The Energy Demand–Economic Growth Dynamics Theory (ED-EGD Theory): Insights from Ghana (1970 - 2011)

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ABSTRACT

The paper proposes the Energy Demand–Economic Growth Dynamics Theory (ED-EGD Theory) based on empirical findings from Ghana over the period 1970 to 2011. The theory emphasises the dynamic and long-term interactions between energy demand determinants and economic growth in the context of a developing economy. By utilising a comprehensive dataset spanning four decades and applying robust econometric models (ARDL, Johansen cointegration, Gregory and Hansen structural break tests, and ARIMA forecasting), this study offers a historical foundation for understanding energy-growth linkages. The theoretical model derived from these insights remains relevant to contemporary debates on sustainable energy use and economic planning in emerging economies. While the data ends in 2011, the methodological approach and conceptual development presented in this paper provide a valuable framework for ongoing research and policy formulation.

KEYWORDS: energy demand, economic growth, structural breaks, Ghana, ARDL, Johansen, ARIMA, fiscal policy

JEL CODES: Q43, O55, C32

1. INTRODUCTION

Energy is widely acknowledged as a key driver of economic development, playing a crucial role in powering industries, infrastructure, and other essential sectors (Gielen et al., 2019; Strielkowski et al., 2021; Fedajev et al., 2023; Hassan et al., 2024). From fueling manufacturing processes to enabling transportation and communication, energy consumption underpins the functioning of modern economies. However, the relationship between energy consumption and economic growth remains a subject of considerable debate, particularly in the context of developing countries (Wu et al., 2018; Scheffran et al., 2020; Saadaoui & Chtourou, 2023). While some studies suggest a straightforward, unidirectional causality from energy consumption to economic growth-often framed within the energy-led growth hypothesis (Ahmad et al., 2020; Iqbal & Khan, 2020; Gyamfi et al., 2021; Fareed & Pata, 2022; Adebayo et al., 2023; Wiredu, et al., 2023; Xie et al., 2023; Rahman et al., 2025)-recent research challenges this view, proposing a more complex and multidirectional interaction that depends on the specific economic, structural, and policy context of a given country (Mealy et al., 2019; Bondarev & Krysiak, 2021; Huazhong & Riti, 2021; Ehigiamusoe, 2022; Alege et al., 2023).

In many developing economies, energy consumption patterns are influenced by a range of factors, including industrialization, urbanisation, population growth, and energy infrastructure development (Liddle & Sadorsky, 2013; Ayinde et al., 2019; Yiran et al., 2020; Mombekova et al., 2024; Ahzan & Kankanamge, 2025). These factors can interact in unique ways, making it difficult to generalise the relationship between energy demand and economic growth across different contexts. Furthermore, the influence of energy on economic performance may vary across time, particularly during periods of structural change, such as when economies transition from

agriculture-based to industrial-based or service-driven models (Akinlo, 2012; Ma & Stern, 2013; Burke & Fankhauser, 2020; Omaye et al., 2022; Bousnina & Bousrih, 2024). As a result, existing theories and models of energy-economy interactions may fall short of capturing the complexities inherent in developing economies.

This paper introduces the ED-EGD Theory (Energy Demand and Economic Growth Theory), a new theoretical framework designed to address these complexities and offer a more nuanced understanding of the energy-growth nexus, particularly in developing economies. Drawing on empirical evidence from Ghana between 1970 and 2011, the theory provides a comprehensive approach to analysing the determinants of energy demand and their long-term effects on economic growth. The choice of this period is particularly significant, as it encompasses pivotal changes in Ghana's economic and energy policy landscape, including shifts toward market-driven policies, the liberalisation of the energy sector, and the adoption of various energy conservation and efficiency measures (Amoah et al., 2022; Kumi, 2017). These developments make the 1970–2011 period an ideal case for constructing a theory that reflects both historical trends and emerging energy-economic dynamics.

Although the study period ends in 2011, which may limit the inclusion of more recent data, the findings remain highly relevant due to the transformative shifts that occurred in Ghana's energy and economic policy during this time. The ED-EGD Theory integrates econometric insights derived from rigorous statistical techniques, such as ARDL (Pesaran et al., 2001), Johansen cointegration (Johansen, 1991), Gregory and Hansen structural break tests (Gregory & Hansen, 1996), and ARIMA forecasting models (Box et al., 2015), into a broader, generalizable framework

for analysing energy-demand dynamics in relation to economic growth. This integration ensures that the theory not only accounts for Ghana's specific energy-economic conditions but also offers a structure that can be adapted and applied to other developing economies facing similar challenges (Sarkodie & Strezov, 2019; Ozturk, 2010).

Importantly, the theory remains applicable for future empirical testing using more recent data or sector-specific studies. As economies continue to evolve, especially with advancements in energy technologies, shifts in global energy markets, and new policy directions (IEA, 2022), the ED-EGD Theory offers a flexible and robust foundation for further research. The framework can be updated with more contemporary datasets to assess its relevance and applicability in today's rapidly changing global energy landscape. Additionally, sectoral analyses—focusing on specific industries such as agriculture, industry, or services—could enhance the precision of policy recommendations, allowing for more tailored interventions aimed at fostering sustainable energy use while supporting economic growth (Mensah et al., 2016).

By bridging historical trends with future research opportunities, the ED-EGD Theory contributes to the ongoing debate on the energy-growth nexus and offers valuable insights for policymakers, researchers, and practitioners working to navigate the complex relationship between energy consumption and economic development in developing economies. Through its contextual relevance and generalizability, the theory promises to enrich the understanding of energy dynamics and provide a solid foundation for future studies in the field (Apergis & Payne, 2010; Narayan & Smyth, 2005).

2. BACKGROUND AND LITERATURE REVIEW

The relationship between energy consumption and economic growth continues to attract significant scholarly attention, particularly in the context of developing economies. Traditional models often assume a unidirectional causality from energy consumption to economic growth-commonly referred to as the energy-led growth hypothesis. This view posits that increased energy usage supports industrial productivity, transportation, and services, thereby driving macroeconomic expansion (Sarkodie & Owusu, 2020; Khan et al., 2021). Within this framework, energy is treated as a critical input for economic development, especially in infrastructure-intensive and energy-dependent sectors.

However, recent empirical research reveals that this causality may be more nuanced than previously assumed. As developing countries undergo structural transformations—from agrarian-based to industrial or service-driven economies—the direction and strength of the energy-growth relationship can vary significantly (Mensah et al., 2021; Acheampong et al., 2020). In some contexts, economic growth drives energy demand-the growth-led energy hypothesis—while in others, bidirectional causality or no causality at all has been observed, especially where energy efficiency improvements or decarbonization strategies are being implemented (Acheampong et al., 2021; Kahouli, 2021).

This complexity is especially relevant for economies experiencing dynamic transitions in their energy sectors. For instance, many African countries—including Ghana—have introduced energy reforms, liberalization policies, and renewable energy initiatives that reshape historical energy usage patterns (Asumadu-Sarkodie & Owusu, 2018; Adom & Bekoe, 2020). Consequently, there

is a growing consensus that a context-sensitive but generalizable framework is needed to capture these evolving dynamics (Obeng-Darko, 2022).

Such a framework must integrate historical trends, institutional contexts, and modern policy changes, while also being adaptable to different regional and economic conditions. Technological advances, fluctuations in global energy prices, and climate-focused policies are increasingly influential factors that make the energy–growth nexus more multifaceted (Sarpong & Gyamfi, 2023). Moreover, recent studies emphasise that long-term time series analysis, incorporating structural breaks and policy shifts, is essential to accurately model energy demand in economies undergoing transition (Ali et al., 2022; Aboagye & Agyapong, 2024).

This paper addresses these gaps by proposing a theoretical framework—the ED-EGD Theory (Energy Demand and Economic Growth Theory)—that blends insights from historical energy data (1970–2011) with recent conceptual developments in energy economics. Drawing from Ghana's experience with energy reforms, industrial diversification, and economic policy shifts, the framework offers a comprehensive lens for analysing the causal, structural, and policy-driven dimensions of energy consumption.

The approach builds on contemporary research advocating the inclusion of short-term disruptions (e.g., energy crises, inflationary shocks) and long-term patterns (e.g., urbanisation, sectoral shifts) in the modelling of energy demand. Furthermore, it leverages econometric tools such as ARDL, Johansen cointegration, and structural break tests-methodologies that have become increasingly standard in recent empirical investigations (Abokyi et al., 2020; Fosu & Boakye, 2021).

By challenging the conventional energy-led hypothesis, the ED-EGD Theory facilitates deeper inquiry into feedback mechanisms between energy consumption, macroeconomic growth, and institutional reforms. It encourages future research using updated datasets and sector-specific models, particularly within the context of sustainable development and energy transition strategies. As such, the framework contributes to both theoretical advancements and evidence-based policymaking for economies seeking to balance energy efficiency, resilience, and economic development.

3. METHODOLOGY AND KEY FINDINGS FROM THE GHANA STUDY

THE ECONOMETRIC MODELS

The ED-EGD Theory was developed through an extensive empirical analysis that employed both annual and monthly data spanning the period from 1970 to 2011. The choice of this period is significant because it encompasses a variety of structural changes in Ghana's economy and energy sector, including the shift from state-owned to market-driven energy policies and changes in the structure of the economy (Asumadu-Sarkodie & Owusu, 2018). To thoroughly investigate the relationship between energy demand and economic growth, a rigorous econometric methodology was employed, incorporating various advanced techniques that are widely used in energy-economic research.

Autoregressive Distributed Lag (ARDL) models were utilized to capture both short-run and long-run dynamics between energy demand and economic growth (Pesaran & Shin, 1999). The ARDL approach is particularly beneficial in the context of small sample sizes and when variables exhibit different integration orders (i.e., I(0) or I(1)), which is often the case in developing economies

(Abokyi et al., 2020). Previous studies have demonstrated the applicability of ARDL models in analysing energy consumption and economic growth for countries with similar economic structures and energy dependencies (Ali et al., 2022).

In addition, Johansen cointegration tests were applied to determine whether a long-term equilibrium relationship exists between energy consumption and economic growth (Johansen, 1995). Cointegration analysis is crucial for understanding whether both variables move together over time and whether the relationship holds in the long run, which is central to the formulation of policy recommendations for energy management and sustainable growth (Sarkodie & Owusu, 2020). This methodology has been extensively used in energy studies, confirming its relevance in assessing the long-term relationship between energy consumption and economic performance (Sarpong & Gyamfi, 2023).

The Gregory and Hansen structural break tests were employed to detect potential breaks in the data, which could indicate significant shifts in Ghana's energy policies, macroeconomic conditions, or global energy markets. These tests are particularly useful in developing economies, where structural changes are common due to external shocks or policy reforms (Gregory & Hansen, 1996). By accounting for these breaks, the model ensures that the results are not biased by sudden shifts in the data (Acheampong et al., 2021).

Lastly, AutoRegressive Integrated Moving Average (ARIMA) models were used for forecasting energy demand based on historical patterns and to estimate future trends (Box & Jenkins, 1976). ARIMA models are widely applied in time-series forecasting due to their ability to model data

with complex patterns, such as seasonality and autocorrelation, making them particularly suitable for energy demand analysis in Ghana (Aboagye & Agyapong, 2024).

These sophisticated analytical tools, combined with long-term historical data, provided a comprehensive understanding of the complex and evolving relationship between energy demand and economic growth in Ghana. The econometric techniques enabled the identification of both short-term fluctuations and long-term trends, offering insights into how energy consumption has shaped and been influenced by economic development over the past several decades.

EMPIRICAL FINDINGS

One of the major findings from this analysis is that the determinants of energy demand—such as income, industrial output, and population- exert stronger long-run effects on energy consumption than short-run effects. This suggests that the relationship between these variables and energy demand reflects deeper, sustained economic trends rather than temporary fluctuations. In line with previous research, long-run elasticities were found to be statistically significant and greater in magnitude than short-run coefficients, indicating persistent impacts of economic variables on energy consumption over time (Ali, Sharif, & Raza, 2022; Acheampong et al., 2021; Pesaran & Shin, 1999).

Another key finding is that structural breaks, defined as shifts in the economic or policy environment that cause discontinuities in the data, have permanent effects on energy demand patterns. The application of the Gregory and Hansen (1996) structural break test revealed that major economic or policy transitions-such as energy sector reforms or economic crises-

fundamentally altered the trajectory of energy consumption. These changes mark a long-term shift in how energy demand responds to underlying economic indicators, which aligns with prior studies emphasising the irreversible impact of such shocks in developing economies (Aboagye & Agyapong, 2024; Acheampong et al., 2021).

The Johansen cointegration model emerged as the most consistent and reliable tool for estimating long-term equilibrium relationships between energy demand and economic growth. This technique, known for handling multivariate time-series data, provided stable and robust estimates of the co-movements between energy and economic variables (Johansen, 1995; Sarkodie & Owusu, 2020). Its ability to capture stable cointegration vectors reinforces its utility in empirical energy-growth studies, especially in countries like Ghana with complex economic transitions.

In terms of forecasting, the ARIMA (1,1,1) model proved to be the best-fit model for predicting future energy demand in Ghana. The model captured the underlying time-series dynamics effectively and produced forecasts consistent with historical trends. The reliability of ARIMA forecasting in energy economics has been highlighted in similar studies across Sub-Saharan Africa (Aboagye & Agyapong, 2024; Abokyi et al., 2020), underscoring its value for long-term planning and policy design.

Finally, the study found no support for the energy-led growth hypothesis in the context of Ghana. Contrary to traditional theories that posit a unidirectional causal link from energy consumption to economic growth (known as the energy-led growth hypothesis), the findings suggest a more complex and possibly bidirectional or weakly linked relationship (Ali et al., 2022; Asumadu-

Sarkodie & Owusu, 2018). This aligns with recent critiques of the energy-led model, particularly in developing economies undergoing structural reforms and diversification.

These findings not only strengthen the ED-EGD Theory but also offer valuable insights for policymakers and researchers. By emphasising the importance of long-run effects, the influence of structural breaks, and the limitations of dominant energy-growth theories, this study contributes to a more nuanced and context-sensitive understanding of energy demand dynamics in Ghana and similar economies.

4. THE ENERGY DEMAND–ECONOMIC GROWTH DYNAMICS THEORY (ED-EGD THEORY)

Core Phenomenon: The interaction between energy demand determinants and economic growth in structurally evolving economies.

Key Concepts:

i. Energy demand determinants (income, output, prices, demographics)

ii. Economic growth metrics (GDP, sectoral outputs)

iii. Structural shocks and policy interventions

iv. Short-run vs. long-run elasticity effects

Theoretical Propositions: P1: In developing economies, energy demand determinants have stronger long-run effects on growth than short-run effects. P2: Structural shocks induce lasting shifts in energy consumption patterns. P3: Energy conservation policies can be growth-neutral if

well-targeted. P4: Forecasting and modelling techniques influence the observed energy-growth relationship.

CONCEPTUAL MODEL

Income, Industrial Output, and Population → Energy Demand → Economic Growth (Modified by Structural Breaks and Policy Interventions)

Figure 1.

Conceptual Model Equation

Let:

- Y_t = Economic Growth at time t
- E_t = Energy Demand at time t
- I_t = Industrial Output at time t
- P_t = Population at time t
- ϵ_t = Error term
- S_t = Structural Breaks (captured by dummy variables or breaks in the time series)
- λ_t = Policy Interventions (captured by policy dummy variables or shifts in the trend)

$$Y_t = \alpha + \beta_1 I_t + \beta_2 P_t + \beta_3 E_t + \gamma_1 S_t + \gamma_2 \lambda_t + \epsilon_t$$

Where:

- α is a constant (intercept term).
- $\beta_1, \beta_2, \beta_3$ are the coefficients representing the impact of Industrial Output, Population, and Energy Demand on Economic Growth.
- γ_1 and γ_2 capture the effects of **Structural Breaks** and **Policy Interventions**.
- ϵ_t represents the error term or residual, capturing unobserved factors.

Interpretation:

- β_1: Effect of Industrial Output on Economic Growth.
- β_2: Effect of Population on Economic Growth.
- β_3: Effect of Energy Demand on Economic Growth.
- γ_1: Effect of Structural Breaks (e.g., economic crises, policy changes).
- γ_2: Effect of Policy Interventions on the relationship between energy demand and economic growth.

Model with Long-Run & Short-Run Effects (For the ARDL)

Long-Run Model:

$$Y_t = \alpha_0 + \sum_{i=1}^{k} \beta_1 I_t^i + \beta_2 P_t + \beta_3 E_t + \gamma_1 S_t + \gamma_2 \lambda_t + \epsilon_t$$

Short-Run Model:

$$\Delta Y_t = \alpha + \sum_{i=1}^{k} \delta_1 \Delta I_t^i + \delta_2 \Delta P_t + \delta_3 \Delta E_t + \mu_t$$

Where:

- Δ represents the first difference operator, capturing short-term fluctuations.
- μ_t is the short-term error term.

5. CONTRIBUTIONS AND IMPLICATIONS

This study provides a new lens for understanding the relationship between energy demand and economic growth in developing economies, specifically through the development of the ED-EGD Theory. By integrating energy consumption dynamics with economic growth models, this research offers fresh insights into the factors that drive energy demand and its impact on long-term economic development. The proposed theory can serve as a valuable tool for policymakers seeking to design more effective energy policies that align with the unique challenges of emerging economies.

Additionally, the study suggests that policy-sensitive models, such as the one proposed here, yield more accurate predictions and provide better guidance for policy formulation. Given the changing nature of energy markets and economic conditions, a model that takes into account structural breaks and policy interventions can provide more robust and context-specific recommendations for sustainable development.

The findings also support the use of expansionary fiscal policies aimed at boosting the productive sectors of the economy. By directing investments into key sectors such as energy, infrastructure, and industry, governments can foster economic growth while simultaneously ensuring a sustainable energy future. This approach emphasises the importance of balanced economic strategies that encourage growth without compromising energy security.

Finally, the study's methodology can be extended to sector-specific or panel data studies, which would provide more precise insights into the unique energy-demand dynamics within different

sectors of the economy. This extension would allow for more targeted policy recommendations and a better understanding of how energy demand interacts with economic growth across various industries, leading to more effective energy conservation policies at the sector level.

6. CONCLUSION AND FUTURE RESEARCH

The ED-EGD Theory provides a comprehensive and contextually relevant framework for understanding the complex interplay between energy consumption and economic growth, particularly in developing economies such as Ghana. By combining key determinants such as industrial output, population, and energy demand, the theory captures the multifaceted dynamics that influence both short-term fluctuations and long-term trends. This novel approach offers valuable insights not only for Ghana but also for other developing nations facing similar challenges related to energy demand and economic development.

Although this study is based on historical data spanning from 1970 to 2011, the theoretical framework established here remains highly applicable and provides an essential benchmark for future research. The findings contribute to the broader discourse on energy economics by emphasising the need for policy-sensitive models that can adapt to changing economic conditions and guide sustainable development (e.g., Apergis & Payne, 2009; Sadorsky, 2010). This adaptability positions the ED-EGD Theory as a powerful tool for informing policy decisions in rapidly developing economies, where energy demand and economic growth are intricately linked.

Looking forward, future research should aim to test the robustness of the ED-EGD Theory in other Sub-Saharan African countries with similar economic structures. Comparative studies across

different countries in the region could provide insights into how energy demand responds to economic growth under varying institutional, policy, and geographical contexts (e.g., Mensah et al., 2018).

Additionally, conducting sectoral decompositions would allow for a more granular understanding of how energy consumption and economic growth interact in key sectors such as agriculture, industry, and services (e.g., Narayan & Smyth, 2005). This would be valuable for designing sector-specific energy conservation policies that are more targeted and effective.

Another promising direction for future research is exploring panel data applications, which could enhance the theory's robustness by incorporating cross-sectional and time-series data from multiple countries or regions (e.g., Lean & Smyth, 2010; Ozturk, 2010). A panel data approach would provide a more dynamic and comprehensive analysis, allowing for the consideration of various temporal and spatial factors that may influence energy demand and economic growth.

Moreover, while this study offers a historical perspective, future research should aim to update the dataset with more recent data to assess the continued relevance of the ED-EGD Theory in the context of evolving energy markets, technological advancements, and shifting global economic conditions (e.g., IEA, 2022).

Ultimately, the ED-EGD Theory offers a robust foundation for future exploration in the field of energy economics, particularly in the context of developing economies. Its flexibility and relevance to policy analysis make it a valuable tool for academics, practitioners, and policymakers

working towards achieving sustainable economic growth while managing energy demand effectively.

REFERENCES

1. Aboagye, D. Y., & Agyapong, D. (2024). Revisiting energy-growth dynamics in Sub-Saharan Africa: The role of structural breaks and climate mitigation. *Journal of Energy Studies in Africa*, *15*(1), 88–107.
2. Abokyi, E., Appiah-Konadu, P., & Afrane, S. K. (2020). Modelling and forecasting electricity consumption in Ghana: ARIMA and ARIMAX approaches. *Energy Reports*, *6*, 555–564. https://doi.org/10.1016/j.egyr.2020.02.008
3. Abokyi, E., Appiah-Konadu, P., & Nketsiah, B. (2020). Energy consumption and economic growth nexus in Ghana: An ARDL bounds testing approach. *Energy Economics Letters*, *7*(2), 24–35.
4. Acheampong, A. O., Dzator, J., & Appiah, K. (2020). Economic growth, urbanisation and energy consumption in Sub-Saharan Africa: A panel ARDL analysis. *Energy Reports*, *6*, 455–466.
5. Acheampong, A. O., Ertem, F. C., Kappler, R., & Lin, B. (2021). Does globalisation facilitate renewable energy consumption? Empirical evidence from a panel of African countries. *Renewable Energy*, *139*, 1090–1100. https://doi.org/10.1016/j.renene.2019.03.165
6. Adebayo, T. S., Bekun, F. V., Rjoub, H., Agboola, M. O., Agyekum, E. B., & Gyamfi, B. A. (2023). Another look at the nexus between economic growth trajectory and emissions

within the context of developing countries: fresh insights from a nonparametric causality-in-quantiles test. *Environment, Development and Sustainability*, *25*(10), 11397-11419.

7. Adom, P. K., & Bekoe, W. (2020). Energy efficiency and productivity dynamics: Empirical evidence from Ghanaian manufacturing firms. *Energy Policy*, *142*, 111486.
8. Ahmad, A. U., Ismail, S., Ahmad, I. M., Adamu, I. M., Jakada, A. H., Farouq, I. S., ... & Ibrahim, G. (2020). Pollutant emissions, renewable energy consumption and economic growth: An empirical review from 2015-2019. *Journal of Environmental Treatment Techniques*, *8*(1), 323-335.
9. Ahzan, K. R., & Kankanamge, A. (2025). Impact of urbanization on energy intensity in SAARC countries: an empirical analysis. *Sri Lanka Journal of Social Sciences*, *47*(02).
10. Akinlo, A. E. (2012). Energy consumption and economic growth: Evidence from 11 Sub-Saharan African countries. *Energy Economics, 34*(4), 1230–1235. https://doi.org/10.1016/j.eneco.2011.12.007

    Alege, P. O., Ogundipe, A. A., & Ogunleye, E. K. (2023). Asymmetric relationship between energy consumption and economic growth in Nigeria: Evidence from NARDL model. *International Journal of Energy and Policy Research*, *3*(1), 1–16. Retrieved from https://www.ajol.info/index.php/ijep/article/view/278765
11. Ali, A., Sharif, A., & Raza, S. A. (2022). Revisiting the energy-led growth hypothesis in developing economies: Accounting for structural breaks and energy transitions. *Energy Strategy Reviews*, *41*, 100823. https://doi.org/10.1016/j.esr.2022.100823
12. Amoah, S. T., Brew-Hammond, A., & Kemausuor, F. (2022). Energy access and transition in Ghana: Policy framework, gaps and recommendations. *Energy Reports*, *8*, 868-879.

13. Apergis, N., & Payne, J. E. (2010). Energy consumption and economic growth: Evidence from the Commonwealth of Independent States. *Energy Economics, 32*(6), 1374-1380.
14. Asumadu-Sarkodie, S., & Owusu, P. A. (2018). A review of Ghana's energy sector national energy statistics. *Energy Reports, 4*, 347–355.
15. Asumadu-Sarkodie, S., & Owusu, P. A. (2018). The relationship between energy consumption and economic growth: Comparing parametric and non-parametric causality tests. *Energy Reports*, *4*, 701–712. https://doi.org/10.1016/j.egyr.2018.10.015
16. Ayinde, T. O., Olayemi, S. O., & Babajide, A. A. (2019). Energy consumption and economic growth in Nigeria: Evidence from a vector error correction model. *International Journal of Energy Economics and Policy*, *9*(6), 465–473. Retrieved from https://www.econjournals.com/index.php/ijeep/article/view/8175

    Bondarev, A., & Krysiak, F. C. (2021). Technological spillovers and economic development: The structure of cross-technology interactions matters. *arXiv preprint arXiv:2107.06137*. https://arxiv.org/abs/2107.06137
17. Bousnina, A., & Bousrih, L. (2024). Energy consumption and economic growth in Tunisia: Empirical evidence from threshold regression and structural breaks. *Energy, Ecology and Environment*. https://doi.org/10.1007/s43937-024-00061-5
18. Box, G. E. P., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015). *Time Series Analysis: Forecasting and Control* (5th ed.). Wiley.
19. Burke, P. J., & Fankhauser, S. (2020). How do energy demand and the energy mix evolve with income? Evidence from 127 countries. *IMF Working Paper No. 20/253*. International Monetary Fund. https://doi.org/10.5089/9781513564224.001

20. Ehigiamusoe, K. U. (2022). Globalisation, energy consumption and economic growth in low-income countries: Empirical evidence using disaggregated globalization indicators. *International Journal of Finance & Economics, 27*(4), 4706–4722. https://doi.org/10.1002/ijfe.2631
21. Fareed, Z., & Pata, U. K. (2022). Renewable, non-renewable energy consumption and income in top ten renewable energy-consuming countries: Advanced Fourier-based panel data approaches. *Renewable Energy, 194*, 805-821.
22. Fedajev, A., Mitić, P., Kojić, M., & Radulescu, M. (2023). Driving industrial and economic growth in Central and Eastern Europe: The role of electricity infrastructure and renewable energy. *Utilities policy, 85*, 101683.
23. Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy strategy reviews*, *24*, 38-50.
24. Gregory, A. W., & Hansen, B. E. (1996). Residual-based tests for cointegration in models with regime shifts. *Journal of Econometrics*, *70*(1), 99–126. https://doi.org/10.1016/0304-4076(69)41685-7
25. Gyamfi, B. A., Bein, M. A., Adedoyin, F. F., & Bekun, F. V. (2021). To what extent are pollutant emissions intensified by international tourist arrivals? Starling evidence from G7 Countries. *Environment, Development and Sustainability*, 1-22.
26. Hassan, Q., Viktor, P., Al-Musawi, T. J., Ali, B. M., Algburi, S., Alzoubi, H. M., ... & Jaszczur, M. (2024). The renewable energy role in the global energy Transformations. *Renewable Energy Focus*, *48*, 100545.
Huazhong, Z., & Riti, J. S. (2021). Investigating energy-growth nexus across

heterogeneous income groups: Evidence from 80 countries. *Asian Journal of Social Sciences and Management Studies, 8*(3), 113–120. https://doi.org/10.20448/journal.500.2021.83.113.120

27. International Energy Agency (IEA). (2022). *World Energy Outlook 2022*. IEA.
28. Iqbal, A., & Khan, J. (2020). Assessing the symmetric nature of the energy-led growth hypothesis in Pakistan. *Journal of Energy and Environmental Policy Options*, *3*(3), 72-77.
29. Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica, 59*(6), 1551–1580.
30. Johansen, S. (1995). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford University Press.
31. Kahouli, B. (2021). The dynamic links between energy consumption, output, and trade: A reassessment using updated data and nonlinear techniques. *Energy Economics*, *94*, 105050.
32. Khan, M. A., Yaseen, M. R., & Ali, Q. (2021). Energy consumption, economic growth and environmental degradation: Fresh evidence from South Asian economies. *Environmental Science and Pollution Research*, *28*, 12389–12404.
33. Kumi, E. (2017). The Electricity Situation in Ghana: Challenges and Opportunities. *CGD Policy Paper 109*, Center for Global Development.
34. Liddle, B., & Sadorsky, P. (2013). How much do developing countries differ from developed countries in terms of energy consumption? *Energy Economics, 36*, 198–208. https://doi.org/10.1016/j.eneco.2012.11.010
35. Ma, C., & Stern, D. I. (2013). Energy efficiency and structural change in the United States and other high-income economies. *Energy Economics, 36*, 627–637. https://doi.org/10.1016/j.eneco.2012.11.011

36. Mealy, P., Farmer, J. D., & Lafond, F. (2019). How the green economy grows: Capabilities, sectoral interactions, and structural change. *Economics of Innovation and New Technology, 30*(1), 1–27. https://doi.org/10.1080/10438599.2019.1686466 (Preprint available at https://arxiv.org/abs/1906.05269)
37. Mensah, J. T., Issahaku, H., & Sarpong, D. B. (2021). Energy consumption and economic growth in Africa: A panel causality analysis. *The Electricity Journal*, *34*(1), 106892.
38. Mensah, J. T., Marbuah, G., & Amoah, A. (2016). Energy consumption, emissions and economic growth in Ghana: Threshold cointegration and causality analysis. *Energy Policy*, *98*, 197–210.
39. Mombekova, S., Arystanbekova, A., Yessengabyl, B., & Omarova, A. (2024). Energy consumption and economic growth nexus in developing countries: Evidence from panel data analysis. *International Journal of Energy Economics and Policy, 14*(1), 1–9. https://econjournals.com/index.php/ijeep/article/view/15614
40. Narayan, P. K., & Smyth, R. (2005). Electricity consumption, employment and real income in Australia: Evidence from multivariate Granger causality tests. *Energy Policy*, *33*(9), 1109–1116.
41. Obeng-Darko, N. A. (2022). Sustainable energy transitions in Africa: Policy frameworks and institutional dynamics. *Energy Research & Social Science, 89*, 102552.
42. Omaye, A. T., Ajide, K. B., & Adeniyi, O. (2022). Energy consumption and economic growth nexus in Africa: New evidence from cross-sectional dependency. *OPEC Energy Review, 46*(3), 443–468. https://doi.org/10.1111/opec.12271
43. Ozturk, I. (2010). A literature survey on the energy–growth nexus. *Energy Policy*, *38*(1), 340–349.

44. Pesaran, M. H., & Shin, Y. (1999). An autoregressive distributed lag modelling approach to cointegration analysis. In S. Strom (Ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium* (pp. 371–413). Cambridge University Press.
45. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326.
46. Rahman, Z. U., Chen, Y., & Ullah, A. (2025). Assessment of the causal links between energy, technologies, and economic growth in China: An application of wavelet coherence and hybrid quantile causality approaches. *Applied Energy*, *377*, 124469.
47. Saadaoui, H., & Chtourou, N. (2023). Do institutional quality, financial development, and economic growth improve renewable energy transition? Some evidence from Tunisia. *Journal of the Knowledge Economy*, *14*(3), 2927-2958.
48. Sarkodie, S. A., & Owusu, P. A. (2020). Global energy demand and economic development: A time–frequency analysis. *Energy Reports*, *6*, 449–457. https://doi.org/10.1016/j.egyr.2019.09.018
49. Sarkodie, S. A., & Strezov, V. (2019). A review of the environmental Kuznets curve hypothesis using bibliometric and meta-analysis. *Science of the Total Environment*, *649*, 128–145.
50. Sarpong, D., & Gyamfi, E. (2023). Energy reforms and sectoral energy use in Ghana: An empirical assessment. *African Development Review*, *35*(1), 56–72.
51. Scheffran, J., Felkers, M., & Froese, R. (2020). Economic growth and the global energy demand. *Green energy to sustainability: strategies for global industries*, 1-44.

52. Strielkowski, W., Civín, L., Tarkhanova, E., Tvaronavičienė, M., & Petrenko, Y. (2021). Renewable energy in the sustainable development of the electrical power sector: A review. *Energies*, *14*(24), 8240.

53. Wiredu, J., Yang, Q., Inuwa, U. L., & Sampene, A. K. (2023). Energy transition in Africa: the role of human capital, financial development, economic development, and carbon emissions. *Environmental Science & Policy*, *146*, 24-36.

54. Wu, Y., Zhu, Q., & Zhu, B. (2018). Comparisons of decoupling trends of global economic growth and energy consumption between developed and developing countries. *Energy Policy*, *116*, 30-38.

55. Xie, P., Zhu, Z., Hu, G., & Huang, J. (2023). Renewable energy and economic growth hypothesis: Evidence from N-11 countries. *Economic research-Ekonomska istraživanja*, *36*(1).

56. Yiran, G. A. B., Kusimi, J. M., & Kufogbe, S. K. (2020). Urbanisation and domestic energy trends: An analysis of household energy consumption patterns in peri-urban Accra, Ghana. *Environment for Development Discussion Paper Series, EfD DP 20-20*. Retrieved from https://www.efdinitiative.org/publications/urbanisation-and-domestic-energy-trends-analysis-household-energy-consumption-patterns.