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Examining the Causality of Energy Between Growth in Asian Countries: Panel Data Analysis

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Abstract

This study explores the relationship between energy consumption and economic growth in 17 Asian countries using a panel framework. The findings reveal a long-run equilibrium where energy consumption positively influences GDP. In the short run, energy consumption drives economic growth, while in the long run, GDP influences energy consumption. These results highlight the immediate role of energy in economic expansion and the evolving dependence of energy use on sustained economic growth. Short-run causality indicates that energy consumption powers industrial and commercial activities, fueling GDP growth. However, in the long run, economic growth determines energy demand, as structural shifts in production and consumption influence energy needs. These findings emphasize the necessity for balanced energy policies that support economic development while ensuring sustainability. Efficient coordination among countries in implementing energy conservation policies is essential for sustainable economic progress. Regional collaboration can facilitate energy efficiency measures, technology transfers, and renewable energy adoption, mitigating the environmental impact of economic growth. Policymakers should focus on optimizing energy use while fostering economic resilience. Future research should explore sectoral variations in energy consumption and the impact of policy interventions on energy efficiency. Understanding these dynamics will enable policymakers to craft targeted strategies that balance economic expansion with environmental sustainability. By integrating energy efficiency into long-term economic planning, countries can achieve sustainable development while reducing dependency on non-renewable energy sources. The study underscores the importance of strategic energy planning to align with evolving economic structures and long-term growth objectives.

Keywords: energy consumption, economic growth, causality

JEL Codes: Q13, P28

1. INTRODUCTION

The escalating trend in energy consumption across Asian countries has been a consistent phenomenon over the past few decades, driven by factors such as population growth and rapid industrial expansion. Projections indicate a trajectory of continued increase, with anticipated energy consumption reaching 159.3 quadrillion BTU in 2015, 187.8 quadrillion BTU in 2020, 217.0 quadrillion BTU in 2025, 246.9 quadrillion BTU in 2030, and 277.3 quadrillion BTU in 2035. These figures underscore the pressing need for strategic and sustainable energy management policies to address the growing demands and ensure the resilience of energy systems in the face of expanding societal and industrial needs. From 2007 to 2035, Asia exhibits a noteworthy average annual percentage change in energy consumption at 2.8 percent, surpassing that of other regions. In comparison, the Middle Eastern countries show a rate of 2.2 percent, while Central and South America, as well as Africa, both register a lower average annual percentage change at 1.8 percent. These regional differentials underscore the dynamic and robust nature of energy consumption trends in Asia, necessitating tailored and proactive measures for sustainable energy planning and resource management.

China and India, as the primary drivers of both global economic growth and escalating energy demand, stand out as the major consumers of energy. Their persistent leadership in these aspects is evident, with China and India jointly representing approximately 10 percent of the world's total energy consumption in 1990, a figure that surged to 20 percent by 2007. This remarkable increase underscores the substantial role these two nations play in shaping global energy dynamics and emphasizes the need for strategic and sustainable energy management strategies on an international scale. The substantial increases in energy consumption by China and India can be attributed to several factors, notably their rapid population growth, accelerated economic expansion, and extensive industrial development extending into various regions of Asia. The confluence of these elements has propelled both countries to the forefront of energy demand, underscoring the intricate interplay between demographic shifts, economic activities, and the broader regional implications of their energy consumption patterns. Recognizing and understanding these dynamics is pivotal for devising effective and regionally responsive energy policies that align with the evolving landscape of Asia's economic and industrial prowess. The intermittent energy crises, coupled with the depletion of finite energy sources, environmental concerns, and heightened levels of energy consumption, have compelled governments worldwide to intensify their scrutiny and oversight of energy markets, as highlighted by the ECSSR in 2004. This necessitated focus on monitoring and managing energy markets reflects a collective global effort to address the multifaceted challenges posed by energy security, sustainability, and environmental impacts, underscoring the imperative for proactive and informed governance in the realm of energy management. The escalating concerns have garnered heightened attention from governments across Asian countries. This growing focus underscores the recognition of the intricate challenges posed by various facets of energy, such as security, sustainability, and environmental impact. As a response to these multifaceted issues, governments are increasingly prioritizing initiatives and policies aimed at fostering responsible and resilient energy practices. The proactive engagement of Asian governments in addressing these concerns reflects a commitment to navigating the complexities of energy management in a manner that aligns with both national interests and global imperatives. These measures encompass collaborative efforts directed towards energy conservation and the implementation of policies geared towards optimizing energy efficiency. In this context, the examination of the long-term relationship between energy consumption and economic growth has been a subject of vibrant empirical scrutiny. Within the energy economics literature, the question of the direction of causality—specifically, whether the adoption of energy savings hampers or fosters economic growth—has been a highly debated and extensively discussed subject.

A nuanced understanding of the intricate interplay between energy consumption and economic growth holds paramount significance in the formulation of effective and forward-thinking energy and environmental policies. Similar arguments about the structural importance of energy have been highlighted by Ahmad (2018), Iqbal (2018), Okurut and Mbulawa (2018), and Wiafe (2018), whose empirical investigations reinforce the centrality of energy use in shaping macroeconomic trajectories. Delving into the multifaceted relationships and causal dynamics between these two factors not only informs policy decisions but also provides a foundation for developing strategies that balance the imperatives of economic development with the imperative of sustainable resource utilization, a perspective echoed in Clark and Adam (2018), Singh and Kumar (2018), and Luna and Luna (2018). Such

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insights become instrumental in fostering a harmonious synergy between economic prosperity and environmental stewardship, ensuring a resilient and responsible trajectory for energy policies that resonate with both present and future needs (Koocheki, 2018; Kumar, 2018). The "growth" hypothesis, positing causality from energy consumption to economic growth. This pattern is observed in energy-dependent countries, as evidenced by various studies, including those conducted by Yu and Choi (1985) for the Philippines, Masih and Masih (1996) for India, Asafu-Adjaye (2000) for India and Indonesia, Soytas and Sari (2003) for Turkey, France, Japan, and Germany, and Lee (2005) for a panel of eighteen developing countries. This logic aligns with findings from Ali and Audi (2016), who emphasize the broader macroeconomic significance of energy dynamics. The "conservation" hypothesis posits a causality in which GDP Granger-causes energy consumption. This pattern is evident in studies such as those by Kraft and Kraft (1978) for the United States, Abosedra and Baghestani (1989) for the US, Cheng and Lai (1997) for Taiwan, Cheng (1999) for India, and Ang (2008). In line with this perspective, Ali and Ahmed (2014), Ali and Bibi (2017), and Ali (2018) argue that well-structured economic progress can reduce the pressure on energy systems. With this objective in mind, policies aimed at reducing greenhouse emissions, and consequently lowering energy consumption and waste, may be implemented without adversely affecting real GDP.

The "neutrality" hypothesis—suggesting a lack of Granger-causality between energy consumption and GDP—is explored in studies conducted by Yu and Hwang (1984) as well as Altinay and Karagol (2004). This hypothesis underscores the complexity of the relationship between energy utilization and economic growth. Similar neutrality findings have been reported by Maurya (2018) in mutual fund–energy interactions and Siddiqi (2018) in sectoral investment dynamics, emphasizing that economic activity may proceed independently of energy use under certain conditions. The "feedback" hypothesis postulates an interdependent relationship between energy consumption and GDP, proposing the existence of bi-directional causality. Studies by Hwang and Gum (1991), Yang (2000), Oh and Lee (2004), and Climent and Pardo (2007) provide insights into this pattern. The recognition of bidirectional causality is consistent with the arguments of Ali and Rehman (2015), Ali et al. (2016), and Sajid and Ali (2018), who note interdependence between economic activity and resource utilization patterns. The existing literature has not reached a consensus on the inherent nature of causal relationships between energy consumption and economic growth. Comparative analyses by Manzoor and Agha (2018), Hussain (2018), and Riaz and Safdar (2018) also highlight the variability of causal structures across economies. In this intricate context, policies geared towards the gradual reduction of energy consumption must carefully consider the potential causal linkages between economic growth and energy consumption. Recognizing the diverse patterns and hypotheses surrounding this relationship becomes imperative for the formulation of effective and context-specific strategies that align with the dynamic interplay between energy dynamics and economic development (Asif & Simsek, 2018; Wali, 2018). A nuanced approach to policy formulation, acknowledging the complexity of these linkages, is essential to foster sustainable energy practices without compromising economic growth, an argument reinforced by Iqbal and Raza (2018) regarding macroeconomic balance in Pakistan. In response to this evolving landscape, the objective of this study is to undertake a comprehensive empirical re-examination, delving into the direction of causality and the sign (in the panel sense) between energy consumption (EC) and real GDP across seventeen Asian countries. This approach is consistent with earlier macroeconomic and environmental assessments conducted by Ali (2011), Ali (2015), and Ali and Audi (2018). The determination of causality serves as a crucial foundation, paving the way for the adoption of judicious energy development policies tailored to the specific dynamics of each country. The insights gained from this empirical analysis will contribute to a more informed and nuanced approach to energy policymaking, aligning with the distinctive needs and characteristics of the respective Asian nations under consideration. The methodological structuring of such studies has also been discussed in Ali and Zulfiqar (2018) and Marc and Ali (2016), reinforcing the importance of econometric rigor. Accordingly, the subsequent sections of this paper unfold as follows. Section 2 offers a succinct yet intuitive overview of the applied econometric methodology. Section 3 delves into a comprehensive discussion of the results obtained. Subsequently, Section 4 outlines pertinent policy implications and draws conclusions based on the findings.

2. ECONOMETRIC MODELING

The initial and fundamental step in the estimation of dynamic panels involves subjecting the relevant variables to unit root tests. In this context, several seminal studies have utilized joint panel unit root tests to assess the stationarity of these variables. Pioneering works, such as those by Maddala and Wu (1999, MW), Hadri (2000, HADRI), Levin et al. (2002, LLC), and Im et al. (2003, IPS), have significantly contributed to the robustness of the unit root testing framework within the context of dynamic panel analyses. These tests serve as a critical diagnostic tool, guiding researchers in determining the order of integration of the variables and laying the groundwork for subsequent dynamic panel estimations. The null hypothesis common to all joint panel unit root tests, except for the HADRI test, asserts the presence of a unit root in the panel series, indicating non-stationarity. It is worth noting that the HADRI test deviates from the conventional augmented Dickey Fuller (ADF) test. Instead, it adopts an approach akin to the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS)-based LM statistic. In the HADRI test, the null hypothesis asserts level (trend) stationarity, with the alternative hypothesis suggesting difference stationarity within the panel. This distinctive feature of the HADRI test provides a nuanced perspective on stationarity considerations, offering a valuable tool in the assessment of unit roots within dynamic panel analyses. Comparing the outcomes derived from a diverse array of panel unit root tests can offer valuable insights into the stationarity properties of the data under scrutiny. When both procedures either fail to reject the null hypothesis or simultaneously reject it, it yields mixed results, indicating a scenario where the data may not provide sufficient information for conclusive determination. This underscores the nuanced nature of assessing stationarity, prompting a careful consideration of the various unit root tests and their outcomes to arrive at a comprehensive understanding of the data's characteristics.

Conversely, when an ADF-type panel unit root test rejects the null hypothesis while a KPSS-type test fails to reject it, a higher level of confidence emerges, indicating that the series under examination is likely stationary. This divergence in results between ADF and KPSS tests provides a valuable diagnostic tool, offering a more refined understanding of the stationarity properties within the dataset. Such complementary outcomes enhance the robustness of the analysis and contribute to a more nuanced interpretation of the time-series characteristics in question. Given the increasing prevalence of panel-based unit root tests in the literature, readers keen on a more in-depth exploration are encouraged to consult the original articles of these tests. Comprehensive discussions, methodologies, and theoretical underpinnings are often detailed in the primary sources, offering a deeper understanding of the intricacies involved in employing these tests for assessing the stationarity of time-series data in

panel settings. Subsequently, our analysis extends to the investigation of potential long-run equilibrium relationships among the variables under scrutiny. To conduct this examination, we employ panel cointegration tests proposed by Pedroni (1999, 2001, 2004) and Kao (1999). These established tests serve as valuable tools in determining the presence of cointegration, a critical aspect indicating a stable and long-term association among the variables, thereby contributing to a more comprehensive understanding of the underlying economic relationships. Pedroni's approach encompasses the consideration of seven distinct statistics, with four rooted in pooling the residuals of the regression along the within-dimension (panel test) of the panel. Simultaneously, the remaining three statistics are derived from pooling the residuals of the regression along the between-dimension (group test) of the panel. This comprehensive set of statistics allows for a robust assessment of panel cointegration, examining both within-group and between-group dimensions to discern potential long-run equilibrium relationships among the variables.

The within-dimension tests in Pedroni's methodology factor in common time elements and permit heterogeneity across countries. This approach considers potential cointegration with variations across countries, offering a nuanced perspective on the within-group dynamics. On the other hand, the between-dimension tests, often referred to as group-mean cointegration tests, accommodate the heterogeneity of parameters across countries. By doing so, these tests facilitate an assessment of potential cointegration relationships by accounting for variations in parameters among countries within the panel, contributing to a more comprehensive understanding of the long-run equilibrium relationships among the variables. The within-dimension tests in Pedroni's methodology factor in common time elements and permit heterogeneity across countries. This approach considers potential cointegration with variations across countries, offering a nuanced perspective on the within-group dynamics. On the other hand, the between-dimension tests, often referred to as group-mean cointegration tests, accommodate the heterogeneity of parameters across countries. By doing so, these tests facilitate an assessment of potential cointegration relationships by accounting for variations in parameters among countries within the panel, contributing to a more comprehensive understanding of the long-run equilibrium relationships among the variables. The Fully Modified Ordinary Least Squares (FMOLS) procedure is designed to accommodate the inherent heterogeneity present in both transitional serial correlation dynamics and long-run cointegrating relationships. By acknowledging and addressing these variations, FMOLS provides a robust framework for estimating parameters in the presence of diverse and potentially changing conditions across the panel. This adaptability enhances the reliability of FMOLS in capturing the complexities of panel data, ensuring a more accurate representation of the relationships under investigation. In the examination of panel causality, our approach involves estimating a panel-based Vector Error Correction Model (VECM) that incorporates a dynamic error correction term. This method is informed by the analytical framework outlined in Holtz-Eakin et al.'s seminal works from 1988 and 1989. The utilization of a panel-based VECM allows for a comprehensive assessment of causality dynamics, taking into account both the contemporaneous relationships and the adjustments toward equilibrium over time across the panel of countries or entities under investigation.

3. EMPIRICAL RESULTS

The cointegration test results presented in Table 1 offer robust evidence of long-run equilibrium relationships between energy consumption and economic growth across Asian countries, based on a panel data framework. Using several test statistics under the Pedroni and Kao methodologies, this analysis assesses whether non-stationary panel variables—presumably energy use and economic output—move together over time, implying a stable long-run relationship despite short-term fluctuations. The presence of cointegration in this context supports the theoretical premise that energy consumption and economic growth are interdependent in the long term, a hypothesis widely investigated in the energy-growth literature (Apergis & Payne, 2009). The Pedroni panel cointegration test results demonstrate significance across multiple dimensions. The panel v-statistic has a value of 4.251 with a p-value of 0.005, suggesting strong evidence against the null hypothesis of no cointegration. This statistic is particularly sensitive to panel-wide co-movement and, in this case, confirms that the energy-growth relationship is not random but systematically interconnected across Asian economies. The panel PP-type statistics and the panel ADF-type t-statistic also indicate significant cointegration, with values of −2.72 ($p = 0.029$), −1.373 ($p = 0.03$), and −4.705 ($p = 0.000$), respectively. These statistics rely on non-parametric and parametric corrections to account for serial correlation and heteroskedasticity, lending further robustness to the findings. Their statistical significance suggests that deviations from the long-term equilibrium path are mean-reverting, even when structural differences exist among countries.

Group mean statistics, which consider cross-sectional independence and heterogeneity, also yield significant results. The group PP-type statistic is 2.636 ($p = 0.033$), the group PP-type t-statistic is 4.999 ($p = 0.000$), and the group ADF-type t-statistic is 3.077 ($p = 0.006$). These findings confirm that long-run cointegration exists not only across the panel as a whole but also within individual country subsets. This supports the argument that both high-income and developing countries within Asia exhibit consistent long-term linkages between energy consumption and economic activity, albeit potentially through different channels. These results align with the diverse energy policy experiences in the region, from energy-intensive growth in China and India to more service-oriented and efficient economies like Japan and South Korea (Chen et al., 2007). The Kao residual-based ADF test provides further confirmation, with a value of 1.599 and a p-value of 0.000, indicating rejection of the null hypothesis of no cointegration. The Kao test, which is based on the Engle-Granger two-step methodology, complements the Pedroni tests by focusing on residual stationarity. Its result strengthens the case for a stable long-run relationship by confirming that the residuals from the estimated panel regression do not follow a random walk. This suggests that shocks to the relationship between energy use and economic growth are temporary, and the variables tend to re-align over time. Collectively, the evidence from these panel cointegration tests confirms that energy consumption and economic growth are cointegrated across Asian economies, implying that any meaningful deviation from their equilibrium relationship is corrected in the long run. This result holds significant implications for energy and macroeconomic policy in the region. First, it suggests that energy infrastructure investments will have lasting effects on economic output, reinforcing the necessity of reliable and sustainable energy access for long-term growth. Second, it indicates that growth-driven energy demand should be managed within a framework of long-term planning that incorporates efficiency, diversification, and environmental sustainability. These findings are particularly relevant given the dual challenge faced by many Asian economies: sustaining rapid economic growth while transitioning toward greener energy systems. The confirmation of cointegration suggests that structural shifts in energy systems—such as renewable adoption or efficiency improvements—must be aligned with long-term economic objectives. Moreover, cointegration findings support the application of vector error correction models (VECMs) and other dynamic panel techniques to examine short-run adjustments toward

equilibrium, allowing researchers to analyze how countries respond to shocks or policy interventions (Narayan & Smyth, 2008). The results in Table 1 affirm the hypothesis of a stable long-term relationship between energy consumption and economic growth in Asian countries. This supports a coordinated approach to energy policy and economic planning, where energy development is recognized not merely as a consequence of economic growth but as a foundational component of its long-term sustainability.

Table 1: Panel Cointegration Tests Results

Test	Value (p-value)
Panel v-statistic	4.251 (0.005)
Panel PP type -statistic	-2.72 (0.029)
Panel PP type t-statistic	-1.373 (0.03)
Panel ADF type t-statistic	-4.705 (0.0)
Group PP type -statistic	2.636 (0.033)
Group PP type t-statistic	4.999 (0.0)
Group ADF type t-statistic	3.077 (0.006)
Test	Value (p-value)
Kao Residual ADF	1.599 (0.0)

The Fully Modified Ordinary Least Squares (FMOLS) estimates presented in Table 2 provide valuable evidence on the long-run elasticity of economic growth with respect to energy consumption across selected Asian countries. Each country's coefficient represents the percentage change in economic output resulting from a one percent change in energy consumption, capturing the long-term influence of energy use on growth. The statistically significant t-statistics (all marked with an asterisk) further reinforce the robustness of the findings. This estimation method is particularly suitable in the context of panel data cointegration because it corrects for both endogeneity and serial correlation, providing reliable inference even in the presence of non-stationary data (Pedroni, 2001). Starting with Bangladesh, the coefficient of 0.923 and a t-statistic of 9.97 suggest a very strong long-run elasticity. This implies that a 1% increase in energy consumption is associated with a 0.923% increase in economic output, highlighting Bangladesh's dependence on energy inputs for sustaining its rapid industrialization and economic growth. As a lower-middle-income country undergoing structural transformation, Bangladesh's result is consistent with empirical findings indicating higher energy-growth elasticity in economies shifting from agrarian to industrial structures (Lee, 2005). Bhutan and Brunei exhibit long-run coefficients of 0.302 and 0.243, respectively, with very high t-statistics, notably 34.203 and 8.898. These suggest significant energy-growth linkages, though of moderate magnitude. Bhutan, with its hydropower-dominated energy system, uses energy both domestically and as an export commodity, which supports its positive growth association. For Brunei, a resource-rich economy reliant on oil and gas, energy consumption is inherently tied to economic performance, but the relatively moderate elasticity suggests a decoupling tendency possibly due to energy efficiency gains or limited diversification (Aqeel & Butt, 2001).

China's coefficient of 0.322 indicates a moderate elasticity of growth with respect to energy, supported by a t-statistic of 2.427. This is in line with its energy policy evolution—while energy has historically fueled China's rapid growth, recent emphasis on energy efficiency and cleaner alternatives has tempered this elasticity. A similar pattern is visible in other East Asian economies like Hong Kong (0.173), Japan (0.49), and Korea (0.216), where energy's contribution to growth is significant but constrained by advanced technology, structural shifts to service sectors, and energy conservation policies. These results reflect the broader trend in developed economies, where energy efficiency and innovation reduce direct dependence on energy input for output expansion (Ang, 2008). India and Indonesia show differentiated elasticities—India with a modest 0.134 and Indonesia with a stronger 0.698. While India's lower coefficient may reflect recent policy emphasis on energy diversification and renewables, Indonesia's higher elasticity reflects continued reliance on fossil fuel-driven industrial growth. These variations underscore the heterogeneity of energy-growth dynamics in developing Asia, shaped by energy resource endowments, industrial policies, and consumption structures. Malaysia (0.2), Philippines (0.857), and Singapore (0.398) reflect varying degrees of energy-growth elasticity, with the Philippines showing one of the highest elasticities among the group. This suggests that electricity and fuel consumption are pivotal in supporting Filipino economic activity, particularly in sectors like manufacturing, services, and transportation. In contrast, Malaysia and Singapore, though highly developed and energy-intensive, show moderate elasticities likely due to efficiency improvements and technology-intensive production systems.

Pakistan's coefficient of 0.264 with a very high t-statistic (38.13) reflects strong statistical significance and a meaningful long-run relationship. This is consistent with Pakistan's historically energy-constrained development pattern, where fluctuations in energy supply often translate directly into variations in industrial and economic performance (Jamil & Ahmad, 2010). Nepal and Sri Lanka, with coefficients of 0.121 and 0.261 respectively, also show statistically significant yet relatively low elasticities, suggesting energy plays a supplementary but not dominant role in output expansion, possibly due to slower industrialization and heavy dependence on non-commercial energy sources. The Maldives' coefficient of 0.314 with a relatively low t-statistic (0.792) is an outlier, indicating weak statistical reliability in the elasticity estimate. This could be due to data limitations, sectoral concentration in tourism, or structural differences in energy use patterns that dilute the energy-growth linkage in this small island economy. The panel estimate of 0.127 with a t-statistic of 44.358 is both statistically significant and economically meaningful. This indicates that, on average across Asian countries in the sample, a 1% increase in energy consumption contributes to a 0.127% increase in GDP in the long run. While the magnitude may seem modest, it reflects a consolidated elasticity that balances higher coefficients in energy-dependent economies with lower ones in more advanced or diversified systems. This average reinforces the conclusion that energy remains a critical driver of economic growth across Asia, but with varying strength depending on national contexts and structural economic characteristics. In sum, the FMOLS results confirm a positive long-run relationship between energy consumption and economic growth across the Asian region, with significant heterogeneity based on development level, energy policy, and structural economic differences. Policymakers should take these differences into account when designing national energy strategies. Countries with high energy-growth elasticities, like Bangladesh and the Philippines,

may prioritize infrastructure investment and energy access expansion, while countries with lower elasticities, such as India and Hong Kong, can focus on efficiency, sustainability, and technological innovation to decouple growth from energy use.

Table 2: FMOLS Estimates

Country	Energy Consumption (t-stat)
Bangladesh	0.923 (9.97)*
Bhutan	0.302 (34.203)*
Brunei	0.243 (8.898)*
China	0.322 (2.427)*
Hong Kong	0.173 (28.096)*
India	0.134 (10.577)*
Indonesia	0.698 (6.671)*
Japan	0.49 (3.083)*
Korea	0.216 (8.572)*
Malaysia	0.2 (10.561)*
Maldives	0.314 (0.792)*
Nepal	0.121 (4.289)*
Pakistan	0.264 (38.13)*
Philippines	0.857 (12.248)*
Singapore	0.398 (8.281)*
Sri Lanka	0.261 (15.341)*
Thailand	0.174 (5.01)*
Panel estimates	0.127 (44.358)*

The results from Table 3 of the panel Granger causality test provide crucial insight into the short- and long-run dynamics between energy consumption and economic growth across the selected Asian countries. The analysis uses a combination of Granger causality testing in first differences (Δ) and error correction terms (ECT) to distinguish between short-run causality, long-run causality, and the direction of adjustment toward equilibrium. This dual framework is critical in panel data settings where relationships may vary across countries but exhibit common dynamic features. In terms of short-run dynamics, the Wald test statistic for the causality from energy consumption to economic growth ($\Delta EC \rightarrow \Delta GDP$) is not reported with a specific χ^2 value but has a p-value of 0.001. This implies a statistically significant causality at the 1% level, indicating that changes in energy consumption Granger-cause changes in economic output in the short run. This direction of causality supports the growth hypothesis, which posits that energy consumption is a driving force behind economic growth. In this context, increased energy availability enables greater industrial activity, transportation, and service provision, which in turn stimulates GDP growth. The empirical evidence here is in line with findings by *Shiu and Lam (2004)* and *Lee and Chang (2007)*, both of which confirm a unidirectional causality from energy consumption to economic growth in Asian economies. In contrast, the causality from economic growth to energy consumption ($\Delta GDP \rightarrow \Delta EC$) is tested via a χ^2 statistic of 2.108 with a p-value of 0.715. This high p-value indicates that changes in GDP do not significantly Granger-cause changes in energy consumption in the short run. This result suggests the absence of feedback or bidirectional causality in the short term. It may reflect the relatively inelastic nature of energy demand in many Asian countries, where energy systems are structured and regulated such that changes in income do not immediately translate into shifts in energy consumption patterns. This aligns with studies such as *Apergis and Payne (2010)*, which found that energy consumption often drives economic activity rather than responding to it, particularly in emerging markets with constrained infrastructure and supply-side limitations.

Turning to the long-run causality, the error correction term (ECT) in the energy consumption equation (ΔEC) is -0.002 with a highly significant t-ratio of -4.056. The negative and statistically significant coefficient confirms the existence of long-run causality running from GDP to energy consumption. In practical terms, this means that even though short-run causality is absent, deviations from the long-run equilibrium are corrected over time via adjustments in energy consumption. This finding is consistent with the feedback hypothesis in the long run, where both energy and output are co-integrated, and energy consumption gradually aligns itself with economic expansion. The small magnitude of the coefficient indicates a slow adjustment process, but the high significance underscores its validity. Studies such as *Narayan and Smyth (2008)* similarly find that while energy may not respond instantly to economic growth, long-term equilibrium adjustments remain significant and economically relevant.

No error correction term is reported for the GDP equation, which implies that the long-run causality from energy consumption to GDP was either statistically insignificant or omitted due to modeling limitations. As such, the long-run dynamics appear to be unidirectional from GDP to energy consumption, contrasting with the short-run unidirectional causality from energy consumption to GDP. This mismatch between short- and long-run dynamics highlights the complexity of the energy-growth nexus. In the short run, energy drives economic expansion; however, in the long run, economic development shapes the energy trajectory, likely through industrial restructuring, technological upgrading, and policy-driven efficiency improvements. Together, the results from Table 3 reveal an asymmetric causality structure. In the short run, energy consumption drives economic growth, emphasizing the importance of uninterrupted energy supply and infrastructure development for immediate output gains. In the long run, however, the causality shifts, with GDP influencing energy use, reflecting how economic development leads to changes in energy demand patterns, efficiency standards, and technological substitution. This dual dynamic structure provides a comprehensive explanation of how energy policy and economic strategy should be aligned across time horizons.

Table 3: Panel Granger Causality Test Results

Dependent Variable	2-statistics	p-value	Coefficient (ECT)	t-ratio
ΔGDP	-	0.001	0.614	
ΔEC	2.108	0.715	-0.002	-4.056

4. DISCUSSION & CONCLUSION

Employing panel estimation techniques for seventeen Asian countries, this paper conducts an empirical examination of the relationship between energy consumption and gross domestic product (GDP). The panel approach allows for a comprehensive analysis that considers both individual country variations and collective trends, providing valuable insights into the intricate dynamics between energy utilization and economic output across the Asian region. Our analysis indicates that the variables exhibited stationarity in their first differences, suggesting they follow an integrated order of 1, commonly denoted as I(1) processes. Furthermore, the panel cointegration results unveil the presence of a long-run equilibrium relationship between the two variables. This finding underscores the likelihood of a stable and sustained association between energy consumption and gross domestic product across the considered panel of Asian countries. The findings from the Fully Modified Ordinary Least Squares (FMOLS) analysis reveal a positive sign associated with the energy consumption variable. This implies that an increase in gross domestic product (GDP) is associated with a corresponding rise in energy consumption. The positive coefficient suggests a direct and proportional relationship, indicating that economic growth in the context of the examined Asian countries is linked to an augmented demand for energy resources.

The results of the Granger causality test indicate the presence of a short-run unidirectional causal relationship running from energy consumption to gross domestic product (GDP). This suggests that changes or fluctuations in energy consumption have a discernible and statistically significant impact on short-term variations in GDP within the examined context of Asian countries. The Granger causality test provides valuable insights into the temporal dynamics between these two variables, highlighting the directional influence from energy consumption to economic output in the short run. The implications drawn from the Granger causality test results suggest a short-run scenario where energy consumption precedes and influences economic growth. This signifies that, in the short term, the economies of the 17 Asian countries under consideration exhibit a dependency on energy, with fluctuations in energy consumption driving changes in economic output. Furthermore, in the long run, the panel results indicate a causality running from GDP to energy consumption, suggesting that over extended periods, the economic growth of these Asian countries plays a significant role in shaping patterns of energy consumption. The observed long-run causality from GDP to energy consumption in the panel reinforces the proposition that energy consumption is a consequence of economic activity, rather than constituting an intrinsic input to production. This additional evidence aligns with the notion that economic growth and structural changes in production patterns drive the demand for energy over the extended term in the context of the examined Asian countries. It underscores the intricate relationship between economic dynamics and energy consumption, shedding light on the nature of their interdependence over varying time horizons.

In the short run, the enactment of energy conservation policies in these Asian countries may result in a notable, albeit temporary, negative impact on economic growth. This suggests that the immediate adjustments and transitions associated with energy conservation measures might temporarily constrain economic activity. However, it is essential to recognize that such short-term effects may be followed by long-term benefits, including enhanced energy efficiency, sustainability, and a more resilient economic foundation. Policymakers need to consider this trade-off when formulating strategies that balance the imperative for immediate economic growth with the longer-term goals of sustainable energy practices. Over the long run, economic development in the Asian countries appears to exhibit reduced dependence on energy. Consequently, fostering cooperation among these nations for the implementation of energy conservation policies emerges as an imperative strategy, one that would not adversely impact GDP. Proactive initiatives focused on research and development in the realm of renewable technologies, especially in response to depleting conventional energy sources, offer a promising avenue. Simultaneously, directing efforts towards enhancing energy transportation facilities and improving overall infrastructure could contribute to heightened delivery efficiency, further aligning with sustainable energy objectives while supporting economic development. This comprehensive approach underscores the potential for synergy between economic growth and sustainable energy practices in the Asian context. Against the backdrop of recent unprecedented surges in energy prices, the depletion of conventional energy sources, and global initiatives such as the Kyoto Protocol, it becomes imperative to establish a steadfast commitment towards the successful implementation of energy conservation policies. The challenges posed by escalating energy costs and environmental concerns necessitate a proactive and concerted effort to prioritize and execute policies that promote energy efficiency, sustainability, and adherence to international agreements. Establishing and reinforcing such commitment at national and international levels will be instrumental in navigating the complexities of the contemporary energy landscape while fostering a resilient and environmentally responsible approach to energy management.

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