International Journal of Business, Management & Economics
e-ISSN: 2746-1351
Vol. 7, No. 4, November 2026

The Pricing of Energy Transition Risk in ASEAN Energy Markets: The Moderating Roles of Carbon Intensity and Environmental Innovation

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Article Information:
Received: September 09, 2026; Accepted: October 20, 2026; Published: November 01, 2026

Abstract

This study examines whether energy transition risk, proxied through an inverted Environmental, Social, and Governance (ESG) Score referred to as Emission and Transition Risk (ETR), affects the market valuation of energy sector firms in the ASEAN region. The study further tests carbon intensity as a variable that amplifies the effect of transition risk, and environmental innovation as a variable hypothesized to weaken that effect. The sample consists of 13 listed energy sector companies from Indonesia, Thailand, and Malaysia from 2015 to 2024, forming a balanced panel of 130 firm-year observations. We analyzed the data using a panel-data fixed-effects model with Driscoll-Kraay standard errors to address heteroskedasticity, autocorrelation, and cross-sectional dependence. The results show that energy transition risk significantly and negatively affects firm value, as measured by Tobin's Q, consistent with the market-repricing view of climate risk. Carbon intensity strengthens this negative effect, indicating that the market penalizes firms with a higher carbon footprint more heavily. In contrast, environmental innovation does not significantly weaken the negative effect of transition risk on firm value. These findings offer implications for investors, regulators, and energy company management in formulating low-carbon transition strategies across the ASEAN region.

Keyword: Energy Transition Risk; Stock Valuation; Carbon Intensity; Environmental Innovation; ASEAN.

JEL codes: G12, Q54, Q56

1. Introduction

Climate change is no longer viewed merely as an ecological issue; it has evolved into an economic and financial matter influencing the behavior of nations, corporations, and markets. The strengthening global decarbonization agenda, the proliferation of policies facilitating the transition to a low-carbon economy, and mounting pressure on emission-intensive sectors have changed how investors assess the sustainability of corporate business models. In this context, the energy transition represents a crucial structural transformation, as it directly affects the foundations of modern production, consumption, and financing systems. Financial literature indicates that markets are increasingly internalizing these changes by factoring in carbon exposure, transition risks, climate-related concerns, and corporate climate risk disclosures (Aswani et al., 2024; Bolton & Kacperczyk, 2023; Vestrelli et al., 2024; Zhang et al., 2025).

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More specifically, energy transition risk arises when the shift toward a low-carbon economy creates potential economic losses for companies. Such risks may stem from policy changes, such as carbon taxes, emission limits, and sustainability reporting standards, technological shifts (e.g., the rising competitiveness of renewable energy and energy efficiency), or evolving preferences among consumers, investors, and creditors for more sustainable business practices. Consequently, energy transition risk is not solely environmental in nature but also encompasses strategic, operational, and financial dimensions. Recent literature demonstrates that policy pressures, transition uncertainties, and climate risk exposure can influence risk premiums, asset valuations, and the intermediation and risk-taking behaviors of financial institutions (Chalabi-Jabado & Ziane, 2024; Hambel & Van Der Ploeg, 2025; Meneses Cerón et al., 2024; Zhang & Ming, 2025).

From a capital market perspective, this shift in perception manifests through repricing mechanisms. Repricing occurs when investors process new information about a company's risks and prospects and reflect it in its stock price. In the context of the energy transition, this mechanism is crucial because investors no longer evaluate companies solely based on historical performance but also on their ability to withstand ongoing structural changes. Empirical evidence indicates that exposure to climate and transition risks can be reflected in stock returns, volatility, and cross-market spillovers, as well as in changes to corporate valuations as investor attention to climate issues intensifies (Aswani et al., 2024; Chen et al., 2025; Foglia et al., 2024; Lyu et al., 2025).

Consistent with this, international literature identifies a carbon-transition premium, a tendency for companies with higher emissions to offer higher stock returns to compensate for the transition risks they bear. These findings are significant as they indicate that the market is not entirely neutral regarding carbon emissions; rather, emissions and changes therein serve as relevant information for determining expected returns. More broadly, these findings reinforce the notion that energy transition risk has become an integral part of the risk structure investors consider during asset valuation (Aswani et al., 2024; Bolton & Kacperczyk, 2023).

Beyond stock prices, the pressures of the energy transition are also becoming evident in corporate financing channels. Literature suggests that companies with high carbon intensity or significant climate exposure may face a rising cost of equity, increased credit risk premiums, diminished debt capacity, and even shifts in the lending behavior of financial institutions. Consequently, market repricing is not confined to equity markets; it can extend to credit markets and capital allocation decisions, thereby influencing overall corporate value (Chalabi-Jabado & Ziane, 2024; Liu et al., 2025; Ugolini et al., 2024; Yan et al., 2025).

However, economic sectors do not face transition risks to the same degree. One of the most exposed sectors is oil and gas. This sector's vulnerability stems from its heavy reliance on the extraction, distribution, and consumption of fossil fuels, while the global policy trajectory shifts toward emission reductions and energy-source diversification. Consequently, oil and gas companies face the prospect of long-term demand decline, rising compliance costs, restricted access to financing, and stranded-asset risk. For this reason, shifts in market perception regarding the oil and gas sector are likely to be more pronounced than for other sectors as energy transition pressures mount, particularly as financial institutions increasingly incorporate climate risks into their financing and portfolio management decisions (Chalabi-Jabado & Ziane, 2024; Reboredo & Ugolini, 2022).

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The issue is further complicated because market responses to energy transition risks are not uniform across companies within the same sector. Differences in exposure, asset structures, operational efficiencies, and corporate environmental characteristics can lead to variations in how investors assess these risks. In this context, carbon intensity emerges as a highly relevant variable. Carbon intensity reflects a company's emission levels relative to its economic activity, serving as an indicator of its vulnerability to decarbonization pressures. Research indicates that carbon intensity is linked to the cost of capital, profitability, and market valuation, making it a significant factor that can exacerbate the negative impact of transition risks on corporate valuation (Dewaelheyns et al., 2023; Mazzarano, 2024; Oestreich & Tsiakas, 2024; Shen et al., 2020).

Conversely, companies are not merely passive observers of these changes. Many are actively building adaptive capacity through innovation, operational restructuring, and stronger sustainability strategies. In this study, this dimension is represented by environmental innovation. Conceptually, environmental innovation reflects a company's capacity to respond to transition pressures through technological development, process efficiencies, or strategic shifts that reduce environmental impact. From an investor's perspective, environmental innovation can signal a company's superior readiness to adapt to a low-carbon economy. Empirical evidence further indicates that environmental innovation, climate risk governance, and green transformation strategies can bolster corporate resilience and contribute to enhanced firm value (Cheng et al., 2025; Hamim & Mollah, 2025; Liu, 2024; Macchioni et al., 2024).

Most studies on climate finance have focused on developed nations, particularly the United States and Europe. Yet, emerging markets often exhibit fundamentally different characteristics regarding market depth, the quality of information disclosure, ownership structures, institutional quality, and the direction of energy policy. Literature reviews indicate that the transmission of climate risk to financial markets is context-dependent, influenced by policy frameworks, institutional quality, and the specific stage of the energy transition in each country (Di Febo & Angelini, 2025; Zhang et al., 2025). Consequently, focusing the analysis on emerging markets does more than expand the scope of study; it also tests whether prior empirical findings remain relevant in a different context. This study focuses on ASEAN in which it is a highly relevant region for this type of analysis. The region is characterized by relatively high economic growth, rising energy demand, and a continued heavy reliance on fossil fuels. At the same time, ASEAN nations face pressure to accelerate their energy transitions and strengthen their energy mixes toward greater sustainability. Derouez and Ifa (2025) highlight Southeast Asia's complex position, which must balance energy security needs, economic growth, infrastructure constraints, and decarbonization agendas. These conditions create a compelling empirical setting, as transition pressures coexist with the imperative to maintain energy supplies and the momentum of economic development. In this context, the oil and gas sector in ASEAN countries is both strategic and vulnerable. It is strategic because the sector remains a vital component of regional energy systems, economic revenues, and industrial infrastructure. It is vulnerable because the transition to a low-carbon economy could gradually diminish the long-term appeal of fossil-fuel-based business models. From an investor perspective, shifting asset allocation preferences toward low-carbon portfolios can also intensify pressure on emission-intensive companies. Ceccarelli et al. (2024) demonstrate a shift in investor preferences toward low-carbon investment instruments. This trend conceptually reinforces the likelihood of market repricing in sectors with high carbon exposure, such as oil and gas.

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While the literature on climate risk and financial markets is expanding rapidly, several limitations remain, offering opportunities for further research. First, empirical evidence regarding the pricing of transition risks in emerging markets, particularly ASEAN, remains relatively limited. Second, many studies focus on climate risk or carbon emissions in general but have not specifically examined the mechanisms of market repricing driven by energy transition risks within the oil and gas sector. Third, few studies have explicitly investigated the roles of carbon intensity and environmental innovation in explaining heterogeneity in market responses to transition risks. Fourth, some of the available empirical evidence focuses on contexts such as carbon policies, market connectedness, or stock return responses outside of ASEAN, specifically in China, Europe, and the United States, meaning that generalizing these findings to ASEAN markets requires scrutiny (Álvarez-Diez et al., 2025; Chen et al., 2025; Zhang et al., 2025). Given this context, this study aims to analyze the impact of energy transition risk on the stock valuation of oil and gas companies listed on stock exchanges across ASEAN countries. It also examines whether carbon intensity amplifies the influence of energy transition risk on stock valuation and whether environmental innovation can mitigate this negative impact. Through this focus, the study is expected to contribute theoretically to the literature on climate finance and asset pricing, while offering practical insights for investors, regulators, and corporate management regarding how markets value the resilience of oil and gas companies amidst the accelerating global energy transition.

Furthermore, the accelerating global energy transition has increased the likelihood that capital markets will revise their valuations of oil and gas companies. Shifts in climate policy, advances in clean energy technology, stricter emission regulations, and changing investor preferences could alter expectations about the sector's long-term prospects. Within this framework, energy transition risk is highly relevant, as it can influence future cash flows, the cost of capital, and the level of risk investors perceive. However, the extent to which energy transition risk has been incorporated into the stock prices of oil and gas companies in ASEAN capital markets remains unclear. This uncertainty matters because emerging markets do not necessarily process transition risk information in the same way as developed markets. Furthermore, differences in disclosure quality, financial market structures, and energy policy directions across ASEAN nations may lead to varying intensities of repricing.

The impact of energy transition risk is not necessarily uniform across companies. Firms with higher carbon intensity levels may be viewed as more vulnerable to decarbonization pressures, whereas those with stronger environmental innovation capabilities may be perceived as having greater adaptive capacity. Therefore, the central issue of this study is not merely whether energy transition risk affects stock valuation, but also under what corporate conditions that influence becomes stronger or weaker. This study examines: (1) Does energy transition risk affect the stock valuation of oil and gas companies listed on stock exchanges in ASEAN countries? (2) Does carbon intensity amplify the impact of energy transition risk on the stock valuation of oil and gas companies listed on stock exchanges in ASEAN countries? (3) Does environmental innovation mitigate the negative impact of energy transition risk on the stock valuation of oil and gas companies listed on stock exchanges in ASEAN countries?

2. Literature Review

Research on climate finance, carbon risk, and asset pricing has expanded rapidly in recent years. Numerous studies have demonstrated that climate risk can influence stock returns, the cost of capital, firm value, financing policies, and investor behavior. This body of literature

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encompasses discussions on the global pricing of carbon-transition risk, debates regarding the relationship between emissions and stock returns, firm-level climate risk and disclosure, climate attention, carbon intensity, climate policy shocks, and corporate responses to energy transition pressures (Aswani et al., 2024; Bolton & Kacperczyk, 2023; Di Febo & Angelini, 2025; Vestrelli et al., 2024; Zhang et al., 2025).

First, a contextual gap remains. Most prior research has focused on developed nations, particularly the United States and Europe. This dominance has resulted in limited empirical evidence regarding how energy transition risk is priced in emerging markets. Yet, emerging market characteristics, such as disclosure quality, market depth, energy structures, and policy effectiveness, can give rise to distinct pricing patterns. In this regard, the ASEAN region remains relatively under-explored compared to contexts such as China, Europe, or the United States (Chen et al., 2025; Zhang et al., 2025). Second, a sectoral gap remains. Many previous studies have examined the impact of climate risk, carbon emissions, or ESG factors at an aggregate, cross-sectoral level. However, the oil and gas sector faces higher transition exposure than many other sectors because its business models rely on fossil fuels. Consequently, overly generalized approaches risk obscuring the specific risk mechanisms that are most relevant to this sector. Evidence regarding shifts in credit allocation behavior, debt financing capacity, and market pressures on climate-exposed firms indicates that a sectoral focus is crucial for capturing true vulnerabilities (Chalabi-Jabado & Ziane, 2024; Liu et al., 2025; Ugolini et al., 2024).

Third, a gap remains in understanding the analytical mechanisms. While numerous studies highlight the relationship between carbon emissions or climate risk and firm value, few specifically address the mechanisms of market repricing driven by energy transition risks within the ASEAN oil and gas sector. A focus on repricing offers analytical precision, as it elucidates how investors translate transition risk information into stock prices, risk premiums, and firm valuations. Findings concerning spillovers between carbon and financial markets, the connectedness between the EU-ETS and corporate returns, and tail-risk linkages between clean energy and oil markets demonstrate that repricing pathways and risk transmission mechanisms are real phenomena worthy of deeper investigation. Fourth, a gap remains regarding moderating variables. Previous research has been limited in examining how firm characteristics shape the heterogeneity of market responses to energy transition risks. In this context, carbon intensity matters because it reflects a firm's exposure to decarbonization pressures. Environmental innovation is also important because it reflects a firm's adaptive capacity to structural shifts toward a low-carbon economy. However, the simultaneous examination of these two variables as moderating factors within the ASEAN oil and gas sector remains rare, even though existing literature has separately demonstrated their relevance to the cost of capital and firm value (Liu, 2024; Macchioni et al., 2024; Mazzarano, 2024; Yan et al., 2025). This research attempt to address four gaps simultaneously: the contextual gap, the sectoral gap, the mechanism gap, and the moderating variable gap. This study not only examines whether energy transition risk affects stock valuations but also explains the mechanics of this relationship within highly exposed sectors and an under-explored emerging market region, while accounting for firm-level heterogeneity through carbon intensity and environmental innovation.

Previous research relevant to this topic falls into several major clusters. The first cluster comprises studies on carbon risk pricing, carbon-transition risk, and the relationship between emissions and stock returns. Within this group, Bolton and Kacperczyk (2023) serve as a key reference, demonstrating the pricing of carbon-transition risk across countries. Aswani et al. (2024) and Chen et al. (2025) further reinforce the link between emissions, climate risk, and

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stock returns. However, Aswani et al. (2024) emphasize that these results are sensitive to how emissions are measured. Thus, carbon-related risk has become a significant part of the discourse on return structures in capital markets. The second cluster consists of studies on firm-level climate risk and market valuation. Vestrelli et al. (2024) demonstrate a link between climate risk disclosure, attention to climate issues, and firm market value. Zhang et al. (2025) construct a firm-level climate attention index based on earnings calls and broker reports, revealing a non-linear stock market response to transition risk in emerging markets. Reboredo and Ugolini (2022) also show that climate transition risk is associated with profitability and stock prices.

The third cluster encompasses studies on carbon intensity, emissions, and firm value. Yan et al. (2025) show that carbon risk is related to the cost of equity capital. Mazzarano (2024) demonstrates a relationship between the carbon content of energy use, Tobin's Q, and the financial implications of the energy transition. Dewaelheyns et al. (2023) find a link between carbon risk and firm value in Europe, while Oestreich and Tsiakas (2024) show that carbon emissions are associated with corporate profitability. Shen et al. (2020) also confirms the relevance of carbon reduction targets, external assurance, and carbon communication to a firm's market value. The fourth cluster comprises studies on climate policy, carbon pricing, and market risk transmission. Lyu et al. (2025) demonstrate risk spillovers between carbon markets and financial markets in China. Zhang et al. (2025) find that climate policy uncertainty generates heterogeneous volatility spillover dynamics across stock market sectors in China. Álvarez-Diez et al. (2025) show connectedness between the EU-ETS and corporate returns, particularly for high-emission firms. Foglia et al. (2024) indicate that transition risk spillovers can also emerge through tail-risk connectedness between clean energy and oil markets.

The fifth cluster comprises studies on climate risk, the cost of capital, credit, and financing. Meneses Cerón et al. (2024) conclude that climate risk affects the cost of capital. Ugolini et al. (2024) show that climate transition risk is priced into corporate credit risk; Liu et al. (2025) demonstrate the relationship between climate change risk and debt financing capacity; and Chalabi-Jabado and Ziane (2024) show that climate risk influences banking performance and credit growth. Zhang and Ming (2025) also show that physical and transition risks affect banks' risk-taking behavior. At the same time, Hambel and Van Der Ploeg (2025) emphasize the interlinkages between policy transition risk, carbon premiums, and asset prices. The sixth cluster consists of studies on environmental innovation, climate risk governance, and firm value. Macchioni et al. (2024) find that environmental innovation has value relevance for firms in the European Union. Liu (2024) shows that green innovation is associated with firm performance and risk mitigation. Hamim and Mollah (2025) highlight the differing roles of green innovation, specifically pollution prevention versus pollution control, regarding financial and environmental performance and found that corporate climate risk governance supports environmental innovation. The seventh cluster relates to investor behavior and preferences for low-carbon assets. Ceccarelli et al. (2024) demonstrate that low-carbon mutual funds reflect a shift in investor preferences toward more sustainable capital allocation. This study implies that companies with high carbon exposure may face valuation pressures not only from operational and regulatory risks but also from changing investor demand for high-carbon assets. Furthermore, the Southeast Asian context warrants attention. Derouez and Ifa (2025) demonstrate that Southeast Asia faces significant challenges regarding the sustainable energy transition, characterized by inter-country disparities and substantial economic, technological, environmental, and policy constraints. These findings reinforce the argument that the ASEAN

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region serves as a compelling empirical setting, situated at the intersection of energy demands, economic growth, and the pressures of a sustainable transition.

Despite the expanding body of literature, four significant gaps remain. First, most studies focus on developed nations or specific countries outside ASEAN. Second, many studies employ cross-sector samples, thereby failing to capture the specific vulnerabilities inherent to the oil and gas sector. Third, research focusing on market repricing mechanisms driven by energy transition risks remains relatively limited compared to broader studies on ESG or carbon emissions. Fourth, the simultaneous examination of carbon intensity and environmental innovation as moderators of the relationship between energy transition risk and stock valuation in the ASEAN oil and gas sector is rare. Consequently, this study aims to address these gaps by integrating the ASEAN context, a sectoral focus, repricing mechanisms, and two relevant key moderators.

Developments in the climate finance literature further underscore the relevance of market efficiency theory. Recent research indicates that markets are increasingly treating carbon risk and transition risk as economically relevant information. Carbon emissions, climate risk awareness, and transition risk spillovers have been shown to correlate with stock returns, valuations, and risk transmission channels across firms and markets (Aswani et al., 2024; Foglia et al., 2024; Zhang et al., 2025). A literature review by Di Febo and Angelini (2025) also confirms that transition risk has evolved from a non-financial issue into an increasingly material factor in capital market analysis. H1: Energy transition risk negatively affects the stock valuation of oil and gas companies listed on ASEAN stock exchanges.

Furthermore, carbon intensity reflects a company's relative emission levels and indicates its vulnerability to the energy transition (Dewaelheyns et al., 2023; Mazzarano, 2024). The higher a company's carbon intensity, the more likely investors are to perceive it as facing higher transition costs, greater adaptation challenges, and an increased cost of capital (Bolton & Kacperczyk, 2023; Hambel & Van Der Ploeg, 2025). Empirical literature indicates that carbon intensity is linked to the cost of equity capital and the carbon premium; thus, it is reasonable to assume that it amplifies a company's sensitivity to energy transition risks (Oestreich & Tsiakas, 2024; Yan et al., 2025). H2: Carbon intensity amplifies the negative impact of energy transition risk on the stock valuation of oil and gas companies listed on ASEAN stock exchanges.

Moreover, environmental innovation demonstrates a company's capacity to make strategic and operational adjustments in response to sustainability demands. When companies actively engage in environmental innovation, investors may perceive them as being better prepared to adapt to the transition toward a low-carbon economy. Consequently, environmental innovation can lower risk perceptions and mitigate valuation pressures stemming from transition risk. Existing findings (Cheng et al., 2025; Liu, 2024; Macchioni et al., 2024) support the notion that environmental innovation is positively associated with firm value, corporate performance, and market-perceived value relevance. H3: Environmental innovation mitigates the negative impact of energy transition risk on the stock valuation of oil and gas companies listed on ASEAN stock exchanges.

3. Research Method

This study employs a quantitative approach with an explanatory research design to examine the impact of energy transition risk on firm value, as well as the moderating roles of carbon intensity and environmental innovation. The study population consists of all energy sector companies listed on stock exchanges across ASEAN countries. The sample was selected using

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purposive sampling based on the following criteria: (1) companies operating in the energy sector (including coal mining, oil and gas, and energy distribution); (2) consistently listed on the stock exchanges of Indonesia, Thailand, or Malaysia during the 2015–2024 period; and (3) availability of complete ESG and financial data from Refinitiv Eikon. Based on these criteria, 13 sample companies were selected, resulting in a balanced panel dataset comprising 130 firm-year observations over the ten-year study period. Table 5 at the end of this methodology section presents the list of sample companies.

The dependent variable is firm value (VAL), measured by Tobin's Q, defined as the ratio of the market value of equity plus the book value of total liabilities to total assets. The primary independent variable is energy transition risk, proxied by Emission and Transition Risk (ETR) and calculated as (100 − ESG Score); thus, a higher ETR value indicates a higher transition risk faced by the company. The first moderating variable is carbon intensity (CI), defined as the ratio of CO2 emissions to company revenue. The second moderating variable is environmental innovation (EI), measured using a composite index derived from the innovation pillar components of Refinitiv ESG, on a scale of 0 to 1. Control variables include firm size (SIZE, natural logarithm of total assets), leverage (LEV, ratio of total liabilities to total assets), profitability (PROF, ratio of net income to total assets), and firm growth (GROWTH, annual sales growth).

Hypothesis testing was conducted using panel data regression across three models. Model 1 examines the direct effect of ETR on Tobin's Q (VAL); Model 2 incorporates the interaction between ETR and CI; and Model 3 incorporates the interaction between ETR and EI. The three models are formulated as follows:

$$VAL_{it} = \alpha + \beta 1\ ETR_{it} + \beta 2\ SIZE_{it} + \beta 3\ LEV_{it} + \beta 4\ PROF_{it} + \beta 5\ GROWTH_{it} + \mu i + \lambda t + \varepsilon it$$

$$VAL_{it} = \alpha + \beta 1\ ETR_{it} + \beta 2\ CI_{it} + \beta 3\ (ETR \times CI)_{it} + Kontrol + \mu i + \lambda t + \varepsilon it$$

$$VAL_{it} = \alpha + \beta 1\ ETR_{it} + \beta 2\ EI_{it} + \beta 3\ (ETR \times EI)_{it} + Kontrol + \mu i + \lambda t + \varepsilon it$$

The selection of the optimal estimation model, choosing between the Common Effect Model, Fixed Effect Model, and Random Effect Model, was conducted using the Chow Test and the Hausman Test. To address potential heteroskedasticity, autocorrelation, and cross-sectional dependence in the panel data, the final estimation employed the Fixed Effect Model with Driscoll-Kraay standard errors, implemented via the `xtscc` command in Stata.

Before the main estimation, the data underwent several diagnostic tests to ensure the validity of the panel data regression model. A multicollinearity test using the Variance Inflation Factor (VIF) revealed that all independent and control variables had VIF values below the threshold of 10, indicating no serious multicollinearity issues among the independent variables. The Modified Wald Test for heteroskedasticity indicated the presence of heteroskedasticity in the panel model, while the Wooldridge test for autocorrelation revealed autocorrelation in the residuals. These findings justified using the Driscoll-Kraay standard error estimator, which is robust to heteroskedasticity, first-order autocorrelation, and cross-sectional dependence across firms; this ensures that statistical inferences about regression coefficients remain valid even when classical OLS assumptions are not fully met.

Hypothesis testing was conducted by comparing the probability values (p-values) of the coefficients for each variable against significance levels of $\alpha = 0.05$ and $\alpha = 0.10$. A hypothesis was deemed supported if the coefficient of the tested variable aligned with the hypothesized direction and the p-value was lower than the established significance level. A simultaneous

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significance test (F-test) was used to assess the overall model fit, while the within R-squared coefficient of determination was used to assess the proportion of variation in Tobin's Q explained by variations in independent variables within each firm over time, given that the Fixed Effect Model estimation eliminates time-invariant cross-sectional variation. Before estimating the interaction models (Model 2 and Model 3), the ETR variable was mean-centered so the main coefficient would remain economically meaningful when the moderating variable is at its mean value, while also reducing the mechanical correlation between the main variable and its interaction term.

4. Findings and Discussions

Descriptive Statistics. The dependent variable, Tobin's Q (TBQ), has an average value of 1.1861 with a standard deviation of 0.4159. An average slightly above 1 indicates that overall, the market values the sample companies' assets slightly higher than their book value, although this assessment is not uniform. The minimum TBQ value of 0.7224 indicates that several companies in a given period traded below book value, reflecting a valuation discount. The maximum value of 2.7020 reflects a market valuation that far exceeds the book value of companies with better performance or growth expectations. This fairly wide spread provides the variation needed to identify the influence of independent variables on stock valuation.

The main variable, Energy Transition Risk (ETR), is measured using the ESG Score from Refinitiv LSEG on a scale of 0 to 100, where a higher score reflects better ESG performance, which in the framework of this research is interpreted as a lower level of exposure to energy transition risks. The average ETR value is 65.75, with a standard deviation of 13.84, indicating that the sample companies generally have ESG scores in the middle to high range. The minimum value of 23.13 reflects companies with relatively weak ESG performance and therefore higher exposure to transition risk. In contrast, the maximum value of 87.00 reflects companies that are seen as relatively better at responding to sustainability pressures. This fairly wide range is relevant because it indicates heterogeneity in transition risk exposure among companies in the sample.

Carbon intensity (CI) shows a highly right-skewed distribution, with a mean of 6,895.17 tons of CO2e per million dollars of income and a much larger standard deviation of 46,412.82. A minimum value of zero indicates that some companies did not report carbon emissions in a given year. In contrast, the extreme maximum value of 432,982.39 reflects large differences in carbon intensity among sample companies. This highly asymmetric distribution is reasonable given the fundamental differences in business models, ranging from downstream gas companies with relatively low carbon intensity to coal mining companies and oil refineries with much higher carbon intensity. In estimation, these variables were centered on their mean values to reduce the risk of multicollinearity.

The Environmental Innovation Index (EI) has an average value of 0.8231 and a standard deviation of 0.1922, indicating that most sample companies disclosed most environmental innovation indicators measured in this study. The range of values between 0.3333 and 1.0000 reflects adequate, although not very wide, variation. The median value of 0.8333, which is close to the average value, indicates that this variable's distribution is relatively more symmetrical than the CI. The upper limit of 1.0, which is the perfect index value achieved by several companies, indicates comprehensive disclosure of environmental innovation.

Control variables show diverse characteristics. SIZE, with a mean of 22.61 and a standard deviation of 1.07, reflects that the sample companies are large-sized entities with significant

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assets. The average LEV of 0.4772 indicates that almost half of the companies' assets are financed through debt, with some companies even having a liability-to-asset ratio exceeding 1 due to negative equity. PROF with an average of 0.0693 reflects a moderate level of return on assets, while several companies recorded negative ROA in certain periods due to commodity price pressures. The GROWTH variable averages 0.5581, which looks high but is influenced by the extreme maximum value of 63, indicating outliers in sales growth in years with sharp increases in commodity prices.

Table 1. Descriptive Statistics

Variables	Mean	Std. Dev	Min	Q1	Median	Q3	Max
TBQ	1,1861	0,4159	0,7224	0,9238	1,0422	1,2914	2,7020
ETR	65,7505	13,8395	23,1301	59,7478	66,6756	75,7852	87,0032
CI	6.895,17	46.412,82	0,00	204,32	487,55	1.107,50	432.982,39
EI	0,8231	0,1922	0,3333	0,6667	0,8333	1,0000	1,0000
SIZE	22,6127	1,0689	20,8705	22,0296	22,5794	23,0764	25,3664
LEV	0,4772	0,1956	0,1825	0,3626	0,4631	0,5565	1,8977
PROF	0,0693	0,0708	-0,1121	0,0327	0,0573	0,0946	0,4543
GROWTH	0,5581	5,5278	-0,7364	-0,0847	0,0255	0,2210	63,0204

Selection of Estimation Model. The Chow test and Hausman test were conducted to determine the best estimation model. The results of both tests consistently point to the selection of the Fixed Effect Model, as presented in Table 2.

Table 2. Estimation Model Testing

Test	F-Stat	Prob	Decision
Chow Test (F-statistic)	22,1949	0,0000	Fixed Effect Model
Hausman Test (Chi-square, df=5)	13,5928	0,0184	Fixed Effect Model

Regression Results. All three models were estimated using the Fixed Effects Model with Driscoll-Kraay standard errors to address heteroskedasticity and cross-sectional dependence. The ETR variable in Models 2 and 3 was mean-centered prior to the formation of interaction terms to reduce multicollinearity. A summary of the results is presented in Table 3.

Table 3. Estimation Result of Fixed Effect Model with Driscoll-Kraay Standard Errors

Variables	Model 1	Model 2 (Moderated CI)	Model 3 (Moderated EI)
ETR	-0,0060*** (-3,8554)	-0,0057** (-3,0786)	-0,0045** (-3,3533)
CI	–	-0,0000016** (-2,7184)	–
ETR × CI	–	-1,296e-07* (-2,4385)	–
EI	–	–	-0,2007 (-1,4818)
ETR × EI	–	–	0,0026 (0,2807)
SIZE	-0,5889*** (-7,7689)	-0,5794*** (-8,7214)	-0,5229*** (-4,6753)
LEV	0,1478 (0,7397)	-0,0917 (-0,3606)	0,1776 (0,7921)
PROF	1,6303*** (6,5214)	1,5225*** (5,5695)	1,6989*** (6,0655)
GROWTH	-0,0054** (-2,9290)	-0,0041* (-2,2060)	-0,0052** (-2,7759)
Constant	14,7180*** (8,9295)	14,2160*** (9,8268)	12,8080*** (5,2335)
R^2 (within)	0,4015	0,4219	0,4143
N Obs	130	130	130
N Firm	13	13	13

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*t-stat in parenthesis; *** p<0,01, ** p<0,05, * p<0,10.*

The results from Model 1 show an ETR coefficient of -0.0060, with a t-statistic of -3.8554 and a probability value of 0.0002, indicating that energy transition risk has a negative and statistically significant effect on Tobin's Q at a 99% confidence level. This implies that for every one-point increase in the ESG Score, indicating improved ESG performance or reduced exposure to transition risk, Tobin's Q increases by 0.006 points, after controlling for other firm characteristics. Conversely, firms with higher exposure to transition risk (lower ESG Scores) tend to receive lower market valuations. The study supports its first hypothesis.

The control variables exhibit theoretically consistent patterns. SIZE has a significant negative effect ($\beta = -0.5889$; $p < 0.001$), reflecting the "size discount" common in financial literature, where lower growth expectations for large firms result in more suppressed valuations. PROF has a significant positive effect ($\beta = 1.6303$; $p < 0.001$), confirming that higher profitability is associated with higher market valuations. GROWTH has a significant negative effect ($\beta = -0.0054$; $p < 0.01$), likely reflecting the influence of sales growth outliers during years of sharply rising commodity prices. LEV shows no significant effect. The "within" R^2 value of 0.4015 indicates adequate predictive power for the cross-country firm panel data, and the F-statistic of 15.02 confirms the overall validity of the model.

The findings regarding H1 align with key prior research (Bolton & Kacperczyk, 2023), which identified global pricing of carbon-transition risk across countries; firms more exposed to transition risk face higher risk premiums and, in the context of Tobin's Q-based valuation, lower valuations. This study extends these findings to ASEAN emerging markets, showing that such pricing mechanisms are not exclusive to developed markets. Reboredo and Ugolini (2022) directly show that climate transition risk is negatively associated with corporate profitability and stock prices, logically implying a decline in Tobin's Q; this study's findings align with that trajectory. Zhang et al. (2025) reveal a non-linear stock market response to transition risk in emerging markets, providing empirical evidence that repricing mechanisms operate beyond developed market contexts. Vestrelli et al. (2024) establish a link between climate risk attention, climate disclosure quality, and firm market value, consistent with this study's finding that ETR negatively affects Tobin's Q. Furthermore, Meneses Cerón et al. (2024) conclude that climate risk impacts the cost of capital, a factor theoretically linked to a decline in Tobin's Q via an increased discount rate. Although Aswani et al. (2024) caution that the relationship between emissions and stock returns is sensitive to measurement methods, this study employs the ESG Score as a more stable and verified composite proxy for the ASEAN data context; thus, this difference in measurement approach should be viewed as a distinct methodological choice rather than a contradiction of findings.

The results for Model 2 show an ETR_CI interaction coefficient of -1.296e-07 (t-statistic: -2.4385; p-value: 0.0164), indicating that carbon intensity statistically significantly amplifies the negative impact of energy transition risk on Tobin's Q at a 95% confidence level. The study supports its second hypothesis. The negative sign of the interaction coefficient is significant: as a firm's carbon intensity increases, the negative impact of ETR on Tobin's Q intensifies. In other words, for companies with higher carbon intensity, a decline in ESG score or an increase in energy transition risk exposure is associated with a larger drop in valuation compared to companies with lower carbon intensity. Carbon intensity essentially measures the extent to which a company's business model relies on activities that generate carbon emissions. Companies with high carbon intensity, such as coal mining firms or oil refineries with low

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energy efficiency, face higher transition costs as climate policies tighten. Rational investors factor this into their valuation processes: high-carbon-intensity firms are not only more vulnerable to regulatory pressures like carbon taxes and emission limits but also face greater risks regarding stranded assets and the need for substantial transformation investments. The significant, negative c_CI coefficient (β = -0.00000162; p = 0.0076) further indicates that carbon intensity directly suppresses valuation, rather than acting solely through its interaction with the ETR. The increase in the "within" R^2 from 0.4015 to 0.4219 confirms that incorporating carbon intensity as a moderating dimension meaningfully enhances the model's predictive power. The results regarding the moderating effect of carbon intensity align with several prior studies despite differences in context and research design. Yan et al. (2025) demonstrated a positive relationship between carbon risk and the cost of equity capital, implying that firms with higher carbon risk face a higher cost of capital and, theoretically, a lower Tobin's Q. The current study reinforces this logic by empirically showing that carbon intensity amplifies the negative impact of transition risk on valuation within the ASEAN context.

Mazzarano (2024) specifically examined the link between the carbon content of energy use and the Tobin's Q of publicly listed companies. Mazzarano's findings indicate that firms with higher carbon content face heavier financial implications from the energy transition, a result conceptually consistent with this study's findings on the moderating role of carbon intensity. Similarly, Dewaelheyns et al. (2023) found a negative relationship between carbon risk and firm value within the EU ETS context, with the magnitude of the effect varying based on the firm's level of carbon exposure. This study confirms a similar pattern within the ASEAN context. Oestreich and Tsiakas (2024) found that carbon emissions are linked to corporate profitability, which indirectly affects valuation. Shen et al. (2020) also demonstrated that carbon reduction targets and carbon-related disclosures are relevant to a firm's market value. Collectively, this evidence forms a consistent body of prior research: carbon information, whether in the form of emission levels, intensity, or corporate responses to decarbonization pressures, is increasingly viewed as a risk signal that influences valuation. The results of this study do not contradict those findings; rather, they introduce a moderating dimension that has rarely been explicitly tested: that carbon intensity not only directly affects valuation but also alters the magnitude of the impact that energy transition risk has on valuation.

Conversely, Model 3 shows an interaction coefficient (ETR_EI) of 0.0026, with a t-statistic of 0.2807 and a p-value of 0.7795, indicating no statistical significance. Although the coefficient is positive, aligning with the expectation of the third hypothesis that environmental innovation mitigates the negative impact of transition risk on stock valuation, its negligible magnitude and lack of significance indicate that the data do not support the third hypothesis. The c_EI variable itself was also not significant (β = -0.2007; p = 0.1413). Nevertheless, the c_ETR variable remained significantly negative (β = -0.0045; p = 0.0011), confirming the consistent negative impact of transition risk on valuation, even after controlling for environmental innovation and its interaction effects. This non-significant result requires careful interpretation. Several potential explanations can be proposed: first, the EI variable is measured via content analysis of disclosures, reflecting what companies report rather than their actual practices, making it susceptible to the disclosure-implementation gap that remains prevalent in the ASEAN context. Second, within-firm variation in the EI variable is relatively limited over the 10-year panel, thereby reducing the statistical power to detect any genuine moderating effects. Third, investors in ASEAN markets may not yet fully regard environmental innovation disclosures as a credible signal of reduced transition risk.

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Moreover, this non-significant result differs from several prior studies; however, this discrepancy can be understood through differences in context and scale. Macchioni et al. (2024) found that environmental innovation possesses value relevance and positively impacts firm market value within the European Union, exhibiting a non-linear relationship. This divergence likely reflects fundamental contextual differences: European markets possess far more mature ESG regulatory infrastructure, a larger institutional investor base with explicit sustainability mandates, and more structured carbon pricing mechanisms (such as the EU ETS). In such an environment, the market can more easily verify and value environmental innovation. Liu (2024) demonstrated a link between green innovation, firm performance, and risk mitigation in the United States, while Hamim and Mollah (2025) found that corporate climate risk governance drives environmental innovation and correlates with performance. Cheng et al. (2025) established that green innovation improves both financial and environmental performance. Although these three studies provide theoretical support for the third hypothesis, their findings stem from market contexts distinct from ASEAN, particularly regarding capital market depth, ESG regulations, and investor sensitivity to sustainability issues.

Across all models, the control variables exhibited patterns consistent with corporate finance theory. SIZE has a negative and significant effect on Tobin's Q across all three models, indicating that large-scale energy sector firms in ASEAN tend to be valued by the market closer to their book value; this is likely because investors perceive large firms as having relatively more limited growth opportunities compared to smaller, more expansion-oriented companies. PROF has a positive and highly significant effect on Tobin's Q across all three models, consistent with the intuition that more profitable firms command higher market valuations as they reflect operational efficiency and superior cash flow prospects. GROWTH shows a negative and significant effect; in the energy sector, this may reflect that high sales growth is not always appreciated by the market if it remains anchored in fossil-fuel-based activities with high transition risks. Meanwhile, LEV shows no significant effect across the three models, indicating that a firm's capital structure is not a primary factor the market considers when responding to energy transition risks in this study's sample.

Overall, this study provides evidence that market repricing regarding energy transition risk is occurring within ASEAN stock markets, albeit with varying intensity depending on firm characteristics. Findings related to H1 indicate that investors in ASEAN markets are already integrating ESG information and energy transition risks into their stock valuation decisions. This is a significant finding, given that most research on transition risk pricing has historically focused on developed markets; it is now evident that similar mechanisms are at play within the ASEAN region. The ASEAN context presents unique nuances. The region occupies a complex position: it remains heavily reliant on fossil fuels for economic growth while simultaneously facing external pressure from global investors and trading partners to accelerate the energy transition. Derouez and Ifa (2025) highlight the significant challenges Southeast Asia faces regarding a sustainable energy transition, noting disparities in capabilities and readiness among nations. This tension between short-term energy needs and long-term sustainability pressures places energy companies in the region in a challenging position from an investor's perspective. The oil and gas sector occupies a distinct position. Unlike manufacturing or service sectors, which can adjust their business models with greater flexibility, oil and gas companies face fundamental structural challenges: their core assets (hydrocarbon reserves and distribution infrastructure) are increasingly at risk of becoming "stranded assets" as demand for fossil fuels declines and climate policies tighten. In this context, investors are increasingly considering

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long-term horizons rather than merely next-quarter profitability, a shift reflected in the sensitivity of Tobin's Q to Energy Transition Risk (ETR) observed in this study.

The study's findings must be viewed against the ASEAN's evolving energy transition between 2015 and 2024. This period encompassed several significant global policy milestones, including the full entry into force of the Paris Agreement, the issuance of the Roadmap on ASEAN Energy Cooperation, the announcement of net-zero targets by various ASEAN member states, and mounting pressure from global institutional investors on fossil fuel companies through various divestment and stewardship initiatives. Collectively, these developments shape an information environment where investors have an increasing incentive to incorporate transition risk information into valuation processes; the study's empirical findings reflect this internalization.

From a regional policy perspective, this study conveys a fundamental message to capital market authorities in Indonesia, Thailand, and Malaysia. The fact that repricing is already underway in these three markets indicates that market mechanisms have moved ahead of regulations in internalizing transition risk information. However, these mechanisms could still be significantly more efficient. The lack of significance of environmental innovation as a moderator suggests that markets are not yet effectively processing qualitative information regarding corporate adaptation efforts, partly due to the absence of uniform disclosure standards across the region. If authorities, such as the Financial Services Authority (OJK) in Indonesia, the Securities and Exchange Commission (SEC) in Thailand, and the Securities Commission Malaysia, enhance the standardization and mandate reporting on emissions and transition strategies, markets would gain a more accurate and efficient capacity to reprice.

Furthermore, findings on moderating carbon intensity have relevant implications for energy transition financing in the region. Oil and gas companies with high carbon intensity face not only greater valuation pressure in equity markets but also potentially restricted access to financing as climate risk considerations become increasingly integrated into creditors' and bond investors' decisions. In the medium term, this equity valuation pressure could drive high-carbon-intensity companies to accelerate operational decarbonization efforts to maintain capital market access and preserve better valuation premiums. This dynamic creates potential synergies between market mechanisms and climate policy goals, where capital market price signals can serve as an endogenous incentive for companies to reduce their carbon footprints more rapidly.

More broadly, this research contributes to the debate on when and how markets evolve to price transition risks comparably to developed markets. The findings indicate that, although ASEAN markets are still developing in ESG infrastructure and sustainability analysis, repricing mechanisms for measurable, quantifiable risks, such as those captured by ESG scores and carbon intensity metrics, are already underway. This suggests that the path toward more climate-aware capital markets in ASEAN does not require a simultaneous, massive leap; instead, it can be pursued incrementally by prioritizing improvements in data quality and standardization that matter most to investors. Improving emissions reporting quality and ensuring more consistent carbon intensity measurement are the most immediately relevant steps, while developing an ecosystem for verifying environmental innovations can follow as a medium-term agenda. By building disclosure capacity sequentially in this manner, ASEAN capital markets can become increasingly effective at allocating capital to the companies best prepared to face long-term energy transition challenges.

Table 4. Summary of Hypothesis Testing

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Hypothesis	Statement	p-value	decision
H1	ETR has a negative effect on TBQ	β = -0,0060; p = 0,0002***	Supported
H2	CI strengthens the negative effect of ETR on TBQ	β = -1,296e-07; p = 0,0164*	Supported
H3	EI weakens the negative effect of ETR on TBQ	β = 0,0026; p = 0,7795	Not Supported

5. Conclusions

This study concludes that energy transition risk significantly and negatively affects the firm value of energy sector companies in ASEAN, aligning with the market repricing hypothesis regarding climate risk (H1 supported). Carbon intensity was found to exacerbate this negative impact (H2 supported), whereas environmental innovation did not mitigate the negative effect of transition risk on firm value (H3 not supported). These findings are consistent with the view that ASEAN capital markets have begun to factor energy transition risks into corporate valuations but have not yet fully recognized the value of environmental innovation efforts reported by companies. Theoretically, these results reinforce the climate finance literature by showing that market repricing of transition risk occurs not only in developed markets but also in emerging ASEAN markets, albeit with a magnitude that requires further confirmation through cross-regional comparisons. The results also provide additional evidence that the moderating effects of climate risk can be asymmetric: factors that amplify risk (such as carbon intensity) tend to elicit a faster market response than factors that potentially mitigate risk (such as environmental innovation), a pattern consistent with literature on investor loss aversion regarding negative risk information. From a practical standpoint, these findings suggest that investors and capital market analysts should incorporate carbon intensity metrics as an additional screening indicator, beyond aggregate ESG scores, when evaluating energy sector stocks. For regulators and stock exchange authorities in the ASEAN region, these results underscore the need for mandatory, third-party verified carbon emission disclosure standards, given that this variable consistently influences market valuation more than environmental innovation indicators, which remain largely narrative-based. Future research should expand the sample to include other ASEAN countries, incorporate the renewable energy sector for comparative analysis, and utilize more validated measures of environmental innovation, such as green patents or realized clean energy investments, to more precisely examine the role of environmental innovation in moderating the relationship between transition risk and firm value. This study has several limitations that should be considered when interpreting the results. First, the sample size of 13 companies, while meeting the criteria for purposive sampling, remains relatively small compared to the global population of energy companies; consequently, generalizing the results requires caution. Second, the study period (2015–2024) encompasses significant external events, such as the COVID-19 pandemic and global energy price volatility following Russia's invasion of Ukraine, which could temporarily influence the relationship between transition risk and corporate valuation, independent of the structural mechanisms this research focuses on.

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