Least Squares, which effectively controls for econometric issues such as heteroscedasticity and autocorrelation in panel data. The research findings reveal that energy consumption has a negative impact on economic growth in the East Asia and Pacific region. In other words, increasing energy consumption not only fails to boost growth but may also hinder economic development in this area. This finding carries a significant implication for policymakers: reducing energy consumption, coupled with enhancing energy efficiency and promoting a transition to cleaner energy sources, could be an appropriate strategy to ensure sustainable growth while mitigating negative impacts on the environment and long-term economic stability.

**Keywords:** East Asia and Pacific Region, Economic Growth, Energy Consumption, FGLS, WDI
**JEL Classifications:** C33, O13, O44, Q43, Q48

## 1. INTRODUCTION

Climate change and recent geopolitical instability have raised profound global concerns regarding energy security and the associated environmental impacts of energy extraction, production, and consumption. These threats not only jeopardize socio-economic stability but also impose an urgent demand on nations to formulate and implement effective energy policies while striving for sustainable economic development (Baranzini et al., 2013). In this context, the relationship between energy consumption and economic growth is increasingly becoming a crucial research topic, attracting widespread attention from scholars, policymakers, and international organizations.

The core question that arises is whether energy consumption drives economic growth, or if economic growth, in turn, increases energy demand. Identifying the causal direction between these two factors is of paramount importance for designing national energy and growth policies. Furthermore, as the global community confronts the challenges of global warming and the urgent need to reduce greenhouse gas emissions, a clear understanding of the energy consumption-economic growth nexus is fundamental for governments to make decisions that simultaneously ensure economic development and minimize adverse environmental impacts (Chontanawat et al., 2008).

To date, numerous empirical studies have been conducted to determine the relationship between energy consumption and economic growth. However, the findings from these studies remain largely inconsistent. Some research supports the hypothesis that energy consumption is a driving factor for economic growth, implying that energy cutbacks could negatively impact national

output. Conversely, other studies suggest that economic growth is the primary cause of increased energy consumption. Additionally, some research has found no clear causal relationship between the two factors, or posited a bidirectional interaction (Wolde-Rufael, 2009). These discrepancies largely stem from variations in research data, study periods, selected proxy variables, econometric methodologies, as well as the institutional characteristics, development levels, and economic structures of the studied countries.

Although the existing literature has significantly contributed to understanding the relationship between energy consumption and economic growth, most studies have focused on developed countries, OECD members, or major economies. In contrast, developing countries in the East Asia and Pacific region – which are undergoing rapid industrialization but still face significant challenges in energy efficiency – have not been adequately researched. The East Asia and Pacific region comprises 37 countries, most of which belong to the group of developing economies with moderate but uneven economic growth rates and a high reliance on fossil fuels. Investigating the relationship between energy consumption and economic growth in this region is crucial to provide scientific evidence for energy policy reforms, improve resource efficiency, and promote sustainable economic growth.

This study aims to investigate the impact of energy consumption – measured by Energy use (kg of oil equivalent per capita) – on economic growth, represented by GDP per capita, in 37 countries within the East Asia and Pacific region during the period from 2001 to 2024. The originality of this research lies in its use of a large dataset, covering a broad spatial and temporal scope, coupled with the application of appropriate quantitative methods to test the causal relationship between the two main variables. The study will not only provide additional empirical evidence for current academic debates but also offer valuable policy implications for policymakers in balancing economic development and energy consumption management within this dynamic developing region.

The remainder of this paper is structured as follows: Section 2 provides a comprehensive literature review of relevant studies; Section 3 describes the research methodology and data used; Section 4 presents the empirical results and discussion; finally, Section 5 concludes with a summary and policy recommendations based on the study's findings.

## 2. LITERATURE REVIEW

The causal relationship between energy consumption and economic growth is a topic that has garnered widespread attention in academia and policymaking, yet it remains a subject of considerable debate. The diversity in datasets, study periods, country specificities, energy policies, and econometric methodologies applied has led to inconsistent results. Generally, three main perspectives have emerged regarding this causal relationship.

One of the prominent and influential hypotheses in the field of energy economics is the "energy-led growth hypothesis." According to this perspective, energy is considered an essential input for production and investment activities, thereby driving economic growth. This is particularly true in developing or rapidly industrializing economies, where high energy demand serves as a crucial engine for economic expansion. Consequently, reducing energy consumption in these countries could potentially slow down their development processes.

This hypothesis is supported by numerous empirical studies. Stern (1993) was among the first to affirm the causal role of energy in U.S. economic growth using a Vector Autoregressive (VAR) model. Cheng and Lai (1997), utilizing Taiwanese data from 1955-1993, found evidence of the impact of energy consumption on GDP. Asafu-Adjaye (2000) extended this research to developing Asian countries such as India, Indonesia, Thailand, and the Philippines, confirming the positive role of energy in their growth.

Large-scale studies by Lee (2005) across 18 developing countries and Chontanawat et al. (2008) across over 100 countries demonstrated that energy consumption significantly influences economic growth, especially in the developing world. In Africa, Odhiambo (2009; 2010) employed the ARDL method to examine the impact in Tanzania, South Africa, and Kenya, revealing a positive correlation between energy consumption and growth. Similarly, Eggoh et al. (2011) substantiated this positive impact across 21 African countries.

Positive evidence has also been found in various country-specific studies. Gozgor et al. (2018) confirmed that both renewable and non-renewable energy support economic growth. Khan et al. (2021) showed that the impact exists in both the short and long run. Other studies in Cameroon, Nigeria, Ghana, Senegal, Sudan (Wolde-Rufael, 2005; 2006; Akinlo, 2008; Ozturk et al. 2010; Okoye et al. 2021) consistently support the argument that energy is a prerequisite factor driving GDP, particularly in low-income economies.

In recent years, numerous research works have continued to strengthen this hypothesis, with a growing focus on renewable energy and sustainable energy policies. Ivanovski et al. (2021) argued that both renewable and non-renewable energy foster growth, with renewable energy having a stronger impact in countries pursuing green energy policies. Konuk et al. (2021) found that biomass energy promotes GDP in Southeast Asian countries, especially Vietnam and Indonesia, with one-way causality from energy consumption to growth confirmed. Prince et al. (2021) affirmed that energy consumption significantly influences Nigeria's GDP in both the short and long run. Bhuiyan et al. (2022), through a systematic literature review, showed that most countries observe a positive impact of renewable energy on economic growth. This effect is more pronounced in developing economies in East Asia, where policies supporting clean energy play a crucial mediating role.

Recent empirical studies further confirm the pivotal role of renewable energy. Gyimah et al. (2022) found a long-term impact of renewable energy consumption on Ghana's GDP, while Hassan et al. (2022) noted a similar relationship in European countries like France, Finland, and Portugal, particularly concerning electricity

consumption. Wang and Lee (2022) demonstrated that clean energy consumption in China positively affects growth, especially when combined with stringent environmental policies, suggesting that policies can amplify energy's positive effects.

In Southeastern China, Hu et al. (2023) discovered that energy consumption plays a significant role in economic growth, particularly in rapidly industrializing areas. Gahlot and Garg (2025) conducted a bibliometric analysis, indicating that the research focus is shifting from traditional energy to renewable energy and energy efficiency. This trend reflects a global paradigm shift towards more sustainable development.

The second perspective in the study of the relationship between energy consumption and economic growth posits that energy consumption does not act as a causal driver of growth. Instead, it argues that actual GDP growth is the factor that leads to an increase in energy demand for energy use. According to this view, energy is merely an intermediate factor or one that reacts to the momentum of growth, rather than being the primary impetus for economic development. This implies that reducing energy consumption, particularly of non-renewable sources, might not significantly impact economic growth – an argument that holds practical value for formulating energy conservation policies or transitioning to cleaner energy sources.

One of the earliest and most influential studies supporting this perspective was by Kraft and Kraft (1978). Based on annual data for the United States during 1947–1974, their research found a unidirectional causal relationship from economic growth to energy consumption. This study laid the groundwork for a series of subsequent analyses in various contexts. For instance, Oh and Lee (2004), using South Korean data from 1981–2000, also concluded that GDP was the cause driving energy consumption, and not vice versa. Al-Iriani (2006) further confirmed a unidirectional causal relationship from GDP to energy consumption in six Gulf Cooperation Council (GCC) countries, including Bahrain, Kuwait, UAE, Oman, Qatar, and Saudi Arabia.

At a broader regional level, Huang et al. (2008) conducted an analysis with data from 82 low-, middle-, and high-income countries, finding that GDP growth influenced energy consumption, while the reverse direction was not statistically significant. Similarly, Akinlo (2008) explored the relationship in several African countries such as Gambia, Ghana, Sudan, Zimbabwe, Congo, and Senegal, discovering that economic growth was the determinant of energy consumption in these nations. Similar findings were also reported in Esso's (2010) study, where GDP was identified as the leading factor for energy consumption in Congo and Ghana.

Wolde-Rufael, in two studies from 2005 and 2006, also provided substantial empirical evidence supporting this view. In his 2005 study, he analyzed the relationship between economic growth and energy consumption in a range of African countries including Algeria, Democratic Republic of Congo, Egypt, Ghana, and Ivory Coast, and found that GDP was the influencing factor on energy consumption, while no evidence was found for the reverse causality. In his 2006 study, countries such as Cameroon, Ghana, Nigeria, Senegal, Zambia, and Zimbabwe showed similar results, affirming the leading role of GDP.

Furthermore, some studies have found that energy consumption has no impact on economic growth whatsoever, thereby reinforcing the argument that energy is not a determinant of growth. Chiou-Wei et al. (2008), analyzing data from eight Asian countries and the United States, found no causal relationship from energy consumption to economic growth. Similarly, Akinlo's (2008) research showed that in countries like Cameroon, Ivory Coast, Nigeria, Kenya, and Togo, energy consumption had no significant effect on GDP. Huang et al. (2008), with their analysis across 82 countries at different income levels, also found no evidence that energy consumption affected economic growth. Esso (2010), in his study of African countries such as Cameroon, Nigeria, Kenya, and South Africa, reached a similar conclusion.

Wolde-Rufael (2005), in an extended study, found no influence of energy consumption on economic growth in a host of other African countries including Benin, Congo, Kenya, Senegal, South Africa, Sudan, Togo, Tunisia, and Zimbabwe. And in his 2006 study, he found no significant link in Algeria, Congo, Kenya, South Africa, and Sudan. These results suggest that, in many contexts, especially in developing or less developed countries, energy consumption does not play a primary role as a causal factor driving economic growth.

The third perspective proposes the existence of a bidirectional causal relationship between energy consumption and economic growth. This implies that these two factors are interdependent and can be complementary in shaping energy and economic development policies. According to this view, on one hand, economic growth drives the demand for energy to meet production and consumption needs; on the other hand, energy consumption serves as an essential input, contributing to increased output and stimulating economic development. This reciprocal relationship necessitates a more holistic approach from countries when formulating development and energy utilization policies.

Numerous empirical studies have affirmed this perspective. Notably, research by Belke et al. (2011) on 25 OECD countries during 1981-2007 found a bidirectional causal relationship between energy consumption and real GDP. Lee et al. (2008) also indicated a bidirectional causal link between these two variables across a multi-country dataset, using cointegration and Granger causality tests. Ouedraogo (2010), with data from Burkina Faso, confirmed the existence of a two-way relationship, showing that the country's economy both depends on energy and drives energy consumption as it develops.

Several studies in Africa have yielded similar results. Akinlo (2008) observed a bidirectional causal relationship in Gambia, Ghana, and Senegal. Ozturk et al. (2010) explored this relationship in middle-income countries, emphasizing that growth and energy are mutually reinforcing in the long run. Esso (2010) found a bidirectional relationship in Côte d'Ivoire, indicating a significant interdependence between GDP and energy consumption.

Additionally, Wolde-Rufael's (2005; 2006) studies further elucidated this phenomenon in several African nations: Gabon, Zambia, Egypt, and Morocco all demonstrated clear bidirectional causal relationships, especially as these countries undergo industrialization and increase production capacity.

More recently, several studies have continued to provide evidence for the argument of a bidirectional relationship between energy consumption and economic growth, particularly in developing or emerging economies. Okoye et al. (2021) analyzed data from countries within the Commonwealth of Independent States (CIS), discovering a robust bidirectional causal relationship between energy consumption and GDP. This suggests that transitional economies are increasingly reliant on energy as a key production factor, while economic growth simultaneously increases pressure on energy demand.

Another study by Iqbal and Noor (2023) employed a Fixed Effects panel regression model and Granger causality tests to investigate the link between energy consumption and GDP in 10 emerging economies, including Malaysia and Thailand, during 2000–2020. The results revealed a bidirectional causal relationship, which was particularly evident in Southeast Asian nations, where rapid industrialization and urbanization demand substantial energy volumes to sustain growth.

A significant contribution to this perspective also comes from Jia et al. (2023), whose research covered 45 countries in the "Belt and Road" initiative, including China, Vietnam, and Indonesia. The authors applied a dynamic panel regression model with the Generalized Method of Moments (GMM) to address potential endogeneity issues among variables. Focusing on renewable energy consumption and GDP from 2005-2020, their study showed that renewable energy consumption positively influences economic growth and vice versa. Notably, in East Asian countries like China and Vietnam – where investment in green energy is rapidly increasing – the bidirectional causal relationship was clearly confirmed. This demonstrates that sustainable energy policies can simultaneously promote economic growth and improve resource efficiency.

In summary, the relationship between energy consumption and economic growth has been a topic of significant academic interest, yet a clear consensus remains elusive. Some studies indicate that energy consumption positively impacts economic growth, while others point to a negative effect or suggest a reverse causality, where economic growth drives energy consumption. Furthermore, some empirical evidence even shows no causal relationship between these two variables. This inconsistency in research findings largely stems from differences in geographical scope, development stages, economic structures, energy policies, and the quantitative analytical methods employed.

Within this context, the "energy-led growth hypothesis" continues to receive substantial support from numerous studies, especially when considering the role of energy—including both traditional and renewable sources—in fostering economic growth in both the short and long run. This perspective is particularly relevant for developing economies such as those in the East Asia and Pacific region, where rapid industrialization and urbanization are taking place. This process entails a significant increase in energy consumption, which becomes a crucial factor driving growth.

Nevertheless, it is also important to note that the impact of energy consumption on economic growth can vary by country, depending on its energy mix, development level, and policy orientation. In a global context increasingly geared towards sustainable development and greenhouse gas emission reduction, many nations are striving to decrease energy consumption while still maintaining growth, underscoring the vital role of energy efficiency and green transitions.

Based on the theoretical and practical foundations outlined above, this study proposes three hypotheses:

- $H_1$: Energy consumption (ENC) has a negative impact on economic growth in the East Asia and Pacific region.
- $H_2$: Energy consumption (ENC) has a positive impact on economic growth in the East Asia and Pacific region.
- $H_3$: Energy consumption (ENC) has no impact on economic growth in the East Asia and Pacific region.

## 3. METHODS AND DATA

### 3.1. Econometric Models

To assess the impact of energy consumption on economic growth, we will establish an econometric model based on the neoclassical production function as follows:

$$Y = f(K,L) \quad (1)$$

Where Y denotes the level of output (i.e., GDP), K represents capital stock, and L represents labor input. Energy consumption (ENC) is incorporated into model (1). The production function is as follows:

$$Y = f(ENC,K,L) \quad (2)$$

From model (2), Y is denoted by economic growth (GRW). The capital factor (K) is represented by Domestic Investment Capital (GCF) and Foreign Direct Investment (FDI). L is denoted by Labor (LAR). Thus, we have:

$$GRW_{it} = \beta_0 + \beta_1 ENC_{it} + \beta_2 GCF_{it} + \beta_3 FDI_{it} + \beta_4 LAR_{it} + \mathcal{E}_{it} \quad (3)$$

Next, the following control variables are introduced to ensure the reliability of the model: Public Consumption Expenditure (GCE) (Solomon and Klyton, 2020; Oyebowale and Algarhi, 2020; Hadush et al., 2023); Private Consumption Expenditure (HCE) (Pandey and Bishnoi, 2023); Economic Openness (EO) (Mazurek, 2017; Hadush et al., 2023); and Inflation (INF) (Samsuddin and Amar, 2020; Aung, 2023; Hadush et al., 2023). Our proposed research model is as follows:

$$GRW_{it} = \beta_0 + \beta_1 ENC_{it} + \beta_2 GCF_{it} + \beta_3 FDI_{it} + \beta_4 LAR_{it} + \beta_5 GCE_{it} + \beta_6 HCE_{it} + \beta_7 OPEN_{it} + \beta_8 INF_{it} + \mathcal{E}_{it} \quad (4)$$

Where $i$ and $t$ represent the country and year, respectively; $\beta_0$ is the constant term/intercept; $\beta_1 - \beta_8$ are the regression coefficients, and $\mathcal{E}_{it}$ is the error term. Details of the variables in the model are described in Table 1.

In empirical economics research, economic growth is typically measured by the annual percentage change in Gross Domestic Product (GDP), both in nominal and real terms. This is a common indicator reflecting the size and growth rate of an economy over time. However, to enhance comparability across countries and regions with varying population sizes, many studies opt for GDP per capita instead of total GDP. According to Bjork (1999), the growth rate of GDP per capita is a more appropriate proxy for assessing the living standards and economic progress of individuals. Therefore, this study uses GDP per capita growth (annual %) as the representative indicator for economic growth.

Regarding energy consumption, the variable Energy use (kg of oil equivalent per capita) is employed to reflect the per capita energy consumed, converted into oil equivalent units. This variable helps clarify the relationship between energy demand—a crucial factor in production and consumption activities—and long-term economic growth.

The relationship between energy consumption and economic growth is examined through the regression coefficient $\beta_1$ in the quantitative analytical models. Specifically, if $\beta_1$ is positive and statistically significant, it indicates that energy consumption has a positive impact on economic growth. Conversely, if $\beta_1$ is negative and statistically significant, energy consumption is considered a hindrance to growth. In cases where the $\beta_1$ coefficient is not statistically significant, it can be concluded that there is no substantial relationship between energy consumption and economic growth in the East Asia and Pacific region.

**Table 1: Describe the variables in the research model**

| Variables | Symbol | Measurement |
|---|---|---|
| Dependent variable | | |
| Economic growth | GRW | GDP per capita growth (annual %) |
| Explanatory variables | | |
| Energy consumption | ENC | Energy use (kg of oil equivalent per capita) |
| Control variables | | |
| Domestic investment capital | GCF | Gross capital formation (% of GDP) |
| Foreign direct investment | FDI | Foreign direct investment, net inflows (% of GDP) |
| Public consumption expenditure | GCE | General government final consumption expenditure (% of GDP) |
| Private consumption expenditure | HCE | Households and NPISHs final consumption expenditure (% of GDP) |
| Labor | LAR | Labor force, total/Population, total |
| Open economic | OPEN | Exports of goods and services (% of GDP) + Imports of goods and services (% of GDP) |
| Inflation | INF | Inflation, consumer prices (annual %) |

To estimate and test the model, the study successively applies three methods: Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE). After implementing these models, the author conducts an F-test to determine the suitability between the OLS and FE models, and simultaneously uses the Hausman test to choose between the FE and RE models—two commonly applied methods in panel data. The results from these tests help identify the most appropriate estimation model for the data characteristics.

Next, to ensure the reliability of the results, the study checks for violations of classical regression assumptions such as heteroskedasticity using the Modified Wald test, and autocorrelation using the Wooldridge test. When these issues are detected, the author employs the Feasible Generalized Least Squares (FGLS) method for correction, aiming to provide more consistent and efficient estimates.

All estimation and testing results are presented in detail in Tables 2 and 3. These results play a pivotal role in determining the nature and magnitude of the relationship between energy consumption and economic growth in the East Asia and Pacific region.

## 3.2. Sample and Data

The sample in this study includes all 37 countries in the East Asia and Pacific region as classified by the World Bank. Data for this paper were collected from the World Development Indicators (WDI) database and the International Energy Agency (IEA) for the period from 2001 to 2024. The data are described in Table 4.

**Table 2: Results of model estimation and testing**

| Variables | Coef/P-value | | |
|---|---|---|---|
| | OLS | FEM | REM |
| ENC | −0.001/0.000 | −0.001/0.381 | −0.001/0.001 |
| GCF | 0.111/0.000 | 0.070/0.023 | 0.087/0.001 |
| FDI | 0.026/0.548 | 0.055/0.230 | 0.033/0.452 |
| GCE | 0.024/0.120 | 0.099/0.000 | 0.056/0.004 |
| HEC | −0.042/0.000 | −0.087/0.000 | −0.051/0.000 |
| LAR | 0.058/0.000 | −0.066/0.484 | 0.066/0.000 |
| OPEN | 0.007/0.035 | 0.036/0.000 | 0.014/0.001 |
| INF | −0.000/0.999 | −0.053/0.002 | −0.024/0.140 |
| Constant | −0.548/0.250 | 3.314/0.316 | −0.857/0.219 |
| F | | 0.000 | |
| Hausman | | 0.000 | |
| Wooldridge | | 0.614 | |
| Modified Wald | | 0.000 | |

**Table 3: Cross-sectional time-series FGLS regression**

| Variables | Coefficient | Std-error | Z | P>\|Z\| | (95% Confidence interval) | |
|---|---|---|---|---|---|---|
| ENC | −0.0003 | 0.0001 | −5.25 | 0.000 | −0.0004 | −0.0002 |
| GCF | 0.1423 | 0.1419 | 10.03 | 0.000 | 0.1145 | 0.1702 |
| FDI | 0.0642 | 0.0293 | 2.19 | 0.028 | 0.0068 | 0.1216 |
| GCE | −0.0733 | 0.0166 | −4.42 | 0.000 | −0.1057 | −0.0408 |
| HEC | −0.0133 | 0.0059 | −2.27 | 0.023 | −0.0248 | −0.0018 |
| LAR | 0.0232 | 0.0079 | 2.92 | 0.003 | 0.0076 | 0.0387 |
| OPEN | 0.0001 | 0.0021 | 0.01 | 0.994 | −0.0042 | 0.0042 |
| INF | 0.0062 | 0.0117 | 0.53 | 0.595 | −0.0167 | 0.0291 |
| cons | 0.1608 | 0.3379 | 4.48 | 0.634 | −0.5014 | 0.8231 |
| F-test | | | | 0.000 | | |

The data used in this study reflects a diverse and heterogeneous picture of economic indicators across countries and over time. The detailed descriptive statistics for the variables are presented in Table 4.

The dependent variable in the study is economic growth (GRW), measured as the annual percentage change in GDP per capita. The average value of GRW across the entire sample is 2.1%, with the lowest recorded growth at −37.2% and the highest at 76.0%. This large disparity between the minimum and maximum values indicates significant fluctuations in economic growth within the region, reflecting considerable differences in economic, political, and policy contexts among countries and across various periods.

Energy consumption (ENC), the primary explanatory variable, is measured in kilograms of oil equivalent per capita. The average value for ENC is 1,132.7 kg/person, ranging from a minimum of 0 to a maximum of 9,645.9 kg/person. This highlights substantial differences in the level of industrialization, economic structure, and access to energy resources among countries in the region.

Additionally, several other control variables were included in the model. Specifically, domestic investment capital (GCF) has an average value of 16.9% of GDP, ranging from 0% to 70.3%. Foreign direct investment (FDI) averages 3.7% of GDP, with a minimum of -7.6% and a maximum of 44.6%, indicating significant variations in the ability of countries to attract FDI. The labor variable (LAR), measured as the labor force as a percentage of the population, has an average value of 36.1%, ranging from 0% to 62.0%.

Public consumption expenditure (GCE) averages 11.9% of GDP, with a range from 0% to 147.7%, while private consumption expenditure (HCE) averages 40.6% of GDP, with values from 0% to 106.4%. Economic openness (OPEN) averages 87.1% of GDP, with a very wide range from 0% to 442.6%, reflecting significantly different levels of international integration among the region's economies. Inflation (INF) has an average value of 4.3% per year, fluctuating from -4.0% to 268.2%.

**Table 4: Descriptive statistics of variables data**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| GRW | 888 | 2.139 | 6.016 | −37.216 | 76.021 |
| ENC | 888 | 1,132.7 | 1,911.7 | 0 | 9,645.9 |
| GCF | 888 | 16.965 | 14.559 | 0 | 70.335 |
| FDI | 859 | 3.645 | 5.985 | −7.596 | 44.551 |
| GCE | 888 | 11.866 | 16.064 | 0 | 147.735 |
| HEC | 888 | 40.556 | 31.272 | 0 | 106.400 |
| LAR | 888 | 36.135 | 20.039 | 0 | 62.020 |
| OPEN | 888 | 87.143 | 80.017 | 0 | 442.620 |
| INF | 888 | 4.334 | 12.254 | -4.009 | 268.151 |

Overall, the descriptive statistics reveal considerable variability among countries and across years, reflecting the heterogeneity in economic characteristics, policies, and development conditions within the East Asia and Pacific region. The 24-year study period further emphasizes the spatial and temporal diversity of the dataset, providing a suitable foundation for analyzing the dynamic relationship between energy consumption and economic growth in the regional context.

## 4. RESULTS AND DISCUSSION

Before proceeding with model estimation, we checked for multicollinearity among the independent variables using STATA version 14, with panel data from 37 countries in the East Asia and Pacific region during 2001–2024. The correlation coefficient matrix, presented in Table 5, provides information on the degree of linear correlation between the variables in the research model. Correlation coefficients reflect the positive or inverse relationship between two quantitative variables but do not imply causality.

According to common evaluation thresholds, if the correlation coefficient between two independent variables exceeds 0.8, severe multicollinearity may occur, potentially distorting estimation results. However, the analysis results indicate that all correlation coefficients between pairs of independent variables are less than 0.7, implying a low and non-alarming level of correlation. Therefore, we can conclude that the research model does not suffer from severe multicollinearity, ensuring the reliability of subsequent regression estimates.

Next, the study proceeds to estimate the model (Model 4) using three common methods in panel data analysis: Ordinary Least Squares (OLS), Fixed Effects Model (FEM), and Random Effects Model (REM). The goal of using all three methods simultaneously is to compare and select the most appropriate estimation model for the research data. Subsequently, to ensure the accuracy of the results, we conducted tests for important assumptions in the regression model, including tests for heteroskedasticity and autocorrelation. The detailed results of these estimations and related tests are specifically presented in Table 2.

**Table 5: Matrix of correlation coefficients of variables**

| | GRW | ENC | GCF | FDI | GEC | HEC | LAR | OPEN | INF |
|---|---|---|---|---|---|---|---|---|---|
| GRW | 1.000 | 0.017 | 0.222 | 0.154 | 0.108 | 0.085 | 0.211 | 0.124 | 0.040 |
| ENC | 0.017 | 1.000 | 0.381 | 0.170 | 0.140 | 0.111 | 0.405 | 0.255 | −0.064 |
| GCF | 0.222 | 0.381 | 1.000 | 0.357 | 0.517 | 0.691 | 0.508 | 0.365 | 0.047 |
| FDI | 0.154 | 0.170 | 0.357 | 1.000 | 0.113 | 0.226 | 0.274 | 0.585 | 0.034 |
| GCE | 0.108 | 0.140 | 0.517 | 0.113 | 1.000 | 0.531 | 0.144 | 0.179 | −0.004 |
| HEC | 0.085 | 0.111 | 0.691 | 0.226 | 0.531 | 1.000 | 0.338 | 0.355 | 0.019 |
| LAR | 0.211 | 0.405 | 0.508 | 0.274 | 0.144 | 0.338 | 1.000 | 0.161 | 0.105 |
| OPEN | 0.124 | 0.255 | 0.365 | 0.585 | 0.179 | 0.355 | 0.161 | 1.000 | 0.003 |
| INF | 0.040 | −0.064 | 0.047 | 0.034 | −0.004 | 0.019 | 0.105 | 0.003 | 1.000 |

The results presented in Table 2 indicate that the F-test value in the Fixed Effects (FE) model is 0.000, which is less than the 5% significance level. This suggests that the FE model is more appropriate than the Ordinary Least Squares (OLS) method. Subsequently, a Hausman test was conducted to choose between the FE model and the Random Effects (RE) model. The test result shows a p-value of 0.000, which is less than 0.05, thus confirming that the FE model is more suitable than the RE model for this study.

Additionally, to evaluate the assumptions of the regression model, we performed the Modified Wald test to check for heteroskedasticity. The result shows a p-value of 0.000, less than the 5% significance level, indicating the presence of heteroskedasticity in the FE model. Meanwhile, the Wooldridge test for autocorrelation yielded a P-value of 0.614, which is >0.05, suggesting no autocorrelation in the model.

To address the issue of heteroskedasticity and ensure the accuracy of the estimated coefficients, the study employs the Feasible Generalized Least Squares (FGLS) method. The detailed estimation results using the FGLS method are presented in Table 3.

Table 3 presents the estimation results from the Feasible Generalized Least Squares (FGLS) method, assessing the impact of energy consumption on economic growth in East Asia and Pacific countries. The p-value of the F-test is 0.000, which is less than the 5% significance level, indicating the model's good fit.

The results in Table 3 show that energy consumption (ENC), measured by Energy use (kg of oil equivalent per capita), has an impact on economic growth in the East Asia and Pacific region. Specifically, the estimated coefficient for energy consumption (ENC) is −0.0003. This coefficient is negative and statistically significant at the 1% level. Thus, energy consumption (ENC) has a negative (inverse) impact on economic growth in East Asia and Pacific countries. This finding suggests that a 1% reduction in energy consumption leads to an average increase of 0.0003 percentage points in economic growth in this region. The study has discovered an inverse impact of energy consumption on economic growth. This implies that reducing energy consumption not only does not negatively affect GDP but also contributes to promoting economic growth in East Asia and Pacific countries in general.

This result has also been supported by some empirical studies, such as Lee and Chang (2008) and Baranzini et al. (2013). This finding aligns with hypothesis $H_1$, implying a potential decoupling between GDP growth and energy consumption. Therefore, energy conservation policies are not necessarily expected to have a negative impact on the economic growth of East Asia and Pacific countries.

However, this result contradicts some other studies. These studies have shown that energy consumption has either a positive (direct) impact or no impact on economic growth (Chontanawat et al., 2008; Wolde-Rufael, 2009; Khan et al., 2021; Okoye et al., 2021). The difference in the findings of these studies compared to the current research is primarily due to the selection of data (spatial and temporal scope). Some studies were conducted in developed countries, while others were carried out in developing or less developed countries, leading to differing findings. Additionally, variations in political institutions, history, specific characteristics, and national leadership capabilities are also factors influencing the findings in these papers. These perspectives may differ because historical energy scarcity-imposed constraints on growth, but the increased availability of modern energy sources has reduced the importance of energy as a growth driver. This empirical result challenges the concerns that reducing energy consumption might harm economic growth.

The East Asia and Pacific region comprises 37 countries, most of which are developing nations. According to Chontanawat et al. (2008), the causal relationship from energy to GDP is more prevalent in developed countries than in developing countries. This implies that policies aimed at reducing energy consumption to curb emissions are likely to have a greater impact on the GDP of developed countries than on developing ones. Since developing countries are nascent economies that developed later than industrialized nations, they are less dependent on traditional energy sources and are gradually replacing them with modern ones, thereby diminishing the importance of energy consumption as a driver of economic growth (Stern, 2019).

In addition to the primary impact of energy consumption on economic growth, Table 3 also reveals reliable estimation results from other independent variables.

The variable Domestic Investment Capital (GCF), measured by Gross Capital Formation (% of GDP), has a regression coefficient of 0.14. This coefficient is positive and statistically significant at the 1% level. Thus, Domestic Investment Capital has a positive impact on economic growth in the East Asia and Pacific region. This means that a 1% increase in Domestic Investment Capital leads to an average increase of 0.14 percentage points in economic growth in this region. The positive impact of increased Domestic Investment Capital on economic growth has been demonstrated in numerous empirical studies (Oyebowale and Algarhi, 2020; Batrancea et al., 2021; Aung, 2023). Based on this result, to foster economic growth in the East Asia and Pacific region, it is crucial to enhance domestic capital accumulation and, concurrently, strengthen institutional reforms to improve capital utilization efficiency.

The estimated coefficient for Foreign Direct Investment (FDI) is 0.06, which is positive and statistically significant at the 5% level. Therefore, Foreign Direct Investment (FDI) has a positive impact on economic growth in East Asia and Pacific countries. Indeed, any 1% increase in the FDI ratio leads to an average increase of 0.06 percentage points in economic growth in these countries. The positive impact of increased FDI on economic growth has been substantiated in many empirical studies (Das and Sethi, 2020; Samsuddin and Amar, 2020; Aung, 2023).

The estimated coefficient for Public Consumption Expenditure (GCE) is −0.07, which is negative and highly statistically

significant at the 1% level. Thus, Public Consumption Expenditure (GCE), measured by General Government Final Consumption Expenditure (% of GDP), has a negative impact on economic growth in East Asia and Pacific countries. This indicates that in these countries, the increase in public spending during the study period has been ineffective in promoting economic growth. This result is consistent with studies by Barro (2003) and Pandey and Bishnoi (2023), but it contradicts some studies that found a positive impact of GCE on economic growth (Oyebowale and Algarhi, 2020; Hadush et al., 2023). The discrepancy in these results is attributable to differences in data sources, sample size, geographical scope, and study periods across various research.

The estimated coefficient for Private Consumption Expenditure (HCE) is −0.01, which is negative and statistically significant at the 5% level. Therefore, Private Consumption (HCE), measured by Households and NPISHs Final Consumption Expenditure (% of GDP), has a negative impact on economic growth in East Asia and Pacific countries. This suggests that in these countries, the increase in private consumption during the study period has not contributed to promoting economic growth. This result indicates that consumer spending in the East Asia and Pacific region primarily serves essential needs rather than being directed towards future investment, thus not contributing to economic growth. The negative impact of Private Consumption on economic growth has been demonstrated in empirical research by Pandey and Bishnoi (2023).

The Labor (LAR) variable, measured by the Labor Force, Total/ Population, Total, has a regression coefficient of 0.023. This coefficient is positive and statistically significant at the 1% level. Thus, the labor factor has a positive impact on economic growth in the East Asia and Pacific region during the study period. This means that a 1% increase in labor will lead to an average increase of 0.02 percentage points in economic growth in this region. The positive impact of labor on economic growth indicates that an increase in the labor force as a proportion of the total population contributes to fostering economic growth in the East Asia and Pacific region during the study period. This finding has been demonstrated in numerous empirical studies (Niebel, 2018). Based on this result, to promote economic growth in the East Asia and Pacific region, it is essential to increase the labor force-to-total population ratio while also enhancing the quality of human resources.

## 5. CONCLUSION

This study aimed to investigate the impact of energy consumption on economic growth in the East Asia and Pacific region, utilizing a combination of OLS, FEM, REM, and FGLS models. We used data from 37 East Asia and Pacific countries over a 24-year period from 2001 to 2024.

Our findings reveal that energy consumption in the East Asia and Pacific region during the study period had an inverse relationship with economic growth. Specifically, energy consumption in this region negatively impacted economic growth. From a policy perspective, this suggests that governments in East Asia and Pacific countries should consider energy conservation policies. Our results indicate that reducing energy consumption not only has no adverse effect but can contribute positively to economic growth in the region.

However, it's important to acknowledge that these results are based on a sample of 37 countries in the East Asia and Pacific region. Therefore, while providing general insights, they may not be universally applicable to all individual countries. The impact of energy consumption on economic growth varies across nations, depending on their economic structure and growth trajectory. Each country should develop tailored energy conservation policies that consider its unique circumstances.

Most countries in the East Asia & Pacific region are developing nations. A key advantage for these developing countries is their ability to keep pace with rapid changes in production processes and high-tech manufacturing. This allows them to rely less on traditional energy sources and increasingly adopt modern ones, thereby reducing the importance of energy consumption as a direct driver of economic growth in these nations (Stern, 2019).

Like any empirical study, this research has certain limitations.

Firstly, while our sample includes 37 countries in the East Asia and Pacific region, the specific characteristics of each country differ significantly. Future research could consider segmenting countries based on characteristics such as income levels, population size, or institutional features to explore a wider range of research hypotheses.

Secondly, our study only used one proxy variable for energy consumption: Energy use (kg of oil equivalent per capita). Subsequent research could expand upon this by including other representative variables to further explore the impact of different energy-related factors on economic growth in the East Asia and Pacific region, as well as in other countries, regions, or continents.

Thirdly, due to data limitations, the study period only spanned 24 years, from 2001 to 2024. Future investigations could extend this timeframe to uncover additional interesting insights into the impact of energy consumption on economic growth across various nations and regions globally.

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