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Corporate innovation capacity, national innovation setting, and renewable energy use

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Abstract

This study combines both the resource-based view and institutional theory to investigate the relationship between a company's innovation capabilities and its consumption of renewable energy sources within well-established innovation ecosystems. Drawing on a comprehensive dataset of 14,506 observations covering 2007 to 2018, we executed the country-industry-year fixed-effects regression. The analysis reveals that a nation's innovation framework significantly influences the connection between a firm's innovation capabilities and its use of renewable energy. This relationship is moderated by key indicators of the nation's innovation climate, including the quality of scientific research institutions, university–industry collaboration, and government involvement in technology procurement. These findings emphasise the importance of institutional factors in fostering synergy between a company's innovation capacity and its consumption of renewable energy sources. They highlight the potential benefits of collaboration between firms and governments in promoting renewable energy consumption, especially in an era where innovative energy solutions are critical. This evidence underscores the need for a supportive macro-level policy environment alongside corporate initiatives to facilitate the transition to cleaner energy sources.

Keywords: firm innovation; national innovation capacity; renewable energy; resource-based view; institutional theory

1. Introduction

Environmental issues are becoming more important for businesses and governments. One of the main issues is moving towards using clean energy. Due to industrial growth, a rising global population, and a higher need for energy, there is a push to find new, eco-friendly energy sources (Liang et al., 2022). Governments, companies, and environmentalist groups are all trying to solve environmental problems and move away from fossil fuels to cleaner alternatives. Companies are being watched closely because of the environmental effects of their actions. They are being pressured to switch to cleaner energy sources by environmentalists, governments, and other parties. Our study aims to examine how a company's ability to innovate interacts with the country's innovation landscape to promote renewable energy consumption. The findings of this investigation have the potential to explain the mechanisms through which companies can increase their utilization of renewable energy.

Drawing on the resource-based view (RBV) perspective, previous research has shown that a company's internal resources, knowledge, and ability to innovate are key for adopting eco-friendly practices and cleaner energy consumption (Hadjimanolis, 2000; Rodríguez and Rodríguez, 2005; Portillo-Tarragona et al., 2018; Uyar et al., 2023). Strategic resources like research and development (R&D) give companies a competitive edge and the power to innovate (Rodríguez and Rodríguez, 2005). R&D helps companies implement eco-friendly practices, such as saving resources, in their operations (Uyar et al., 2023). Therefore, we employ the RBV theory to examine the potential impact of firms' innovation capabilities on their consumption of renewable energy.

For the interaction between firms’ innovation capacity and national innovation setting, we use institutional theory because we wanted to understand how the environment created by institutions affects what organizations do and how they come up with new ideas. This theory, which builds on the important work of scholars, such as Meyer and Rowan (1977), Powell and DiMaggio

(1991), and Scott (1995), looks at how different forces in the environment where organizations operate influence their behaviour. Institutional theory explores how laws, rules, societal expectations, and common beliefs impact organizations.

Fuenfschilling and Truffer (2014) showed how important it is to examine the whole environment around organizations, including rules, norms, and beliefs, to understand how organizations decide to adopt new technologies or practices. Institutional theory explains the ways that an organization's own resources and external pressures work together. Simply focusing on the structure of institutions, like specific laws or policies, does not give us the full picture. Institutional theory allows us to understand the deeper processes at work that affect how organizations behave, such as how they gain acceptance, get resources, and decide to use new, sustainable practices that society expects from them.

This is especially relevant when we talk about introducing renewable energy consumption. The policies that encourage renewable energy use, the laws that require sustainable practices, and the societal push for being responsible for the environment are all part of a complex setting that organizations have to navigate. Lawrence et al. (2011) further expand this by explaining how organizations actively engage with their environment to either support, create, or challenge institutions. This means organizations are not just waiting and accepting what comes; they are actively involved in shaping their environment. By using institutional theory, we aim to figure out how the setting created by institutions can either help or block organizations from coming up with renewable energy innovations. This helps us add to the conversation about how to operate sustainably and follow environmental policies, by showing how important the role of institutions is in making it easier (or harder) for organizations to choose cleaner energy options. Our research goes beyond a simple view of institutions to a more detailed look at how institutional theory can reveal the ways organizations navigate and are influenced by their environment in their quest to innovate for renewable energy sources. Crucially, consistent with the foundational work of DiMaggio and Powell (1983), Meyer and Rowan (1977), Powell and DiMaggio (1991), and Scott (1995), and incorporating insights from Fuenfschilling and Truffer (2014), our study examines how the national innovation context, through its coercive (i.e., government support to innovation) and normative (i.e., quality of research institutions and university-industry collaboration) mechanisms, moderates the relationship between firm-level innovation capabilities and renewable energy consumption, thereby contributing to the broader discourse on sustainable development and the transition towards a more sustainable energy future.

The RBV and institutional theory enable to get a full picture of how a firm's internal strengths (i.e., firms' innovation capabilities) and external pressures from the institutional environment (i.e., national-level innovation landscape) interplay and determine the use of renewable sources of energy by firms. This combined (multiple) theoretical approach helps us understand the synergetic relationship between organizations and the world around them, showing how both their internal resources and external pressures can either help or hinder their efforts to innovate in renewable energy.

Most previous studies have looked at renewable energy use from a macro perspective, focusing less on companies-level determinants of renewable energy consumption (Apergis et al., 2010; Omri et al., 2014; Andreas et al., 2017; Ergun et al., 2019; Chen et al., 2021). Fewer studies have looked at companies (Atif et al., 2021; Zhang et al., 2021b) but from different perspectives, such as how board diversity affects renewable energy use (Atif et al., 2021; Zhang et al., 2021b). Our study is different because it looks at how a firm's ability to innovate and the national innovation context can predict a firm's renewable energy use. We make a significant contribution to the literature by focusing on the national innovation setting, using three proxies for firms' renewable energy use: the quality of scientific research institutions, university-industry collaboration in R&D, and government support for innovation (World Economic Forum [WEF], 2018). We chose these measures for specific reasons. High-quality research institutions are linked to new knowledge and renewable energy tech advancements (Xie et al., 2023). The university-industry collaboration reflects how academic research is used in business (Di Maria et al., 2019; Caloghirou et al., 2021; Goel, 2022). Government support for innovation includes policies and funding to encourage innovation within a country (Kung et al., 2016; Zhang and Guan, 2018; Cirillo et al., 2019; Adjei-Bamfo et al., 2023). Additionally, the energy mix of countries may influence firms' consumption of renewable energy. We posit that a higher proportion of renewable energy in a country's energy mix suggests that a company's proportion of renewable energy in its energy consumption will increase correspondingly. This assumption has prompted us to further investigate the role of countries' renewable energy consumption in the empirical section of our study.

Our study raises questions about whether private-public collaboration can lead to meaningful progress on climate issues. We use data from 14,506 company-year observations from 2007 to 2018. Our findings show that a company's innovation ability and the wider national innovation context are important for using more renewable energy. The national innovation setting affects how a company's innovation ability leads to renewable energy use.

Our research supports the idea that both internal company resources and external factors, like government support, are important for eco-friendly practices and cleaner energy use. It also shows how external factors can influence companies to adopt certain practices. Our work contributes to the literature by showing the complex relationship between a company's innovation ability, the national innovation context, and renewable energy use. It highlights the need for considering both company-level and national-level dynamics for more renewable energy use and environmental sustainability.

The rest of the study is organized as follows: The next section provides the theoretical background, followed by the methodology and findings, and finally, the conclusions and implications.

2. Theoretical background and hypothesis

2.1. Theoretical framework: RBV and Institutional theory

Building on Oliver's (1997) seminal work, our approach integrates the RBV with institutional theory to thoroughly understand specific internal (i.e., firms' innovation capabilities) and external factors (i.e., national innovation setting) influencing a firm's consumption of renewable energy sources. Oliver's (1997) pioneering work effectively bridges RBV and institutional theory, highlighting the importance of firm-level analyses due to the considerable variability in how companies respond to institutional pressures.

Initially, we apply the RBV to explain how a corporation's innovation capabilities impact its use of renewable energy. As a cornerstone in strategic management, the RBV examines how an organization's unique internal resources and capabilities contribute to its competitive advantage and overall performance. Specifically, in the context of environmental sustainability and the consumption of cleaner energy sources, the RBV has been extensively used to examine the role of internal firm assets, knowledge, and capabilities. This discussion emphasizes the critical importance of these factors, focusing particularly on R&D as a strategic resource. Hadjimanolis (2000) highlights the crucial role of internal resources in shaping a firm's approach to eco-friendly practices. Companies equipped with valuable, rare, and inimitable resources are better prepared to develop and implement sustainable initiatives. These resources include not only tangible assets but also intangible ones, such as knowledge and expertise, aligning with the RBV's perspective that firms can achieve a competitive advantage by leveraging their unique resources.

Furthermore, Rodríguez and Rodríguez (2005) build on this concept by highlighting how strategic resources, such as R&D, can act as sources of sustainable competitive advantage. R&D efforts enable firms to expand their knowledge bases and improve their technological capabilities in renewable energy use. Regarding eco-friendly practices, R&D is instrumental in driving innovation in products and processes. Companies investing in R&D are more likely to incorporate cleaner energy sources into their operational strategies. This is in line with the RBV's principle that firms should utilize their valuable resources to maintain a competitive advantage.

Moreover, R&D allows firms to integrate eco-friendly practices into their operations, including resource conservation, emissions reduction, and eco-innovation, as noted by Uyar et al. (2023). Through ongoing R&D investments, firms can discover new ways to reduce their environmental impact, advance renewable energy technologies, and optimize their processes. These initiatives not only enhance the firm's competitive advantage but also contribute to the broader societal goal of environmental sustainability.

Collectively, leveraging the RBV, previous research highlights the critical role of internal firm resources, knowledge, and capabilities in fostering eco-friendly practices and adopting cleaner energy sources. As a strategic resource, R&D provides firms with a competitive edge and the ability to innovate in product and process areas. R&D enables companies to integrate eco-friendly practices, such as the use of renewable energy, into their operations, thereby reinforcing the link between strategic resources and sustainable practices (Rodríguez and Rodríguez, 2005; Uyar et al., 2023).

Further, we employ institutional theory to explore the moderating role of the national innovation context; it is imperative to explore the complexities of how this context influences the relationship between firms' innovation capabilities and the consumption of renewable energy. Fuenfschilling and Truffer (2014) provide a comprehensive framework for understanding these dynamics, suggesting that the national innovation context is not merely a backdrop against which innovation occurs but an active shaping force that interacts with firm-level capabilities and strategies.

The national innovation context comprises a range of institutional arrangements, including policies, cultural norms, and industry standards, which collectively influence firms' innovation activities and sustainability practices (Edquist, 2013). This context can either facilitate or hinder the adoption of renewable energy technologies, depending on the alignment of firm capabilities with national priorities, regulatory frameworks, and societal expectations for sustainability.

Coercive, normative, and mimetic forces influence firms' approaches to innovation and sustainability, particularly in the adoption of renewable energy technologies. In our study, we employ both normative and coercive forces to explain the role of the national innovation landscape in the innovation-renewable energy consumption nexus. Coercive forces, exerted through government regulations and standards, do more than enforce compliance; they encourage innovation, through government support to innovation, by setting environmental goals and providing financial incentives by governments for developing clean technologies. This dual push-and-pull effect not only mandates adoption but also incentivizes firms to seek competitive advantages through sustainable practices (Hoffman, 1999). Normative forces, reflecting societal values and professional standards, play a crucial role in integrating sustainability into a company's core values and operations. In our study, normative forces are proxied by both the quality of scientific research institutions and university-industry collaboration in R&D, which promote the professional standards of advancing innovation by firms. These types of forces drive a cultural and professional shift within organizations towards sustainability, making renewable energy consumption a natural aspect of business rather than a regulatory requirement. This transformation is especially impactful in industries where sustainability is key to leadership and customer retention (Bansal and Roth, 2000).

The interplay of these institutional forces within the national innovation context creates a fertile ground for firms to leverage their innovation capabilities towards renewable energy consumption. It is important to note that the national innovation context itself is dynamic, and shaped by global trends, technological advancements, and societal shifts towards sustainability (Geels et al., 2015). As such, firms' ability to navigate this context and align their innovation strategies with institutional pressures and opportunities becomes a key determinant of their success in adopting renewable energy technologies.

Collectively, our study expands upon the foundational work of DiMaggio and Powell (1983), Meyer and Rowan (1977), Powell and DiMaggio (1991), and Scott (1995), by integrating insights from Fuenfschilling and Truffer (2014). It examines how the national innovation context—through its coercive dimensions (i.e., government support for innovation) and normative dimensions (i.e., the quality of research institutions and the collaboration between universities and industries)—influences the relationship between a firm's innovation capabilities and its renewable energy consumption. This investigation is crucial for understanding the ways in which institutional settings either support or hinder innovation in renewable energy. Such insights are valuable to the ongoing discussion on sustainable development and the shift towards a more sustainable energy future.

2.2. Hypothesis development

In our research, we aim to contribute to the literature by examining whether firms' innovation capabilities, along with national innovation capacity, influence their consumption of renewable energy sources. This investigation is vital for understanding how both internal and external factors influence firms' decisions regarding sustainable energy use. By examining the interaction between innovation and the broader institutional environment, our study intends to illuminate the complexities of renewable energy consumption within firms.

In this study, we measure firm innovation capacity[1] by evaluating R&D intensity (Cui and Mak, 2002; Chintrakarn et al., 2016). National innovation capacity is assessed using the average of three country-level proxies for firms' renewable energy use: the quality of scientific research institutions, the extent of university–industry collaboration on R&D, and government support for fostering innovation (Ndou et al., 2018; Cirillo et al., 2019; Yönkul and Ünlü, 2022).

Notably, the quality of scientific research institutions is crucial for generating new knowledge and technological innovations (Xie et al., 2023). Prestigious research institutions often lead groundbreaking research, contributing to the development of intellectual assets (Roh et al., 2021). The excellence of these institutions provides insights into a nation's research capabilities

[1] These three national innovation indicators' data were retrieved from the Global Competitiveness Report issued by the World Economic Forum. These indicators are defined in more detail in the "Variables" section and Table 1.

and its potential to advance renewable energy technologies and initiatives (Bao et al., 2019). Similarly, collaboration between universities and industries in R&D signifies the practical application of academic research in the corporate world (Hille et al., 2020; Goel, 2022). Such collaborations can lead to the commercialization of research findings and the innovation of renewable energy technologies and services (Ghisetti, 2017).

Government support for innovation is also a crucial driver of a nation's innovation capabilities (Wijayasundara et al., 2022). This support includes policies, incentives, funding, and infrastructure development aimed at promoting innovation in renewable energy within a country (Negro et al., 2012; Adjei-Bamfo et al., 2023). Maasoumi et al. (2021) and Awijen et al. (2022) argue that the advancement of national innovation is heavily influenced by regulatory, economic, and institutional factors, which are key drivers of innovative efforts. A comprehensive macro-level study shows that a nation's investment in R&D catalyzes the consumption of renewable energy, as demonstrated in the contexts of China and Japan by Li and Ullah (2022). Regarding the public sector's influence on the private sector, Plank and Doblinger (2018) empirically show that government funding for R&D affects the patent count in the renewable energy sector. This highlights the positive role of institutional forces in the development of renewable energy technology.

Negro et al. (2012), in a review of 50 case studies, discuss the reasons behind the failures of renewable energy systems. Among the identified issues, the lack of government intervention was highlighted as a critical factor in the energy transformation equation. They argued for the need for infrastructure development and collaborative efforts between businesses and government entities. Such a transformation relies on robust institutional frameworks that include both tangible aspects, such as technical standards, and intangible aspects, like social norms, values, regulations, and entrepreneurial spirit. Thus, following Oliver (1997), we merge the insights of the RBV and institutional theory into a single hypothesis:

> ***Hypothesis****: Firms with greater innovation capacity are more likely to use renewable energy in countries with stronger national innovation environments.*

3. Research methodology

This quantitative study uses regression analysis to measure the impact of corporate innovation capacity on renewable energy use with the moderating effect of the national innovation setting. In the following subsections, we define the research variables, describe the sample formation and distribution, and then explain the empirical methodology.

3.1. Variables

3.1.1. Dependent variables

To measure the use of corporate renewable energy, renewable energy data are proxied by two indicators: the natural logarithm of renewable energy use in gigajoules (LNRENR) and industry-adjusted renewable energy consumption (RENRR) (Atif et al., 2021; Zhang et al., 2021b). Whereas we use LNRENR as the main dependent variable, we use RENRR as an alternative renewable energy proxy. Industry-adjusted renewable energy consumption is calculated by dividing a firm's renewable energy consumption by the median of the total energy use of the sector, and it considers variations across sectors in terms of renewable energy use (Atif et al., 2021). The sectors are based on Thomson Reuters Eikon's TRBC economic sector name. The data for this firm-level variable are retrieved from the Thomson Reuters Eikon database.

3.1.2. Independent variable

Firm innovation capacity (INNCAP) is proxied by R&D expenditure scaled by total assets (Cui and Mak, 2002; Chintrakarn et al., 2016). Scaling R&D expenditure with total assets helps normalise the R&D intensity of firms with firm size. In line with prior studies, we replace missing R&D values with 0 (Miller and del Carmen Triana, 2009; Uyar et al., 2023). The data for this firm-level variable are from the Thomson Reuters Eikon database.

3.1.3. Moderating variable

In line with several prior studies (Ndou et al., 2018; Cirillo et al., 2019; Yönkul and Ünlü, 2022), we measure national innovation capacity in our study with three proxies for firms' renewable energy use: quality of scientific research institutions (RESINST), the extent of university–industry collaboration on R&D (UNIVINDCO), and government support for fostering innovation is measured by the extent of government purchasing to foster innovation (GOVPROTEC). The national innovation capacity (NATINNSET) is a composite indicator and was calculated as the average of RESINST, UNIVINDCO, and GOVPROTEC. As defined in more detail in Table 1, these variables have a common scale of 1 to 7, such that 1 shows a poor national innovation setting and 7 shows an excellent national innovation setting. The data for these country-level variables are retrieved from the Global Competitiveness Report issued by the World Economic Forum (WEF, 2018). The Global Competitiveness Report provides the most comprehensive worldwide evaluation of countries' competitiveness, ranking more than 140 countries yearly (Ali et al., 2020). It is a reliable and rich source of data for assessing the public sector efficiency and institutional strength of nations (Uyar et al., 2021).

3.1.4. Control variables

We control for a battery of firm attributes, including board, financial, and ownership characteristics of firms and countries' public governance strength. The board structure is controlled by board size (BOARDSIZE), board gender diversity (BOARDGDIV), board tenure (BOARDTEN), board independence (BOARDIND), and CEO duality (CEODUAL) (Atif et al., 2021; Zhang et al., 2021b; Uyar et al., 2023). The board of directors and its composition play a critical role in corporate decision-making and policies, including environmental engagement. We control for financial characteristics, namely firm size (FIRMSIZE), profitability (ROA), leverage (LEVERAGE), and cash holding (CASHHOLD), as these attributes facilitate or limit firms' renewable energy use (Atif et al., 2021; Zhang et al., 2021b; Uyar et al., 2023). Shareholders are the primary decisive parties in corporate practices; hence, we controlled the ownership structure by the free float percentage (FREEFLOAT) (Uyar et al., 2023). We also control for public governance quality using the Worldwide Governance Indicators (WGI) as coercive forces that affect firms' environmental practices. Whereas WGI controls for public governance quality (institutional environment), all other variables are firm-level controls. All control variables except WGI are firm-level, whereas WGI is a country-level variable. The data for the firm-level variables are retrieved from the Thomson Reuters Eikon database, while the WGI data are from the World Bank (2021). All variables are defined in detail in Table 1.

INSERT TABLE 1 RIGHT HERE

3.2. Sample

Our sample covers the period between 2007 and 2018 due to the existence of data for national innovation setting variables in this period. To determine the sample period, we consider the availability of national innovation capacity data from the Global Competitiveness Report issued by the World Economic Forum. Thus, we match the data retrieved from the World Economic Forum, the Thomson Reuters Eikon database, and the World Bank for this period.

We examine the research sample before empirical analysis as the crucial step (Hair et al., 2019). Initially, the raw data are retrieved, cleaned, purified, and transferred into the software for the forthcoming analysis steps. The research sample excludes the financial sector, observations with missing renewable energy use values, countries with less than 10 firms, observations with missing values of the quality of scientific research institutions (RESINST) variable, and significant outliers.

Next, we checked the initial descriptive statistics, which indicated that some of the variables had skewness and large variabilities around the mean value. Therefore, firm innovation capacity (INNCAP), board size (BOARDSIZE), return on assets (ROA), firm leverage (LEVERAGE), and cash holding (CASHHOLD) are winsorised (Cox, 2006) at a one per cent level of the lower and upper tails. Moreover, the research sample is subject to the outliers' detection step using the minimum covariance determinant (Verardi and Dehon, 2010). After the analysis, we detected and eliminated 19 observations from the research sample.

In the next step, we examine the missing values of the research variables. Accordingly, some of the research variables[2] have less than five per cent missing values, which can be inconsequential (Schafer, 1999) or do not cause any estimation bias during the analysis (Bennett, 2001). Finally, we impute the missing values of the variables using the Markov chain Monte Carlo method.

[2] The variables including INNCAP, BOARDSIZE, BOARDGDIV, BOARDIND, FIRMSIZE, ROA, LEVERAGE, CASHHOLD, FREEFLOAT, & BOARDTEN had less than five per cent missing observations.

Sample distributions: We start with 46,152 observations, out of which the observations associated with the following are excluded from the sample: the financial sector (10,410 records), non-reported energy use (20,845 records), countries with less than 10 firms (226 records), missing the quality of scientific research institutions (RESINST) values (146 records), and significant outliers (19 records) (Table 2, Panel A).

Regarding sector-level distribution, the ratios range between 22.43% (industrials) and 4.28% (telecommunications services). Regarding year, the sample distribution reveals that the ratios range between 2.69% (the year 2007) and 14.28% (the year 2018) (Table 2, Panel B).

INSERT TABLE 2 RIGHT HERE

Finally, regarding the country-level distributions, the research sample includes 37 countries with 2,385 unique firms and 14,506 data points. All the countries have at least 10 unique firms (Table A1, Appendix section).

3.3. Empirical models

We formulate the research models using the country, industry, and year fixed-effects (FE) regression models, which can reduce the potential time-invariant endogeneity issue caused by omitted variable bias (Schons and Steinmeier, 2016; Rjiba et al., 2020). The formulation of the linear associations among the research variables is presented in Equation 1:

$$(Y)_{i,t,c} = \beta_0 + \beta_1(X)_{i,t,c} + \beta_2(Controls)_{i,t,c} + \beta_3\sum(Country)_c + \beta_4\sum(Industry)_i + \beta_5\sum(Year)_t + \varepsilon_{i,t,c} \quad (1)$$

In Equation 1, renewable energy use (LNRENR) and industry-adjusted renewable energy use (RENRR) are the dependent variables denoted as the "Y" term. Firm innovation capacity

(INNCAP) and national innovation setting (NATINNSET) are the independent variables of interest, denoted as the "X" term. Board size (BOARDSIZE), board gender diversity (BOARDGDIV), board tenure (BOARDTEN), board independence (BOARDIND), CEO duality (CEODUAL), firm size (FIRMSIZE), return on assets (ROA), firm leverage (LEVERAGE), cash holding (CASHHOLD), free float (FREEFLOAT), and the Worldwide Governance Indicators (WGI) are the control variables in the equation.

Moderation effects: The research models also incorporate the moderating effects of national innovation setting (NATINNSET) and its three components (RESINST, UNIVINDCO, and GOVPROTEC) on the association between firm innovation capacity (INNCAP) and renewable energy use (LNRENR). The formulation of the moderation models is provided in Equation 2 below:

$$(Y)_{i,t,c} = \beta_0 + \beta_1(X)_{i,t,c} + \beta_2(M)_{i,t,c} + \beta_3(X{*}M)_{i,t,c} + \beta_4(Controls)_{i,t,c} + \beta_5\sum(Country)_c + \beta_6\sum(Industry)_i + \beta_7\sum(Year)_t + \varepsilon_{i,t,c} \quad (2)$$

In Equation 2, the dependent variable (Y) is renewable energy use (LNRENR), the independent variable of interest (X) is firm innovation capacity (INNCAP), and the moderating variables (M) are national innovation setting (NATINNSET) and its three components (RESINST, UNIVINDCO, and GOVPROTEC). The control variables are the same as in Equation 1. Similarly, the moderating models are based on country, industry, and year FE.

Finally, the robust standard errors clustered by country are reported when running the regression analyses to control for the heteroscedasticity issue (Wooldridge, 2020).

4. Findings

4.1. Summary statistics

The descriptive statistics of the research variables are shown in Table 3. Regarding the dependent variables, the mean natural logarithm of renewable energy use (LNRENR) is 2.39, and the mean industry-adjusted renewable energy consumption (RENRR) is 0.11. In terms of the independent variables of interest, firm innovation capacity (INNCAP) is 0.01, and the national innovation setting of the country (NATIONNSET) is 4.75. Regarding the moderating variables, the average for assessing the quality of scientific research institutions (RESINST) is 5.37, the collaboration of business and universities on R&D (UNIVINDCO) is 4.88, and government support for fostering innovation (i.e., government purchasing decisions fostering innovation (GOVPROTEC)) is 3.99.

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4.2. Correlation analysis and multicollinearity

The linear correlation analysis results based on Pearson's correlation coefficients are reported in Table 4. The results show that firm innovation capacity (INNCAP) and national innovation setting (NATINNSET) and its two components (RESINST and UNIVINDCO) have a significantly positive linear correlation with renewable energy use (LNRENR), while only firm innovation capacity (INNCAP) has a significantly positive linear correlation with industry-adjusted renewable energy use (RENRR) ($p < 0.05$).

INSERT TABLE 4 RIGHT HERE

We also examine the issue of multicollinearity among the independent variables of the research models. We calculate the variance inflation factors (VIF) (Table A2 in the Appendix section), which range between 1.03 and 1.90. The VIF values are significantly less than the suggested cut-off value of 10 (Neter et al., 1996; Kennedy, 2008; Hair et al., 2019). Thus, there is no multicollinearity threat among the independent variables.

4.3 Baseline analysis

The baseline linear research models are analysed using the country, industry, and year FE regression analysis (Table 5). The results reveal that firm innovation capacity (INNCAP) and national innovation setting (NATINNSET) have a significant and positive relationship with renewable energy use (LNRENR) and industry-adjusted renewable energy use (RENRR). The results of the moderation effects of the national innovation setting (NATINNSET) and its three components (RESINST, UNIVINDCO, and GOVPROTEC) on the relationship between firm innovation capacity (INNCAP) and renewable energy use (LNRENR) are reported in Table 6. The product terms, including INNCAP*NATINNSET, INNCAP*RESINST, INNCAP*UNIVINDCO, and INNCAP*GOVPROTEC, have significantly positive associations with LNRENR. Thus, the results lend support to the hypothesis positing that firms with greater innovation capacity use more renewable energy in countries with stronger national innovation settings. The hypothesis is supported by the composite national innovation setting proxy (NATINNSET) as well as its three components (RESINST, UNIVINDCO, and GOVPROTEC) since their interaction with firm innovation capacity (INNCAP) has a significant positive effect on renewable energy use (LNRENR).

Our findings confirm prior studies that have outlined, drawing on resource-based theory, the critical role of firms' internal resources, knowledge, and capabilities in adopting eco-friendly practices and the use of green energy sources (Rodríguez and Rodríguez, 2005; Portillo-Tarragona et al., 2018; Uyar et al., 2023). Within the resource-based theoretical background, investing in research and development enables firms to develop a competitive advantage in both product and process development (Rodríguez and Rodríguez, 2005) and also fosters firms' embedding of eco-friendly practices into their operations (Uyar et al., 2023).

However, as a complement to firms' efforts to transform to cleaner energy use, our results indicate the importance of the public sector's role in this transformation (Plank and Doblinger, 2018). According to institutional theory, coercive forces, normative forces, and mimetic forces shape corporate behaviours (DiMaggio and Powell, 1983). In our case, by testing the national innovation context's role in renewable energy use, we provide evidence that coercive forces stimulate firms' energy transformation through scientific research institutions, university–industry collaboration on R&D, and government purchasing to foster innovation.

Scientific research institutions, as a proxy for normative forces, play a fundamental role in knowledge development, cutting-edge technological improvements (Xie et al., 2023), cultivating intellectual assets (Roh et al., 2021), and advancing renewable energy technologies (Bao et al., 2019). Importantly, from a normative perspective, university–industry cooperation in research and development is of critical importance for transforming knowledge into practice in the corporate domain (Hille et al., 2020; Goel, 2022) and innovating renewable energy technologies (Ghisetti, 2017). Further, drawing on coercive isomorphism, governmental support by formulating policies, providing incentives, funds, and infrastructure development encourages firms to innovate renewable energy technologies within a country (Negro et al., 2012; Adjei-Bamfo et al., 2023). Our evidence complements extant macro-level studies (Apergis et al., 2010; Andreas et al., 2017; Ergun et al., 2019, among others), addressing the paucity of firm-level studies focusing on board structure and the renewable energy nexus (Atif et al., 2021; Zhang et al., 2021b). Hence, our evidence shows that firms' innovative abilities and national innovation setting, along with the three pillars cited above, create a synergy in using more renewable energy sources by firms that bear firm-level and policy-making implications.

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INSERT TABLE 6 RIGHT HERE

4.4. Robustness tests

Alternative dependent variable: We incorporate an alternative dependent variable in the moderating analysis. We rerun the model with the moderating effects with the industry-adjusted renewable energy use proxy (RENRR) as the alternative dependent variable (Table 7). The results are consistent with the initial baseline moderation analysis: national innovation setting (NATINNSET) and its three components (RESINST, UNIVINDCO, and GOVPROTEC) are significant moderators of the relationship between firm innovation capacity (INNCAP) and the alternative dependent variable, namely industry-adjusted renewable energy use (RENRR).

INSERT TABLE 7 RIGHT HERE

Endogeneity: We address the potential endogeneity concern by employing entropy balance (Hainmueller and Xu, 2013) and propensity score matching (PSM) (Leuven and Sianesi, 2003). These two approaches are used to address the potential endogeneity issue stemming from omitted variable bias in light of the recent literature (Hill et al., 2021; Garcia et al., 2021; Zhang et al., 2022).

We create treatment and control groups using the top quartile of the testing variable of interest, such as firm innovation capacity (INNCAP) and national innovation setting

(NATINNSET), for both approaches. We assign a value of one for the top quartile of INNCAP and NATINNSET to create the treatment groups, and we assign a value of zero for the rest of INNCAP and NATINNSET to generate the control groups. The results of the entropy balance and PSM are reported in Table 8. Accordingly, the results are compatible with the initial baseline analysis results, where the coefficients of firm innovation capacity (INNCAP) and national innovation setting (NATINNSET) are significantly positive.

INSERT TABLE 8 RIGHT HERE

We re-examine the moderating effects of the composite national innovation setting proxy (NATINNSET) as well as its three components (RESINST, UNIVINDCO, and GOVPROTEC) using the entropy balance and PSM methods (Table 9 and Table 10). Similarly, the results of the product terms are significantly positive, which yields consistency with the initial baseline moderation analysis results.

INSERT TABLE 9 RIGHT HERE

INSERT TABLE 10 RIGHT HERE

Lagged variables of interest: We use the one-year lag of the testing variables of interest in the baseline research models to address the causal inference (Reed, 2014) and to alleviate any potential risk of reverse causality (Steinberg and Malhotra, 2014). The results of the linear associations are reported in Table 11, where the coefficients of the one-year lag of the testing variables are significantly positive. Thus, the results are consistent with the baseline analysis results. Moreover, the moderating models were re-executed using the lag of the testing and moderating variables (Table 12). Similarly, the product variables are significantly positive. The results are compatible with the initial moderation analysis results.

INSERT TABLE 11 RIGHT HERE

INSERT TABLE 12 RIGHT HERE

Alternative sample: We generate an alternative sub-sample, including the observations with positive values of renewable energy use (LNRENR). The baseline linear association and the moderation effects were re-examined using the alternative sample (Table 13 and Table 14). The coefficients of the testing variables of interest and the product terms in the moderation analysis are significantly positive. Thus, the results of the linear associations and moderation effects are consistent with the baseline analysis results.

INSERT TABLE 13 RIGHT HERE

INSERT TABLE 14 RIGHT HERE

According to the robustness tests, the baseline analysis results survive the battery of robustness checks with alternative samples, addressing endogeneity and providing an alternative dependent variable.

4.5. Further tests[3]

To further explicate the association between corporate innovation capacity and renewable energy use, we conducted several additional tests.

First, following prior studies examining the relationship between economic development and renewable energy use (Sharma et al., 2021; Das et al., 2022)[4], we rerun Equations 1 and 2 by controlling the gross domestic product (GDP)[5] per capita, presuming that national wealth might play a role in firms' renewable energy use. Our results still hold, supporting both the direct

[3] We appreciate the anonymous reviewers' suggestions to undertake these additional analyses. We report here only the outcomes of the analyses without tables so as not to overload the paper anymore with tables.
[4] These studies are country-level studies unlike our study focusing on firm-level renewable energy use.
[5] We take the natural logarithm of GDP and data are retrieved from the World Bank.

association between corporate innovation capacity and renewable energy use and the moderating effect of the national innovation setting between them. In addition, we test the moderating role of GDP between corporate innovation capacity and renewable energy use and find no significant moderating effect. Thus, incorporating GDP into research models does not alter the hypothesised relationship.

Second, it is also possible that the renewable energy production and consumption of countries might affect firms' renewable energy use. It is expected that a greater share of renewable energy in the energy mix of countries implies that a company's share of renewable energy in its energy consumption will also increase. That is because companies only have partial control over the share of renewable energy in their consumption, particularly for the ones supplied by external organizations. Thus, we retrieve two types of data from the World Bank: electricity production from renewable sources[6] (kWh) and renewable energy consumption (% of total final energy consumption). When we ran the research models again by integrating these two variables as additional controls, the main findings largely held again. In addition, when we integrate these two country-level renewable energy variables into the models as moderating factors, we find positive, significant evidence. This implies that countries' renewable energy production and consumption levels reinforce innovative firms' renewable energy use. This could be related to the availability of national facilities for the renewable energy use of firms or collaboration between firms and national energy agencies.

Third, we split the sample into two based on the median of the national innovation setting (NATINNSET) variable, such that we name the sub-sample having NATINNSET >= the median

[6] Electricity production from renewable sources, excluding hydroelectric, includes geothermal, solar, tides, wind, biomass, and biofuels.

of NATINNSET as High-NATINNSET, and the sub-sample having NATINNSET < the median of NATINNSET as Low-NATINNSET. Upon this sample splitting, we re-ran the main research model (Equation 1) and found that the significant positive association between corporate innovation capacity and renewable energy use is strongly maintained in the High-NATINNSET sub-sample than in the Low-NATINNSET sub-sample. More specifically, we find that while the natural logarithm of renewable energy use in gigajoules (LNRENR) is still significantly associated with renewable energy use in both sub-samples, the industry-adjusted renewable energy consumption (RENRR) is significantly associated with renewable energy use only in the High-NATINNSET sub-sample. This implies that innovative firms' struggle to use renewable energy weakens if the national innovation setting is not encouraging.

5. Conclusions and implications

Ecological concerns caused by fossil energy use and pollution are increasingly becoming a dominant issue for companies and public authorities. Thus, governments and firms are striving to enable energy transformation from fossil resources to cleaner energy types. In particular, firms' renewable energy use will contribute to pollution prevention as they immensely engage with production, trading, and logistics services. Nevertheless, the government's layout for supporting firms' innovations plays a catalyst role in this transformation. Hence, our study draws attention to the renewable energy consumption of firms enabled by the interaction between firms' innovation ability and the national innovation setting.

We find that corporate innovation capacity and national innovation setting per se augment renewable energy use, and national innovation setting moderates the relationship between firm innovation capacity and renewable energy consumption. The moderating effect is verified by the three national innovation-setting proxies, namely the quality of scientific research institutions, university–industry collaboration, and the government's procurement decisions to foster innovation. Thus, the outcome confirms the positive role of the national setting in creating synergy between firms' innovation capacity and renewable energy use.

Our findings confirm the interplay between the RBV and institutional theory in enriching firms' greater renewable energy use. The results suggest several policy implications. The findings highlight the synergy created by firm–government collaboration in stimulating firms' renewable energy use. As alternative energy solutions demand innovation, firms need the government's backing to lay out ideal settings. Our study proves that establishing high-quality research institutions, aligning firms and universities, and the government's purchasing decisions to foster innovation facilitate firms' renewable energy use. The findings suggest the need for concrete guidance of public governance mechanisms concerning how to formulate a national innovation set to develop solutions for ecological concerns and clean energy use. Thus, energy transformation requires macro policies as well as enterprise initiatives.

The results should be considered for the data period (2007–2018) and the nine sectors the sample covers. The validity of the results for particular periods and sectors might require further justification. For example, the war period between Russia and Ukraine and the associated energy crisis requires further study to determine whether the results change for that specific period. Further potential studies could test whether other firm and national characteristics, such as ownership structures (e.g., institutional ownership), sectoral affiliations, and national environmental regulations, as well as stakeholder power, such as environmentalists, might play a role in firms' renewable energy use.

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Table 1: Variables

Variable	Definition
Dependent variables:	
LNRENR	Natural logarithm of renewable energy use in gigajoules.
RENRR	Industry-adjusted renewable energy consumption is calculated by dividing a firm's renewable energy consumption by the median of the total energy use of the sector.
Independent variable:	
INNCAP	Firm innovation capacity is proxied by the research and development expenditure scaled by total assets.
Moderating variables:	
NATINNSET	The national innovation setting of the country is calculated by the average of the RESINST, UNIVINDCO, and GOVPROTEC (please see below).
RESINST	Response to the survey question, "In your country, how do you assess the quality of scientific research institutions?" [1 = extremely poor; 7 = extremely good] (WEF, 2018).
UNIVINDCO	Response to the survey question "In your country, to what extent do businesses and universities collaborate on research and development (R&D)?" [1 = do not collaborate at all; 7 = collaborate extensively] (WEF, 2018).
GOVPROTEC	Response to the survey question "In your country, to what extent do government purchasing decisions foster innovation?" [1 = not at all; 7 = to a great extent] (WEF, 2018).
Control variables:	
BOARDSIZE	The number of directors on boards.
BOARDGDIV	The proportion of female directors on boards.
BOARDTEN	The average number of years directors serve on boards.
BOARDIND	The proportion of non-executive directors on boards.
CEODUAL	CEO duality is specified with a binary variable, computed as 1 if the board chair serves as CEO or vice versa and 0 otherwise.
FIRMSIZE	Total assets' natural logarithm.
ROA	Income before interest and tax is deflated by total assets.
LEVERAGE	Total debt is deflated by total assets.
CASHHOLD	Cash and cash equivalents deflated by total assets.
FREEFLOAT	Free float percentage of shares traded in the stock market.
WGI	World Governance Indicators' average covers government effectiveness, voice and accountability, control of corruption, rule of law, political stability and absence of violence/terrorism, and regulatory quality (values range from -2.5 to 2.5).

Table 2: Sample distribution

Panel A:

Initial sample	*46,152*
(-) Financial sector	10,410
(-) Observations that do not report energy use	20,845
(-) Countries with less than 10 firms	226
(-) Observations with missing values of RESINST	146
(-) Outliers	19
Final Sample	*14,506*

Panel B:

Variable	Category	Freq.	Percent
Sector	Basic Materials	2,607	17.97
	Consumer Cyclicals	2,317	15.97
	Consumer Non-Cyclicals	1,417	9.77
	Energy	1,135	7.82
	Healthcare	959	6.61
	Industrials	3,254	22.43
	Technology	1,396	9.62
	Telecommunications Services	621	4.28
	Utilities	800	5.51
	Total	14,506	100.00
Year	2007	390	2.69
	2008	630	4.34
	2009	781	5.38
	2010	936	6.45
	2011	1,077	7.42
	2012	1,199	8.27
	2013	1,277	8.80
	2014	1,347	9.29
	2015	1,416	9.76
	2016	1,564	10.78
	2017	1,817	12.53
	2018	2,072	14.28
	Total	14,506	100.00

Table 3: Summary of the variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
LNRENR	14,506	2.39	5.09	0.00	18.83
RENRR	14,506	0.11	0.82	0.00	32.75
INNCAP	14,506	0.01	0.03	0.00	0.27
NATINNSET	14,506	4.75	0.59	2.66	5.69
RESINST	14,506	5.37	0.73	2.39	6.55
UNIVINDCO	14,506	4.88	0.72	2.29	5.97
GOVPROTEC	14,506	3.99	0.52	2.61	5.53
BOARDSIZE	14,506	11.08	3.43	4.00	21.00
BOARDGDIV	14,506	14.50	12.86	0.00	85.71
BOARDTEN	14,506	50.50	26.47	0.12	99.89
BOARDIND	14,506	72.74	24.73	0.00	100.00
CEODUAL	14,506	0.38	0.48	0.00	1.00
FIRMSIZE	14,506	22.84	1.38	17.04	27.41
ROA	14,506	0.09	0.07	-0.37	0.36
LEVERAGE	14,506	0.26	0.16	0.00	0.83
CASHHOLD	14,506	0.09	0.07	0.00	0.59
FREEFLOAT	14,506	75.66	25.53	0.00	100.00
WGI	14,506	1.08	0.63	-0.83	1.89

Table 4: Correlation analysis

	Variables	1	2	3	4	5	6	7	8	9
1	LNRENR	1								
2	RENRR	0.371*	1							
3	INNCAP	0.055*	0.020*	1						
4	NATINNSET	0.040*	0.002	0.155*	1					
5	RESINST	0.048*	-0.016	0.139*	0.918*	1				
6	UNIVINDCO	0.051*	0.01	0.131*	0.960*	0.870*	1			
7	GOVPROTEC	-0.004	0.016	0.149*	0.766*	0.499*	0.642*	1		
8	BOARDSIZE	0.109*	0.054*	-0.065*	-0.126*	-0.119*	-0.148*	-0.054*	1	
9	BOARDGDIV	0.178*	0.052*	-0.016	0.174*	0.228*	0.195*	-0.001	0.004	1
10	BOARDTEN	0	0.007	0.026*	-0.005	0.006	-0.005	-0.017*	-0.018*	-0.034*
11	BOARDIND	0.146*	0.065*	-0.022*	0.085*	0.025*	0.130*	0.072*	-0.021*	0.434*
12	CEODUAL	-0.002	-0.007	0.111*	0.097*	0.073*	0.051*	0.156*	0.088*	-0.028*
13	FIRMSIZE	0.182*	0.132*	-0.021*	0.058*	0.028*	0.008	0.145*	0.411*	0.005
14	ROA	0.039*	0.004	0.030*	0.024*	0.007	0.034*	0.025*	-0.079*	0.126*
15	LEVERAGE	0.053*	0.032*	-0.173*	-0.045*	-0.055*	-0.032*	-0.029*	0.119*	0.019*
16	CASHHOLD	-0.068*	-0.039*	0.221*	0.081*	0.078*	0.064*	0.078*	-0.102*	-0.124*
17	FREEFLOAT	0.032*	-0.005	0.161*	0.435*	0.486*	0.421*	0.207*	-0.048*	0.101*
18	WGI	0.039*	-0.029*	0.138*	0.640*	0.739*	0.591*	0.312*	-0.107*	0.186*
	Variables	10	11	12	13	14	15	16	17	18
10	BOARDTEN	1								
11	BOARDIND	-0.029*	1							
12	CEODUAL	0.107*	-0.072*	1						
13	FIRMSIZE	-0.043*	0.012	0.148*	1					
14	ROA	0.098*	0.147*	0.003	-0.128*	1				
15	LEVERAGE	-0.065*	0.070*	0.023*	0.205*	-0.176*	1			
16	CASHHOLD	0.050*	-0.157*	0.024*	-0.170*	0.075*	-0.237*	1		
17	FREEFLOAT	0.021*	-0.048*	0.118*	0.070*	-0.014	0.015	0.034*	1	
18	WGI	0.008	0.019*	0.017*	0.002	-0.081*	-0.069*	0.032*	0.454*	1

$^*p<0.05$

Table 5: Country, industry, and year fixed-effects regression analysis

Independent variables	(1) LNRENR	(2) RENRR	(3) LNRENR	(4) RENRR
INNCAP	12.8***	0.67**		
	(7.75)	(2.35)		
NATINNSET			0.26*	0.077***
			(1.67)	(2.76)
BOARDSIZE	0.044***	-0.0010	0.043***	-0.00093
	(3.09)	(-0.41)	(2.99)	(-0.38)
BOARDGDIV	0.031***	0.0014*	0.031***	0.0013*
	(7.26)	(1.80)	(7.10)	(1.72)
BOARDTEN	-0.00036	0.00045*	-0.00043	0.00045*
	(-0.24)	(1.73)	(-0.28)	(1.74)
BOARDIND	0.00029	0.00050	0.00024	0.00049
	(0.09)	(0.95)	(0.08)	(0.93)
CEODUAL	0.020	-0.019	0.033	-0.016
	(0.21)	(-1.15)	(0.35)	(-1.01)
FIRMSIZE	0.77***	0.097***	0.76***	0.096***
	(21.72)	(15.79)	(21.43)	(15.63)
ROA	1.48**	0.045	1.34**	0.036
	(2.42)	(0.42)	(2.19)	(0.34)
LEVERAGE	0.086	-0.079*	-0.086	-0.088*
	(0.32)	(-1.70)	(-0.32)	(-1.91)
CASHHOLD	-0.19	-0.17*	0.28	-0.15
	(-0.32)	(-1.67)	(0.47)	(-1.49)
FREEFLOAT	0.0059***	-0.00015	0.0066***	-0.00014
	(2.86)	(-0.42)	(3.20)	(-0.39)
WGI	0.73***	0.057	0.68***	0.035
	(3.60)	(1.60)	(3.24)	(0.97)
Constant	-19.4***	-2.31***	-20.0***	-2.54***
	(-21.44)	(-14.74)	(-19.33)	(-14.19)
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	14,506	14,506	14,506	14,506
Adj. R^2	0.171	0.050	0.168	0.050
F-stat.	45.67***	12.34***	44.63***	12.37***

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Moderation effects

Independent variables	(1) LNRENR	(2) LNRENR	(3) LNRENR	(4) LNRENR
INNCAP	-19.4*	-18.2	-9.79	-14.3
	(-1.72)	(-1.60)	(-1.11)	(-1.29)
NATINNSET	0.15			
	(0.87)			
INNCAP*NATINNSET	6.55***			
	(2.89)			
RESINST		0.19		
		(1.26)		
INNCAP*RESINST		5.58***		
		(2.77)		
UNIVINDCO			0.16	
			(1.06)	
INNCAP*UNIVINDCO			4.47***	
			(2.61)	
GOVPROTEC				-0.0020
				(-0.01)
INNCAP*GOVPROTEC				6.53**
				(2.48)
BOARDSIZE	0.044***	0.045***	0.044***	0.044***
	(3.08)	(3.11)	(3.07)	(3.07)
BOARDGDIV	0.031***	0.031***	0.031***	0.032***
	(7.26)	(7.19)	(7.22)	(7.31)
BOARDTEN	-0.00029	-0.00028	-0.00030	-0.00034
	(-0.19)	(-0.19)	(-0.20)	(-0.22)
BOARDIND	0.00044	0.00064	0.00049	0.00034
	(0.15)	(0.21)	(0.16)	(0.11)
CEODUAL	0.037	0.037	0.034	0.030
	(0.39)	(0.39)	(0.36)	(0.32)
FIRMSIZE	0.76***	0.76***	0.76***	0.76***
	(21.47)	(21.50)	(21.49)	(21.57)
ROA	1.44**	1.42**	1.45**	1.46**
	(2.36)	(2.33)	(2.38)	(2.39)
LEVERAGE	0.090	0.093	0.083	0.088
	(0.33)	(0.35)	(0.31)	(0.33)
CASHHOLD	-0.26	-0.26	-0.24	-0.25
	(-0.43)	(-0.44)	(-0.41)	(-0.41)
FREEFLOAT	0.0058***	0.0058***	0.0058***	0.0059***
	(2.83)	(2.81)	(2.81)	(2.87)
WGI	0.65***	0.59***	0.64***	0.74***
	(3.13)	(2.79)	(3.03)	(3.61)
Constant	-19.5***	-19.7***	-19.4***	-19.2***
	(-18.13)	(-18.05)	(-19.40)	(-18.81)
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	14,506	14,506	14,506	14,506
Adj. R^2	0.172	0.172	0.172	0.171
F-stat.	44.54***	44.55***	44.52***	44.46***

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Moderation analysis with alternative dependent variable

Independent variables	(1) RENRR	(2) RENRR	(3) RENRR	(4) RENRR
INNCAP	-3.85**	-3.70*	-2.10	-4.44**
	(-1.97)	(-1.88)	(-1.37)	(-2.32)
NATINNSET	0.059**			
	(2.00)			
INNCAP*NATINNSET	0.92**			
	(2.35)			
RESINST		0.024		
		(0.93)		
INNCAP*RESINST		0.79**		
		(2.26)		
UNIVINDCO			0.042	
			(1.64)	
INNCAP*UNIVINDCO			0.55*	
			(1.85)	
GOVPROTEC				0.062**
				(2.49)
INNCAP*GOVPROTEC				1.23***
				(2.71)
Controls	Included	Included	Included	Included
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	14,506	14,506	14,506	14,506
Adj. R^2	0.051	0.050	0.050	0.051
F-stat.	12.19***	12.10***	12.11***	12.27***

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Entropy balance and PSM

	(1) LNRENR	(2) RENRR	(3) LNRENR	(4) RENRR	(5) LNRENR	(6) RENRR	(7) LNRENR	(8) RENRR
	Entropy Balance	Entropy Balance	Entropy Balance	Entropy Balance	PSM	PSM	PSM	PSM
INNCAP	14.8***	1.19***			13.7***	0.85***		
	(7.59)	(4.31)			(8.09)	(2.91)		
NATINNSET			0.20*	0.10***			0.020*	0.13***
			(1.67)	(3.17)			(1.69)	(2.90)
Controls	Included	Included	Included	Included	Included	Included	Included	Included
Country, industry, & year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	14,506	14,506	14,506	14,506	5,500	5,500	5,500	5,500
Adj. R^2	0.191	0.058	0.179	0.055	0.210	0.062	0.201	0.062
F-stat.	22.60***	5.51***	21.02***	5.45***	25.40***	7.02***	24.02***	7.02***

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
PSM: Propensity score matching

Table 9: Entropy balance - Moderation effects (Table 6)

Independent variables	(1) LNRENR	(2) LNRENR	(3) LNRENR	(4) LNRENR
INNCAP	-35.5***	-31.0***	-21.5**	-28.6**
	(-3.16)	(-2.86)	(-2.47)	(-2.28)
NATINNSET	-0.57*			
	(-1.79)			
INNCAP*NATINNSET	10.2***			
	(4.36)			
RESINST		-0.44*		
		(-1.65)		
INNCAP*RESINST		8.18***		
		(4.08)		
UNIVINDCO			-0.42	
			(-1.60)	
INNCAP*UNIVINDCO			7.13***	
			(4.04)	
GOVPROTEC				-0.52*
				(-1.76)
INNCAP*GOVPROTEC				10.4***
				(3.44)
Controls	Included	Included	Included	Included
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	14,506	14,506	14,506	14,506
Adj. R^2	0.193	0.193	0.193	0.193
F-stat.	22.35***	22.36***	22.29***	22.20***

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: PSM – Moderation effects (Table 6)

Independent variables	(1) LNRENR	(2) LNRENR	(3) LNRENR	(4) LNRENR
INNCAP	-30.2**	-33.4***	-18.1*	-15.9
	(-2.43)	(-2.66)	(-1.87)	(-1.30)
NATINNSET	-0.41			
	(-1.49)			
INNCAP*NATINNSET	8.90***			
	(3.57)			
RESINST		-0.62**		
		(-2.43)		
INNCAP*RESINST		8.44***		
		(3.78)		
UNIVINDCO			-0.28	
			(-1.17)	
INNCAP*UNIVINDCO			6.27***	
			(3.34)	
GOVPROTEC				-0.11
				(-0.45)
INNCAP*GOVPROTEC				7.11**
				(2.45)
Controls	Included	Included	Included	Included
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	5,500	5,500	5,500	5,500
Adj. R^2	0.212	0.212	0.212	0.211
F-stat.	24.83***	24.89***	24.80***	24.71***

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Lagged testing variables (Table 5)

Independent variables	(1) LNRENR	(2) RENRR	(3) LNRENR	(4) RENRR
INNCAP(t-1)	12.6***	0.61**		
	(7.46)	(2.04)		
NATINNSET(t-1)			0.062*	0.031*
			(1.78)	(1.86)
Controls	Included	Included	Included	Included
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	13,750	13,750	13,270	13,270
Adj. R^2	0.172	0.051	0.170	0.051
F-stat.	43.65***	12.00***	42.07***	11.81***

t statistics in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Lagged testing and moderating variables (Table 6)

Independent variables	(1) LNRENR	(2) LNRENR	(3) LNRENR	(4) LNRENR
INNCAP(t-1)	-15.9	-15.4	-8.49	-7.02
	(-1.38)	(-1.37)	(-0.96)	(-0.56)
NATINNSET(t-1)	-0.042			
	(-0.25)			
INNCAP(t-1)*NATINNSET(t-1)	5.88**			
	(2.55)			
RESINST(t-1)		0.037		
		(0.24)		
INNCAP(t-1)*RESINST(t-1)		5.12**		
		(2.57)		
UNIVINDCO(t-1)			0.059	
			(0.41)	
INNCAP(t-1)*UNIVINDCO(t-1)			4.25**	
			(2.49)	
GOVPROTEC(t-1)				-0.21
				(-1.28)
INNCAP(t-1)*GOVPROTEC(t-1)				4.84*
				(1.67)
Controls	Included	Included	Included	Included
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	13,270	13,270	13,270	13,270
Adj. R^2	0.173	0.174	0.174	0.173
F-stat.	41.95***	41.97***	41.97***	41.89***

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Alternative sample (Table 5)

Independent variables	(1) LNRENR	(2) RENRR	(3) LNRENR	(4) RENRR
INNCAP	0.62*	0.38*		
	(1.77)	(1.80)		
NATINNSET			0.15*	0.34**
			(1.77)	(2.34)
Controls	Included	Included	Included	Included
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	2,755	2,755	2,755	2,755
Adj. R^2	0.409	0.139	0.409	0.141
F-stat.	29.82***	7.74***	29.83***	7.83***

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Alternative sample generated using the positive values of renewable energy use (LNRENR)>0

Table 14: Alternative sample (Table 6)

Independent variables	(1) LNRENR	(2) LNRENR	(3) LNRENR	(4) LNRENR
INNCAP	-23.9*	-28.9*	-14.6	-14.9
	(-1.73)	(-1.92)	(-1.35)	(-1.30)
NATINNSET	0.026			
	(0.13)			
INNCAP*NATINNSET	4.74*			
	(1.78)			
RESINST		0.29		
		(1.59)		
INNCAP*RESINST		5.07**		
		(1.97)		
UNIVINDCO			0.11	
			(0.65)	
INNCAP*UNIVINDCO			2.80*	
			(1.71)	
GOVPROTEC				-0.25
				(-1.61)
INNCAP*GOVPROTEC				3.61*
				(1.78)
Controls	Included	Included	Included	Included
Country, industry, & year FE	Yes	Yes	Yes	Yes
N	2,755	2,755	2,755	2,755
Adj. R^2	0.409	0.410	0.409	0.409
F-stat.	29.02***	29.15***	29.01***	29.01***

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
An alternative sample generated using the positive values of renewable energy use (LNRENR)>0

Appendix

Table A1: Sample distributions of the countries

	Country	Unique firms	Percent	Data points	Percent
1	Australia	101	4.23	586	4.04
2	Austria	17	0.71	92	0.63
3	Belgium	17	0.71	126	0.87
4	Brazil	51	2.14	311	2.14
5	Canada	95	3.98	578	3.98
6	Chile	18	0.75	92	0.63
7	China	70	2.94	222	1.53
8	Colombia	13	0.55	49	0.34
9	Denmark	28	1.17	162	1.12
10	Finland	30	1.26	230	1.59
11	France	100	4.19	730	5.03
12	Germany	91	3.82	528	3.64
13	Hong Kong	148	6.21	398	2.74
14	India	55	2.31	348	2.40
15	Indonesia	19	0.80	105	0.72
16	Italy	59	2.47	255	1.76
17	Japan	273	11.45	2,438	16.81
18	Korea; Republic (S. Korea)	62	2.60	451	3.11
19	Malaysia	35	1.47	141	0.97
20	Mexico	25	1.05	145	1.00
21	Netherlands	31	1.30	234	1.61
22	New Zealand	13	0.55	50	0.34
23	Norway	27	1.13	143	0.99
24	Philippines	10	0.42	36	0.25
25	Poland	16	0.67	65	0.45
26	Portugal	10	0.42	57	0.39
27	Russia	27	1.13	190	1.31
28	Singapore	20	0.84	91	0.63
29	South Africa	71	2.98	464	3.20
30	Spain	41	1.72	304	2.10
31	Sweden	55	2.31	348	2.40
32	Switzerland	49	2.05	313	2.16
33	Taiwan	70	2.94	368	2.54
34	Thailand	22	0.92	144	0.99
35	Turkey	18	0.75	84	0.58
36	United Kingdom	156	6.54	1,099	7.58
37	United States of America	442	18.53	2,529	17.43
	Total	2,385	100.00	14,506	100.00

Table A2: Multicollinearity analysis

Variable	VIF	Variable	VIF
WGI	1.34	WGI	1.90
FREEFLOAT	1.31	NATINNSET	1.87
BOARDGDIV	1.31	FREEFLOAT	1.35
FIRMSIZE	1.30	FIRMSIZE	1.31
BOARDIND	1.29	BOARDGDIV	1.31
BOARDSIZE	1.23	BOARDIND	1.30
LEVERAGE	1.15	BOARDSIZE	1.25
CASHHOLD	1.15	LEVERAGE	1.13
INNCAP	1.12	CASHHOLD	1.13
ROA	1.11	ROA	1.11
CEODUAL	1.07	CEODUAL	1.07
BOARDTEN	1.03	BOARDTEN	1.03
Mean VIF	1.20	Mean VIF	1.31

VIF: Variance inflation factor