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Research Article

Institutional quality role in oil price uncertainty-renewable energy consumption nexus: ASEAN-8 Bayesian evidence

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Abstract. Amid escalating climate change pressures and global energy market volatility, accelerating the green energy transition is critical yet challenging for developing economies. ASEAN nations face a stark “energy paradox”: rapid economic growth accompanied by heavy reliance on fossil fuels and sluggish renewable energy adoption. Against this backdrop, this study investigates the impact of oil price uncertainty (OPU) on renewable energy consumption in ASEAN-8 countries over the 2002–2022 period and examines the moderating role of institutional quality. We employ a Bayesian linear regression framework using Markov Chain Monte Carlo (MCMC) algorithms, specifically Gibbs sampling, further validated by Feasible Generalized Least Squares (FGLS). This probabilistic approach effectively overcomes small-sample bias, data heterogeneity, and missing data inherent in emerging market datasets. The empirical results reveal that OPU significantly hinders renewable energy consumption, supporting the Real Options Theory wherein market instability compels investors and consumers to defer high-cost, irreversible green projects. Crucially, institutional quality fails to provide the expected moderating effect to shield the green sector from oil market shocks. Furthermore, the findings uncover a critical “institutional paradox”: higher institutional quality adversely correlates with renewable energy adoption, suggesting that improved governance in early-stage ASEAN economies temporarily prioritizes rapid industrialization and traditional fossil-fuel stability over the green transition. As one of the first studies to explore the OPU–renewable energy nexus through a Bayesian lens with institutional moderation, this research challenges conventional assumptions in a heterogeneous region. To achieve Net Zero 2050 targets, ASEAN policymakers must implement decisive green governance reforms and leverage Public-Private Partnerships to attract sustainable capital and decouple regional energy transitions from global commodity shocks.

Keywords: ASEAN, Bayesian, green economy, oil price uncertainty, renewable energy consumption

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1. Introduction

The global energy landscape is undergoing profound transformations, driven by escalating climate change pressures that are prompting a shift from a “brown” to a “green” economy (Shayegh *et al.*, 2023). Moreover, climate change is no longer just an environmental concern but a significant economic threat that harms key sectors such as agriculture and international tourism (Chamma, 2025; Tonsakunthaweeteam *et al.*, 2025). While positive trends in global renewable energy consumption are emerging, the transition remains notably slow. Yolcan (2023) highlights that by 2021, only 12.8% of the world’s total electricity generation came from renewable sources (up from 7.4% in 2016), and just 0.95 Gtoe of global primary energy consumption was met by renewables (an increase from 0.24 Gtoe in 2012).

This sluggish adoption of renewable energy poses significant challenges to achieving the United Nations’ 17 Sustainable Development Goals, which aim for a prosperous, sustainable future for all by 2030 (Mishra *et al.*, 2024). Specifically, fossil fuel price volatility, particularly in crude oil, presents substantial risks to global renewable energy investments (Henriques and Sadorsky, 2011; Phan *et al.*, 2019) and to companies within the renewable energy sector (Dutta, 2017; Lyócsa and Todorova, 2024). Conversely, oil price instability also underscores the imperative for energy source diversification, driving increased investment in and consumption of renewables to reduce reliance on fossil fuels (Lee *et al.*, 2017; Murshed and Tanha, 2021). Thus, transitioning to renewable energy is a strategic pathway to ensure sustainable energy security (Cergibozan, 2022; Khan *et al.*, 2023).

Price volatility is inherent in commodity markets but has accelerated in crude oil over the past decade, reflecting its status as the most globalized commodity (Ebrahim *et al.*, 2014). Fluctuations in energy markets influence all economic activities by affecting energy prices and investment decisions (Işık *et al.*, 2024). High oil price volatility can impact renewable energy consumption through its broader consequences, including economic and financial instability (Yu *et al.*, 2022), reduced economic growth (Jarrett *et al.*, 2019; Van Eyden *et al.*, 2019), high unemployment (Chan and Dong, 2022; Kocaaslan, 2019), and elevated inflation (Aladwani, 2025; Sek *et al.*, 2015). Despite its importance, most previous studies have focused primarily on the impact of oil price levels rather than the uncertainty surrounding them (Karlilar Pata and Balcilar, 2025; Zafeiriou *et al.*, 2018), which often plays a more critical role in delaying long-term green investments. While some studies, such as Tardini and Suharjito (2024), focus on

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improving the forecasting accuracy of specific regional commodities like crude palm oil using deep learning architectures, our research shifts the focus toward the broader "uncertainty" of global crude oil prices and its systemic impact on energy transition through a Bayesian lens. This reveals a significant research gap, as traditional volatility models often fail to isolate the purely exogenous and unforecastable shocks, captured by news-based metrics such as OPU, that truly drive market anxiety and hinder the energy transition.

Furthermore, studies measuring the influence of oil price volatility, using the OPU metric developed by Abiad and Qureshi (2023), on energy consumption across countries and regions are genuinely scarce. To the best of our knowledge, this is only the second study to employ OPU to assess the impact of oil price uncertainty on renewable energy, following a recent publication by Liu *et al.* (2025). By utilizing this newly developed index, our study provides a more precise and timely measure of uncertainty than traditional proxies, addressing a critical gap in the existing literature. This highlights a novel and crucial research direction, particularly as the demand for cleaner, greener, and more sustainable economies becomes increasingly urgent and challenging (Gehring, 2016; Söderholm, 2020). Consequently, no prior research has evaluated this impact specifically within ASEAN countries, a region characterized by high economic growth and significant renewable energy demand, yet heavily reliant on fossil fuels (Nathaniel and Khan, 2020). Moreover, a critical missing link in the current literature is the "moderating" role of institutional quality; most studies treat institutions as a direct determinant rather than a filter that can either amplify or mitigate external shocks like OPU (Wang *et al.*, 2022).

ASEAN was selected for this study because its nations are emerging as global economic drivers, albeit with escalating environmental pollution, including increased CO2 emissions, water and air pollution, transboundary haze, and a growing ecological footprint (Rehman *et al.*, 2023). Ahmed *et al.* (2017) also identify ASEAN as the third-largest emitter of greenhouse gases globally. This status reveals a stark "energy paradox" within the region: while ASEAN is a powerhouse of growth, its transition to renewable energy remains alarmingly slow and faces significant structural hurdles compared to other emerging blocs. Due to rapid economic growth, the region's energy demand has surged by over 50% in the last decade. Moreover, these countries' predominant reliance on fossil fuels creates immense pressure on supply security and exacerbates environmental pollution (Islam *et al.*, 2022). Therefore, research on ASEAN holds significant empirical value, as this growth engine within a polluted global context urgently needs to accelerate its transition to a lower-emission economy (Nguyen *et al.*, 2023; Xuan *et al.*, 2024).

To bridge these identified gaps, the primary objective of this study is to provide a rigorous analysis of how oil price uncertainty influences renewable energy consumption in ASEAN-8 from 2002 to 2022. Specifically, the research aims to: (i) provide a more nuanced, probabilistic estimation of the OPU-renewable energy consumption nexus using an Bayesian framework; (ii) evaluate whether institutional quality acts as a catalyst or a barrier to the energy transition in this regional context; and (iii) assess the moderating effect of institutions in shielding the green sector from global oil market instability. This study employs a novel estimation method, the Bayesian approach, which offers several advantages over traditional frequentist statistical methods (Lee *et al.*, 2007; Wagenmakers *et al.*, 2018). The Bayesian approach is particularly suited for small samples or missing data (Smith and Roberts, 1993), accounts for all potentially influential factors (Martin *et al.*, 2024), and effectively addresses data heterogeneity (Ansari *et al.*, 2002; Iešmantas and Alzbutas, 2016). The Bayesian approach is particularly suited for the ASEAN-8 context, where the sample size is relatively small and data points for certain years may be missing. Unlike traditional frequentist methods that rely on large-sample asymptotics, the Bayesian framework handles small-sample bias and missing data more robustly through iterative sampling and the incorporation of prior distributions. This methodological choice enhances the reliability of our assessment regarding the impact of oil price uncertainty on renewable energy consumption in ASEAN-8 by addressing data heterogeneity more effectively than conventional panel regressions.

Furthermore, this research makes a more significant contribution by being the first to examine the moderating role of institutional quality on the impact of OPU on renewable energy consumption. We comprehensively investigate this moderating effect by utilizing both the average value of the six dimensions of Kaufmann and Kraay (2024)'s Worldwide Governance Indicators and each individual indicator. The findings from this analysis will provide a comprehensive understanding of the moderating role of institutional quality, if any, in the relationship between OPU and renewable energy consumption in ASEAN-8 countries.

In summary, this research offers three primary contributions. First, it addresses the scarcity of empirical evidence on oil price uncertainty by utilizing the novel OPU index (Abiad and Qureshi, 2023) in the ASEAN-8 context. Second, it employs a robust Bayesian framework with Gibbs sampling to overcome data limitations and heterogeneity inherent in emerging markets. Third, it is the first to examine the moderating role of institutional quality, uncovering a critical "institutional paradox" that challenges current assumptions about green energy transitions in developing nations, thereby providing actionable insights for achieving Net Zero 2050 targets.

To achieve these contributions, this study is structured into five sections. Following this Introduction, Section 2 presents the Literature Review, Section 3 details the Methodology, Section 4 presents Results and Discussions, and Section 5 concludes the paper.

2. Literature review

2.1 Oil price uncertainty and renewable energy consumption

The relationship between OPU and renewable energy consumption (REC) is theoretically complex, characterized by two competing perspectives: the "Real Options Theory" and the "Substitution Effect".

The real options theory of investment decision-making under uncertainty suggests delaying irreversible, high-cost investments, such as those in renewable energy, during periods of volatility in traditional energy markets (Elder and Serletis, 2010; González-Muñoz *et al.*, 2024; Zhang *et al.*, 2020). Moreover, oil price uncertainty can trigger inflation (Köse and Ünal, 2021), unemployment, economic growth deceleration (Al-Sasi *et al.*, 2017; Elder and Serletis, 2010; Jo, 2014), and other economic instabilities (Ebrahim *et al.*, 2014). Consequently, oil price uncertainty introduces economic uncertainty, prompting firms and individuals to postpone major investment and expenditure decisions (Schneider, 2004). As a result, renewable energy investment and consumption tend to decline when oil prices are volatile.

Furthermore, oil price uncertainty implies the potential for future energy price reversals, dissuading new energy investors from making hasty decisions to avoid potential regret (Kuper and van Soest, 2006). Higher uncertainty often signals a greater likelihood of such reversals. Therefore, when oil price uncertainty is elevated, delaying investments - including those in renewable energy - to await new information can help investors avoid future regrettable expenditures (Bernanke, 1983; Kuper and van Soest, 2006; Pindyck, 1991).

Indeed, Zhao *et al.* (2024) found that oil price uncertainty curtails corporate investment in renewable energy in China due to its potential negative economic repercussions. These authors also argued that oil price uncertainty makes investors cautious, leading them to await market stability before committing to a nascent and inherently volatile sector like renewable energy.

A study by Cao *et al.* (2020) similarly revealed that oil price uncertainty significantly negatively impacted investments across a sample of publicly listed renewable energy companies in China from 2002 to 2016. Furthermore, smaller firms demonstrated greater sensitivity to oil price volatility than larger ones. Using a sample of 4,017 energy sector companies from 1996 to 2022, Chen *et al.* (2024) affirmed that oil price uncertainty adversely affects corporate energy investments, with a more pronounced impact in oil-producing nations compared to oil-consuming countries. This is also consistent with recent findings in BRIC nations (Pessoa *et al.*, 2024) regarding the dominant role of energy price shocks.

Conversely, an alternative theoretical framework posits that oil price instability serves as a catalyst for transitioning from fossil fuels to more stable and market-shock-resilient renewable energy sources, termed the substitution effect (Karacan *et al.*, 2021). Under this view, volatile oil prices incentivize businesses and households to reduce reliance on traditional energy sources (Koutroumanidis *et al.*, 2009), seeking more economical and stable energy alternatives, thereby boosting renewable energy consumption (Liu *et al.*, 2025). Saliba (2024) observed that higher energy-related uncertainty actually promotes renewable energy consumption, as countries tend to seek more stable renewable alternatives when traditional energy markets are volatile or unstable. Earlier, Ayodele and Alege (2021) confirmed that unstable oil prices prompted Nigerians and the Nigerian government to increase renewable energy usage to mitigate risks.

In summary, the empirical evidence regarding OPU's impact is highly inconsistent. While some studies support the investment-delaying effect (Cao *et al.*, 2020), others highlight a strategic shift toward renewables (Saliba, 2024). Su *et al.* (2025) found a dual impact of energy-related uncertainty on renewable energy. On one hand, escalating risks from energy-related uncertainty create an urgent need to reduce reliance on traditional sources, encouraging renewable energy investment. On the other hand, high costs associated with energy-related uncertainty diminish the attractiveness of renewable energy projects, thus hindering the transition in certain countries. Riaz *et al.* (2025) indicated that energy market uncertainty affects different types of renewable energy in the U.S. dissimilarly and that this impact varies over time. While most renewable sources were negatively affected in the short term, wind and especially solar energy demonstrated resilience and strong growth potential, particularly after the COVID-19 pandemic.

Urom *et al.* (2022) revealed that the impact of oil price uncertainty on various segments of the clean energy sector in the U.S. is complex, varying by time, market conditions, and specific industry. Notably, spillovers from oil prices to clean energy strengthen in the long term, but are negligible in the short term. Meanwhile, Tambari and Failler (2020) demonstrated that renewable energy investments in Africa exhibit an immediate negative response to oil price volatility, but later become positive after an initial phase (i.e., initial decline in renewable energy investment due to oil price volatility, followed by a subsequent boost). Avazkhodjaev *et al.* (2024), studying the U.S. from January 2000 to June 2024, found that renewable energy consumption initially responded positively to crude oil price volatility in the short term, but this effect became significantly negative in the long term. In contrast, Karlilar Pata and Balcilar (2024) observed that oil price volatility significantly impacted wind and biofuel deployment but had no clear effect on solar energy in the U.S. between 1989 and 2023.

Lin and Wang (2023) confirmed a dual-directional impact of oil price uncertainty on renewable energy corporate investment. On one hand, sharp oil price fluctuations signal uncertainty in traditional energy sources, increasing market expectations for renewable energy firms and stimulating their investments. However, oil price instability can negatively affect the economy (e.g., slowing growth, inflation), leading renewable energy companies to exercise greater caution in their investment decisions. Recently, Liu *et al.* (2025) confirmed an N-shaped relationship between oil price uncertainty and renewable energy transition (both production and consumption) based on a global dataset of 71 countries from 1980 to 2022. However, this N-shaped relationship was significant in OECD countries but not in non-OECD countries, suggesting that more developed economies respond to oil price shocks by accelerating their renewable energy transition. Resource-rich nations, potentially suffering from the resource curse, might exhibit a slower pace of renewable energy transition.

Despite these global findings, a critical research gap remains: there is a lack of evidence specifically focusing on the ASEAN-8 region, where economic structures and energy policies differ significantly from OECD or African contexts. Moreover, the existing literature rarely accounts for the specific "energy paradox" of ASEAN - high growth coupled with fossil fuel dependency - which may make the "Real Options" effect more dominant than the "Substitution" effect. This study posits that oil price uncertainty may hinder renewable energy consumption in ASEAN-8 countries. This is because, with the exception of Singapore, these are still developing nations with limited government resources allocated to renewable energy development. Furthermore, the high cost of renewable energy consumption presents a barrier for most developing ASEAN-8 countries. Specifically, renewable energy investors in these nations face obstacles such as limited access to finance, a shortage of skilled labor, underdeveloped physical and logistical infrastructure, and insufficient government and policy support (Gabriel, 2016; Mohammed *et al.*, 2013). Consequently, these countries may face a challenging energy transition (Saculsan and Mori, 2020).

H1: Increased oil price uncertainty reduces renewable energy consumption in ASEAN-8 countries.

2.2 The moderating role of institutional quality

Institutional quality, assessed by factors such as Control of Corruption, Rule of Law, Regulatory Quality, Government Effectiveness, Political Stability, and Voice and Accountability (Kaufmann and Kraay, 2024), is anticipated to mitigate the adverse effects of instability, including oil price uncertainty, on economic performance (Musikavanhu and Gamariel, 2024). Research by Feng and Zheng (2022) indicates that economic policy uncertainty enhances renewable energy innovation only in countries with high institutional quality, with negligible impact in those with low institutional quality. Similarly, Borojo *et al.* (2023) demonstrate that while economic policy instability increases emissions, robust institutional quality can curb this effect in emerging and low-income developing countries.

However, the literature also points to a significant conflict: while strong institutions should theoretically promote green energy, the actual energy structure of a region can create counter-intuitive results. In many developing regions, "renewable energy" often encompasses traditional biomass, which may decrease as institutions modernize and shift toward cleaner (but not necessarily renewable) fossil fuels. Furthermore, strong institutional quality can reduce the negative impact of macroeconomic instabilities on foreign direct investment (Asamoah *et al.*, 2016), domestic corporate investment (Farooq *et al.*, 2022) and the stability of the banking system, which is the primary source of capital for both domestic and foreign enterprises (Shabir *et al.*, 2021). Consequently, this can facilitate increased investment and renewable energy consumption in countries with strong institutional foundations, even amidst heightened instability.

Policymakers play a crucial role in safeguarding economies from instabilities by establishing and maintaining a fair and robust financial system, and by promoting the stability and recovery of macroeconomic variables affected by shocks (Smets, 2025). Conversely, weak institutions create inherent vulnerabilities and deficiencies within the financial system, fostering corruption and opportunism, which in turn support the use of fossil fuels and technologies detrimental to renewable energy (Olaniyi *et al.*, 2025). Poor institutional quality, often accompanied by bureaucracy and corruption, leads to the inefficient utilization of significant natural resource revenues, thereby hindering infrastructure modernization for transitioning to renewable energy production and use (Olaniyi and Odhiambo, 2025).

High-quality institutions are expected to accelerate renewable energy production and consumption, primarily due to the government's role in formulating and implementing sustainable energy strategies (Uzar, 2020). Moreover, political power and institutional quality influence renewable energy adoption, as these projects demand specialized knowledge, experience, infrastructure, and supportive government regulations and investment policies (Burke and Stephens, 2018). Government support through tax credit programs, subsidies, quota allocations, green certificates, and other financial and non-financial incentives is critical for promoting renewable energy production and consumption (Gennaioli and Tavoni, 2016). Robust institutional quality help clarify property rights (Tee *et al.*, 2021), reduce transaction costs (Obenpong Kwabi *et al.*, 2024), and create a safer and more efficient environment for renewable energy investment. Indeed, strong institutional quality positively impacts renewable energy consumption (Iormom *et al.*, 2025; Wang *et al.*, 2022).

Poor institutional quality, characterized by a lack of transparency and accountability, is considered a barrier to renewable energy investment projects, with bureaucratic corruption further increasing risks (Komendantova *et al.*, 2014). Additionally, legal and political risks can impede the transition to renewable energy in many countries (Komendantova *et al.*, 2012). Conversely, Pfeiffer and Mulder (2013) assert that the proliferation of renewable energy increases with stable democratic regimes. In countries with sound institutions, governments implement policies that facilitate greater citizen access to renewable energy (Stritzke *et al.*, 2021). Similarly, Iyer *et al.* (2015) found that investment is constrained in countries with low institutional quality. Therefore, governments can promote integrity policies to further enhance national energy efficiency (Lu *et al.*, 2021).

Despite the theoretical importance of institutions, their moderating effect remains under-explored in the context of energy uncertainty, especially in regions with high heterogeneity like ASEAN. With the exception of Singapore, the ASEAN-8 countries are not generally considered to possess high institutional quality (Kaufmann and Kraay, 2024). Over the past two decades, ASEAN-8 countries have been characterized by significant political instability, particularly in Thailand (Ganjanakhundee, 2021), Philippines (Teehankee and Calimbahin, 2020), Malaysia (Chin, 2022; Hunter, 2021) and Indonesia (Tjandrasa, 2021). Notably, prolonged political instability and the ongoing civil conflict in Myanmar have had enduring impacts on economic, political, and security stability across the region (Manurung, 2021). Consequently, researchers largely agree that, excluding Singapore, ASEAN is a region with poor institutional quality (Buracom, 2014; Masron and Naseem, 2017; Nuyen and Ha, 2021; Omeje, 2024). Among the most significant institutional weaknesses in this region are government effectiveness and control of corruption. Cambodia, Indonesia, Laos, and Myanmar demonstrate very poor performance in these areas, while Vietnam, the Philippines, and Thailand also exhibit deficiencies (Tautho, 2016). The regional literature often highlights that bureaucracy and corruption lead to inefficient utilization of natural resource revenues, hindering infrastructure modernization (Olaniyi and Odhiambo, 2025). This institutional weakness may "break" the expected moderating link between OPU and energy transition.

Given the inherent weak institutional quality prevalent across most ASEAN countries in the sample, this study posits that institutional quality may not play a significant role in mitigating the negative impact of oil price fluctuations on energy consumption in the ASEAN-8.

H2: Institutional quality does not significantly mitigate the negative impact of OPU on renewable energy consumption.

3. Methodology

3.1 Models

This study's baseline model is developed based on the frameworks proposed by Karacan *et al.* (2021) and Islam *et al.* (2022). To specifically address the impact of oil price uncertainty on renewable energy consumption, *OPU* is incorporated into the baseline model. Furthermore, the baseline model is augmented with additional variables to comprehensively capture factors influencing renewable energy consumption. These variables include trade openness (Amoah *et al.*, 2020; Han *et al.*, 2022), population (Islami *et al.*, 2022; Salim and Shafiei, 2014) and economic freedom (Amoah *et al.*, 2020; Sart *et al.*, 2025).

Consequently, the baseline model takes the following form (Model 1):

$$\begin{aligned} REC_{i,t} = \beta_0 + \beta_1 OPU_{i,t} + \beta_2 Emission_{i,t} \\ + \beta_3 Non\_REC_{i,t} \\ + \beta_4 Tradeopen_{i,t} + \beta_5 POP_{i,t} \\ + \beta_6 GDP_{i,t} + \beta_7 INF_{i,t} \\ + \beta_8 Ecofree_{i,t} + \beta_9 FDI_{i,t} \\ + \beta_{10} Inst_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{1}$$

To evaluate the moderating role of institutional quality, the full model (Model 2) incorporates an interaction term, *OPU x Inst.* This interaction term is crucial for examining how institutional quality influences the relationship between oil price uncertainty and renewable energy consumption.

Specifically, Model 2 takes the following form:

$$\begin{aligned} REC_{i,t} = \beta_0 + \beta_1 OPU_{i,t} + \beta_2 Emission_{i,t} \\ + \beta_3 Non\_REC_{i,t} + \beta_4 Tradeopen_{i,t} \\ + \beta_5 POP_{i,t} + \beta_6 GDP_{i,t} + \beta_7 INF_{i,t} \\ + \beta_8 Ecofree_{i,t} + \beta_9 FDI_{i,t} \\ + \beta_{10} Inst_{i,t} \\ + \beta_{11} OPUxInst_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{2}$$

where:

- $\varepsilon_{i,t}$ represents the error term.
- t denotes the year, ranging from 2002 to 2022.
- i represents the countries in the sample: Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam.

Brunei and Myanmar were excluded from the sample due to a lack of available data.

3.2 Data

The data utilized in this study are derived from publicly available and verifiable sources, forming a balanced panel dataset covering eight ASEAN countries (ASEAN-8: Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam) over a 21-year period from 2002 to 2022. The selection of this timeframe and country group is driven by both the availability of the OPU index and the critical period of energy transition in the region. *OPU* data are sourced from Abiad and Qureshi (2023) and are accessible for download at: https://www.policyuncertainty.com/. Data for Renewable Energy Consumption (*REC*), Emissions, Non-Renewable Energy Consumption (*Non_REC*), Trade Openness (*Tradeopen*), Population (*POP*), Gross Domestic Product (*GDP*), Inflation (*INF*), and Foreign Direct Investment (*FDI*) are all obtained from the World Bank's World Development Indicators (WDI). Institutional quality data are provided by Kaufmann and Kraay (2024). Finally, Economic Freedom (*Ecofree*) data are collected from the Heritage Foundation.

A detailed breakdown of each variable's calculation methodology and its corresponding data source is presented in Table 1. As detailed in Table 1, renewable energy consumption (*REC*) varies significantly among ASEAN-8 nations, although the regional average remains low at 30.58% of total final energy consumption. Surprisingly, Cambodia exhibited the highest share of *REC*, reaching 81% in 2002 and 2004. Conversely, Malaysia recorded the lowest *REC* share within the sample, dropping to just 2% in 2010. Overall, the current *REC* levels across ASEAN-8 are considerably low, necessitating a substantial transition in the near future.

The Oil Price Uncertainty index, constructed by Abiad and Qureshi (2023) using a frequency-based methodology adapted from Baker *et al.* (2016). This index is derived by counting the occurrence of oil-related price uncertainty keywords across 50 major global English-language newspapers. The resulting series is normalized to a mean value of 100, where values exceeding 100 indicate higher-than-historical average instability. For the ASEAN-8 countries in our sample, the average *OPU* during 2002 - 2022 was 120.95, signaling a relatively high degree of oil price instability over this period. The highest OPU value, 228.72, occurred in 2008, reflecting extreme oil price volatility during the global financial crisis. However, some years saw low *OPU*, such as 2017 (70.74) and 2002 (71.89).

According to Kaufmann and Kraay (2024), the six dimensions of governance indicators range from -2.5 to 2.5. The average institutional quality for ASEAN-8 from 2002 to 2022 was -0.1705, indicating a generally low institutional quality across the region. With the exception of Singapore, the remaining seven ASEAN-8 nations consistently exhibit low institutional quality. Laos registered the lowest institutional quality in the sample, reaching -1.2701 in 2003. Furthermore, apart from Malaysia and Thailand, the institutional quality values for Cambodia, Indonesia, Laos, the Philippines, and Vietnam remained negative throughout the entire 2002 - 2022 period.

Regarding renewable energy consumption, Malaysia exhibits the lowest utilization rate in the region, fluctuating between 2% and 7.5%, despite its relatively high institutional quality. According to Leong *et al.* (2023) , although Malaysia has implemented numerous policies to stimulate green energy

Table 1.
Variable's descriptions

Variables	Notation	Measurements	Obs	Mean	Std.Dev	Min	Max	Sources
Dependent variable								
Renewable energy consumption	REC	Renewable energy consumption (% of total final energy consumption)	168	0.3058	0.2377	0.0200	0.8100	WDI
Main independent variable								
Oil Price Uncertainty Index	OPU	Abiad and Qureshi (2023)	168	120.9544	43.4089	70.7398	228.7241	https://www.policyuncertainty.com
Control variables								
Greenhouse gas emissions	Emission	Natural logarithm of total greenhouse gas emissions excluding LULUCF (Mt CO2e)	168	4.9705	1.2599	2.3475	7.0499	WDI
Non renewable energy	Non_REC	Electricity production from oil, gas and coal sources (% of total)	168	0.7204	0.2791	0.0000	0.9763	WDI
Trade openness	Tradeopen	Imports and exports of goods and services (% of GDP)	168	1.3620	0.9694	0.3297	4.3733	WDI
Population growth	POP	Population growth (annual %)	168	0.0133	0.0082	-0.0417	0.0532	WDI
Growth	GDP	Gross domestic products (annual %)	168	0.0532	0.0308	-0.0952	0.1452	WDI
Inflation rate	INF	Inflation (annual %)	168	0.0409	0.0406	-0.0124	0.2410	WDI
Economic freedom	Ecofree	Economic freedom index	168	62.2280	11.8515	36.8000	89.7000	Heritage Foundation
Foreign direct investment	FDI	Foreign direct investment, net inflows (% of GDP)	168	6.2556	6.8448	-0.9886	31.6207	WDI
Institutional quality	Inst	Average value of six dimensions of governance indicators.	168	-0.1705	0.7496	-1.2701	1.6229	Kaufmann and Kraay (2024)

Notes: Minimum values exclude missing data.

(Sources: author)

production and aimed to integrate 20% of renewables into its total energy supply by 2025, achieving this ambitious target remains a significant challenge. Conversely, Cambodia and Laos - two of the region's lower-income economies with institutional quality scores among the lowest - rank as the top two leaders in renewable energy adoption. These nations effectively leverage the natural endowment of the Mekong River for hydropower generation, significantly elevating the share of REC in their total energy mix (Theang and Thuon, 2022). Notably, Laos has even emerged as a net energy exporter, supplying electricity to its neighboring countries (Nakajima *et al.*, 2025).

3.3 Estimation methods

This study employs Bayesian regression to assess the impact of oil price uncertainty on renewable energy consumption in ASEAN-8, leveraging its advantages over traditional frequentist statistical methods (Grzenda, 2015). The benefits of the Bayesian approach, as affirmed by Wagenmakers *et al.* (2018), include: (i) It allows researchers to incorporate existing knowledge (prior beliefs) into the data analysis process, enabling the inclusion of crucial information and reasonable constraints for the statistical model: (ii) Beyond providing the most probable value for a parameter, it precisely quantifies the probability that a parameter falls within a specific range of interest; (iii) Bayesian estimates and inference are entirely based on the specific available data, ensuring that all conclusions are drawn directly from the dataset under analysis; (iv) Bayesian inference ensures consistency, meaning all inferential statements are mutually compatible and independent of how a problem is presented or analyzed; and (v) Regardless of model complexity, Bayesian inference uses a single estimator: the posterior distribution. When this distribution cannot be obtained analytically, it can be sampled using numerical algorithms such as MCMC. The development of methods like MCMC and Gibbs sampling has significantly enhanced the ability to analyze complex models and accelerate the parameter estimation process in Bayesian statistics (Paap, 2002). Following the principles for effective Bayesian estimation suggested by Nguyen *et al.* (2024), this study implements the Bayesian linear regression using the Gibbs sampling algorithm to obtain posterior distributions. To ensure the robustness and reproducibility of the results, the estimation process is conducted with two independent Markov chains using a fixed random seed. For the prior specifications, a weakly informative normal prior N(0, 1) is assigned to the regression coefficients, while an inverse-gamma distribution with shape and scale parameters set at 0.01 is used for the variance. This approach allows the observed data from the ASEAN-8 countries to primarily drive the posterior estimates while maintaining objective constraints. The rationale for selecting N(0, 1) is to provide a conservative yet flexible regularizing effect that prevents over-estimation in a small-sample context while avoiding subjective bias. Furthermore, we experimented with alternative sets of prior variances, including more diffuse specifications such as N(0, 10^2) and more restrictive ones like N(0, 0.5^2), to evaluate the model's sensitivity. The sensitivity analysis revealed that the posterior means and credible intervals were remarkably stable across different priors, with the sign and significance of key parameters remains unchanged, thus confirming that our results are robust and not overly sensitive to the initial parameter choice.

Furthermore, Martin *et al.* (2024) confirm that Bayesian methods offer probabilistic forecasting capabilities, allowing for the quantification of uncertainty in predictions by comprehensively considering all factors that might influence the outcome, while presenting estimation results clearly and understandably. Bayesian estimation can also mitigate issues such as multicollinearity in data (Assaf and Tsionas, 2021) and skewed distributions (Gong *et al.*, 2023). Crucially, Bayesian methods can address potential challenges associated with data heterogeneity (Ansari *et al.*, 2002; Iešmantas and Alzbutas, 2016), a concern relevant to this study.

By integrating prior information, accurately determining the number of factors, and providing improved estimates for financial data, this method offers advantages over traditional maximum likelihood estimation (Lee *et al.*, 2007). According to Gelman and Rubin (1992), when using MCMC techniques to generate posterior distributions, stability and convergence must be ensured. Specifically, an Efficiency value approaching 1 indicates a stable estimate, and an Rc statistic (Gelman-Rubin statistic) value below 1.1 suggests sufficient MCMC convergence. Our empirical results strictly satisfy these criteria, with the Rc statistic for all parameters remaining below 1.05. This confirms that the dual chains have successfully converged to a stable posterior distribution, providing reliable Bayesian inference for the ASEAN-8 context.

Finally, according to Bayes (1958), Bayesian regression can identify optimal estimates for all model parameters. It achieves this by reflecting the relationship between the prior probability (our initial belief about an event) and the posterior probability (our updated belief after obtaining additional evidence).
This relationship is formalized by Bayess theorem:

$$P(A|B) = \frac{P(B|A) * P(A)}{P(B)} \qquad (3)$$

where

- A and B are events;
- P(A|B) is the Posterior probability of event A given event B.
- P(B|A) is the Likelihood of event B given event A.
- P(A) is the Prior probability of event A.
- P(B) is the standardization constant.

4. Results and Discussions

4.1 Correlation matrix

The correlation matrix presented in Table 2 reveals a negative, albeit weak, correlation between *OPU* and *REC*, with a coefficient of -0.0168. In contrast, the correlation between *Inst* and *REC* is notably stronger at -0.807, also indicating a negative relationship. This matrix suggests that both *OPU* and Inst may negatively impact renewable energy consumption in ASEAN-8 countries.

Furthermore, *Emissions, Non_REC, Tradeopen, Ecofree*, and *FDI* exhibit potential negative correlations with *REC*. Excluding *FDI*, the remaining correlation coefficients are substantial, particularly the strong negative correlation between *Ecofree* and *REC* (-0.7211). Conversely, *POP*, *GDP*, and *INF* show positive correlations with *REC*, although the correlation between *POP* and *REC* is relatively small at 0.0378.

However, notable correlations exist among several independent variables, specifically between *Inst* and *Tradeopen* (0.8472), *Inst* and *Ecofree* (0.9218), and *Ecofree* and *Tradeopen* (0.7854). While these figures suggest potential multicollinearity, the Bayesian estimation framework effectively mitigates this issue, ensuring robust parameter estimates (Assaf and Tsionas, 2021).

4.2 OPU and renewable energy consumption

The estimated impact of oil price uncertainty on renewable energy consumption in ASEAN-8 countries, derived

Table 2.
Correlation matrix

Variables	REC	OPU	Emission	Non_REC	Tradeopen	POP	GDP	INF	Ecofree	FDI	Inst
REC	1										
OPU	-0.0168	1									
Emission	-0.5039	-0.0302	1								
Non_REC	-0.6096	0.0240	0.5419	1							
Tradeopen	-0.5481	0.0759	-0.2105	0.4146	1						
POP	0.0378	0.1788	-0.2420	-0.0184	0.1168	1					
GDP	0.2818	0.0892	-0.2636	-0.1795	0.0284	0.1125	1				
INF	0.3705	0.4208	-0.0666	-0.2584	-0.2508	0.0862	0.1916	1			
Ecofree	-0.7211	-0.0794	0.0291	0.6246	0.7854	-0.0054	-0.2107	-0.4601	1		
FDI	-0.2407	-0.0405	-0.4257	0.1605	0.7519	-0.0440	0.1020	-0.1690	0.6329	1	
Inst	-0.8070	-0.0284	0.0764	0.5823	0.8472	0.0559	-0.1530	-0.3675	0.9218	0.6337	1

from the Bayesian regression analysis, is presented in Table 3. As presented in Table 3, the mean of the parameter for *OPU* is -0.0006, with a probability of mean of 0.9993 (99.93%). This indicates that *OPU* has a highly significant negative impact on renewable energy consumption in ASEAN-8 during the 2002–2022 period, with a probability close to 100%. This suggests that increased oil price uncertainty may lead to a decrease in renewable energy consumption in ASEAN-8. Conversely, a reduction in oil price uncertainty could stimulate renewable energy consumption in the region during the surveyed period.

This finding aligns with the real options theory regarding investment decisions under uncertainty. In such conditions, renewable energy investors may defer investment decisions when oil prices are unstable, given that renewable energy

Table 3.
Impact of oil price uncertainty on renewable energy consumption

Independent variables	Mean	Probability of mean	MCMC diagnostics	
			Efficiency	Rc
OPU	-0.0006 [-0.0009 -0.0002]	0.9993	1.0000	1.0001
Emission	-0.0988 [-0.1167 -0.0804]	1.0000	1.0000	1.0000
Non_REC	0.2126 [0.1294 0.2949]	1.0000	1.0000	1.0000
Tradeopen	-0.0122 [-0.0442 0.0199]	0.7716	1.0000	1.0000
POP	-0.3711 [-1.6853 0.9456]	0.7076	1.0000	1.0000
GDP	0.1480 [-0.3018 0.5864]	0.7435	0.9895	1.0000
INF	0.5577 [0.1634 0.9504]	0.9972	1.0000	1.0000
Ecofree	-0.0026 [-0.0061 0.0009]	0.9299	1.0000	1.0001
FDI	0.0046 [0.0011 0.0080]	0.9967	1.0000	1.0001
Inst	-0.2531 [-0.3110 -0.1957]	1.0000	1.0000	1.0000
_cons	0.7922 [0.5298 1.0537]	1.0000	1.0000	1.0000
sigma2	0.0070 [0.0056 0.0087]	-	0.8950	1.0000

Notes: Interval is expressed in square brackets. Convergence rule: Rc < 1.05.

(Sources: Author's calculations)

projects are typically costly and irreversible (Başkaya *et al.*, 2013; González-Muñoz *et al.*, 2024; Zhang *et al.*, 2020). Furthermore, heightened oil price uncertainty often correlates with macroeconomic instability, including increased inflation, economic slowdowns, rising unemployment, and general economic instability. These factors can suppress renewable energy consumption due to its higher cost and less widespread adoption (Al-Sasi *et al.*, 2017; Jo, 2014; Köse and Ünal, 2021). Consumers also tend to increase precautionary savings when oil price uncertainty rises (Başkaya *et al.*, 2013; Xu *et al.*, 2022), further reducing renewable energy consumption, primarily due to its perceived expensiveness and lack of stability.

This empirical study has limited prior empirical research for comparison. As noted in the Introduction, this is only the second study on this topic, following Liu *et al.* (2025). Liu *et al.* (2025) found that developed countries tend to accelerate their transition to renewable energy production and consumption amidst increasing oil price uncertainty, while resource-cursed nations appear to transition more slowly. In contrast, our results for ASEAN-8, which comprises countries with lower development levels (excluding Singapore) and are not resource-rich, suggest that oil price uncertainty may impede their transition to renewable energy utilization.

Institutional quality also exhibits a negative impact on the transition to renewable energy consumption in ASEAN-8 nations. Specifically, the mean of the parameter for *Inst* is -0.2531, with a probability of mean of 100%. This implies that higher institutional quality does not appear to encourage the transition to renewable energy. In fact, countries with lower institutional quality seem to be consuming more renewable energy in the ASEAN-8 region. For example, Cambodia, Laos, and Vietnam, despite their lower institutional quality, possess significant renewable energy potential and have made notable strides in renewable energy consumption (Handayani *et al.*, 2023; Nguyen *et al.*, 2025; Sarraf *et al.*, 2013). Conversely, Singapore, which boasts the highest institutional quality in the region, sources approximately 95% of its electricity from fossil fuels supplied by Indonesia and Malaysia (Quek *et al.*, 2018). Similarly, Malaysia, with the second-highest institutional quality in ASEAN-8, derives only 2% of its total electricity generation from renewable sources (Abdullah *et al.*, 2019). Therefore, consistent with Islami *et al.* (2022) and Wenlong *et al.* (2023), institutional quality appears to negatively affect sustainable development and environmental quality in the ASEAN region.

The negative impact of institutional quality on renewable energy consumption may stem from existing institutions prioritizing traditional energy sources, thereby disincentivizing

Table 4.
Moderating role of institutional quality
(Institutional quality as the average of 6 dimensions of governance indicators)

Independent variables	Mean	Probability of mean	MCMC diagnostics	
			Efficiency	Rc
OPU	-0.0005 [-0.0009 -0.0002]	0.9982	0.9871	1.0001
Emission	-0.0997 [-0.1179 -0.0812]	1.0000	1.0000	1.0001
Non_REC	0.2161 [0.1316 0.3000]	1.0000	1.0000	1.0000
Tradeopen	-0.0138 [-0.0464 0.0187]	0.7980	1.0000	1.0001
POP	-0.4991 [-1.9009 0.9005]	0.7618	1.0000	1.0000
GDP	0.1458 [-0.3055 0.5888]	0.7401	1.0000	1.0000
INF	0.5714 [0.1781 0.9653]	0.9975	0.9907	1.0001
Ecofree	-0.0027 [-0.0061 0.0008]	0.9329	1.0000	1.0000
FDI	0.0046 [0.0012 0.0080]	0.9959	1.0000	1.0000
Inst	-0.2678 [-0.3413 -0.1946]	1.0000	1.0000	1.0000
OPU x Inst	0.0001 [-0.0003 0.0005]	0.7493	1.0000	1.0000
_cons	0.7990 [0.5301 1.0617]	1.0000	1.0000	1.0000
sigma2	0.0070 [0.0056 0.0087]	-	0.8559	1.0000

Notes: Interval is expressed in square brackets; Convergence rule: Rc < 1.05.

(Sources: Author's calculations)

the transition to renewable energy due to high costs, limited viable renewable energy alternatives, and other barriers. For instance, Yap and Notteboom (2024) assert that solar power is the sole suitable renewable energy source for Singapore. Meanwhile, failures in renewable energy development programs, coupled with policies protecting the market share and profits of traditional power producers, have resulted in

Table 5
Moderating role of institutional quality
(Institutional quality measured by each dimension of governance indicators)

Independent variables	Mean			Probability of mean			MCMC diagnostics					
							Efficiency			Rc		
	CC	RL	RQ	CC	RL	RQ	CC	RL	RQ	CC	RL	RQ
OPU	-0.0006 [-0.0010 -0.0002]	-0.0005 [-0.0008 -0.0001]	-0.0005 [-0.0008 -0.0001]	0.9972	0.9969	0.9962	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Emission	-0.1170 [-0.1366 -0.0970]	-0.0824 [-0.1022 -0.0622]	-0.1183 [-0.1359 -0.1005]	1.0000	1.0000	1.0000	1.0000	0.9991	0.9980	1.0001	1.0001	1.0001
Non_REC	0.2303 [0.1346 0.3255]	0.1307 [0.0412 0.2186]	0.3532 [0.2682 0.4375]	1.0000	0.9974	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Tradeopen	-0.0233 [-0.0637 0.0175]	0.0198 [-0.0159 0.0556]	-0.0476 [-0.0777 -0.0175]	0.8665	0.8610	0.9991	1.0000	1.0000	1.0000	1.0002	1.0002	1.0002
POP	-1.1536 [-2.6275 0.3258]	-1.1418 [-2.5128 0.2334]	-0.9041 [-2.3169 0.5075]	0.9385	0.9489	0.8982	1.0000	1.0000	1.0000	1.0000	1.0001	1.0000
GDP	0.1277 [-0.3698 0.6175]	0.0119 [-0.4325 0.4486]	0.0562 [-0.4096 0.5164]	0.6957	0.5242	0.5991	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
INF	0.6813 [0.2338 1.1306]	0.4504 [0.0604 0.8391]	0.4551 [0.0456 0.8655]	0.9984	0.9883	0.9854	0.9992	0.9937	0.9940	1.0000	1.0000	1.0000
Ecofree	-0.0073 [-0.0110 -0.0037]	-0.0032 [-0.0065 0.0001]	-0.0013 [-0.0054 0.0027]	1.0000	0.9726	0.7402	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
FDI	0.0032 [-0.0005 0.0070]	0.0029 [-0.0005 0.0062]	0.0051 [0.0015 0.0086]	0.9538	0.9545	0.9977	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CC	-0.1481 [-0.2070 -0.0892]	-	-	1.0000	-	-	0.9892	-	-	1.0001	-	-

Table 5 (Cont'd)
Moderating role of institutional quality
(Institutional quality measured by each dimension of governance indicators)

Independent variables	Mean			Probability of mean			MCMC diagnostics					
							Efficiency			Rc		
	CC	RL	RQ	CC	RL	RQ	CC	RL	RQ	CC	RL	RQ
RL	-	-0.2317 [-0.2935 -0.1703]	-	-	1.0000	-	-	0.9876	-	-	1.0001	-
RQ	-	-	-0.2510 [-0.3241 -0.1773]	-	-	1.0000	-	-	1.0000	-	-	1.0003
OPU x CC	0.0003 [-0.0001 0.0006]	-	-	0.9274	-	-	0.9493	-	-	1.0001	-	-
OPU x RL	-	0.0000 [-0.0003 0.0004]	-	-	0.5712	-	-	0.9493	-	-	1.0002	-
OPU x RQ	-	-	0.0002 [-0.0002 0.0006]	-	-	0.8482	-	-	0.9424	-	-	1.0002
_cons	1.2069 [0.9340 1.4757]	0.7919 [0.5316 1.0496]	0.8151 [0.5234 1.1055]	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
sigma2	0.0087 [0.0069 0.0108]	0.0067 [0.0054 0.0084]	0.0075 [0.0060 0.0094]	-	-	-	0.8452	0.8470	0.8509	1.0000	1.0000	1.0000

Notes: Interval is expressed in square brackets; Convergence rule: Rc < 1.05; RQ: Regulatory Quality, RL: Rule of Law, CC: Control of Corruption.

(Sources: Author's calculations)

Malaysia's renewable energy consumption stagnating at 2% of its total energy consumption by 2022 (Abd Aziz *et al.*, 2024).

Furthermore, the control variables, including *Non_REC, INF*, and *FDI*, demonstrate a positive impact on renewable energy consumption in the region. This indicates that increases in electricity production from traditional fossil fuels, inflation, and foreign direct investment contribute to higher renewable energy consumption in ASEAN-8 countries. Conversely, *Emission* exhibit an inverse relationship with renewable energy

Table 6.
Moderating role of institutional quality (continued)
(Institutional quality measured by each dimension of governance indicators)

Independent variables	Mean			Probability of mean			MCMC diagnostics					
							Efficiency			Rc		
	GE	PS	VA	GE	PS	VA	GE	PS	VA	GE	PS	VA
OPU	-0.0005 [-0.0008 -0.0002]	-0.0005 [-0.0009 -0.0001]	-0.0005 [-0.0010 0.0000]	0.9987	0.9865	0.9666	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Emission	-0.0794 [-0.0964 -0.0622]	-0.1317 [-0.1506 -0.1125]	-0.1308 [-0.1506 -0.1106]	1.0000	1.0000	1.0000	0.9982	0.9979	0.9990	1.0001	1.0001	1.0001
Non_REC	0.1547 [0.0796 0.2290]	0.2481 [0.1484 0.3466]	0.3236 [0.2198 0.4264]	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Tradeopen	0.0172 [-0.0119 0.0462]	-0.0715 [-0.1053 -0.0380]	-0.1013 [-0.1366 -0.0663]	0.8770	1.0000	1.0000	1.0000	1.0000	1.0000	1.0002	1.0001	1.0001
POP	0.0562 [-1.2537 1.3512]	-1.2267 [-2.6868 0.2353]	-0.9172 [-2.4080 0.5740]	0.5363	0.9510	0.8894	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
GDP	-0.0465 [-0.4414 0.3404]	0.0926 [-0.4273 0.6045]	0.1997 [-0.3484 0.7356]	0.5897	0.6408	0.7653	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
INF	0.4398 [0.0946 0.7867]	0.3905 [-0.0661 0.8451]	0.4072 [-0.0715 0.8838]	0.9937	0.9530	0.9534	0.9856	0.9849	0.9880	1.0000	1.0000	1.0001
Ecofree	-0.0018 [-0.0046 0.0011]	-0.0130 [-0.0159 -0.0102]	-0.0120 [-0.0156 -0.0083]	0.8880	1.0000	1.0000	1.0000	0.9656	1.0000	1.0000	1.0002	1.0002
FDI	0.0023 [-0.0007 0.0052]	0.0059 [0.0018 0.0101]	0.0034 [-0.0007 0.0075]	0.9331	0.9981	0.9487	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
GE	-0.2355 [-0.2830 -0.1875]	-	-	1.0000	-	-	0.9856	-	-	1.0001	-	-
PS	-	-0.0799 [-0.1371 -0.0212]	-	-	0.9968	-	-	0.9377	-	-	1.0001	-
VA	-	-	-0.0231 [-0.1036 0.0578]	-	-	0.7122	-	-	0.9992	-	-	1.0000
OPU x GE	0.0001 [-0.0002 0.0004]	-	-	0.7007	-	-	0.9440	-	-	1.0003	-	-

Table 6. (Cont'd)
Moderating role of institutional quality (continued)
(Institutional quality measured by each dimension of governance indicators)

Independent variables	Mean			Probability of mean			MCMC diagnostics					
							Efficiency			Rc		
	GE	PS	VA	GE	PS	VA	GE	PS	VA	GE	PS	VA
OPU x PS	-	0.0003 [-0.0001 0.0007]	-	-	0.9023	-	-	1.0000	-	-	1.0002	-
OPU x VA	-	-	-0.0001 [-0.0006 0.0005]	-	-	0.5787	-	-	0.9641	-	-	1.0002
_cons	0.7461 [0.5339 0.9572]	1.6957 [1.5179 1.8730]	1.6079 [1.3338 1.8776]	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0001	1.0001
sigma2	0.0052 [0.0042 0.0065]	0.0095 [0.0076 0.0118]	0.0101 [0.0081 0.0126]	-	-	-	0.8579	0.8445	0.8502	1.0000	1.0000	1.0000

Notes: Interval is expressed in square brackets; Convergence rule: Rc < 1.05; GE: Government Effectiveness, PS: Political Stability, VA: Voice and Accountability.

(Sources: Author's calculations)

consumption in the region. The remaining control variables did not show a significant influence on renewable energy consumption in ASEAN-8 during the 2002–2022 period.

4.3 Moderating role of Institustion quality

This study investigates whether institutional quality moderates the negative impact of oil price uncertainty on renewable energy consumption in ASEAN-8 countries. We represent institutional quality using both the average value of six dimensions of governance indicators and each individual dimension. This multi-faceted approach ensures a comprehensive evaluation of institutional quality's potential moderating role in mitigating the adverse effects of oil price uncertainty on regional renewable energy consumption. The estimated results for Model 2, derived from Bayesian regression, are presented in Table 4.

In the model incorporating the interaction term *OPU x Inst*, *OPU* continues to exhibit a negative impact. Specifically, the mean of the parameter for *OPU* is -0.0005, with a probability of mean of 0.9982 (99.82%). Furthermore, higher institutional quality is associated with lower renewable energy consumption in ASEAN-8. The mean of the Inst parameter is -0.2678, with a probability of mean of 1.0000 (100%). These findings are consistent with the results obtained prior to considering the moderating role of institutional quality (Table 3).

When institutional quality is represented by the average of the six dimensions of governance indicators, the mean of the parameter for the interaction term *OPU x Inst* is 0.0001, with a probability of mean of 0.7493 (74.93%). Concurrently, the mean value ranges from [-0.0003; 0.0005]. This suggests that *OPU x Inst* has no significant effect on renewable energy consumption in ASEAN-8 countries. In other words, institutional quality does not play a moderating role in the impact of *OPU* on renewable energy consumption. This aligns with Hypothesis H2 of this study, indicating that the generally low institutional quality in the region fails to mitigate the negative impact of oil price uncertainty on renewable energy consumption during the study period. Thus, while oil price fluctuations have hindered the transition to renewable energy sources, the institutions in ASEAN-8 countries have not demonstrated an ability to balance or curb these adverse effects.

Following the analysis using institutional quality as the average of the six governance indicators, this study further explores the role of institutional quality by individually examining each dimension: Control of Corruption, Rule of Law, Regulatory Quality, Government Effectiveness, Political Stability, and Voice and Accountability (Kaufmann and Kraay, 2024). The results are presented in Table 5 and Table 6.

. Table 5 presents the estimation results when institutional quality is measured by Regulatory Quality (RQ), Rule of Law (RL), and Control of Corruption (CC), respectively. In all these cases, OPU consistently demonstrates a negative impact, hindering the transition to a renewable energy-consuming economy. Higher institutional quality does not facilitate a stronger transition; instead, it indicates the opposite trend. Finally, the interaction terms between institutional quality and oil price volatility (OPU x CC, OPU x RL, and OPU x RQ) show no significant impact on renewable energy consumption. This suggests that, regardless of the specific measure used, institutional quality does not play a moderating role in mitigating the negative effects of oil price uncertainty on renewable energy consumption in the ASEAN-8 region from 2002 to 2022.

Table 6 further corroborates that Government Effectiveness, Political Stability, and Voice and Accountability similarly fail to mitigate the negative impact of oil price

Table 7.
OPU and renewable energy consumption by FGLS estimation

Independent variables	Model 1	Model 2
OPU	-0.0006*** (0.0002)	-0.0005*** (0.0002)
Emission	-0.1008*** (0.0092)	-0.1026*** (0.0094)
Non_REC	0.2182*** (0.0411)	0.2234*** (0.0414)
Tradeopen	-0.0125 (0.0156)	-0.0147 (0.0158)
POP	-0.7111 (0.8629)	-1.0515 (0.9352)
GDP	0.1492 (0.2223)	0.1540 (0.2218)
INF	0.5739*** (0.1951)	0.5989*** (0.1964)
Ecofree	-0.0028* (0.0017)	-0.0029** (0.0017)
FDI	0.0043** (0.0017)	0.0042** (0.0017)
Inst	-0.2484*** (0.0286)	-0.2678*** (0.0353)
OPU x Inst	-	0.0002 (0.0002)
_cons	0.8192*** (0.1331)	0.8333*** (0.1337)

Notes*: ***, **, *: significance levels at 1%, 5%, 10%, respectively. Standard errors are in parentheses.*

(Sources: Author's calculations)

uncertainty on renewable energy consumption in ASEAN-8 countries. These consistent results provide robust evidence regarding the ineffectiveness of institutional quality in ASEAN-8 in moderating the adverse effects of *OPU* on regional renewable energy consumption. Countries in this region remain heavily reliant on fossil fuels. Notably, even nations with the highest institutional quality, such as Singapore and Malaysia, exhibit the lowest rates of renewable energy consumption. Furthermore, the findings suggest that higher institutional quality has not aided these economies in transitioning towards greener and more sustainable practices.

These outcomes raise significant concerns for the green transition in ASEAN. The shift to a low-emission economy critically depends on government involvement in providing financing, infrastructure, knowledge, expertise, regulations, and supportive investment policies (Burke and Stephens, 2018; Smirnova *et al.*, 2021). Moreover, specific governmental support, including subsidies, energy quota trading policies, green bonds, and other financial and non-financial incentives, is essential for renewable energy development (Anwar and Shuangjie, 2021; Li and Wang, 2024; Ye and Rasoulinezhad, 2023). Therefore, ASEAN-8 necessitates substantial institutional reforms and a multi-tiered approach that integrates macro-level institutional improvements with the promotion of corporate-level green governance (Farooq and Salam, 2025), geared towards fostering sustainable development to achieve a greener future.

4.4 Robustness tests

To ensure the robustness of our findings, this study employs two distinct methods to re-evaluate the impact of *OPU* on renewable energy consumption in ASEAN-8. First, we utilize FGLS regression as an alternative to Bayesian estimation. FGLS is particularly effective in addressing issues of serial and cross-sectional correlation and heteroskedasticity, thereby enhancing the reliability of our estimates (Bai *et al.*, 2021). Second, we address potential outliers by winsorizing 1% of the largest and smallest values for the *REC, OPU*, and *Inst* variables, denoted as *REC_w, OPU_w*, and *Inst_w*, respectively (Blaine, 2018; Luo *et al.*, 2024). Subsequently, Bayesian modeling is reapplied to reassess the effect of *OPU* on renewable energy consumption and the moderating role of institutional quality.

Table 7 presents the estimated impact of *OPU* on renewable energy consumption using FGLS regression. The results are highly consistent with those obtained from the Bayesian approach. In Model 1, the coefficient for *OPU* is -0.0006, statistically significant at the 1% level. This confirms that greater *OPU* tends to suppress renewable energy adoption in ASEAN-8 countries. Similarly, the coefficient for *Inst* is -0.2484, also statistically significant at the 1% level. This implies that within ASEAN-8, countries with higher institutional quality exhibit lower renewable energy consumption.

For Model 2, the coefficients for *OPU* and *Inst* are -0.0005 and -0.2678, respectively, both statistically significant at the 1% level. These findings reinforce the inverse relationship between both *OPU* and institutional quality and renewable energy consumption in these nations. Crucially, the interaction term *OPU x Inst* is not statistically significant. This result aligns with our Bayesian regression findings, indicating that higher institutional quality does not mitigate the negative impact of *OPU* on renewable energy consumption in the region.

The Bayesian regression results, utilizing data with 1% winsorized outliers for the variables *REC*, *OPU*, and *Inst*, are presented in Table 8. These findings consistently align with previous estimations regarding the impact of *OPU* on renewable energy consumption, as well as the role of the interaction term *OPU_w x Inst_w*.

In Model 1, the mean of the parameter for *OPU_w* is -0.0006, with a probability of mean of 0.9993 (99.93%). This indicates that an increase in *OPU* leads to a decrease in renewable energy consumption in the region. Additionally, the mean of the parameter for *Inst_w* is -0.2528, with a probability of mean of 1.0000 (100%), also demonstrating a negative impact on renewable energy consumption in ASEAN-8 countries.

For Model 2, the mean of the parameter for *OPU_w* is -0.0005, with a probability of mean of 0.9983 (99.83%),

Table 8.
OPU and renewable energy consumption after winsorizing

Independent variables	Mean		Probability of mean		MCMC diagnostics			
					Efficiency		Rc	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
OPU_w	-0.0006 [-0.0009 -0.0002]	-0.0005 [-0.0009 -0.0002]	0.9993	0.9983	1.0000	1.0000	1.0000	1.0000
Emission	-0.0990 [-0.1176 -0.0810]	-0.0999 [-0.1181 -0.0813]	1.0000	1.0000	1.0000	1.0000	1.0000	1.0001
Non_REC	0.2125 [0.1293 0.2955]	0.2153 [0.1313 0.2983]	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Tradeopen	-0.0120 [-0.0442 0.0201]	-0.0136 [-0.0459 0.0188]	0.7707	0.7916	1.0000	1.0000	1.0003	1.0002
POP	-0.3668 [-1.6909 0.9389]	-0.5039 [-1.9103 0.8902]	0.7069	0.7639	1.0000	1.0000	1.0000	1.0000
GDP	0.1460 [-0.2977 0.5933]	0.1428 [-0.3071 0.5849]	0.7421	0.7361	1.0000	1.0000	1.0000	1.0000
INF	0.5638 [0.1725 0.9572]	0.5821 [0.1853 0.9800]	0.9978	0.9978	1.0000	0.9952	1.0000	1.0000
Ecofree	-0.0026 [-0.0061 0.0009]	-0.0027 [-0.0062 0.0008]	0.9282	0.9340	1.0000	1.0000	1.0000	1.0000
FDI	0.0045 [0.0011 0.0079]	0.0045 [0.0011 0.0079]	0.9951	0.9959	1.0000	1.0000	1.0001	1.0000
Inst_w	-0.2528 [-0.3105 -0.1948]	-0.2685 [-0.3415 -0.1958]	1.0000	1.0000	1.0000	0.9890	1.0000	1.0001
OPU_w x Inst_w	-	0.0001 [-0.0003 0.0006]	-	0.7624	-	0.9485	-	1.0001
_cons	0.7949 [0.5300 1.0567]	0.7998 [0.5319 1.0654]	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
sigma2	0.0070 [0.0056 0.0087]	0.0070 [0.0056 0.0087]	-	-	0.8933	0.8562	1.0000	1.0000

Notes: Interval is expressed in square brackets; Convergence rule: Rc < 1.05

continuing to show a suppressive effect on renewable energy consumption. Furthermore, the mean of the parameter for *Inst_w* is -0.2685, with a probability of mean of 1.0000 (100%). Notably, the interaction term *OPU_w x Inst_w* does not indicate any moderating influence of institutional quality on the negative impact of *OPU* on *REC*. This robustness check further confirms that the institutional quality of ASEAN-8 does not enhance renewable energy consumption in the face of increased oil price uncertainty.

5. Conclusion

This study leverages the strengths of the Bayesian approach to address a research gap by examining the impact of oil price uncertainty on renewable energy consumption in ASEAN-8 countries. It further extends this inquiry by investigating the expected moderating role of institutional quality in this relationship. Our findings reveal that increased volatility significantly reduces green energy adoption in this region, which already exhibits very low consumption levels. This result aligns with the "Real Options Theory" and is consistent with Liu *et al.* (2025) and Urom *et al.* (2022), suggesting that market instability acts as a deterrent to long-term sustainable investments in emerging economies.

Furthermore, institutional quality not only fails to promote renewable energy consumption but actually appear to hinder it. This study contributes to new theoretical insights by identifying an "institutional paradox" in the ASEAN-8 context; as governance improved, these nations prioritized rapid industrialization and energy security, predominantly achieved through fossil-fuel infrastructure rather than high-cost green projects. This finding adds to the existing body of knowledge by demonstrating that "better governance" in early-stage emerging markets may temporarily favor traditional energy stability over transition. The moderating analysis also demonstrated no capacity to mitigate the negative effects of OPU, suggesting that current reforms have not yet reached a maturity level capable of decoupling energy transitions from global shocks.

These outcomes highlight a critical dilemma for ASEAN nations, necessitating a robust reform process to align with Net Zero 2050 targets. To bridge the gap between current fossil-fuel reliance and mid-century decarbonization goals, governments must pivot toward decisive green policies. This is particularly crucial for countries like Singapore and Malaysia, where achieving Net Zero requires a fundamental shift away from traditional energy structures. To attract necessary capital while alleviating fiscal pressures amid volatile oil prices, ASEAN-8 authorities should adopt Public-Private Partnerships, an institutional mechanism successfully implemented in Pakistan (Rehman *et al.*, 2018) to foster a resilient, low-carbon economy.

Despite these insights, this study has certain limitations. First, the small sample size of eight countries and the reliance on a global OPU index may not capture all country-specific nuances. Second, the aggregate nature of the data may overlook the varying sensitivities of different renewable sources (e.g., solar vs. wind). Future research could enhance these findings by employing hierarchical Bayesian models to better account for country-level heterogeneity. Additionally, investigating the impact of non-linear shocks using threshold Bayesian models or disaggregating energy types could provide deeper insights into the regional energy transition "tipping points" and offer more tailored policy recommendations.

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