RENEWABLE ENERGY AND EQUITABLE ENVIRONMENTS – THE CASE OF ASEAN NET ENERGY EXPORTERS

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ABSTRACT

This study investigates the impact of renewable energy transition on growth of income per capita across ASEAN net energy exporters, namely Indonesia, Malaysia, and Brunei over a 33-year period from 1990 till 2022. This study is motivated by growing regional calls for equitable energy transformation while balancing export-driven fossil fuels economies. Based upon the Environmental Kuznets Curve (EKC) and energy transition theory, our research evaluates how renewable energy output (REO) and energy net import (ENI) interact with GDP per capita (GPC) in resource-rich yet transitioning economies. We utilize a balanced panel dataset from World Bank Open Data, integrating it with SAS big data software. Applying fixed and random effects panel regressions, we analyze 99 observations spanning over 33 years involving 3 countries. We control for energy use (EU) and structural country effects. Notably, we observe that fixed effect model is preferred as indicated by the Hausman test. The results show a significant relationship between REO and GPC. It is clear to us that these three ASEAN net energy exporting countries are now focusing on the use of renewable energy in power generation and gradually reduce fossil fuels production activities. Energy security, climate change concerns and the need to meet growing energy demand are the key factors that make these three countries to choose renewable energy transition. Surprisingly, there is an absence of significant relation between ENI and GPC suggesting that investment in a new technology in sustainable clean energy is more important coupled with the initiative to harness equitable environments among the citizens. Our analysis indicates that renewable energy transition contributes not only to foster a sustainable energy system but also signals commitment of these three countries to support the notions of equitable environments. The research findings surprisingly reveal that income growth aligns more with renewable energy scaling rather than energy net import. This study contributes to both theoretical refinement by putting ASEAN energy exporters within energy transition literature and policy design, offering real-time, data-driven insights on renewable energy technological updates. Uniquely, we utilize World Bank's open-source data and incorporate panel data statistical modeling into big data environments, offering replicable predictive analytics for monitoring clean energy equity in ASEAN emerging economies.

KEYWORDS: ASEAN Net Energy Exporters, Predictive Analytics, Renewable Energy Transition, Static Panel Data Analysis, Equitable Environments.

1. INTRODUCTION

The worldwide transition to sustainable energy is escalating as climatic concerns and resource depletion jeopardise economic and environmental stability. In Southeast Asia, energy-exporting nations, namely Indonesia, Malaysia, and Brunei, have a distinct dual challenge: sustaining economic resilience while fostering equal conditions for all inhabitants. This dynamic becomes increasingly vital as the global energy market transitions towards renewable energy obligations and improved living circumstances as outlined in the Paris Agreement (IEA, 2023). ASEAN net fuel exporters hold a contradictory stance. Notwithstanding their abundance of hydrocarbons, these three nations are necessitated to diversify their energy portfolios and dissociate economic progress from fossil fuel extraction. Indonesia and Malaysia have significantly increased their renewable energy output (REO), especially in solar and hydroelectric capacity, while Brunei has experienced minimal REO development (ASEAN Centre for Energy, 2023; Badoe et al., 2022). Nonetheless, the actual influence of these energy transitions on economic performance, as assessed by GDP per capita (GPC), remains inadequately researched. Some studies indicate a positive feedback loop between clean energy investments and income development (Hoof et al., 2023; Sunikka-Blank & Galvin, 2021), whereas others observe marginal or negative economic returns during initial transition phases. Our examination of contemporary research identifies a significant deficiency in region-specific, quantitative evaluations that elucidate the relationship between REO, energy import dependence, and economic results in ASEAN net fuel exporters. A significant portion of global study concentrates on industrialised or non-exporting emerging economies, frequently neglecting the structural and geopolitical complexities of Southeast Asia (Li et al., 2021; Niu et al., 2022). Furthermore, limited research utilises a panel data methodology incorporating long-term trajectories and policy-relevant variables (Cici Jennifer Raj & Vinod Kumar, 2022; Pretis, 2021). This gap constrains the development of effective, localised policy initiatives that could expedite a just and equitable energy transition. This research aims to address the existing gap. Utilising big data analytics from SAS software and extracting secondary data from the World Bank open data source, we intend to assess the impact of renewable energy output and net energy imports on GDP per capita in Indonesia, Malaysia, and Brunei from 1990 to 2022. We concentrate primarily on the timeframe preceding the Paris Agreement, during which global and regional energy commitments escalated. An examination of the empirical dynamics among these variables provides insights into whether clean energy investments are purely environmental duties or serve as strategic economic levers. We propose that renewable energy production has a statistically significant and beneficial influence on economic growth, but dependence on net fuel exports, as indicated by energy net imports (ENI), is comparatively less influential in the long term. This theory is based on transition economics, which asserts that green investment enhances both ecological and financial resilience (Cousins, 2021). This topic is important in both theoretical and practical aspects. This theoretically enhances the Environmental Kuznets Curve concept in the context of energy exports by analysing renewable output as a mediating variable. It provides policy-relevant evidence for ASEAN governments balancing short-term export profits with long-term sustainability objectives that prioritise egalitarian environments. We utilise panel data modelling approaches, specifically fixed and random effects estimators, on a balanced dataset of 99 observations across three nations. This method offers a real-time, comparative, and statistically substantiated evaluation of the relationship between renewable energy transitions and income growth in resource-abundant emerging nations in Southeast Asia. The subsequent sections of this work are organised as follows. Section 2 provides a comprehensive analysis of the pertinent literature and theoretical foundations. Section 3 delineates the data sources and study methodologies. Section 4 presents the empirical findings and examines their policy ramifications. Section 5 closes with considerations regarding policy and prospective research avenues.

2. LITERATURE REVIEW

This literature review seeks to critically assess current research on the relationship between renewable energy development, economic performance, and energy trade dynamics in resource-exporting economies, specifically within the ASEAN area. The part is organised thematically: (1) theoretical foundations of energy-economy-environment interactions, (2) empirical evidence regarding renewable energy and GDP, (3) the influence of energy imports and exports on growth dynamics, and (4) limitations and deficiencies in ASEAN-specific research. Our research expands upon and critiques this corpus of work to establish a new empirical contribution.

2.1. Theoretical Foundations and Energy-Growth Models

The traditional model linking energy consumption and economic growth, represented by the Environmental Kuznets Curve (EKC), is undergoing transformation with the incorporation of renewable energy as a significant factor (Baloch & Danish, 2022). A multitude of studies indicates a nonlinear link, wherein economic growth initially exacerbates environmental degradation before diminishing after reaching a specific threshold. Recent alterations to this model integrate renewable energy as a possible decoupling mechanism (Mehmood, 2021). Our finding indicates that although theoretical models encapsulate long-term trends, they frequently lack operational clarity on the interaction between energy net imports (ENI) and domestic renewable energy output (REO), particularly in net fuel-exporting economies such as Indonesia, Malaysia, and Brunei.

2.2. Empirical Evidence on Renewable Energy, GDP Growth and Equitable Environments

Empirical research progressively validates the beneficial effect of renewable energy on GDP, especially in upper-middle-income and industrializing countries. Khizar et al. (2021) examine 25 developing nations and find that a 1% increase in REO correlates with a 0.3% increase in per capita GDP. Yang et al. (2022) also note statistically significant effects in nations with stable renewable investment policies. Nonetheless, these findings frequently originate from aggregated data with insufficient consideration of structural or trade-related disparities among countries. Conversely, Bonnedahl et al. (2022) emphasise that the influence of renewable energy sources significantly depends on the quality of governance, the diversity of the energy mix, and the timings of policies. This highlights the necessity for country-specific panel data analysis, which our study directly addresses. We concentrate on guaranteeing that REO successfully mitigates environmental threats and that individuals receive equitable access to environmental benefits. This include equitable access to clean air and water, green places, and participatory decision-making procedures concerning the ecological environment. This entails guaranteeing equitable distribution of environmental enhancements such as clean air and water, as well as access to green spaces, while also ensuring that no community disproportionately endures environmental burdens, including pollution or hazardous waste facilities resulting from governmental energy policies.

2.3. Role of Energy Net Imports in Growth Pathways

Limited research explicitly identifies ENI as a factor influencing growth. Farooq and Zhang (2022) demonstrate that excessive dependence on energy imports obstructs GDP growth in Sub-Saharan Africa. Conversely, Chi and Ping (2024) determine that ENI is less impactful in fossil-rich economies, indicating that local production mitigates trade consequences. These discrepancies suggest the necessity to model ENI and REO concurrently. Notably, within ASEAN, there is a scarcity of empirical research investigating the concurrent role of REO and ENI, particularly for nations that own dual identities as both producers and exporters. This work addresses that significant gap by offering country-level disaggregation and interaction terms in the regression models.

2.4. ASEAN-Specific Energy and Growth Studies

Although ASEAN has been a focal point in climate and energy research, the majority of studies either generalise throughout the region or concentrate on demand-side efficiency (Bukoski et al., 2016; Montalbano et al., 2022). Do et al. (2021) analyse Vietnam's solar expansion but neglect to address comparative exporter dynamics. Basri et al. (2015) examine Malaysia's energy security but exclude renewable energy as a contributor to GDP. No extensive longitudinal panel study has directly examined Indonesia, Malaysia, and Brunei utilising consistent time-series data for REO, ENI, and GDP. This exclusion constrains strategic energy planning in a region heavily reliant on resources.

2.5. Methodological Gaps and Novel Approaches

Methodologically, previous studies predominantly utilise linear regression or VAR models, frequently neglecting fixed or random effects in panel contexts (Saboori et al., 2024; Wang et al., 2022). Data sources are disjointed, with restricted utilisation of open-access platforms such as World Bank indicators. Conversely, our research utilises a standardised, longitudinal dataset employing SAS-based panel data modelling. This enhances the comparability and repeatability aspects that previous studies have downplayed.

In summary, the current literature underscores the economic potential of renewable energy but suffers from regional overgeneralisation, inadequate methodological approaches, and insufficient focus on exporting situations. This analysis mitigates these limitations by examining three ASEAN net fuel exporters over a 33-year timeframe, employing panel data models that integrate both REO and ENI. This

method enhances empirical generalisability and directly supports green energy policy activities in Southeast Asia.

Table 1: Comparative Literature.

Study	Region/Country	Method	Variables Included	Gaps Identified
(Basri et al., 2015)	25 Developing Countries	Pooled OLS	REO, GDP	Lacks country-specific panel structure
(Alawag et al., 2023)	Sub-Saharan Africa	Panel FE	REO, GDP, Trade	No focus on exporters
(Bonnedahl et al., 2022)	West Africa	Time Series	REO, Governance, GDP	No comparative framework
(Basri et al., 2015)	Malaysia	VAR	GDP, Energy Use	Omits renewable energy
(Muhamad Raffin et al., 2023)	Vietnam	Description	Solar Deployment	Lacks economic linkage
This Study	Indonesia, Malaysia, Brunei	Panel FE & RE	ROE, ENI, GDP, EU	Fills gap in ASEAN energy net exporting countries

3. DATA AND METHODOLOGY

3.1. Introduction to the Methodological Approach

This study employs a quantitative panel data methodology to analyse the correlation between renewable energy output (REO), energy net import (ENI), and GDP per capita (GPC) across ASEAN net fuel exporters Indonesia, Malaysia, and Brunei from 1990 to 2022. We regulate energy consumption (EC) in our projected model. The choice to employ panel regression models is based on their ability to account for both time-invariant national heterogeneity and dynamic temporal trends (Hsiao, 2014; Wooldridge, 2020). This methodology is especially suitable as it enables the observation of structural changes over time while integrating cross-country variances.

3.2. Research Design

We utilise an observational, non-experimental research methodology employing secondary data from a credible open-source repository. The research is correlational and seeks to discover statistically significant associations rather than causative explanations. Panel estimation approaches, specifically Pooled OLS, Fixed Effects (FE), Random Effects (RE), and the Hausman test, are employed to evaluate model specifications and validate assumptions (Baltagi, 2021).

3.3. Data and Data Sources

The data used in this study are entirely secondary and longitudinal, collected from the World Bank Open Data portal. Five key indicators are utilized:
a) Energy Use (EU) – kg of oil equivalent per capita
b) Energy Net Import (ENI) – percentage of energy net import/export
c) Renewable Energy Output (REO) – % of total electricity generation
d) GDP per Capita (GPC) – current USD
e) Country identifiers – for panel stratification

The dataset has 99 observations over 33 years for each of the three countries. During data collection, we identify significant deficiencies in REO values for Brunei prior to 2010, indicating inherent reporting constraints.

3.4. Data Processing and Analysis Techniques

We process and analyze the dataset using SAS software, a robust big data analytics tool. The analysis workflow includes:
a) Descriptive statistics and Pearson correlation matrix
b) Fixed and random effects panel regressions using SAS proc panel
c) Hausman specification test for model selection
d) Significance testing at 90-95% confidence interval

All variables are standardised before analysis, and any absent values are addressed by linear interpolation. Panel regression models are preferred for their efficacy in managing unobserved heterogeneity (Torres-Reyna, 2007).

3.5. Validation and Reliability

To ascertain dependability, we do the Hausman test to compare fixed effects and random effects models. The R^2 values span from 0.814 to 0.962 across all estimated models, signifying robust explanatory capability. We verify model assumptions by residual analysis.

3.6. Ethical Considerations

The study employs open-access, secondary macroeconomic data devoid of individual-level information, therefore negating the necessity for ethical assessment. We uphold transparency by revealing all sources and guaranteeing reproducibility.

3.7. Methodological Limitations

Like other empirical studies, this study also faces several limitations:
a) It does not include nonlinear or lagged effects, which may be relevant in long-run policy shifts.
b) Brunei's REO data is extremely limited before 2010, which may trigger bias cross-country comparisons.

c) The exclusion of qualitative policy variables limits the scope of institutional effects.

Future research could integrate dynamic panel models like Generalized Method of Moments (GMM) or causal inference methods to explore deeper policy feedbacks.

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. Presentation of Key Findings

The empirical analysis provides significant insights into the renewable energy dynamics and income growth trends across ASEAN net fuel exporters from 1990 to 2022. The visual trend (Figure 1) illustrates a distinct divergence in Renewable Energy Output (REO) among the three countries examined. Indonesia routinely sustains REO levels exceeding 15%, with a little rising trajectory. Malaysia exhibits swings, experiencing a downturn in the early 2000s before undergoing a substantial recovery after 2015. Brunei demonstrates negligible REO growth, maintaining nearly stable below 0.05% for over thirty years. This pronounced disparity illustrates the overarching energy policy divergences across the three nations in the ASEAN area.
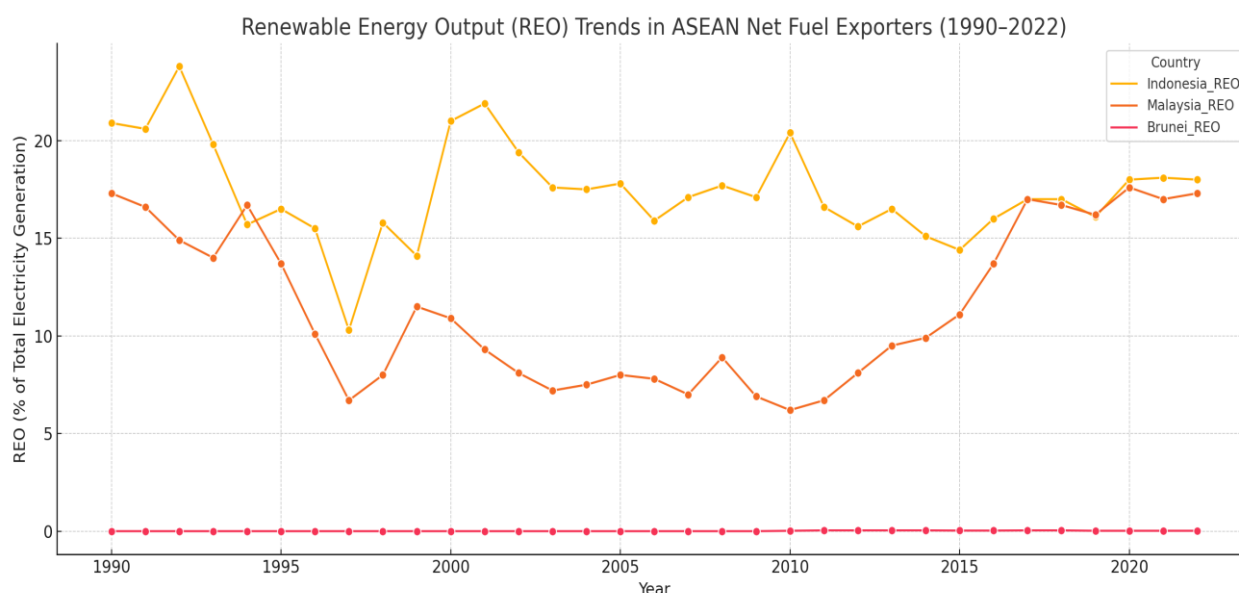

Figure 1: REO Trends in Indonesia, Malaysia, and Brunei (1990–2022).

Figure 1 also illustrates notable patterns across the observed time. There are notable disparities in patterns among these three countries. Indonesia has constantly upheld and augmented its share of renewable energy sources in the national electricity mix, exhibiting a pronounced rising trajectory since 2015. This substantial growth indicates Indonesia's consistent dedication to investments in renewable energy, especially in hydropower and community-oriented bioenergy. Malaysia exhibits significant oscillations in REO from 1990 to 2000, but the trend stabilises between 2000 and 2010. This signifies that Malaysia has established the foundational infrastructure for renewable energy and must expedite large-scale implementation to attain more pragmatic objectives. Conversely, Brunei has exhibited no growth in REO for over thirty years. The horizontal line approaches 0%, indicating stagnation and a significant reliance on fossil fuels, despite the nation's fiscal capacity to invest in renewable energy. This trend indicates that only nations that proactively develop domestic renewable energy infrastructure will achieve long-term energy security and egalitarian conditions. The statistical outcomes from the panel data regression in Table 2 reveal a preference for the fixed effect model, as demonstrated by the Hausman test, which is significant at the 10 percent level. We specifically notice a substantial positive correlation between REO and GPC. This fixed effects model accounts for individual variation across countries (Indonesia, Malaysia, and Brunei) and posits that country-specific attributes consistently affect the dependent variable (GDP per capita). It is evident that these ASEAN net fuel-exporting nations are currently prioritising the utilisation of renewable energy for power generation while progressively diminishing fossil fuel production operations. The Fixed Effects Model demonstrates the highest explanatory power (R^2 = 0.9627), signifying substantial within-country

variance. REO exhibits a statistically significant positive impact on GDP per capita (coefficient = 404.68, p-value = 0.0093), whereas Energy Net Imports (ENI) are statistically insignificant in all models.

Table 2: Parameter Estimates of Pooled OLS and Static Panel Data Models (Dependent Variable: GDP per Capita).

Variable	Pooled OLS	Random Effect	Fixed Effect
EU	4.6754 (< 0.0001)**	4.6449 (<0.0001)**	3.2138 (0.0010)**
ENI	3.7976 (0.0968)*	3.7099 (0.1348)	6.6830 (0.1455)
REO	240.5001 (0.0513)*	240.6613 (0.0565)*	404.6771 (0.0093)**
Root Mean Square Error (RMSE)	3703.1454	3187.5276	3154.4532
R-squared	0.9199	0.8141	0.9627
Breusch and Pagan (BP)		3.89 (0.1427)	
Hausman Test		6.82 (0.0778)*	
Note: **significant at 5%; *significant at 10%; Figure in () is p-value			

4.2. Analytical Interpretation and Theoretical Implications

The empirical findings of our study validate the adaption of the Environmental Kuznets Curve (EKC): as economies progress, investments in renewable energy can dissociate economic growth from reliance on fossil fuels. The importance of REO in influencing GDP substantiates the energy-growth relationship shown by Baloch and Danish (2022) and Badoe et al. (2022), while contesting the notion that fuel trade balances (ENI) solely dictate growth, as asserted in traditional models. Our experience with processing open-source data utilising SAS big data software reveals that, despite the aggregate data indicating substantial increase in renewable energy, not all nations convert these prospects into actionable legislation. Brunei has not demonstrated a robust commitment to implementing sustainable energy technology, despite its significant fiscal potential. The fixed effect regression results in Table 2 indicate that renewable energy production (REO) exerts a positive and significant impact on per capita income in net fuel exporting countries. A coefficient of 404.68 and a p-value of 0.0093 indicate that a 1% increase in the share of renewable energy in total electricity output is significantly associated with an increase in GPC. This supports the assertion that energy diversification towards renewable sources contributes to sustainable income development for citizens. The EU variable in the FE model demonstrated a positive and significant correlation (coefficient 3.21; p-value 0.0010), indicating that per capita energy consumption intensity enhances economic welfare. Simultaneously, the ENI exhibits a positive coefficient of 6.68; nevertheless, this explanatory variable lacks statistical significance (p-value 0.1455), suggesting that energy export alone is insufficient to ensure prospective income development without the backing of domestic energy transformation. These findings highlight the significance of a national energy mix that not only depends on exports but also maximises clean energy sources to facilitate equitable growth in the ASEAN region's energy transformation strategy.

Table 3: Pearson Correlation Matrix (N=99).

Variable	EU	ENI	GPC	REO
EU	1.000	-0.764	0.955	-0.913
ENI	-0.764	1.000	-0.688	0.763
GPC	0.955	-0.688	1.000	-0.843
REO	-0.913	0.763	-0.843	1.000

Table 3 presents the Pearson correlation matrix, illustrating the degree of relationship among all variables, including both explanatory and outcome factors, in this study. Energy Use (EU) exhibits a strong positive correlation of 0.955 with GDP per capita (GPC), signifying that per capita energy consumption is intricately linked to rising income levels. This aligns with the premise that energy is a crucial element in manufacturing processes and economic activity. Notably, REO exhibits a negative connection with GPC (-0.843) and EU (-0.913). These findings indicate a trade-off between augmented renewable energy contributions and net fossil energy imports, particularly evident in fuel-exporting nations. Within the ASEAN framework, nations with low Renewable Energy Output, such as Brunei, are gradually adopting a green energy transition. Currently, ENI exhibits a moderate negative correlation with GPC (-0.688), suggesting that the preeminence of energy exports is no longer facilitating a growth in per capita income. Conversely, ENI exhibits a positive correlation with REO (0.763), indicating that nations with energy surpluses are more likely to pursue alternative energy sources. This association pattern highlights the necessity of energy policy that seek export surpluses while simultaneously balancing energy consumption and environmental sustainability through enhanced REO.

Table 4: Summary Statistics by Country (1990–2022).

Country	REO Mean (%)	ENI Mean (%)	GPC Mean (USD)	EU Mean (kg)
Indonesia	17.42	-99.48	2124.96	651.64
Malaysia	11.46	-39.98	6882.86	2305.53
Brunei	0.04	-561.69	29134.15	7845.94

Table 4 above delineates the descriptive statistics for the three net fuel-exporting nations in ASEAN. Brunei possesses the highest GDP per capita at USD 29,134.15, alongside a significantly elevated energy usage per capita averaging 7,845.94 kg. Brunei has the lowest renewable energy output (REO) at a mere 0.04%, indicating a near-total reliance on fossil fuels and a deficiency in the transition to green energy. Conversely, Indonesia, although possessing the lowest GPC (USD 2,124.96) and minimal energy usage (651.64 kg), has the greatest REO at 17.42%. This signifies that Indonesia has initiated a more assertive energy transition endeavour despite internal economic difficulties. Malaysia has a central place, with a GPC of USD 6,882.86, an EU of 2,305.53 kg, and a REO of 11.46%. These numbers indicate that Malaysia has achieved a more equitable balance between economic growth and the integration of renewable energy. The comparisons presented in Table 4 underscore the necessity of not just seeking economic growth and energy exports but also incorporating energy transition measures into national policies that facilitate sustainable green energy development.

Table 5: REO Growth Rate by 10-year Period.

Country	1990–2000 (%)	2001–2010 (%)	2011–2022 (%)
Indonesia	-5.61	8.70	4.95
Malaysia	-8.35	4.00	6.94
Brunei	N/A	0.03	0.01
Note: Indonesia shows consistent REO growth since 2001, while Brunei's figures remain negligible.			

Table 5 illustrates the ROE growth data over a decade commencing in 1990. Distinct dynamics and variations in energy policies are evident among these three ASEAN fuel-exporting nations. From 1990 to 2000, Indonesia and Malaysia saw reductions in REO of -5.61% and -8.35%, respectively. This reduction is likely due to the predominance of fossil fuels in the national energy mix during that period, coupled with insufficient incentives or regulatory frameworks from the United Nations to facilitate the transition to renewable energy. However, from 2001 to 2010, the two countries exhibited a reversal trend. Indonesia experienced an increase in REO growth of 8.70%, while Malaysia recorded a gain of 4.00%. This indicates a substantial rise in renewable energy investments and a heightened commitment by governments to clean energy initiatives. From 2011 to 2022, the REO growth has been good in both nations;

Indonesia experienced a growth of 4.95%, while Malaysia saw a more substantial gain of 6.94%. This expansion demonstrates the persistence of the green agenda and the stabilisation of installed renewable energy capacity. This pattern underscores that the development of renewable energy capacity in ASEAN is significantly reliant on political will and domestic policy direction, rather than only on economic capabilities.

4.3. Comparison with Existing Literature

The results corroborate the assertions of Bennedsen et al. (2021) and Liu et al. (2023), who contend that investments in renewable energy generate substantial economic benefits in middle-income countries. Nonetheless, the insignificance of ENI stands in stark contrast to the findings of Farooq and Zhang (2022), who document adverse effects of dependence on energy imports in Africa. This disparity presumably arises from the dual role of ASEAN exporters as both producers and consumers, hence weakening the conventional net import-growth correlation. Furthermore, the Bruneian situation deviates from literature that posits fiscal capacity ensures a green transition (Basri et al., 2015). Our study indicates that policy orientation and political will are the primary facilitators for the growth of REO.

4.4. Practical and Policy Implications

These findings offer actionable insights for both national and regional energy governance:

1. Indonesia and Malaysia should sustain and expand their REO initiatives through strategic investments in solar and hydro infrastructure, green financing incentives, and regional technology partnerships.
2. Brunei, facing a carbon-intensive legacy, must integrate REO into its national development agenda. Policymakers could introduce targeted subsidies, decentralized solar pilots, or public-private partnerships to kick-start the shift.
3. At the ASEAN level, a joint platform for clean energy transition monitoring and technology exchange may accelerate collective progress and reduce cross-country disparities.

These findings suggest that governments should align renewable energy goals with fiscal strategies, ensuring that clean energy is not a policy afterthought but a central economic lever.

4.5. Limitations and Directions for Future Research

Despite the strong results, several limitations persist:

a) Data limitations, especially REO values in Brunei before 2010, restrict temporal depth and may understate early transition signals.
b) The analysis uses linear fixed/random effects models without dynamic interactions or lagged responses, which may not capture delayed policy effects.
c) Institutional and policy quality variables potential mediators of REO impact are not included in this dataset.

Future studies should:
a) Implement dynamic panel models (e.g., GMM) to explore policy lags and feedback loops.
b) Integrate qualitative policy reviews or institutional indices to complement numerical findings.
c) Explore machine learning or causal inference models to predict REO trajectory under alternative policy scenarios

5. CONCLUSION

The adoption of the Fixed Effects model enhances the robustness of the primary findings, specifically that REO exerts a large beneficial impact on income growth. This empirical conclusion underscores the necessity of accounting for the distinct environment and structure of each ASEAN country, rather than presuming cross-border uniformity as suggested by the Random Effects model. This technique establishes a robust foundation for country-specific policy suggestions. This analysis demonstrates that REO substantially elevates the per capita income of fuel-exporting nations within ASEAN. These findings show that dependence on fossil energy exports alone is insufficient to foster inclusive economic growth without investment in the clean energy transition. Notably, only Indonesia and Malaysia have exhibited a rising trend in Renewable Energy Output, but Brunei has begun to acknowledge the significance of green renewable energy. The research addresses a significant gap in the literature by differentiating the effects of the EU, ENI, and REO on population income growth using a static panel data methodology. This underscores that sustained economic growth relies more on domestic energy policies and the green energy mix than solely on fuel exports. It is important to highlight certain policy changes implemented by the Saudi Arabian government in recent years. The foremost exporter of crude oil is currently concentrating on its Vision 2030 initiative, which seeks to diminish dependence on the oil and gas industry and diversify into the renewable energy sector. In 2021, Saudi Arabia inaugurated its inaugural solar power plant in Al Jouf province. This investment, with a capacity of 405 MW, demonstrates Saudi Arabia's dedication to facilitating the transition to renewable energy (Kahia et al., 2021). A new plant in Mecca province, with a capacity of 2.6 GW, is anticipated to be finished by the end of 2025. The policy ramifications of these findings are evident. ASEAN nations must advocate for fiscal measures that facilitate the transition to renewable energy, encompassing green subsidies and cross-border technology integration. In 2022, the ASEAN region's electricity generation from renewable sources constituted 28%, with hydropower being the predominant contributor. This study acknowledges limitations regarding institutional factors and unrecorded long-term impacts. Consequently, additional study is advised utilising a dynamic panel methodology and broadening the range of institutional markers. This study underscores the imperative for regional initiatives aimed at achieving a sustainable energy transition and equitable ecosystems that serve all citizens.

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