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Low-Carbon Energy Transition and Corporate Carbon Emissions: The Critical Role of Climate Change Mitigation Policies and Institutional Context

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ABSTRACT

This study examines the strategic efficacy of corporate low-carbon energy transition, such as through nuclear energy adoption, as a response to decarbonization pressures. Analyzing an international sample of energy firms, we demonstrate that the relationship between this form of transition and emission reductions is not technologically determined but institutionally channeled. Our analysis reveals that the contribution of a low-carbon transition strategy to corporate decarbonization is significant only when embedded within a robust institutional framework characterized by stringent climate policies and a strong rule of law. The empirical evidence further highlights a fundamental divergence in outcomes between pronuclear and antinuclear regulatory environments, particularly within the context of the EU's sustainable finance taxonomy. These findings compel a strategic reappraisal. For corporate leaders, pursuing a low-carbon transition via contested technologies represents not merely an engineering choice but a sophisticated legitimacy-management instrument whose success is contingent on institutional context. For policymakers, our results underscore that realizing the decarbonization potential of such transitions requires deliberate institutional architecture rather than mere technological adoption.

1 | Introduction

The global energy sector is navigating a profound legitimacy crisis, compelled to decarbonize while maintaining security of supply. Within this transition, nuclear energy represents a central tension. It is a source of firm, low-carbon power capable of displacing fossil fuels at scale (Davis and Brear 2022; Nagabhushan et al. 2021), yet it is constantly contested, associated with catastrophic risk, long-term waste, and intense social opposition (Burke 2007; Piazza and Perretti 2020; Wittneben 2012). This paradox places energy firms in a critical bind, leveraging nuclear power to meet stakeholder demands for decarbonization, while simultaneously managing the significant legitimacy deficits that come with it (Ferguson-Cradler 2022; Grougiou et al. 2016).

Events like the Fukushima Daiichi disaster crystallize this challenge, acting as exogenous legitimacy shocks that trigger massive re-evaluations of corporate and national energy strategies (Bonetti et al. 2023; Lopatta and Kaspereit 2014). The resulting divergence in national policies, from nuclear phase-outs to renewed commitments, creates a complex institutional landscape for firms to navigate (Kim 2021; Wittneben 2012). Although the macroeconomic and policy debates are well-documented, a critical microlevel question remains: "How do firms strategically manage the legitimacy trade-offs of nuclear energy, and what

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are the tangible outcomes for their corporate environmental performance?"

This study investigates the nexus between nuclear energy transition, corporate carbon emissions, and climate policy through an integrated theoretical lens of legitimacy, stakeholder, and institutional theories. We posit that a firm's adoption of nuclear power is a strategic legitimacy-management tactic, aimed primarily at mitigating pressures from stakeholders, particularly investors and regulators, concerned with climate change (Bolton and Kacperczyk 2023; Dai 2019; Piazza and Perretti 2020). We argue that this strategic choice should manifest in a measurable reduction in the firm's operational (Scope 2) carbon emissions. However, we further theorize that this relationship is not automatic; it is critically moderated by the institutional environment, specifically the stringency of climate policies and the quality of a nation's rule of law, which shape the coercive and normative pressures firms face.

Using a unique international dataset of energy sector firms, we test this theoretical model. Our research makes several key contributions. First, we reframe the discussion on corporate decarbonization from a purely technological or governance-based issue (Barroso et al. 2024; Ding et al. 2023; Ferguson-Cradler 2022; Fernández et al. 2022; Nuber and Velte 2021; Rjiba and Thavaharan 2022) to a core problem of strategic legitimacy management under conflicting stakeholder pressures. Second, we provide a novel theoretical integration, explaining how institutional pressures condition the effectiveness of a firm's legitimacy-seeking strategies. Our findings demonstrate that the mere adoption of nuclear energy is an insufficient legitimacy strategy on its own. The negative relationship between nuclear use and Scope 2 emissions, the core of its legitimacy claim as a low-carbon solution, is not universally true. It only becomes robust and statistically significant under specific institutional conditions: namely, in the presence of stringent climate policies and a strong rule of law. This empirically validates our theoretical model. It shows that a firm's legitimacy-seeking strategy (using nuclear power to claim low-carbon status) is not a simple, direct action. Instead, its success is *contingent* on the external institutional environment. In countries with weak policies or poor governance, the low-carbon signal of nuclear power is muted or unreliable, perhaps because the operational and regulatory environment fails to ensure its efficient and safe use as a genuine substitute for fossil fuels. However, in a strong institutional setting, coercive policy pressures (e.g., carbon prices) and the stability provided by the rule of law create the necessary conditions for this legitimacy strategy to be effective and verifiable. Thus, we move beyond stating that "firms seek legitimacy" to explaining the *specific institutional prerequisites* that determine whether such a complex and contested legitimacy strategy will succeed in delivering its intended outcome. Finally, we offer timely empirical evidence for policymakers and corporate strategists debating the role of nuclear power in sustainable finance taxonomies and national energy transitions, demonstrating the conditions under which it delivers tangible corporate-level emissions benefits.

The remainder of this paper is organized as follows. Section 2 has established the theoretical framework and literature review. Section 3 describes the data and methodology. Section 4 presents the empirical results, including baseline findings, mechanism analyses, and robustness checks. Section 5 discusses the results and limitations, and Section 6 concludes with implications and future research directions.

2 | Literature Review and Theory

2.1 | An Institutional and Legitimacy-Theoretic View of the Nuclear Energy Transition

The strategic behavior of energy firms regarding nuclear power cannot be understood through a purely economic lens; it is fundamentally shaped by the quest for organizational legitimacy within a complex institutional field. Legitimacy, a central resource for organizational survival, is defined as a generalized perception or assumption that an entity's actions are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions (Suchman 1995). Nuclear energy firms operate under a perpetual legitimacy deficit (Grougiou et al. 2016), stemming from public perceptions of catastrophic risk, the intractable problem of radioactive waste, and its association with weapons proliferation (Burke 2007; Wittneben 2012). This deficit necessitates continuous and active legitimacy management strategies.

The 2011 Fukushima Daiichi accident was a profound legitimacy shock for the global nuclear industry. It triggered massive de-legitimation, evidenced by dramatic stock price declines for nuclear-reliant firms (Ferstl et al. 2012; Jaussaud et al. 2015; Lopatta and Kaspereit 2014) and a re-evaluation of national energy policies, most notably in Germany (Ferguson-Cradler 2022; Wittneben 2012). This event underscored that a firm's social license to operate is as critical as its regulatory licenses. In this context, a firm's commitment to nuclear energy is not merely a technological choice but a strategic stance that invites intense scrutiny from a wide array of stakeholders, including regulators, investors, local communities, and social movements (Arena et al. 2020).

Empirical research at the macro and sectoral levels corroborates the technical potential of nuclear power to displace fossil fuels and mitigate emissions. Studies leveraging exogenous shocks, such as nuclear plant openings, forced outages, or decommissioning, demonstrate that nuclear generation substitutes significantly for coal-fired power, leading to measurable changes in carbon emissions (Adler et al. 2020; Cho et al. 2016; Petach 2025). For instance, Cho et al. (2016) find that the post-Fukushima nuclear shutdowns in Japan increased national CO_2 emissions, whereas Petach (2025) shows that nuclear plant closures in the United States raised state-level per capita emissions by 6%–8%, primarily through increased coal generation. Adler et al. (2020) further highlight that the substitution between nuclear and coal is not one-to-one and varies with market and regulatory conditions. Although these studies establish a clear technical and aggregate economic link between nuclear power and emissions, they operate at the plant, regional, or national level and do not examine the strategic, firm-level decision-making process or the institutional contingencies that govern how this technical potential translates into corporate environmental performance. Furthermore, recent multicountry

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analyses, such as those in BRICS economies, confirm a complex relationship where nuclear energy adoption can simultaneously support economic growth yet present an environmental trade-off by being positively associated with CO_2 emissions at an aggregate level, highlighting the critical moderating role of complementary green investments and climate financing (Xu et al. 2025). Our study bridges this gap by shifting the focus from the macrotechnical link to the micro-strategic one, investigating nuclear adoption as a firm-level legitimacy tactic whose efficacy in reducing corporate carbon emissions is institutionally channeled. This firm-level focus aligns with a broader scholarly recognition that successful decarbonization within the energy ecosystem requires understanding specific business models, strategies, and implementation dynamics that vary across contexts (Talwar et al. 2025).

2.2 | Stakeholder Pressure, Carbon Emissions, and Legitimacy Management

In the contemporary era, a primary source of stakeholder pressure is the demand for climate change mitigation. Firms are increasingly held accountable for their carbon emissions, with investors pricing carbon-transition risk (Bolton and Kacperczyk 2023) and stakeholders rewarding transparency (Ding et al. 2023). For energy firms, this creates a critical nexus between their energy generation portfolio and their legitimacy. Recent international evidence further suggests that operational CO_2 abatement can be a value-creating capability for firms, with its profitability mediated by the information environment and stakeholder attention rather than headline policy alone (Aliano et al. 2025). This underscores the financial materiality of emission reduction strategies and the importance of how such strategies are perceived by key stakeholders.

From a stakeholder theory perspective, nuclear energy presents a unique dilemma. On one hand, it offers a pathway to substantially reduce operational carbon emissions (Scope 2), directly addressing the demands of stakeholders concerned with climate change. A firm can thus leverage its nuclear assets to build legitimacy based on its environmental performance, positioning itself as a provider of firm, low-carbon electricity essential for deep decarbonization (Davis and Brear 2022; Nagabhushan et al. 2021). This aligns with the broader discourse on sustainability in the energy sector, which identifies the integration of diverse energy sources, including nuclear, as a critical theme, though the effectiveness of this integration is heavily dependent on the policy and regulatory context (Handoyo 2026). On the other hand, it simultaneously exacerbates concerns for other stakeholders worried about safety and environmental justice, potentially triggering activism and opposition (Piazza and Perretti 2020). This tension forces firms to navigate a complex stakeholder landscape, often leading to heightened CSR reporting and disclosure to manage these conflicting pressures and neutralize stigma (Bonetti et al. 2023; Grougiou et al. 2016).

We therefore posit that a firm's use of nuclear energy is a strategic response to powerful stakeholder demands for decarbonization. The primary hypothesis flowing from this legitimacy-management perspective is

Hypothesis 1. *A firm's transition to nuclear energy lowers its corporate carbon emissions, ceteris paribus.*

2.3 | The Moderating Role of Institutional Pressures: Policy and the Rule of Law

The relationship proposed in the first hypothesis is not uniform; it is critically moderated by the institutional environment. Institutional theory emphasizes that organizations conform to regulatory, normative, and cognitive pressures to secure legitimacy and resources (DiMaggio and Powell 1983; Powell and DiMaggio 2012). In the context of climate change, the most salient institutional pressures are codified in national and international climate change mitigation policies. We conceptualize policy stringency as a key regulative pillar of institutions. Stricter domestic and international climate policies (e.g., carbon pricing and emissions trading schemes) create coercive pressures that increase the cost of carbon-intensive operations (Bolton and Kacperczyk 2023; Zhang et al. 2022). In such an environment, the carbon-free attribute of nuclear power becomes not just a legitimacy tool but a direct economic imperative. The institutional "rules of the game" reward low-carbon generation, thereby strengthening the strategic value of nuclear energy in reducing a firm's carbon footprint and maintaining its legitimacy with regulators and investors. This view is supported by systematic reviews of energy policy instruments, which find that integrated economic and regulatory tools are most effective in driving the adoption of low-carbon technologies, though their success is context-dependent (Handoyo 2026).

We theorize that the institutional environment moderates the nuclear-emissions relationship through two primary mechanisms: enforcement credibility and investment certainty. First, enforcement credibility (*policy stringency*): Stringent climate policies (e.g., carbon pricing and emissions trading) increase the *marginal cost* of carbon-intensive generation. In such an environment, nuclear energy's zero-operational-emissions attribute provides not just a legitimacy signal but a direct economic advantage. Firms are financially compelled to optimize nuclear output and use it to displace fossil fuels within their portfolio. Where policies are weak or unenforced, this economic incentive disappears; nuclear may be operated as a baseload source without actively displacing carbon-intensive assets (Adler et al. 2020), leading to no net emission reduction at the firm level. Second, investment certainty (*rule of law*): Nuclear energy requires massive, irreversible capital investments and decades-long operational horizons. A strong rule of law reduces regulatory risk, policy volatility, and expropriation threat. This stability enables firms to plan, finance, and operate nuclear facilities efficiently, ensuring high capacity factors and reliable low-carbon output. In weak rule-of-law contexts, regulatory uncertainty can lead to suboptimal operation, frequent shutdowns, underinvestment in maintenance, and a greater reliance on flexible fossil backups, eroding the emission-reduction potential. Thus, the institutional framework does not alter the technology's intrinsic carbon content but determines whether firms can operationally realize and economically capitalize on that low-carbon potential. This contingent realization is a specific instance of a broader principle in modelling decarbonization pathways, where the effectiveness of any technology or strategy is not intrinsic but depends on the

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surrounding system of policies, infrastructure, and economic assumptions (Sang et al. 2026).

However, the effectiveness of these policies is contingent upon a deeper institutional foundation: the rule of law. The rule of law ensures that policies are credibly enforced and that the regulatory environment is stable and predictable (Palea and Drogo 2020). A strong rule of law ensures policy credibility and contractual enforcement, which are non-negotiable for capital-intensive, long-lived nuclear assets. It reduces the risk of regulatory holdup, arbitrary license changes, or politically motivated shutdowns, thereby allowing firms to optimize nuclear plant performance and achieve the high-capacity factors necessary for substantial fossil fuel displacement. Without this stability, even stringent climate policies may be rendered ineffective due to inconsistent application. For nuclear energy, characterized by massive, long-lived investments and intense regulatory oversight, this stability is paramount. A strong rule of law reduces expropriation risk and policy uncertainty, providing the confidence firms need to operate and maintain nuclear facilities effectively. It also underpins the transparent and fair processes necessary for maintaining a social license (Dai 2019). Where the rule of law is weak, even stringent climate policies may be ineffective because firms cannot rely on their consistent application, undermining the link between nuclear operation and emissions performance. This leads to our second and third hypotheses:

Hypothesis 2. *The negative relationship between nuclear energy transition and corporate carbon emissions is strengthened in the presence of more stringent climate change mitigation policies.*

Hypothesis 3. *The moderating effect of climate policy stringency is stronger in countries with a higher quality of rule of law.*

Our theoretical framework also intersects with key concepts in energy economics. The potential for nuclear-renewable substitution or complementarity could influence a firm's overall emissions trajectory, though our focus is on the net effect of nuclear adoption. Advanced time-frequency analyses, such as wavelet techniques, reveal that the relationship between nuclear energy and environmental outcomes is dynamic and horizon-specific, often shifting from negative to neutral or positive depending on the period and the concurrent evolution of other factors like renewable energy penetration (Olanrewaju 2026). We acknowledge the possibility of rebound effects at the system level (e.g., lower electricity prices from nuclear baseload stimulating demand), but our firm-level analysis captures the direct operational substitution within the firm's generation mix. Furthermore, the institutional variables we emphasize, policy and rule of law, can either reinforce carbon lock-in (in weak settings) or enable socio-technical path creation toward decarbonization (in strong settings). By conditioning the success of nuclear strategy, institutions shape whether nuclear adoption becomes part of a low-carbon pathway or remains an isolated, underutilized asset.

Hence, our theoretical framework integrates legitimacy, stakeholder, and institutional theories to argue that a firm's transition to nuclear energy is a strategic response to decarbonization pressures. This relationship is posited to reduce Scope 2 emissions (addressing stakeholder and legitimacy concerns), an effect that is amplified by coercive policy pressures and the stabilizing force of a strong rule of law.

2.4 | Financial Market Legitimacy as an Alternative Outcome of Nuclear Transition

Although our core hypotheses focus on the environmental performance outcome of nuclear adoption, legitimacy theory suggests that successful legitimacy-management strategies should also elicit positive responses from key resource-providing stakeholders, particularly investors (Suchman 1995). Financial markets play a crucial role in conferring legitimacy, as reflected in firm valuation metrics such as Tobin's Q (Khan and Khan 2025), which captures the market's assessment of a firm's future growth prospects and risk profile (Bolton and Kacperczyk 2023). Investors may perceive nuclear energy adoption as a credible, strategic response to decarbonization pressures (Fan et al. 2024; Prăvălie and Bandoc 2018; Seneviratne 2026). This perception mitigates transition risk, aligns the firm with regulations, and should thereby enhance its legitimacy and market valuation (Salehi et al. 2025; Shi et al. 2025). According to Singh et al. (2018, 183), Tobin's Q provides an objective assessment of a company's performance by reflecting market perception on its past performance and future prospects.

However, this financial legitimacy benefit is also likely to be institutionally contingent. In countries with stringent climate policies, the economic rationale for low-carbon nuclear power is sharpened, making the strategy more credible and valuable to investors. Furthermore, a strong rule of law ensures policy stability and reduces regulatory risk, giving investors greater confidence in the long-term viability of nuclear assets. Therefore, we posit that the positive effect of nuclear adoption on firm valuation will be strongest in institutional environments characterized by both stringent climate policies and a high-quality rule of law. This leads to our fourth hypothesis:

Hypothesis 4. *A firm's transition to nuclear energy is associated with a higher market valuation (proxied by Tobin's Q), and this relationship is strengthened in the presence of stringent climate change mitigation policies and a strong rule of law.*

3 | Data and Methodology

3.1 | Data and Sample Description

To test our hypotheses, we constructed a sample of publicly traded international energy firms with the required data available from 2018 to 2023. We obtained firm-level data on corporate carbon emissions (Scope 2), nuclear energy use, financial variables, and corporate governance metrics from the LSEG Refinitiv database. Country-level macroeconomic and institutional data, including GDP per capita, energy intensity, and the rule of law, were sourced from the World Bank. Data on climate change mitigation policy tightness were gathered from Germanwatch. We follow prior literature in order to construct our climate change mitigation policies variables, international policy tightness (INTPOLICY) and domestic policy tightness (DOMPOLICY).[1] These variables measure climate-related

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TABLE 1 | Country-wise sample distribution.

Country	Firms	Firm-year observations	Percent	Cum.
Australia	25	150	7.84	7.84
Austria	4	24	1.25	9.09
Canada	60	360	18.81	27.90
Chile	2	12	0.63	28.53
Colombia	5	30	1.57	30.09
Denmark	2	12	0.63	30.72
Finland	2	12	0.63	31.35
France	8	48	2.51	33.86
Germany	6	36	1.88	35.74
Greece	4	24	1.25	36.99
Hungary	2	12	0.63	37.62
Italy	8	48	2.51	40.13
Japan	7	42	2.19	42.32
Mexico	2	12	0.63	42.95
Netherlands	3	18	0.94	43.89
Norway	20	120	6.27	50.16
Poland	5	30	1.57	51.72
Portugal	1	6	0.31	52.04
Spain	6	36	1.88	53.92
Sweden	6	36	1.88	55.80
Turkey	4	24	1.25	57.05
United Kingdom	24	144	7.52	64.58
United States	113	678	35.42	100.00
Total	319	1914	100	

policies' performance at the country-level in a grading system from 1 (*very low*) to 5 (*very high*), where 5 is the best grade (Bingler et al. 2024). Specifically, a higher value means a stricter regulatory regime (Bolton and Kacperczyk 2023).

Our final sample comprises 1914 firm-year observations from 319 energy sector firms across 23 countries. Table 1 details the country-wise distribution. The United States is the most represented country (678 observations, 35.42%), followed by Canada (360 observations, 18.81%) and Australia (150 observations, 7.84%). This provides a broad international perspective, covering both developed and emerging markets.

Our sample consists exclusively of OECD member countries. This focus is strategic: OECD nations represent the world's major developed and emerging economies, are responsible for the vast majority of existing nuclear energy capacity, and are at the forefront of designing and implementing climate change mitigation policies. Crucially, these countries exhibit profound heterogeneity in their institutional approaches to nuclear power and decarbonization, from strong pronuclear stances to active phase-outs, and varying levels of climate policy stringency and rule of law. This within-OECD institutional variance provides the ideal empirical setting to test our core theoretical proposition: that the effectiveness of a firm's nuclear strategy is contingent on the national institutional environment. Although this heterogeneity can introduce econometric challenges such as slope heterogeneity, we explicitly test for and address these issues in our diagnostic procedures (see Appendix A).

The countries within our sample exhibit divergent policy stances regarding nuclear energy, providing a natural setting to examine how different institutional environments shape corporate outcomes. This allows for a meaningful comparison between pronuclear taxonomy EU countries, such as Finland, France, Hungary, Poland, and Sweden, and antinuclear EU member states, including Austria, Denmark, and Germany, which have vocally opposed the inclusion of nuclear power in the EU's taxonomy for sustainable investments. The remaining

TABLE 2 | Descriptive statistics.

Variable	Obs.	Mean	Std. dev.	Min	Max
LSCOPE2	1914	4.511	1.385	−0.022	7.041
R&D	1914	7.805	7.764	0	44.21
SIZE	1914	15.84	2.496	0	26.39
LEV	1914	27.578	18.51	0	74.03
ROA	1914	2.407	13.124	−82.57	89.45
LGDPPC	1914	4.687	0.177	3.768	4.9
ENINT	1914	4.122	1.589	0	6.94
DOMPOLICY	1914	1.924	0.888	1	4
INTPOLICY	1914	2.382	1.245	1	4
RULELAW	1914	1.341	0.499	−0.806	2.035

Note: All variables are defined in Table 4.

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countries in our sample, such as the United States, Canada, Australia, Japan, and the United Kingdom, are classified as non-EU countries, each with their own distinct national energy policies. This classification provides a robust setting to examine how different institutional and policy environments shape the relationship between nuclear energy use and corporate emissions.

Table 2 presents the summary statistics for the variables used in our analysis. The dependent variable, *LSCOPE2*, represents the natural logarithm of a firm's annual Scope 2 carbon emissions, measured in tons of CO_2 equivalent. The sample mean of *LSCOPE2* is 4.511, with a standard deviation of 1.385, and its values range from −0.022 to 7.041. We did not include the dummy variables (*NE* and *EMTeam*) in descriptive statistics; however, these variables are included in the subsequent correlation and regression analyses. To mitigate the influence of outliers, all continuous variables were winsorized at the 1% level (Ma et al. 2023).

To assess potential multicollinearity, we computed the variance inflation factor (VIF) for all explanatory variables. As shown in Table 3, the mean VIF is 1.94, and all individual VIF values are well below the common threshold of 5 (Kalnins 2018), indicating that multicollinearity is not a general concern. However, the correlation coefficient between *DOMPOLICY* and *INTPOLICY* exceeds 0.7. To avoid any multicollinearity issues arising from this high correlation, we include these two policy variables in separate regression specifications throughout our analysis.

3.2 | Empirical Approach

We follow existing studies (Abbas et al. 2025; Khan et al. 2025; Rafique et al. 2025b) and employ a panel regression model to empirically test the hypotheses developed in our theoretical framework. This model allows us to examine the relationship between a firm's low-carbon energy transition and its corporate carbon emissions while accounting for the moderating roles of climate policy stringency and the rule of law.

Our empirical design employs a panel regression model, which is the most suitable framework for our research questions for several reasons. First, our data structure consists of repeated observations of firms over time, allowing us to control for unobserved time-invariant heterogeneity (e.g., a firm's foundational technological capabilities or a country's geographic constraints) through the inclusion of firm, country, and year fixed effects. This mitigates potential omitted variable bias. Second, the panel framework enables us to model the dynamic and contingent nature of the hypothesized relationships, specifically, to test how time-varying institutional factors (climate policy stringency, rule of law) moderate the effect of a firm's strategic choice (nuclear adoption) on its environmental performance. Although alternative methods like cross-sectional analysis could test for correlations, they would fail to account for unobserved heterogeneity and temporal dynamics.

Prior to estimating our models, we conduct standard panel data diagnostics to ensure the validity of our estimators. We

TABLE 3 | Multicollinearity tests.

Variables	VIF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) LSCOPE2							1.000						
(2) NE	1.03	−0.083	1.000										
(3) R&D	1.14	−0.110	0.101	1.000									
(4) SIZE	1.37	0.513	−0.093	−0.130	1.000								
(5) LEV	1.11	0.139	−0.039	−0.051	0.194	1.000							
(6) ROA	1.14	0.113	0.018	0.227	0.146	−0.128	1.000						
(7) EMTeam	1.1	0.214	−0.095	0.004	0.210	0.197	0.083	1.000					
(8) LGDPPC	2.68	−0.101	0.025	0.040	−0.359	0.006	−0.074	−0.038	1.000				
(9) ENINT	2.42	0.100	0.017	0.195	−0.123	0.008	0.005	−0.028	0.167	1.000			
(10) RULELAW	3.59	−0.068	−0.028	0.073	−0.191	0.013	−0.083	−0.052	0.439	0.572	1.000		
(11) DOMPOLICY	3.16	−0.187	−0.020	−0.029	0.026	−0.068	0.043	−0.013	−0.230	−0.256	−0.009	1.000	
(12) INTPOLICY	2.58	−0.168	0.004	0.004	−0.054	−0.074	0.057	0.002	−0.223	−0.031	−0.023	0.747	1.000
Mean VIF							1.94						

Note: All variables are defined in Table 4.

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follow existing literature (De Blander and Dhaene 2012; Im et al. 2003; Levin et al. 2002; Sheraz et al. 2024) and perform unit root tests (Levin–Lin–Chu, Harris–Tzavalis, and CIPS), which confirm that all variables are stationary (see Table A1 in Appendix A). We also test for cross-sectional dependence using Pesaran's CD test, which fails to reject the null of no dependence, suggesting that shock spillovers across countries are not a primary concern in our setting. However, the Pesaran and Yamagata (2008) test rejects the null of slope homogeneity, indicating that the relationship between nuclear adoption and emissions varies across countries, a finding that is consistent with our theoretical focus on institutional contingency. To address this heterogeneity, we employ country and year fixed effects, which absorb time-invariant cross-country differences and common temporal shocks. Finally, the Hausman test further confirms that a fixed-effects specification is preferred over random effects. These diagnostics support the robustness of our chosen empirical strategy.

To further address concerns regarding endogeneity, such as reverse causality where a firm's emission profile might influence its nuclear adoption strategy, we complement our fixed-effects models with a two-step system generalized method of moments (GMM) estimator (Arellano and Bond 1991; Blundell and Bond 1998). The system GMM is specifically designed for dynamic panel data where the dependent variable may be persistent and where explanatory variables could be correlated with the error term. It uses lagged levels and differences as instruments, allowing us to better isolate the causal direction of the relationship. The results of this robustness check are presented and discussed in Section 4.4. Together, the fixed-effects panel models and the system GMM estimator provide a comprehensive and rigorous basis for testing our theoretically derived hypotheses regarding institutional contingency.

The baseline model is specified as follows:

$$LSCOPE2_{i,t} = \beta_0 + \beta_1 NE_{i,t} + \beta_2 X_{i,t} + \vartheta_i + \partial_j + \theta_t + \varepsilon_{i,t} \quad (1)$$

TABLE 4 | Variables description.

Variable	Abbreviations	Description	Source
CO_2 equivalent emissions, Scope 2	LSCOPE2	Natural logarithm of firm-level Scope 2 emissions. Scope 2 emissions (CO_2 and CO_2 equivalent emissions in tons) come from the generation of purchased heat, steam, and electricity consumed by the firm.	LSEG Refinitiv
Low-carbon energy transition	NE	We use the adoption of nuclear energy by energy firms as a measure of the low-carbon energy transition. A dummy variable that takes the value of one if the firm is using nuclear reactors to produce nuclear energy, and zero otherwise.	LSEG Refinitiv
Domestic policy tightness	DOMPOLICY	DOMPOLICY is the climate change mitigation policy and measures the domestic policy tightness.	Germanwatch
International policy tightness	INTPOLICY	INTPOLICY is the climate change mitigation policy and measures international policy tightness.	Germanwatch
Rule of law	RULELAW	The estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e., ranging from approximately −2.5 to 2.5.	World Bank data
Research & development	R&D	Research and development expenditure divided by sales	LSEG Refinitiv
Firm size	SIZE	Natural logarithm of total assets	LSEG Refinitiv
Leverage	LEV	Total debt to total assets	LSEG Refinitiv
Return on assets	ROA	Return on assets is a measure of profitability.	LSEG Refinitiv
Environmental management team	EMTeam	A dummy variable that takes the value of one if the firm has an environmental management team, and zero otherwise	LSEG Refinitiv
GDP per capita	LGDPPC		World Bank data
Energy intensity	ENINT	ENINT is the energy intensity of a country. Energy intensity is an indication of how much energy is used to produce one unit of economic output. A lower ratio indicates that less energy is used to produce one unit of output.	World Bank data

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where $LSCOPE2_{i,t}$ is the natural logarithm of Scope 2 carbon emissions for the firm "i" in year "t." $NE_{i,t}$ is a dummy variable indicating whether the firm "i" uses nuclear energy in a year "t" as a measure of low-carbon energy transition. $X_{i,t}$ is a vector of firm- and country-level control variables. ϑ_i, ∂_j, and θ_t represent firm, country, and year fixed effects. $\varepsilon_{i,t}$ is the error term. The definitions and data sources of all variables used in this study are provided in Table 4.

To test the moderating effect of climate policy stringency (Hypothesis 2), we extend the baseline model by including interaction terms of nuclear energy with domestic policy tightness (*DOMPOLICY*) and international policy tightness (*INTPOLICY*) as follows:

$$\begin{aligned} LSCOPE2_{i,t} = {} & \gamma_0 + \gamma_1 NE_{i,t} + \gamma_2 DOMPOLICY_{i,t} + \gamma_3 INTPOLICY_{i,t} \\ & + \gamma_4 \left(NE_{i,t} * DOMPOLICY_{i,t}\right) + \gamma_5 \left(NE_{i,t} * INTPOLICY_{i,t}\right) \\ & + \gamma_6 X_{i,t} + \vartheta_i + \partial_j + \theta_t + \varepsilon_{i,t} \end{aligned} \tag{2}$$

To further examine whether the moderating effect of policy stringency is conditional on the rule of law (Hypothesis 3), we introduce a triple interaction term as follows:

$$\begin{aligned} LSCOPE2_{i,t} = {} & \gamma_0 + \gamma_1 NE_{i,t} + \gamma_2 DOMPOLICY_{i,t} + \gamma_3 INTPOLICY_{i,t} \\ & + \gamma_4 RULELAW_{i,t} + \gamma_5 \left(NE_{i,t} * DOMPOLICY_{i,t} * RULELAW_{i,t}\right) \\ & + \gamma_6 \left(NE_{i,t} * INTPOLICY_{i,t} * RULELAW_{i,t}\right) \\ & + \gamma_7 X_{i,t} + \vartheta_i + \partial_j + \theta_t + \varepsilon_{i,t} \end{aligned} \tag{3}$$

4 | Empirical Results

4.1 | Baseline Findings

Table 5 presents the baseline results examining the direct relationship between a firm's low-carbon energy transition (*NE*) and its Scope 2 emissions (*LSCOPE2*).

The results across all three specifications reveal a critical initial insight: The coefficient for NE is consistently negative, as hypothesized, yet it fails to achieve statistical significance. This finding suggests that simply adopting nuclear energy does not, by itself, directly lower reported operational carbon emissions in a statistically significant way. To see this legitimacy benefit, one must account for the institutional context. This evidence is consistent with our integrated theoretical framework. It suggests that the legitimacy-seeking strategy of employing nuclear energy is not a simple, universally effective technological fix. As posited earlier, nuclear energy is a contested resource, perpetually shadowed by a legitimacy deficit (Grougiou et al. 2016; Wittneben 2012). The absence of a direct effect implies that the low-carbon signal of nuclear power is, on its own, insufficient. The control variables show expected signs; for instance, firm size (*SIZE*) is positively associated with emissions, whereas the presence of an environmental management team (*EMTeam*) shows a significant negative relationship, underscoring the role of internal governance structures in managing environmental performance. The substantial increase in *R*-squared when country fixed effects are introduced in Column (3) further underscores the importance of national context, providing support for our moderation analysis in the subsequent section.

TABLE 5 | Impact of low-carbon energy transition on corporate carbon emissions.

	(1)	(2)	(3)
Variables	**LSCOPE2**	**LSCOPE2**	**LSCOPE2**
NE	−0.196	−0.196	−0.281
	(0.245)	(0.246)	(0.225)
R&D	−0.0162***	−0.0161***	−0.0146***
	(0.00488)	(0.00490)	(0.00450)
SIZE	0.283***	0.283***	0.376***
	(0.0163)	(0.0163)	(0.0180)
LEV	0.00149	0.00146	−0.000911
	(0.00202)	(0.00203)	(0.00191)
ROA	0.00605**	0.00593**	0.00324
	(0.00288)	(0.00290)	(0.00273)
EMTeam	−0.318***	−0.319***	−0.193**
	(0.0822)	(0.0824)	(0.0768)
LGDPPC	0.515**	0.516**	−2.581
	(0.218)	(0.219)	(2.630)
ENINT	0.150***	0.150***	0.0521
	(0.0232)	(0.0233)	(0.0464)
Constant	−2.968**	−2.962**	9.048
	(1.155)	(1.161)	(10.57)
Year effects	NO	YES	NO
Firm and country effects	NO	NO	YES
Observations	1914	1914	1914
R-squared	0.315	0.315	0.464

Note: All variables are defined in Table 4. Standard errors in parentheses.
$^{***}p<0.01$.
$^{**}p<0.05$.
$^{*}p<0.1$.

4.2 | Mechanism Analysis

Having established the baseline relationship, we now turn to our main theoretical model: "testing the mechanisms through which the institutional environment conditions the efficacy of a firm's nuclear energy strategy." Our framework posits that the legitimacy benefits of nuclear adoption, manifested as reduced Scope 2 emissions, are not automatic but are critically moderated by external pressures. We theorize that stringent climate policies create the coercive impetus for this strategy, whereas a strong rule of law provides the necessary stabilizing foundation for its effective execution. The following analyses empirically test these hypothesized mechanisms, examining

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the moderating roles of domestic and international policy stringency, and their subsequent dependence on the quality of a nation's rule of law.

Table 6 introduces the crucial moderating variable of domestic climate policy tightness (*DOMPOLICY*). The results provide compelling support for Hypothesis 2. Although the direct effect of NE remains insignificant, the interaction term between nuclear energy and domestic policy (*NEXDOMPOLICY*) in Columns (2) and (3) is negative and statistically significant at the 5% level. This finding empirically validates our theoretical claim that the institutional environment, specifically coercive regulatory pressures, conditions the effectiveness of a firm's legitimacy strategy. In countries with more stringent domestic climate policies, the adoption of nuclear energy becomes a materially consequential and verifiable strategy for reducing Scope 2 emissions. This aligns with institutional theory (DiMaggio and Powell 1983), which posits that organizations conform to regulatory pressures to secure resources and legitimacy. Here, stringent policies transform nuclear power from a symbolic gesture into a substantive economic imperative, as its carbon-free attribute is directly rewarded or its fossil-fuel competitors are penalized (Bolton and Kacperczyk 2023). The significance of the interaction term diminishes when country fixed effects are added in Column (4), which is not unexpected given that much of the policy variation is absorbed by the country dummies, but the consistent pattern across specifications reinforces the moderating role of policy.

TABLE 6 | Low-carbon energy transition, domestic policy tightness, and corporate carbon emissions.

	(1)	(2)	(3)	(4)
Variables	**LSCOPE2**	**LSCOPE2**	**LSCOPE2**	**LSCOPE2**
NE	−0.230	−0.785	−0.793	−0.485
	(0.241)	(0.568)	(0.570)	(0.527)
DOMPOLICY	−0.252***	−0.232	−0.236	−0.279
	(0.0418)	(0.249)	(0.250)	(0.238)
NEXDOMPOLICY		−0.497**	−0.502**	−0.382
		(0.252)	(0.253)	(0.235)
R&D	−0.0160***	−0.0160***	−0.0159***	−0.0145***
	(0.00480)	(0.00479)	(0.00481)	(0.00450)
SIZE	0.276***	0.278***	0.278***	0.377***
	(0.0161)	(0.0161)	(0.0161)	(0.0180)
LEV	0.000946	0.000555	0.000568	−0.00128
	(0.00199)	(0.00200)	(0.00201)	(0.00192)
ROA	0.00660**	0.00668**	0.00665**	0.00351
	(0.00283)	(0.00283)	(0.00285)	(0.00273)
EMTeam	−0.314***	−0.315***	−0.315***	−0.193**
	(0.0809)	(0.0808)	(0.0810)	(0.0768)
LGDPPC	0.242	0.251	0.248	−2.372
	(0.219)	(0.219)	(0.220)	(2.640)
ENINT	0.118***	0.118***	0.117***	0.0383
	(0.0234)	(0.0234)	(0.0235)	(0.0471)
Constant	−0.913	−1.966	−1.962	7.733
	(1.186)	(1.299)	(1.305)	(10.59)
Year effects	No	No	Yes	No
Firm and country effects	No	No	No	Yes
Observations	1914	1914	1914	1914
R-squared	0.339	0.341	0.341	0.466

Note: All variables are defined in Table 4. Standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

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Table 7 presents the results of the moderating effect of international policy tightness (*INTPOLICY*).

The results, however, provide different evidence. The interaction term (*NEXINTPOLICY*) is negative but insignificant in all specifications. This divergence from the domestic policy findings is theoretically informative. It suggests that for the specific outcome of corporate-level Scope 2 emissions, the coercive and normative pressures emanating from a firm's immediate, national regulatory environment (*DOMPOLICY*) are more potent and directly consequential than those from broader international policy frameworks (*INTPOLICY*). Domestic policies, such as carbon pricing or emissions trading schemes, create a direct and tangible cost for carbon emissions within the firm's operational jurisdiction. International policies, although influential in shaping global norms and discourse, may lack the same immediate, enforceable mechanism to directly alter firm-level operational decisions and their resulting emissions. This evidence refines our theoretical model, highlighting that not all institutional pressures are created equal; their impact is contingent on their proximity and enforceability.

Table 8 presents a sophisticated test of our full theoretical model by introducing a triple interaction between nuclear energy, domestic policy, and the rule of law (*NEXDOMPOLICYXRULELAW*).

TABLE 7 | Low-carbon energy transition, international policy tightness, and carbon emissions.

Variables	(1) LSCOPE2	(2) LSCOPE2	(3) LSCOPE2	(4) LSCOPE2
NE	−0.199	−0.574	−0.569	−0.216
	(0.243)	(0.542)	(0.544)	(0.501)
INTPOLICY	−0.148***	−0.174	−0.173	−0.143
	(0.0294)	(0.204)	(0.205)	(0.190)
NEXINTPOLICY		−0.328	−0.327	−0.210
		(0.206)	(0.207)	(0.190)
R&D	−0.0167***	−0.0167***	−0.0167***	−0.0147***
	(0.00483)	(0.00482)	(0.00484)	(0.00452)
SIZE	0.271***	0.272***	0.272***	0.376***
	(0.0163)	(0.0163)	(0.0163)	(0.0181)
LEV	0.00109	0.000852	0.000857	−0.00114
	(0.00200)	(0.00201)	(0.00202)	(0.00193)
ROA	0.00685**	0.00688**	0.00683**	0.00318
	(0.00285)	(0.00285)	(0.00287)	(0.00275)
EMTeam	−0.330***	−0.331***	−0.331***	−0.195**
	(0.0813)	(0.0813)	(0.0815)	(0.0770)
LGDPPC	0.231	0.231	0.230	−1.689
	(0.223)	(0.223)	(0.223)	(2.703)
ENINT	0.150***	0.150***	0.150***	0.0354
	(0.0229)	(0.0229)	(0.0230)	(0.0478)
Constant	−1.090	−1.854	−1.827	5.315
	(1.202)	(1.293)	(1.300)	(10.83)
Year effects	No	No	Yes	No
Firm and country effects	No	No	No	Yes
Observations	1914	1914	1914	1914
R-squared	0.332	0.333	0.333	0.466

Note: All variables are defined in Table 4. Standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

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The results are compelling and provide robust support for Hypothesis 3. In Columns (2) and (3), the triple interaction term is negative and statistically significant at the 1% level. This finding is the cornerstone of our contribution. It demonstrates that the moderating effect of stringent climate policy is itself conditional upon a deeper institutional foundation: a strong rule of law. We theorized that for nuclear energy, a technology requiring massive, long-term capital commitments and intensive regulatory oversight, policy stringency alone is an unreliable signal if the institutional environment is weak. A strong rule of law ensures policy credibility, reduces expropriation risk, and provides the stable, predictable regulatory environment necessary for firms to operate nuclear facilities efficiently and safely (Dai 2019; Palea and Drogo 2020). In such environments, the legitimacy claim of being a low-carbon nuclear operator is not only made but is also verifiable and trustworthy, thereby translating into a tangible emissions reduction. The significance of this triple interaction moves our analysis beyond stating that "institutions matter" to precisely explaining *how* they matter: by creating the necessary conditions for a complex and contested legitimacy strategy to succeed.

TABLE 8 | Low-carbon energy transition, domestic policy tightness, rule of law, and carbon emissions.

Variables	(1) LSCOPE2	(2) LSCOPE2	(3) LSCOPE2	(4) LSCOPE2
NE	−0.295	−0.562	−0.558	−0.0616
	(0.240)	(0.366)	(0.368)	(0.379)
DOMPOLICY	−0.170***	−0.226*	−0.225*	−0.00363
	(0.0462)	(0.136)	(0.137)	(0.151)
RULELAW	−0.526***	−0.168	−0.160	−0.736*
	(0.130)	(0.259)	(0.261)	(0.423)
NEXDOMPOLICYXRULELAW		−0.287***	−0.286***	−0.0743
		(0.0930)	(0.0933)	(0.105)
R&D	−0.0167***	−0.0167***	−0.0166***	−0.0144***
	(0.00477)	(0.00475)	(0.00477)	(0.00450)
SIZE	0.288***	0.293***	0.293***	0.375***
	(0.0162)	(0.0162)	(0.0163)	(0.0180)
LEV	0.000912	0.000682	0.000672	−0.00106
	(0.00198)	(0.00197)	(0.00198)	(0.00192)
ROA	0.00543*	0.00552*	0.00541*	0.00341
	(0.00283)	(0.00282)	(0.00283)	(0.00273)
EMTeam	−0.298***	−0.287***	−0.287***	−0.193**
	(0.0804)	(0.0801)	(0.0803)	(0.0768)
LGDPPC	1.197***	1.156***	1.165***	−3.646
	(0.321)	(0.320)	(0.321)	(2.767)
ENINT	0.209***	0.201***	0.201***	−0.169
	(0.0324)	(0.0324)	(0.0325)	(0.138)
Constant	−5.320***	−6.971***	−6.995***	14.03
	(1.603)	(1.684)	(1.696)	(13.10)
Year effects	No	No	Yes	No
Firm and country effects	No	No	No	Yes
Observations	1914	1914	1914	1914
R-squared	0.349	0.355	0.355	0.467

Note: All variables are defined in Table 4. Standard errors in parentheses.
***$p<0.01$.
**$p<0.05$.
*$p<0.1$.

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Consistent with the findings in Table 7, Table 9 shows that the triple interaction involving international policy tightness does not yield a statistically significant result. This further corroborates the earlier insight that international policy pressures, in this specific context, are not as directly consequential for firm-level emissions outcomes as domestic pressures. Even under a strong rule of law, international policies remain indirect to reliably activate the nuclear-emissions relationship, unlike their domestic counterparts. This reinforces the importance of the national institutional environment in shaping corporate strategic responses to legitimacy pressures concerning decarbonization.

The results in Table 10 test our supplementary hypothesis (Hypothesis 4), which posited that nuclear adoption serves as a legitimacy-management tactic that can be rewarded by financial markets. To test our Hypothesis 4, we follow existing studies (Khan and Khan 2025; Unsal et al. 2016) and calculate Tobin's *Q* as follows: (Book Value of Assets + Market Value of Common Stock − Book Value of Common Stock)/Book Value of Assets.

Consistent with the theoretical framework outlined in Section 2.4, we find that the adoption of nuclear energy is associated with a

TABLE 9 | Low-carbon energy transition, international policy tightness, rule of law, and carbon emissions.

Variables	(1) LSCOPE2	(2) LSCOPE2	(3) LSCOPE2	(4) LSCOPE2
NE	−0.290	0.304	0.301	−0.192
	(0.240)	(0.329)	(0.330)	(0.356)
INTPOLICY	−0.112***	0.125	0.125	−0.0315
	(0.0298)	(0.0949)	(0.0952)	(0.122)
RULELAW	−0.635***	−0.140	−0.147	0.592
	(0.120)	(0.223)	(0.224)	(0.395)
NEXINTPOLICYXRULELAW		−0.072	−0.072	−0.0228
		(0.0655)	(0.0657)	(0.0802)
R&D	−0.0173***	−0.0175***	−0.0174***	−0.0145***
	(0.00477)	(0.00475)	(0.00477)	(0.00450)
SIZE	0.285***	0.290***	0.290***	0.374***
	(0.0163)	(0.0164)	(0.0164)	(0.0180)
LEV	0.000932	0.000996	0.000987	−0.000942
	(0.00198)	(0.00197)	(0.00198)	(0.00191)
ROA	0.00546*	0.00532*	0.00522*	0.00325
	(0.00283)	(0.00282)	(0.00284)	(0.00273)
EMTeam	−0.305***	−0.303***	−0.303***	−0.197**
	(0.0804)	(0.0802)	(0.0804)	(0.0768)
LGDPPC	1.345***	1.263***	1.271***	3.010
	(0.304)	(0.305)	(0.306)	(2.819)
ENINT	0.248***	0.255***	0.255***	0.156
	(0.0292)	(0.0292)	(0.0293)	(0.139)
Constant	−6.051***	−7.046***	−7.071***	11.25
	(1.511)	(1.553)	(1.560)	(13.35)
Year effects	No	No	Yes	No
Firm and country effects	No	No	No	Yes
Observations	1914	1914	1914	1914
R-squared	0.349	0.354	0.354	0.466

Note: All variables are defined in Table 4. Standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

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TABLE 10 | Low-carbon energy transition, policy tightness, rule of law, and firms' market valuation.

Variables	(1) Tobin's *Q*	(2) Tobin's *Q*	(3) Tobin's *Q*	(4) Tobin's *Q*
NE	0.238*	0.451**	0.448***	0.050
	(0.128)	(0.195)	(0.195)	(0.201)
DOMPOLICY	0.091***	0.130*	0.130*	0.002
	(0.024)	(0.073)	(0.073)	(0.081)
RULELAW	0.280***	0.244*	0.214	0.989***
	(0.069)	(0.138)	(0.138)	(0.225)
NEXDOMPOLICYXRULELAW		0.152***	0.152***	0.099*
		(0.049)	(0.049)	(0.055)
Constant	2.829***	3.708***	3.721***	4.462***
	(0.853)	(0.896)	(0.902)	(0.968)
Control variables	YES	YES	YES	YES
Year effects	NO	NO	YES	NO
Firm and country effects	NO	NO	NO	YES
Observations	1914	1914	1914	1914
R-squared	0.615	0.624	0.630	0.765
Variables	**(5) Tobin's *Q***	**(6) Tobin's *Q***	**(7) Tobin's *Q***	**(8) Tobin's *Q***
NE	0.268*	0.374*	0.370*	0.479**
	(0.147)	(0.202)	(0.202)	(0.218)
INTPOLICY	0.069***	0.087***	0.087***	0.020
	(0.018)	(0.028)	(0.029)	(0.037)
RULELAW	0.390***	0.300**	0.321**	0.364
	(0.073)	(0.137)	(0.137)	(0.242)
NEXINTPOLICYXRULELAW		0.077*	0.079**	0.089*
		(0.040)	(0.040)	(0.050)
Constant	3.714***	4.324***	4.340***	6.906***
	(0.927)	(0.952)	(0.958)	(2.255)
Control variables	Yes	Yes	Yes	Yes
Year effects	No	No	Yes	No
Firm and country effects	No	No	No	Yes
Observations	1914	1914	1914	1914
R-squared	0.581	0.599	0.614	0.738

Note: All variables are defined in Table 4. Standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

higher market valuation, proxied by Tobin's *Q*. Crucially, this positive valuation effect is not unconditional; it is significantly amplified in institutional environments characterized by both stringent climate policies and a strong rule of law, as evidenced by the positive and statistically significant triple-interaction terms.

This finding provides critical complementary evidence to our main results. It demonstrates that nuclear adoption can function as a successful dual-purpose legitimacy strategy: It can lead to tangible decarbonization (reduced emissions intensity) and enhance financial-market legitimacy (higher valuation) under

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the same supportive institutional conditions. The market's positive valuation in such contexts suggests that investors perceive nuclear energy as a credible, low-risk, and strategically sound response to decarbonization pressures, thereby conferring legitimacy and reducing the firm's perceived transition risk. The weaker effect for international policy further underscores the primacy of national, enforceable institutional architecture in shaping stakeholder responses.

4.3 | Robustness Check

In this section, we conduct robustness checks to strengthen the causal interpretation of our findings. A primary concern in our analysis is endogeneity, which could arise from reverse causality (e.g., a firm's emission profile influencing its nuclear adoption strategy) or omitted time-varying variables. To address this, we employ a two-step system GMM estimator (Arellano and Bond 1991; Blundell and Bond 1998).

TABLE 11 | Addressing the endogeneity issue.

	(1)
Variables	**LSCOPE2**
l.Scope2	0.652***
	(0.0995)
NE	−0.520*
	(0.285)
R&D	−0.0879***
	(0.00612)
SIZE	0.124***
	(0.0330)
LEV	0.00353
	(0.00583)
ROA	0.00135***
	(0.000403)
EMTeam	−0.282**
	(0.134)
LGDPPC	10.72*
	(6.381)
ENINT	0.0411
	(0.0405)
Constant	0.315**
	(0.152)
AR (1) (*p*-value)	0.000
AR (2) (*p*-value)	0.562
Sargan test (overidentifying) *p*-value	0.388
Number of instruments	42
Observations	1914

Note: All variables are defined in Table 4. Standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

The system GMM is particularly suited for dynamic panel models where the dependent variable may be persistent and regressors are potentially correlated with the error term. It uses internal instruments, lagged levels, and differences of the explanatory variables to mitigate endogeneity and provide consistent estimates. The specification includes the lagged dependent variable to account for the dynamic nature of corporate emissions. The results, presented in Table 11, support the robustness of our baseline findings. The coefficient for the lagged dependent variable is highly significant, confirming the dynamic nature of corporate emissions. Most importantly, the coefficient for nuclear energy (*NE*) is negative and statistically significant at the 10% level, lending greater confidence to a causal interpretation that the transition to nuclear energy leads to a reduction in Scope 2 emissions. The *p*-values for the AR(2) and Sargan tests indicate valid instruments and an appropriate specification. Overall, these findings strongly corroborate our main results.

Second, our primary analysis uses total Scope 2 emissions as the outcome variable. However, changes in total emissions could reflect shifts in a firm's operational scale rather than its carbon efficiency. To distinguish between scale and efficiency effects, we conduct a complementary analysis using corporate carbon intensity, measured as Scope 2 emissions per unit of firm revenue (*LSCOPE2_INT*). This metric isolates whether nuclear adoption leads to a cleaner production profile. Table 12 presents the results, which consistently reinforce the institutional contingency of the nuclear transition-emissions relationship.

4.4 | Additional Analysis

To further strengthen the robustness of our findings and investigate the role of national policy contexts, we conduct a country-level analysis. Following the approach of Rafique et al. (2025a), we introduce interaction terms between the nuclear energy transition (*NE*) and individual countries. We then apply stepwise regression with a 5% significance threshold to isolate the significant country-specific effects of the nuclear transition on corporate carbon emissions. This method moves beyond aggregate institutional variables to reveal how the nuclear energy-emissions relationship manifests within distinct national environments. Results are reported in Table 13.

The results in Table 13 demonstrate a statistically significant negative relationship for pronuclear countries, including EU taxonomy members such as Finland, France, Hungary, Poland, and Sweden. This finding offers direct, country-level validation of our core mechanism: the emissions-reducing effect of nuclear energy materializes only within a supportive institutional and political environment. Conversely, and critically, the analysis finds no significant effect in antinuclear member states like Austria, Denmark, and Germany. This

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TABLE 12 | Low-carbon energy transition, policy tightness, rule of law, and carbon intensity.

Variables	(1) LSCOPE2_INT	(2) LSCOPE2_INT	(3) LSCOPE2_INT	(4) LSCOPE2_INT
NE	−0.080	−0.152	−0.151	−0.017
	(0.065)	(0.099)	(0.099)	(0.102)
DOMPOLICY	−0.046***	−0.061*	−0.061*	−0.001
	(0.012)	(0.037)	(0.037)	(0.041)
RULELAW	−0.142***	−0.045	−0.043	−0.199*
	(0.035)	(0.070)	(0.070)	(0.114)
NEXDOMPOLICYXRULELAW		−0.077***	−0.077***	−0.020
		(0.025)	(0.025)	(0.028)
Constant	−1.436***	−1.882***	−1.889***	3.788
	(0.433)	(0.455)	(0.458)	(3.537)
Control variables	YES	YES	YES	YES
Year effects	NO	NO	YES	NO
Firm and country effects	NO	NO	NO	YES
Observations	1914	1914	1914	1914
R-squared	0.405	0.420	0.428	0.581
Variables	**(5) LSCOPE2_INT**	**(6) LSCOPE2_INT**	**(7) LSCOPE2_INT**	**(8) LSCOPE2_INT**
NE	−0.090	0.094	0.093	−0.060
	(0.074)	(0.102)	(0.102)	(0.110)
INTPOLICY	−0.035***	0.039	0.039	−0.010
	(0.009)	(0.029)	(0.030)	(0.038)
RULELAW	−0.197***	−0.043	−0.046	0.184
	(0.037)	(0.069)	(0.069)	(0.122)
NEXINTPOLICYXRULELAW		−0.022	−0.022	−0.007
		(0.020)	(0.020)	(0.025)
Constant	−1.876***	−2.184***	−2.192***	3.488
	(0.468)	(0.481)	(0.484)	(4.139)
Control variables	YES	YES	YES	YES
Year effects	NO	NO	YES	NO
Firm and country effects	NO	NO	NO	YES
Observations	1914	1914	1914	1914
R-squared	0.381	0.402	0.407	0.572

Note: All variables are defined in Table 4. Standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

pronounced divergence corroborates our central argument: the legitimacy and operational benefits of nuclear energy are not intrinsic but are contingent upon a supportive institutional and policy framework.

5 | Discussion of Results

Our finding that nuclear adoption does not significantly reduce emissions in countries with weak climate policies or rule

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TABLE 13 | Low-carbon energy transition and corporate carbon emissions across pronuclear and antinuclear EU taxonomy countries.

Variables	(1) LSCOPE2	(2) LSCOPE2
NEXAustralia	−0.503***	−0.503***
	(0.121)	(0.121)
NEXUnited_Kingdom	−0.889***	−0.889***
	(0.124)	(0.124)
NEXSweden	−1.217***	−1.217***
	(0.317)	(0.317)
NEXChile	−2.185***	−2.185***
	(0.486)	(0.486)
NEX Finland	−3.345***	−3.345***
	(0.345)	(0.345)
NEXPortugal	−0.821**	−0.821**
	(0.319)	(0.319)
NEXFrance	−0.687***	−0.687***
	(0.203)	(0.203)
NEXHungary	−1.464***	−1.464***
	(0.477)	(0.477)
NEXJapan	−1.677***	−1.677***
	(0.250)	(0.250)
NEXNetherlands	−1.099***	−1.099***
	(0.369)	(0.369)
NEXPoland	−1.460***	−1.460***
	(0.349)	(0.349)
NEXNorway	−1.623***	−1.623***
	(0.143)	(0.143)
NEXAustria	0.429	0.425
	(0.942)	(0.941)
NEXDenmark	0.387	0.377
	(1.025)	(1.022)
NEXGermany	0.241	0.255
	(0.779)	(0.766)
Constant	−1.012***	−1.012***
	(0.263)	(0.263)
Control variables	YES	YES
Year and firm effects	NO	YES
Observations	1914	1914
R-squared	0.452	0.452

Note: All variables are defined in Table 4. Standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

of law requires careful interpretation. We are not suggesting that nuclear technology ceases to be low carbon in these settings. Rather, the institutional environment appears to disrupt the strategic and operational pathway through which a firm translates nuclear capacity into lower corporate emissions. In contexts of poor governance, regulatory uncertainty, or lack of credible climate policy, firms may be unable to reliably operate nuclear plants at high capacity, may face inconsistent grid integration that favors fossil backups, or may lack the incentive to use nuclear output to actively displace their own carbon-intensive generation. Consequently, the firm-level carbon footprint does not reflect the technical potential of the technology, a divergence that our model is designed to detect. This aligns with institutional theory, which emphasizes that the effectiveness of a strategic asset depends on the surrounding "rules of the game" (DiMaggio and Powell 1983).

From a legitimacy theory perspective, the initial finding that nuclear energy transition alone does not guarantee a legitimacy payoff is critical. It confirms that for a resource as contested as nuclear energy, possessing a technically low-carbon attribute is insufficient to overcome its inherent legitimacy deficit. The social license to operate must be actively constructed and is not conferred by technological fact alone (Dai 2019; Suchman 1995). This aligns with events like Fukushima, which acted as exogenous shocks that crystallized the fragility of the nuclear industry's social license (Lopatta and Kaspereit 2014).

Through the lens of stakeholder theory, we can interpret the conditional nature of this relationship. The firm must strategically navigate a landscape of powerful, conflicting stakeholder groups: investors and regulators demanding decarbonization on one hand, and constituencies such as local communities and social movements, concerned with safety and environmental risk, on the other (Piazza and Perretti 2020). In this context, adopting nuclear energy is a high-stakes strategy aimed primarily at appeasing the decarbonization demands of powerful stakeholders. However, our findings indicate that this strategy only yields a tangible legitimacy benefit and reduced corporate carbon emissions when the institutional environment amplifies their voice and reshapes their economic and regulatory incentives.

This is where institutional theory provides the final, and important, explanatory layer. The moderating role of climate policy stringency represents the coercive pillar of institutions in action (DiMaggio and Powell 1983). Stringent policies materially increase the cost of ignoring decarbonization pressures, thereby transforming nuclear energy from a symbolic gesture into a substantive, economically rational response to investor and regulatory demands (Bolton and Kacperczyk 2023). However, the further finding that this moderating effect is itself contingent on a strong rule of law reveals the profound importance of the normative and cognitive pillars. For long-term, capital-intensive strategies like nuclear energy, coercive policies are only effective if actors have confidence in their consistent and predictable application. A strong rule of law reduces expropriation risk and policy uncertainty, providing the stable environment necessary for this legitimacy strategy to be operationalized effectively and its outcomes, the promised emissions reductions, to be reliably realized (Dai 2019).

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5.1 | Limitations

Although this study provides new insights into the institutional contingency of corporate nuclear strategy, it is subject to several limitations that suggest avenues for future research. First, our measure of nuclear energy adoption is binary (*NE*), indicating whether a firm uses nuclear reactors. This may not capture the intensity of nuclear reliance (e.g., share of nuclear in the generation mix) or the vintage and efficiency of the nuclear fleet, which could influence emissions outcomes. Second, although our sample includes a broad range of energy firms, the reporting standards and strategic incentives for nuclear adoption may vary across ownership structures (e.g., state-owned, publicly traded, privately held, or family-controlled entities). Although we control for country-level institutional factors, unobserved heterogeneity related to ownership type could influence both the decision to adopt nuclear energy and the resulting emissions outcomes. Third, although we employ fixed effects and system GMM to address endogeneity, unobserved time-varying factors, such as shifts in public sentiment or firm-specific managerial initiatives, could simultaneously influence nuclear adoption and emissions. Although our institutional moderation tests help mitigate this by focusing on differential effects, causal claims should be interpreted with appropriate caution. Finally, our sample period (2018–2023) covers a specific phase of the energy transition; longer time series that include earlier periods of nuclear expansion or retrenchment could provide additional historical perspective.

6 | Conclusion, Implications, and Avenues for Future Research

6.1 | Conclusion

This study demonstrates that the corporate adoption of nuclear energy is a high-stakes legitimacy strategy, the success of which is not guaranteed by the technology itself but is strongly and consistently contingent upon a supportive institutional environment. Based on robust panel data analysis coupled with dynamic panel method (system GMM) estimation, we find that the pathway to achieving lower emissions through nuclear power is only activated and rendered credible within nations that possess both stringent climate policies to create coercive pressure and a strong rule of law to ensure regulatory stability and predictability. Consequently, the debate must shift from whether nuclear energy is inherently low-carbon to identifying the specific institutional conditions under which it can reliably fulfill its decarbonization potential at the corporate level.

6.2 | Managerial Implications

For corporate leaders and strategists in the global energy sector, these findings carry insightful implications for capital allocation, risk management, and stakeholder communication. The decision to pursue or maintain nuclear assets must be fundamentally re-evaluated as a decision that extends beyond engineering and economics into the realm of institutional analysis. Managers must recognize that the profitability and strategic value of a nuclear fleet are not intrinsic but are externally conferred by the host country's policy and regulatory landscape. This necessitates a rigorous and dynamic assessment of a nation's institutional quality before committing to such long-lived investments. A country with weak or volatile governance, even if it currently expresses pronuclear sentiments, represents a significant strategic risk, as our evidence shows the emissions-reduction benefits and thus the legitimacy payoff with investors are unlikely to materialize reliably.

Furthermore, this study provides a convincing narrative for engaging with a key stakeholder group: Investors focused on environmental, social, and governance (ESG) criteria. Managers of firms operating nuclear assets within strong institutional contexts can and should leverage these findings to articulate a more compelling investment case. They can demonstrate that their nuclear portfolio is not merely a technological choice but a verifiable, institutionally backed decarbonization asset, directly responsive to climate policy pressures. This allows for a more sophisticated communication strategy that moves beyond defending nuclear power against its historical stigmas and toward proactively framing it as a high-impact, policy-compliant solution for deep decarbonization. Conversely, managers in weak institutional settings face a heightened risk: their nuclear strategy may fail to deliver the expected firm-level emissions reductions, and thus the associated legitimacy and climate performance benefits, despite the technology's low-carbon nature. This is because weak governance can undermine the operational efficacy, grid integration, and fossil-fuel displacement potential of nuclear assets. They must be transparent about this risk with stakeholders. This reality may necessitate a strategic pivot toward other low-carbon technologies to meet stakeholder demands. Ultimately, the primary managerial contribution of this study is a diagnostic framework that reframes the nuclear investment decision. It moves the evaluation beyond engineering and finance to a more fundamental strategic issue: the ability of the nuclear energy transition to deliver tangible legitimacy within a given institutional context.

6.3 | Social and Practical Implications

The social and practical implications of this study extend directly to the domains of public policy, sustainable finance, and the broader societal discourse on the future of energy. For policymakers, our findings suggest that nuclear power's decarbonization potential is realized only through deliberate institutional design. Legislating for a stringent climate policy, such as a robust carbon price, is a necessary first step to create the economic signal that makes nuclear energy a rational corporate choice. However, this must be coupled with an unwavering commitment to strengthening the rule of law, ensuring regulatory independence, and fostering a stable, predictable environment for energy investments. Policymakers must understand that promoting nuclear power without this foundational institutional strength is likely to be an ineffective strategy, as corporate actors will be unable to reliably convert it into tangible emissions reductions, thereby undermining both climate goals and public trust.

For citizens and the broader public, these findings offer a more nuanced lens through which to evaluate the heated debate surrounding nuclear energy. The discussion often becomes

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polarized between unqualified support and blanket opposition, but this research suggests that the more critical question is about governance. The public should demand not just a decision on whether to use nuclear power, but a clear plan for how it will be governed, how safety will be guaranteed, how waste will be managed, and how policies will be consistently enforced over the decades-long lifecycle of a plant. The social license for nuclear energy is not granted based on its theoretical potential but on the demonstrable competence and trustworthiness of the institutions that will oversee it. Therefore, citizen engagement should focus on holding governments accountable for building the high-quality institutional capacity that our evidence shows is a prerequisite for nuclear power to deliver on its low-carbon promise. This shifts the civic conversation from a purely technological debate to one about institutional integrity and long-term regulatory commitment, which are the true bedrock upon which a safe and effective nuclear energy strategy must be built.

6.4 | Future Research Directions

Our findings open several promising avenues for future research. First, scholars could extend our framework by examining other contested low-carbon technologies (e.g., carbon capture and storage and large-scale hydropower) to test whether their corporate adoption is similarly institutionally contingent. Second, future work could employ more granular data on nuclear generation share, plant-level efficiency, or firm-level capital allocation to better understand the operational mechanisms behind the institutional effects we document. Third, qualitative case studies of nuclear-adopting firms in divergent institutional settings could provide deeper insight into the managerial decision-making and stakeholder negotiations that underlie our quantitative results.

Author Contributions

All authors contributed conceptually, formally, and in original drafting. Responsibilities are as follows: **Bilal Ahmed Abbasi:** conceptualization, formal methodology, writing – original draft preparation, revision. **Mushtaq Hussain Khan:** conceptualization, data curation, formal analysis, formal methodology, writing – original draft preparation, revision, submission. **Ambreen Gul:** conceptualization, writing – original draft preparation, writing – review and editing. **Inam Ul Haq:** supervision, validation, writing – review and editing. **Muhammad Umer Azeem:** supervision, validation, writing – review and editing.

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During the preparation of this work, the authors used DeepSeek in order to improve the language of the article. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Conflicts of Interest

The authors declare no conflicts of interest.

Research Involving Human Participants and/or Animals

This paper does not contain any studies with the involvement of human participants and animals.

Endnotes

[1] More details on the methodology behind the policy measures are available on the Germanwatch website at https://www.germanwatch.org/en/21110.

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Appendix A

TABLE A1 | Diagnostic tests.

Unit roots test

Levin–Lin–Chu (LLC)

Variable	*t*-value	*p*	Conclusion
LSCOPE2	−390.00	0.0000	Stationary
R&D	−260.00	0.0000	Stationary
SIZE	−310.00	0.0000	Stationary
LEV	−51.28	0.0000	Stationary
ROA	−150.00	0.0000	Stationary
LGDPPC	−160.00	0.0000	Stationary
ENINT	−260.00	0.0000	Stationary
RULELAW	−63.48	0.0000	Stationary
DOMPOLICY	−21.53	0.0000	Stationary
INTPOLICY	−29.21	0.0000	Stationary

Harris-Tzavalis (HT)

Variable	Test statistics	*p*	Conclusion
LSCOPE2	$\rho = 0.379, z = -6.02$	0.0000	Stationary
R&D	$\rho = 0.025, z = -17.09$	0.0000	Stationary
SIZE	$\rho = 0.371, z = -6.28$	0.0000	Stationary
LEV	$\rho = 0.275, z = -9.26$	0.0000	Stationary
ROA	$\rho = -0.117, z = -21.52$	0.0000	Stationary
LGDPPC	$\rho = 0.469, z = -3.19$	0.0007	Stationary
ENINT	$\rho = 0.211, z = -11.27$	0.0000	Stationary
RULELAW	$\rho = 0.139, z = -13.52$	0.0000	Stationary
DOMPOLICY	$\rho = 0.204, z = -11.48$	0.0000	Stationary
INTPOLICY	$\rho = 0.103, z = -14.65$	0.0000	Stationary

CIPS (cross-sectionally augmented)

Variable	CIPS	Critical value	Conclusion
LSCOPE2	−2.865	−2.25 (1%)	Stationary
R&D	−3.052	−2.25 (1%)	Stationary
SIZE	−2.716	−2.25 (1%)	Stationary
LEV	−2.423	−2.08 (5%)	Stationary
ROA	−2.345	−2.08 (5%)	Stationary
LGDPPC	−2.260	−2.08 (5%)	Stationary
ENINT	−2.944	−2.25 (1%)	Stationary
RULELAW	−2.312	−2.08 (5%)	Stationary
DOMPOLICY	−2.616	−2.25 (1%)	Stationary
INTPOLICY	−2.848	−2.25 (1%)	Stationary

Cross-sectional dependence

Pesaran's CD test

CD test	*p*	Conclusion
−0.469	0.6393	No dependence

Slope heterogeneity

Pesaran and Yamagata 2008

Delta	*p*	Conclusion
−12.746	0.000	Heterogeneous slopes

Model selection

Hausman test

chi2	*p*	Conclusion
35.53	0.0270	Fixed effects preferred

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