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Can Mergers and Acquisitions Promote Technological Innovation in the New Energy Industry? An Empirical Analysis Based on China's Lithium Battery Industry

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Abstract: The advancement of technological capabilities within lithium battery enterprises crucially facilitates the high-quality development of the new energy industry. This study aims to empirically investigate the impact of mergers and acquisitions (M&A) on the technological innovation capacities of these enterprises, with a specific focus on the lithium battery sector in China. Utilizing data from 34 publicly listed companies spanning the period from 2012 to 2022, we employ the multi-period double-difference method for comprehensive analysis. Researchers have observed that the implementation of merger and acquisition (M&A) strategies by new energy companies leads to an approximately 1.5 percentage point increase in their technological innovation level. However, the improvement in the green technological innovation level is not significant. After a series of robustness tests, the aforementioned conclusion remains valid. Additionally, with the enhancement of firms' knowledge absorption capacity and regional intellectual property protection, M&A activities can further promote technological innovation in new energy companies and contribute to the enhancement of green technological innovation. Heterogeneity analysis has revealed that technological M&A crucially facilitates the improvement of technological innovation levels among listed companies in the lithium battery industry. Implementing M&A strategies not only benefits the enhancement of firms' technological innovation levels but also significantly fosters green technological innovation. Furthermore, further research has indicated that changes in the level of green technological innovation after the implementation of M&A strategies by new energy companies facilitate the reduction of industrial wastewater and sulfur dioxide emissions. The main innovation of this study, which utilizes new energy companies as the research object, is as follows: it reveals the causal relationship and regulatory mechanism between M&A, technological innovation, and green technological innovation in new energy companies. Furthermore, the study analyzes the mechanism that promotes green technological innovation in new energy companies from the intellectual property protection perspective. Moreover, it assesses the heterogeneous impacts of changes in both technological innovation levels and green technological innovation levels on environmental governance after the implementation of M&A activities.

Keywords: new energy industry; green technology innovation; mergers and acquisitions (M&A); lithium battery

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1. Introduction

Technological innovation is not only the key to gaining a competitive advantage for new energy companies but also the core factor in enhancing the high-quality development of the new energy industry. It is crucial for achieving the "carbon peaking" goal in a planned and step-by-step manner. As a critical industry in the new energy field, the lithium battery industry fundamentally determines the development of new energy vehicles; thus, it crucially affects the new energy sector. The lithium battery industry relies on technological research and development innovation as its core competitiveness, through which it continuously overcomes key technological limits. The aforementioned industry critically influences the economic and social transition towards a green and low-carbon society. In an increasingly competitive external environment, the following research question is paramount: how can Chinese lithium battery companies enhance their technological innovation capabilities? By answering this question, the green and low-carbon transformation of the modern economy and society can be achieved. The state and relevant departments have also attached immense importance to this issue. Since 2021, the State Council's "14th Five-Year Plan and 2035 Long-term Goal Outline" and the National Development and Reform Commission's "14th Five-Year" New Energy Storage Development Implementation Plan have emphasized the need to enhance the innovation capability of new energy storage technologies such as the lithium battery industry and to actively perform research and development in key technologies for new energy storage. Existing theories indicate that enterprises (i.e., the main body of innovation) can realize technological innovation through two paths, namely closed innovation and open innovation. Mergers and acquisitions (M&A) are a crucial method of open innovation [1]. By implementing M&A, enterprises can obtain the technical knowledge of the target company in a short period and produce innovative synergies. The level of innovation provides a theoretical basis.

In recent years, as the external competitive environment has become increasingly fierce, capital in China's lithium battery industry has been quite active, with frequent M&A. Relevant listed companies not only extend vertically to upstream resources but also focus on the M&A associated with new materials and technologies for lithium batteries [2]. For listed lithium battery-industry companies, M&A began in 2016, the M&A amount exceeded 148.4 billion yuan, and the number of M&A attained 87; this amount will attain a new high in 2022 (>212.2 billion yuan), and the number of M&A will attain 272 pens (Figure 1A). Meanwhile, with the accumulation of M&A in the lithium battery industry, the number of patent applications in the lithium battery industry has exhibited a fluctuating upward trend. In 2016, the number of patent applications was approximately 5700, and it will increase to >7500 in 2022. Although large fluctuations exist, the number generally exhibited an upward trend. Thus, it can be observed that vertical mergers and technology mergers are crucial factors that affect the technological innovation of enterprises, and there may be a positive correlation between them. Can listed companies in China's lithium battery industry enhance their technological innovation capabilities through the implementation of M&A strategies? Which type of M&A are the key factors for facilitating the enhancement of technological innovation capabilities of enterprises? How can new energy companies enhance their level of green technological innovation under the M&A context? What impact does the change in the technological innovation of new energy companies after implementing M&A strategies exert on environmental governance? The answers to the preceding questions can provide empirical evidence for the effective implementation of M&A strategies by new energy companies, which is crucial for enhancing the high-quality development level of the new energy industry.

Aiming at the relationship between M&A and corporate technological innovation, existing studies have further analyzed the impact of M&A in different sectors, such as agriculture, manufacturing, and high-tech industries, on technological innovation based on focusing on the mechanism of M&A affecting corporate technological innovation. It is observed that for different industries, there is heterogeneity in the impact of M&A activities in different industries on corporate technological innovation, which is apparently an inhibitory effect or a promotional effect. In the process of developing the new energy industry, M&A inevitably yields significant implications for technological innovation and green technological innovation in the lithium battery industry. However, there has been limited research on the relationship between M&A and technological innovation in the lithium battery industry, and the direction of M&A's impact on technological innovation in new energy companies remains uncertain, with unclear underlying mechanisms. Additionally, the environmental governance implications of changes in technological innovation and green technological innovation in new energy companies after M&A activities are not comprehensively understood, which highlights the urgent need for relevant studies.

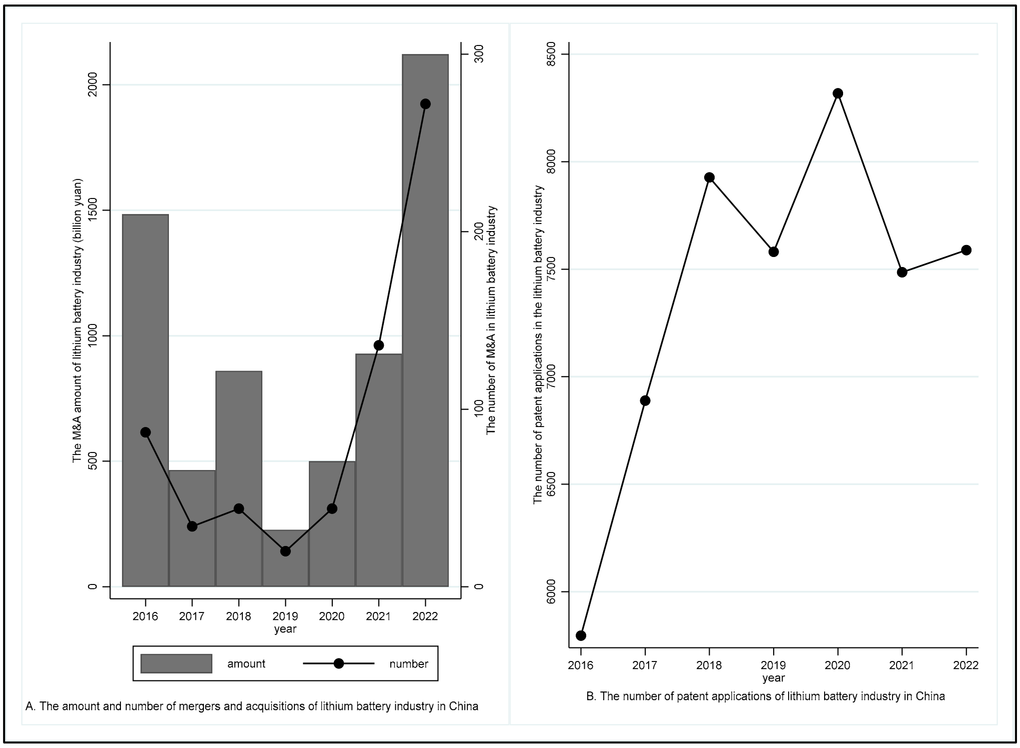

Figure 1. China's lithium battery industry: 2016–2022 M&A transactions and trends in enterprise technological innovation.

Compared with existing research, this study contributes to the existing literature in four main aspects. First, it examines the impact of M&A on technological innovation and green technological innovation in the new energy industry, specifically focusing on the lithium battery sector. Existing research has primarily investigated the effects of M&A activities on technological innovation in sectors such as the agriculture industry, manufacturing industry, and high-tech industry. Due to the rapid development of the new energy sector, analyzing the influence of M&A on technological innovation in listed lithium battery companies not only enriches the literature pertaining to the effects of M&A on innovation across different industries but also provides empirical evidence that can promote high-quality development in the lithium battery industry and facilitate the green and low-carbon transformation of the economy and society. Second, it reveals the mechanisms through which lithium battery listed companies enhance their innovation performance and green innovation performance under the M&A scenario, considering factors such as firms' knowledge absorption capabilities and intellectual property protection. Thus, the researchers' understanding of technological innovation in the new energy industry is deepened. Third, it reveals the key factors that facilitate the enhancement of technological innovation levels among lithium battery-listed companies based on different purposes of M&A in the industry. Last, from the perspective of environmental pollution control, it evaluates the impacts of changes in technological innovation and green technological innovation on pollutant emissions following M&A activities.

This paper is structured as follows: Section 2 presents a literature review, upon which hypotheses pertaining to the impact of M&A on technological innovation and green technological innovation in the new energy industry are proposed. Section 3 describes the utilized empirical data and methodology. Section 4 presents and discusses the main results of the econometric model. Finally, Section 5 provides targeted policy recommendations for new energy companies based on a summary of the empirical research findings.

2. Literature Review and Hypothesizes Proposed

2.1. Literature Review

In the existing research on the technological innovation of enterprises, many studies begin their analysis with factors such as environmental regulation [3,4], stakeholder pressure [5,6], enterprise resource capability and executive characteristics [7–10], and corporate M&A behavior [11,12], which represent the driving factors for enterprise technological innovation activities. The relationship between M&A and technological innovation activities has attracted immense research attention; however, the research conclusions remain controversial. On the one hand, some researchers propose that M&A can provide enterprises with complementary innovation resources, expand the knowledge stock of enterprises, and reduce the risk and cost of innovation [13]. Meanwhile, M&A integration is conducive to expanding the scale of innovation and realizing economies of scale and scope in R&D [14], which enhances the innovation level. On the other hand, some studies have observed that corporate M&A weakens competition within the industry and between upstream and downstream sectors, thereby reducing R&D investment and hindering technological innovation [11]; meanwhile, M&A may create a scenario in which companies accumulate more debts, and the increased debt will compel companies to reduce R&D investment [15,16].

Therefore, some studies further analyze the impact of M&A on corporate innovation performance based on the M&A exhibited by different industries. First, some scholars divide M&A into horizontal mergers, vertical mergers, and hybrid mergers, and they observe that horizontal mergers and vertical mergers facilitate technological innovation among listed agricultural companies, whereas hybrid mergers will reduce their R&D investment [17]. Some studies divide M&A into technical M&A and non-technical M&A, and they observe that technological M&A can directly reduce the repetitive R&D investment pertaining to the closed innovation of listed manufacturing companies, overcome the rigidity of inherent innovation capabilities, and enhance enterprises' breakthrough innovation capabilities [18–20], whereas non-technological M&A exert a negative impact on innovation in manufacturing listed companies [21]. Meanwhile, some scholars have further investigated the impact of M&A in the equipment manufacturing industry on corporate technological innovation, and they observed that for the equipment manufacturing industry, M&A has promoted a substantial increase in the R&D capital and R&D level of listed companies [22,23]. In addition, some studies have analyzed the impact of M&A pertaining to high-tech industries on corporate technological innovation and observed that although there is a significant "inverted U-shaped" relationship between the scale of M&A and innovation performance, and that the absorptive capacity can move the inflection point of the "inverted U-shaped" to the right.

The aforementioned studies have analyzed the relationship between M&A and corporate technological innovation, and they have examined the heterogeneous impact of M&A on the technological innovation of listed companies in agriculture, manufacturing, and equipment manufacturing. However, due to the increasing demand for new energy vehicles under the current scenario, the lithium battery industry is rapidly developing, capital competition is fierce, and M&A are frequent [23,24]; however, few scholars have investigated the impact of M&A on the technological innovation of the lithium battery industry and the impact of M&A on the technological innovation of lithium battery enterprises. Because this relationship remains unclear, relevant research is urgently required. For the existing research on the lithium battery industry M&A, only a limited number of scholars have investigated the characteristics and driving factors of M&A. Monge et al. (2018) considered the M&A of US oil and gas companies in the lithium battery industry. With regard to the lithium battery industry, natural gas companies are dedicating an increasing amount of research attention to M&A [25]. Monge et al. (2020) analyzed the time series characteristics of M&A activities in the lithium battery industry [26]. Monge et al. (2021) utilized time series data to examine the impact of lithium ore resource prices on M&A behavior in the lithium battery industry, and they observed that the two are highly correlated [27].

In summary, the existing research has extensively discussed the causal relationship between M&A and corporate technological innovation, which provides an effective reference for this study; however, the following points should be enhanced. First, in the existing research on M&A and corporate technological innovation, only the M&A of enterprises associated with industries such as agriculture, manufacturing, and equipment manufacturing are considered. Therefore, further research on the M&A of the lithium battery industry is imperative. Second, in the existing research on the M&A behavior of the lithium battery industry, several studies are limited to examining the characteristics and driving factors of the M&A behavior. To overcome the limitation pertaining to lithium resource supply, the technological innovation capabilities of enterprises in the lithium battery industry should be enhanced; therefore, further research is imperative. The impact of M&A on the technological innovation of lithium battery enterprises should be investigated. Finally, studies on the relationship between M&A and corporate technological innovation utilize either the facilitation theory or suppression theory, two opposite perspectives, and the impact of M&A on corporate technological innovation at different industry levels (e.g., agriculture, manufacturing, and equipment manufacturing) has not been determined. The unified conclusion is as follows: there is an urgent need to further investigate the impact of M&A on the technological innovation of lithium battery enterprises; thus, further empirical evidence for the relationship between the two can be provided.

2.2. Hypothesis Proposed

Based on the objective of corporate transaction M&A, the strategy is divided into the following categories: technical M&A and non-technical M&A [21]; According to the direction of corporate transaction M&A, the strategy can be divided into vertical mergers, horizontal mergers, and hybrid mergers [17]. On the one hand, from the perspective of M&A in the lithium battery industry, the trend pertaining to vertical M&A of battery companies and battery material companies is apparent, and they mainly extend upstream to ensure the supply of raw materials and cost control. On the other hand, in regard to the objectives of M&A in the lithium battery industry, technological M&A is gradually becoming a new trend, with a focus on new materials and technologies (e.g., silicon-based anodes and solid-state batteries), which have attracted significant attention from acquiring capital [2]. Therefore, China's lithium battery industry mainly exhibits vertical M&A. In the analysis, it is necessary to focus on the vertical M&A of the lithium battery industry and technology mergers and to respectively explain the impact of the two on the technological innovation of enterprises.

The technological innovation concept originated from Joseph Schumpeter's theory of innovation theory, which proposes that "innovation" is an economic process of rearranging and combining original factors of production into new production methods to improve efficiency and reduce costs. The theory entails introducing new combinations of production factors and conditions into the production system; thus, a new production function with the aim of attaining potential profits can be established. Scholars subsequently categorized innovation into product innovation, process innovation, market innovation, resource allocation innovation, and organizational management innovation based on the preceding discourse. The technological innovation theory, which emerged as a distinct field from Schumpeter's innovation theory beginning in the 1950s, is defined as an integrated process where entrepreneurs seize market opportunities for potential profitability; restructure production conditions and factors; continuously develop and introduce new products, processes, and technologies; and aim for market recognition while pursuing economic benefits. Based on the object of technological innovation, it can be classified into product innovation and process innovation. Product innovation lacks a strict and unified definition, and the OECD (Organization for Economic Co-operation and Development) defines it as the technical changes of a product that provide novel or enhanced services to product users. Process innovation, also referred to as process technological change, encompasses innovations in production techniques, including new processes, equipment, and organizational management methods. In the following analysis, which considers new energy companies, the technological innovation effects of implementing M&A strategies will be primarily examined from the product innovation and process innovation perspectives.

First, from the perspective of vertical M&A in the lithium battery industry, lithium battery companies can reduce the production cost and enhance competitiveness by acquiring upstream lithium mining resources, thereby gaining a competitive advantage, accelerating capital accumulation, increasing investment in research and development, and promoting technological innovation within the company. Additionally, vertical integration through upstream M&A facilitates the substitution of internal mechanisms for market transaction mechanisms, reducing transaction costs associated with knowledge exchange. Moreover, the aforementioned strategy enables the utilization of coordination advantages within the organization, which promotes knowledge transfer, recombines knowledge components, and ultimately enhances the company's technological innovation capabilities [28,29].

Second, from the perspective of technological M&A in the lithium battery industry, such strategies provide external research and development resources to the company, which enables synergistic innovation effects through the collaboration of external and internal research and development, thereby enhancing R&D efficiency [12,14]. External R&D effectively complements internal R&D. Through technology M&A, companies can introduce cutting-edge technologies from external competitors and products, convert external knowledge into internal knowledge, and transform external technologies into internal technologies, which reduces the internal R&D risks associated with innovation investment and enhances the company's internal R&D capabilities. On the other hand, internal R&D capabilities crucially enhance the efficiency induced by incorporating external R&D. Internal R&D ensures that the acquired technology and knowledge are absorbed internally, which leads to technological innovation, new products, and new technologies. The aforementioned activity enhances the utilization efficiency of technological M&A. Based on the preceding analysis, this study proposes the following hypothesis:

Hypothesis 1. *Lithium battery industry M&A crucially enhance the level of technological innovation of enterprises*.

Although green technological innovation is encompassed within technological innovation, it is distinguished by its focus on addressing environmental issues and achieving specific sustainable development-oriented environmental goals. Green technological innovation encompasses the design of green products and process innovations in enterprises, including aspects related to energy efficiency, pollution prevention, and waste recycling, and it also entails supportive organizational management and innovative implementation. In comparison to technological innovation, green technological innovation often exhibits characteristics such as high investment, long cycles, and significant risks. New energy companies, following M&A, may lack strong intentions for green innovation. Furthermore, the issue of incomplete and inadequate intellectual property protection in China still persists, and green technological innovation exhibits externalities, allowing competitors to utilize green innovation technologies through imitation or other means at no cost. Consequently, new energy companies lack incentives for green innovation after implementing M&A strategies. Therefore, due to the high investment, long cycles, and significant risks associated with green technological innovation, coupled with issues related to incomplete intellectual property protection in China, M&A may not significantly enhance the level of green technological innovation in new energy companies. Based on the preceding analysis, this study proposes the following hypothesis:

Hypothesis 2. *The implementation of acquisition strategies by new energy companies exerts an insignificant impact on green technological innovation.*

The knowledge absorption capacity of new energy companies is an inherent capability for identifying, acquiring, and transforming external innovation resources within the M&A context. While the implementation of acquisition strategies enables access to external innovation resources, these resources cannot be directly translated into technological innovation. Instead, new energy companies should absorb and integrate internal and external knowledge to leverage it for technological innovation [30]. Therefore, the knowledge absorption capacity of new energy companies serves as a crucial moderating mechanism that significantly impacts the relationship between M&A and innovation. The innovation effects of M&A are reliant on the recombination of knowledge components. The stronger the knowledge absorption capacity of new energy companies, the faster they can integrate external innovation knowledge, which results in higher knowledge reconfiguration efficiency. This phenomenon enables more effective utilization of the various innovative resources obtained through M&A, which facilitates the internalization of external technological expertise and strengthens the positive effects of implementing M&A on technological innovation. Thus, companies with a higher knowledge absorption capacity can rapidly assimilate and leverage external heterogeneous technologies, which accelerates the pace of technology transfer and facilitates enterprise innovation. Additionally, from the perspective of green technological innovation in new energy companies, organizations with a stronger absorption capacity tend to exhibit more robust internal mechanisms, which are advantageous in mitigating risks associated with green technological innovation. Furthermore, these companies often embrace more modernized management concepts, which contribute to an increased willingness for green innovation in new energy companies. Based on the aforementioned analysis, this study proposes the following hypothesis:

Hypothesis 3. *The stronger the knowledge absorption capacity of new energy companies, the more beneficial the implementation of acquisition strategies that promote technological innovation and enhance the level of green technological innovation in new energy companies.*

The external nature of technological innovation implies that the strength of intellectual property protection at the regional or national level in which a company operates will significantly impact the willingness and propensity for technological innovation. For new energy companies, the positive impact of the implementation of acquisition strategies on technological innovation is influenced by the level of intellectual property protection in their respective regions or countries. Strengthening intellectual property protection can somewhat restrict imitation by peers or competitors, which mitigates potential risks associated with innovation and increases the value of research and development outcomes. Consequently, the innovation willingness of new energy companies following M&A is enhanced, thereby promoting technological innovation. Additionally, strengthening intellectual property protection can reduce the externalities of green technological innovation, which safeguards it and boosts the willingness for green innovation in new energy companies post-acquisition. Furthermore, intellectual property protection can enhance the market competitiveness of energy companies, bolstering their ability to resist risks associated with green innovation. Post-acquisition, new energy companies are more willing to integrate resources and strengthen green technological innovation, which yields more significant positive effects on green technological innovation in new energy companies. Based on the preceding analysis, this study proposes the following hypothesis:

Hypothesis 4. *Strengthening intellectual property protection will facilitate the implementation of acquisition strategies that promote technological innovation and enhance the level of green innovation in new energy companies.*

The M&A activities of new energy companies can generally be divided into two categories: technology-based mergers and non-technology-based mergers. On the one hand, non-technology-based mergers in the lithium battery industry mainly entail vertical mergers. Vertical mergers refer to the acquisition of companies that are upstream or downstream of the acquiring company, with a direct relationship in regard to production processes or business operations. Vertical mergers can reduce search costs, negotiation costs, and transaction costs pertaining to the merger process, which mitigates opportunistic behavior and resulting breach costs, and ultimately enhances overall performance and achieves monopolistic profits. However, the motivation to implement such mergers rarely stems from the innovative resources of the target company, as they may not transfer suitable technological resources or R&D talents to the acquiring company. On the other hand, new energy companies achieve technological innovation through two modes of technology-based mergers, namely related mergers and unrelated mergers. In the lithium battery industry, related mergers, where the acquiring and target companies belong to the same industry and possess similar technological domains, are more prevalent. Using technology-based mergers, the acquiring company can complement its existing strengths; integrate, refine, and explore the merger resources; advance along the existing technological path; achieve technological breakthroughs; and benefit from the advantages of low information asymmetry, low merger risks, short learning time, high learning efficiency, and strong synergy effects. Moreover, mergers can induce suitable R&D resources and talents to the acquiring company. Talent is the primary driving force and decisive factor for green technological innovation. The entire process pertaining to R&D activities, the application of technological innovation outcomes, and industrialization are heavily reliant on the strong support of high-level human capital. The implementation of technology-based mergers by new energy companies can accumulate human capital for green technological innovation, reduce green innovation risks, and enhance green innovation efficiency. Based on the preceding analysis, this study proposes the following hypothesis:

Hypothesis 5. *Compared with non-technology-based mergers, the implementation of technology-based merger strategies not only enhances technological innovation levels but also improves the level of green innovation in new energy companies.*

3. Research Framework

3.1. Empirical Model Setting

The decision-making process for technological innovation in lithium battery companies is highly complex and influenced by various factors. The double-difference model, which strictly delineates treatment and control groups, utilizes the method of differencing before and after interventions and simultaneously differencing treatment and control groups; thus, the influence of other time-varying factors on technological innovation is effectively eliminated. Under certain conditions, the model enables the estimation pertaining to the net effect of M&A on technological innovation in new energy companies. Moreover, considering the simultaneous impact of inherent firm characteristics and macroeconomic conditions as confounding factors on both M&A and technological innovation decisions in the lithium battery industry, this study incorporates firm-fixed effects, year-fixed effects, and firm-level control variables into the double-difference model represented by Equation (1). By utilizing panel data obtained from the lithium battery industry, the study aims to assess the impact of M&A on technological innovation in lithium battery companies.

$$innovation_{i,t} = \alpha_0 + \alpha_1 merge_{i,t} + \beta X_{i,t} + \mu_i + \eta_t + \varepsilon_{i,t} \quad (1)$$

In Equation (1), $innovation_{i,t}$ represents the technological innovation level of company i in year t; $merge_{i,t}$ represents the M&A behavior of company i in year t, as a dummy variable; α_0 represents the constant term; α_1 represents the estimated coefficient of the key explanatory variable $merge_{i,t}$, and $\varepsilon_{i,t}$ represents the error term. In the empirical analysis, the estimated coefficient α_1 of the key explanatory variable $merge_{i,t}$. represents the main factor. A significant positive α_1 indicates that M&A are beneficial for enhancing the technological innovation level of new energy companies, whereas a negative α_1 indicates the opposite (i.e., M&A are not conducive to enhancing the technological innovation level of new energy companies).

The technological innovation of new energy enterprises is not only influenced by M&A strategies but also by other factors. Failure to control for other confounding factors would result in the correlation between residuals and the key explanatory variable, which leads to biased coefficient estimates.

First, to address this issue, we first consider the enterprise-level characteristics (i.e., the size, operational status, and market value of new energy companies), which simultaneously affect both their M&A decisions and innovation efficiency. By including these characteristics as control variables, herein denoted as $X_{i,t}$, endogeneity issues can be alleviated. Therefore, we further incorporate a series of control variables $X_{i,t}$ in the empirical model, with β representing the estimated coefficients of the control variables.

Second, specific factors related to new energy enterprises (i.e., corporate culture, strategic objectives, management expertise, organizational structure, and resource endowment), which cannot be quantified, may introduce biases into the estimation results. Because obtaining data on these characteristics is not feasible, we assume that they do not change over time, and we control for them by adding firm fixed effects denoted by μ_i in the empirical model.

Finally, the M&A decisions and technological innovation of new energy enterprises are also influenced by factors such as macroeconomic conditions and the COVID-19 pandemic. In the empirical model, we assume that the impact of macroeconomic conditions and the COVID-19 pandemic on new energy enterprises is homogeneous and can be controlled by introducing year-fixed effects denoted by η_i.

Figure 2 represents the research design flowchart.

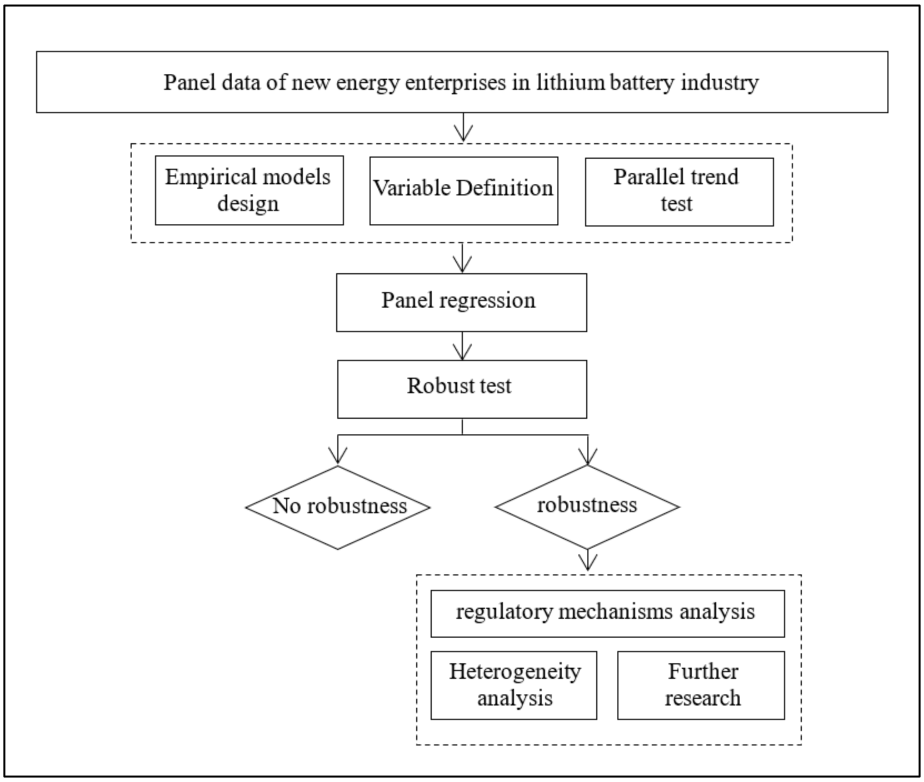

Figure 2. Research Design Flowchart.

3.2. Variable Definition

(1) Sample selection

Considering the specific influence of factors such as the 2008 financial crisis and economic collapse on the development of the new energy industry, this study selects publicly listed companies in the lithium battery industry from 2012 to 2022 as the research subjects: (1) According to the main business field of companies recorded in the CSMAR listed company database, 34 listed companies whose main business covers lithium resources are screened. (2) Based on the stock code fields of 34 lithium resources listed companies, it is matched with the CSMAR M&A database, and after excluding the failed M&A, a total of 257 M&A of 34 lithium-resource listed companies were obtained during the sample observation period. According to the merger and reorganization ID defined by the CSMAR database, the final sample mainly includes three types of M&A events, namely: asset M&A (S3001), absorption mergers (S3004), and equity transfers (S3008). (3) Multiple M&A by listed companies in the same year. Among the 34 lithium resources listed companies, 24 listed companies affected M&A during the sample observation period, and 10 listed companies had never conducted M&A. The data pertaining to M&A, financial indicators, and corporate governance of 34 lithium resources listed companies was obtained from the CSMAR database.

(2) Explained variable

First, enterprise technological innovation includes green technological innovation, which is crucial for the green and low-carbon transformation of lithium battery companies. Therefore, this study selects both technological innovation and green technological innovation as the dependent variables. Second, to accurately measure enterprise technological innovation and green technological innovation, it is necessary to analyze the number of patents held by new energy companies, as well as examine the novelty, value, and significance of these patents to the new energy industry. Because the novelty and value of patents are difficult to measure directly, this study adopts measurement methods utilized by scholars such as Hagedoorn and Cloodt, as well as Issah [31,32]. Patents are recognized as generated knowledge [33] and serve as indicators of successful R&D efforts by companies [34]. Therefore, this study primarily measures technological innovation in the new energy industry from the innovation output perspective. Finally, the number of patents includes both patent applications and patent grants. Considering the longer timeframe for patent grants in China, by selecting the number of patent applications and green patent applications, researchers can examine the impact of M&A on technological innovation in the lithium battery industry in a more timely and effective manner [35,36]. The data on the number of patent applications and green patent applications for the 34 listed lithium resource companies are obtained from the CNRDS database.

(3) Core explanatory variable

During the sample observation period, 10 listed companies had never been subjected to M&A, and 24 listed companies had experienced multiple M&A. The multi-period, double-difference model can be utilized to estimate the relationship between M&A and the technological innovation of Chinese lithium industry enterprises. Utilize 24 listed companies with M&A as the treatment group, and set 10 listed companies without M&A as the control group. Based on the year when the 18 listed companies in the lithium battery industry first implemented M&A during the sample observation period, the merger value is 1 after the year of the first merger, and the merger value is 0 for the subsequent mergers. In addition, because the 18 lithium resource-listed companies with M&A implemented only M&A strategies in certain years, assigning values based on the year of the first M&A may lead to crucial estimation errors. In the robustness test, this study re-measures the core explanatory variables based on whether listed companies in the lithium battery industry implement M&A year by year. If enterprise i implements M&A in year t, the value is set at 1; otherwise, the value is set at 0.

(4) Other variables

This study adds the following control variables to the empirical model to control the impact of enterprises' observable characteristics on technological innovation. (1) Size of listed companies (*size*): the logarithmic value pertaining to the company's total assets; (2) performance of listed companies (*roa*), which is determined by the return on assets; (3) financial leverage of listed companies (*lev*), which is determined by the asset–liability ratio; (4) listed companies' company growth (*growth*), which is determined by the main business income growth rate; (5) and enterprise value (*tobin*), which is expressed as (stock market value + net debt)/total assets.

Additionally, the following variables should be measured in the empirical analysis: (1) Knowledge absorption capacity of lithium battery companies (*absorb*), referring to the measurement methods developed by Cohen and Levintha [13], which utilize the ratio pertaining to the R&D investment and patent applications of listed companies in the lithium industry to measure enterprises' absorptive capacity; this indicator measures the R&D investment consumption of a single patent application, and the smaller the ratio, the stronger the corporate absorptive capacity. (2) Intellectual property rights protection (*IPRP*), which is based on Lv et al.'s measurement of intellectual property rights protection [37], utilizes the quasi-natural experiment pertaining to the Chinese government's establishment of the Intellectual Property Demonstration City policy; after the policy implementation, a dummy variable is assigned a value of 1, whereas, in all other scenarios, the dummy variable is assigned a value of 0. (3) Technology M&A (*technology*) is based on the field "whether it involves intellectual property M&A" in the CSMAR merger and reorganization database; technology is assigned a value of 1, whereas it is assigned a value of 0 in other scenarios. (4) Listed company wastewater discharge (ln*Water*) represents the natural logarithm of wastewater discharge contained in the annual reports of listed companies. (5) Listed company sulfur dioxide emissions ($\ln SO_2$) represent the natural logarithm of sulfur dioxide emissions contained in the annual reports of listed companies. The measurement is based on the wastewater discharge contained in the annual reports of listed companies, and all continuous variables are subject to truncation at the 1st percentile.

The descriptive statistics of all the aforementioned variables are depicted in Table 1. There is a significant disparity in the level of technological innovation among new energy companies. On the one hand, in regard to technological innovation, the mean number of patent applications for listed companies in the lithium battery industry is 33.0025, with a maximum of 1051, a minimum of 0, and a standard deviation of 116.6709. On the other hand, with regard to green technology innovation, the mean number of green patent applications for listed companies in the lithium battery industry is 7.9237, with a maximum of 232, a minimum of 0, and a standard deviation of 30.2514. This observation indicates a significant disparity and high volatility in the technological innovation and green technology innovation within the lithium battery industry among listed companies. Therefore, in the empirical model, this study utilizes the logarithm pertaining to the sum of 1 added to the number of patent applications and green patent applications for listed companies in the lithium battery industry. Moreover, the mean value of the core explanatory variable is 0.2735, which indicates that 27.35% of the listed company samples in the research sample implemented M&A strategies.

Table 1. Descriptive statistics.

Variables	Obs	Mean	Std.dev	Min	Max
patent	315	33.0025	116.6709	0.0000	1051
ln*patent*	315	2.0212	1.5731	0.0000	6.9565
gpatent	315	7.9237	30.2514	0.0000	232
ln*gpatent*	315	0.5425	1.2555	0.0000	5.4467
merge	315	0.2735	0.4464	0.0000	1.0000

Table 1. *Cont.*

Variables	Obs	Mean	Std.dev	Min	Max
size	315	21.6542	1.1425	17.9652	22.9562
roa	315	0.0552	0.0541	0.0072	0.2625
lev	315	3.1475	2.1426	1.5865	13.2695
growth	315	0.3256	0.3526	−0.1028	2.3175
tobin	315	2.2651	1.0213	1.2517	8.4562
absorb	315	15.1617	1.0340	12.1837	18.0357
IPRP	315	0.2875	0.3845	0	1
technology	315	0.2941	0.4561	0	1
ln*Water*	312	3.2445	2.3527	0	9.3984
$\ln SO_2$	308	4.5043	1.9146	0	12.2294

4. Empirical Analysis

4.1. Parallel Trend Test

Before evaluating the impact of lithium battery industry M&A on corporate technological innovation, it is necessary to verify whether the treatment group and the control group satisfy the parallel trend assumption. Based on the year when the listed companies in the lithium battery industry first implemented M&A as the base period, construct dummy variables merge_6, merge_5, merge_4, merge_3, merge_2, and merge_1 to respectively represent 5 years, 4 years, 3 years, 2 years, and 1 year before the implementation of M&A; and construct dummy variables merge1, merge2, merge3, merge4, merge5, and merge6 to represent 1 year, 2 years, 3 years, 4 years, 5 years, and 6 years after the implementation of the merger, respectively. The core explanatory variable merge, contained in Model (1), is replaced by the aforementioned dummy variables, and Figure 3 depicts the results of the parallel trend test. Before the listed companies in the lithium battery industry implement the M&A strategy, the estimated coefficients of the dummy variables are insignificant, which indicates that there is no significant difference in technological innovation between the listed lithium battery-industry companies in the treatment group and those in the control group; thus, the parallel trend assumption is satisfied, and the multi-period difference-in-differences approach can be utilized to assess the impact of M&A on lithium battery listed companies. Meanwhile, after the implementation of the M&A strategy, the estimated coefficient of the dummy variable is significantly positive at the 10% level, which initially indicates that M&A can enhance the technological innovation capabilities of listed lithium battery companies.

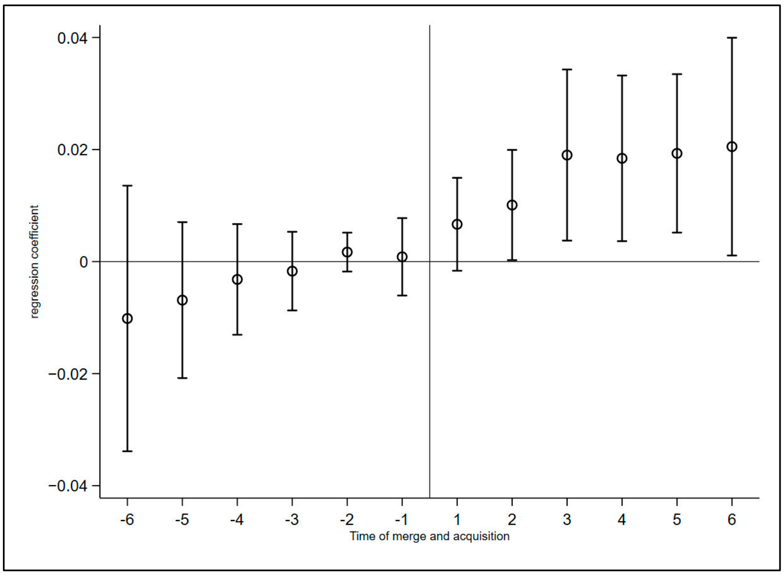

Figure 3. Parallel trend test.

4.2. Basic Regression

The parallel trend test indicates that there is no significant difference in the level of technological innovation between the treatment group and the control group before the implementation of M&A and that the multi-period double difference model (1) can be estimated. Table 2 illustrates the estimation results. All empirical models include firm-fixed effects and year-fixed effects. The dependent variables in columns (1) and (2) are the number of patent applications. Regardless of whether control variables are included or not, the estimated coefficient of the core explanatory variable is approximately 0.015, which is significant at a 5% level or lower, and this value indicates a positive effect. In other words, compared with lithium battery industry-listed companies that have not implemented M&A, those that have implemented M&A in the lithium battery industry exhibit a significant increase of approximately 1.5% in the number of post-merger patent applications. This observation verifies Hypothesis 1. The empirical results indicate that approximately 2% of the patent application quantity in the lithium battery industry can be attributed to the M&A activities of new energy companies. Because M&A in the lithium battery industry significantly enhances the technological innovation level of listed companies, this observation bears significant economic implications. In columns (3) and (4), the dependent variable is the number of green patent applications. The estimated coefficients of the core explanatory variable are positive and significant when control variables are not included; however, they become insignificant after controlling for other factors. This observation indicates that the positive effect of M&A on the green technology innovation capacity of the listed lithium battery-industry is not statistically significant, thereby confirming Hypothesis 2, which may be attributed to the characteristics of green technology innovation (e.g., long cycles, high investment, and high risks). Additionally, the incomplete intellectual property protection system in China and the low willingness of new energy companies to engage in green technology innovation after M&A could contribute to this result.

Table 2. Basic regression.

	(1)	**(2)**	**(3)**	**(4)**
	patent	***patent***	***gpatent***	***gpatent***
merge	0.0152 ***	0.0147 **	0.0043 *	0.0025
	(0.0032)	(0.0073)	(0.0025)	(0.0031)
size		−0.7952 ***		−0.3414
		(0.2552)		(0.2854)
roa		6.6712		1.5754
		(4.3785)		(5.2754)
lev		0.0051		−0.0741
		(0.3758)		(0.2785)
growth		0.0092		−0.3932
		(0.3452)		(0.2946)
tobin		0.3120		0.5886 **
		(0.4125)		(0.2586)
constant	2.6852 ***	19.3586 ***	1.2586 ***	7.6875
	(0.1400)	(5.4856)	(0.1305)	(6.2385)
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	315	315	315	315
R^2	0.7836	0.9458	0.7836	0.9458

*, **, *** Significantly at the 10%, 5%, and 1% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses.

Examining the dynamic impact of M&A conducted by new energy companies on technological innovation is a crucial research focus herein. The examination not only clarifies the sustainability pertaining to the innovation effects of merger strategies but also provides further evidence for Hypotheses 1 and 2. In the empirical analysis, the core explanatory variable is lagged by one period, two periods, three periods, and four periods; thus, Model (1) is re-estimated, and the sustained impact of new energy company M&A on technological innovation is examined. Table 3 illustrates the estimation results with technological innovation as the dependent variable. The results in columns (1), (2), (3), and (4) correspond to the estimation results, with the core explanatory variable lagged by one period, two periods, three periods, and four periods, respectively. It can be observed that the lagged coefficients of the core explanatory variable are significant, at least at a 10% level, which further validates Hypothesis 1. Additionally, based on the magnitudes of the estimated coefficients, the lagged coefficients of the core explanatory variable in periods one to four are greater than the coefficient without lag, which indicates the sustainability pertaining to the impact of new energy company M&A on technological innovation. This observation could be attributed to the initial phase of merger strategies, where the integration of innovative resources is limited and exerts a smaller influence on technological innovation. However, within 2–4 years of implementing merger strategies, the deep integration of acquired innovative resources leads to a greater impact on technological innovation.

Table 3. Dynamic effects analysis: mergers and acquisitions and technological innovation in the new energy sector.

	(1)	**(2)**	**(3)**	**(4)**
	patent	***patent***	***patent***	***patent***
L1.*merge*	0.0163 **			
	(0.0079)			
L2.*merge*		0.0282 ***		
		(0.0053)		
L3.*merge*			0.0268 **	
			(0.0063)	
L4.*merge*				0.0232 *
				(0.0124)
constant	3.3385 ***	4.5861 ***	4.8675 ***	2.1358 ***
	(0.1200)	(0.5286)	(0.8564)	(0.1202)
control variables	Yes	Yes	Yes	Yes
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	280	245	210	172
R^2	0.9485	0.8652	0.7963	0.6852

*, **, *** Significantly at the 10%, 5%, and 1% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses

Table 4 depicts the estimation results with green technological innovation as the dependent variable. The results in columns (1), (2), (3), and (4) correspond to the estimation results, with the core explanatory variable lagged by one period, two periods, three periods, and four periods, respectively. It can be observed that the lagged coefficients of the core explanatory variable are positive but not statistically significant. This observation indicates that the implementation of M&A by new energy companies does not significantly enhance their level of green technological innovation. This observation provides further validates Hypothesis 2, which indicates that the weak willingness of new energy companies to engage in green innovation after M&A is attributable to the large investment, high risks, and long cycles associated with green technological innovation, as well as the need for further improvements in China's intellectual property protection system.

Table 4. Dynamic effects analysis: mergers and acquisitions and green technological innovation in the new energy sector.

	(1)	(2)	(3)	(4)
	ln*gpatent*	ln*gpatent*	ln*gpatent*	ln*gpatent*
L1.*merge*	0.0008 (0.0175)			
L2.*merge*		0.0014 (0.0027)		
L3.*merge*			0.0032 (0.0025)	
L4.*merge*				0.0023 (0.0458)
constant	2.4824 *** (0.1200)	2.7958 *** (0.0789)	2.7652 *** (0.3985)	1.1358 *** (0.1478)
control variables	Yes	Yes	Yes	Yes
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	278	241	205	168
R^2	0.9028	0.8635	0.8482	0.8062

*** Significantly at the 1% level. The robust standard error of heteroscedasticity is reported in parentheses

5. Robustness Test

(1) Time placebo test

In the benchmark regression results, the impact of M&A on the technological innovation level of listed companies in the lithium battery industry is attributable to the enterprise-level intervention occasioned by the pre-merger processing group. To exclude the potentially competitive explanations, this study advances the M&A time of 24 listed lithium battery-industry companies by 3 and 5 years and re-estimates the multi-period double difference model (1) as a placebo test. Table 5 depicts the placebo test pertaining to the estimated results. Items (1) and (2) are listed as the estimated results after the M&A year was advanced by 3 years, and the estimated coefficients of the core explanatory variable merge are insignificant; items (3) and (4) are listed as the estimation results after the M&A year is advanced by 5 years, and the core explanatory variables (i.e., merge i and t estimation coefficients) are still insignificant, which indicates that for the benchmark regression results, the positive impact of M&A on the technological innovation of listed lithium battery-industry companies is not occasioned by intervention at the level of other enterprises but by the net effect of the M&A activities of listed lithium battery companies.

Table 5. Time placebo test.

	(1)	(3)	(2)	(4)
	patent	*gpatent*	*patent*	*gpatent*
merge	−0.0003 (0.0039)	0.0072 (0.0041)	0.0027 (0.0045)	0.0057 (0.0078)
size	0.0035 (0.7543)	0.5468 (0.6583)	0.0004 (0.8054)	0.5719 (0.8759)
roa	9.0135 ** (4.1298)	6.0709 (5.3857)	10.5331 ** (4.1298)	5.0791 (5.4805)
lev	0.4013 ** (0.1688)	0.1119 (0.1845)	0.4134 ** (0.1718)	0.1891 (0.2397)
growth	0.1854 (0.3594)	−0.1352 (0.4009)	0.1994 (0.4695)	−0.0750 (0.3736)
tobin	−0.0167 (0.3225)	0. 5854 (0.3598)	−0.0287 (0.3762)	0.3484 (0.3195)
constant	2.7463 *** (0.1268)	1.2493 *** (0.1338)	0.6850 (18.3011)	−13.3128 (19.6353)
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	248	248	190	190
R^2	0.8384	0.8296	0.9619	0.9258

, * Significantly at the 5%, 1% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses.

(2) Replace the core explanatory variables

In the preceding empirical analysis, this study constructs a dummy variable as the core explanatory variable directly based on the year when the listed company first implemented M&A. However, listed companies in the lithium battery industry did not implement M&A in some years, and the positive effect in the benchmark regression results is attributable to variable measurement bias. To exclude the aforementioned competitive explanations, this study measures the core explanatory variables based on the year-by-year M&A of listed lithium battery-industry companies. If company i implements M&A in year t, a value of 1 is assigned; otherwise, a value of 0 is assigned. The estimated results after replacing the core explanatory variables are depicted in Table 6. The explanatory variables in columns (1) and (2) represent the technological innovations of enterprises, and the estimated coefficient of merge is significantly positive at the >10% level; (3), (4) The explanatory variable contained in column is enterprise green technology innovation, and the estimated coefficient is significantly positive, but not significant; this observation is consistent with the benchmark regression results. To a certain extent, the aforementioned competitive explanations are excluded, which provides a more reliable basis for the establishment of Hypothesis 1.

Table 6. Replace core explanatory variable.

	(1)	**(2)**	**(3)**	**(4)**
	patent	***patent***	***gpatent***	***gpatent***
merge	0.0103 **	0.0133 *	0.0043	0.0011
	(0.3005)	(0.0079)	(0.0861)	(0.0069)
size		−0.8318 ***		−0.2036
		(0.2465)		(0.3128)
roa		8.2436		0.2531
		(5.0346)		(5.3603)
lev		0.0083		−0.1492
		(0.2297)		(0.2378)
growth		0.0435		−0.3078
		(0.3520)		(0.3086)
tobin		0.1381		0.7337 **
		(0.3913)		(0.3282)
constant	2.4610 ***	19.9657 ***	1.0846 ***	4.7037
	(0.0903)	(5.5333)	(0.0904)	(6.8378)
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	153	50	153	50
R^2	0.7750	0.9395	0.7306	0.8967

*, **, *** Significantly at the 10%, 5%, and 1% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses.

(3) Robustness Testing Considering Multiple Confounding Factors

Technological innovation in enterprises is a complex process that can be influenced not only by the characteristics of the companies but also by other factors such as regional environmental regulations, technological innovation trends in different industries upstream and downstream of the new energy sector, and the marketization degree. The observed effect of technological innovation in the benchmark regression results may be influenced by the aforementioned factors. Therefore, this study progressively includes industry × time trends, city × time trends, regional environmental regulatory intensity, and regional marketization level as control variables in the empirical model. The measurement method for regional environmental regulatory intensity follows the approach of Yin [38], with data sourced from the "China Urban Statistical Yearbook," and the marketization level data is directly obtained from the China Marketization Index Database.

Table 7 depicts the estimation results with the aforementioned control variables progressively included. The estimation results in columns (1) and (2) correspond to the dependent variable of technological innovation, where the estimated coefficients of the core explanatory variable are significantly positive at the 10% level. The estimation results in columns (3) and (4) correspond to the dependent variable of green technological innovation, where the estimated coefficients of the core explanatory variable are not statistically significant. This observation is consistent with the benchmark regression results, which indicates that the benchmark regression results are less influenced by regional government environmental regulations, industry-specific technological development trends, and market competition. Thus, the credibility of Hypotheses 1 and 2 is enhanced.

Table 7. Considering Multiple Confounding Factors.

	(1)	(2)	(3)	(4)
	patent	*patent*	*gpatent*	*gpatent*
merge	0.0094 *	0.0098 *	0.0015	0.0009
	(0.0053)	(0.0057)	(0.0861)	(0.0069)
size	−0.7215 **	−0.7045 ***	−0.8569 ***	−0.5621 *
	(0.2854)	(0.1954)	(0.2438)	(0.3088)
roa	7.5284	7.9876	1.5248	1.5482
	(4.9578)	(5.8512)	(5.6875)	(4.5213)
lev	0.0102	0.0095	−0.0085	−0.0109
	(0.3014)	(0.2845)	(0.2356)	(0.2486)
growth	0.0435	0.0435	−0.0435	−0.3078
	(0.3520)	(0.3520)	(0.3520)	(0.3086)
tobin	0.1586	0.1435	0.8456 *	0.7337 **
	(0.4258)	(0.4019)	(0.3256)	(0.3786)
constant	2.1258 ***	2.1023 ***	4.0825	4.7037
	(0.0903)	(0.9658)	(5.8623)	(6.8378)
industry × time trends	Yes	Yes	Yes	Yes
city × time trends	Yes	Yes	Yes	Yes
environmental regulatory intensity	No	Yes	No	Yes
marketization level	No	Yes	No	Yes
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	312	310	312	310
R^2	0.8745	0.8564	0.8912	0.8643

*, **, *** Significantly at the 10%, 5%, and 1% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses.

6. Moderating Mechanism Analysis

(1) Absorptive capacity of new energy companies

The strength of knowledge absorption capability in new energy companies directly impacts the synergy of internal and external innovative resources and the rate at which knowledge costs are recombined. Additionally, stronger knowledge absorption capabilities lead to more sophisticated internal organizational structures, higher risk resilience, and greater willingness and enthusiasm for green innovation. Therefore, stronger knowledge absorption capabilities in new energy companies facilitate technological innovation and contribute to the enhancement of green technological innovation levels through the implementation of M&A. To further validate the moderating role of knowledge absorption capability in listed lithium battery-industry companies, this study constructs an interaction model as illustrated in Equation (2).

$$innovation_{i,t} = \alpha_0 + \alpha_1 merge_{i,t} \times absorb_{i,t} + \alpha_2 merge_{i,t} + \beta X_{i,t} + \mu_i + \eta_{p,t} + \varepsilon_{i,t} \quad (2)$$

The larger the value of variable $absorb_{i,t}$, the weaker the absorption capability of the enterprise. The estimated coefficient α_1 of the expected interaction term is significantly negative. As the absorption capability of listed companies decreases, the positive effect of M&A on technological innovation gradually weakens. In other words, enhancing the absorption capability of listed companies will lead to a stronger stimulating effect of M&A on technological innovation and green technological innovation. The estimation results of the interaction model are depicted in Table 8, where columns (1) and (2) correspond to the dependent variables of technological innovation and green technological innovation, respectively. The heteroscedasticity-robust standard errors are reported in parentheses. The estimated coefficients of the interaction terms are −0.0063 and −0.0046, and they are both significant at the 10% level, which indicates a negative effect. Additionally, in columns (3) and (4), the estimation results cluster the standard errors at the industry level, which increases their magnitude. The coefficients remain significantly negative at the 11% level, consistent with the expected results. These empirical results demonstrate that, in the context of M&A, enhancing the knowledge absorption capability of new energy companies can simultaneously enhance the levels of technological innovation and green technological innovation, which validates Hypothesis 3.

Table 8. Analysis of moderating mechanisms: absorptive capacity.

	(1)	**(2)**	**(3)**	**(4)**
	patent	***gpatent***	***patent***	***gpatent***
Merge × *absorb*	−0.0063 ***	−0.0046 *	−0.0063 **	−0.0046
	(0.0018)	(0.0021)	(0.0021)	(0.0027)
merge	1.1369	−1.7424	1.1369	−1.7424
	(2.1619)	(6.6443)	(1.2714)	(5.0204)
absorb	−0.4508 *	−1.2425 **	−0.4508 ***	−1.2425 **
	(0.1932)	(0.4142)	(0.0824)	(0.3589)
size	−1.4007 **	0.6025	−1.4007 **	0.6025
	(0.5039)	(1.3077)	(0.3838)	(0.9349)
roa	−0.2253	−14.7900	−0.2253	−14.7900 *
	(4.0680)	(8.6456)	(2.8608)	(6.1018)
lev	0.5268 ***	0.0227	0.5268 ***	0.0227
	(0.1298)	(0.2591)	(0.1132)	(0.2019)
growth	−0.4861 *	−0.5946	−0.4861	−0.5946 *
	(0.2298)	(0.5293)	(0.2499)	(0.2912)
tobin	−0.3005	0.1758	−0.3005	0.1758
	(0.2583)	(0.4401)	(0.3328)	(0.1651)
constant	40.8669 ***	7.4343	40.8669 ***	7.4343
	(9.8690)	(27.6524)	(9.0488)	(17.6252)
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	315	315	315	315
R^2	0.9731	0.9193	0.9731	0.9193

*, **, *** Significantly at the 10%, 5%, and 1% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses in columns (1) and (2), and the standard error of clustering residuals to the enterprise level is reported in parentheses in columns (3) and (4).

(2) The level of intellectual property protection

The level of intellectual property protection is a critical factor that affects the innovation willingness of listed lithium battery-industry companies. The lack of intellectual property protection can significantly restrain green technological innovation in new energy enterprises. By strengthening the level of intellectual property protection, new energy companies are more likely to actively integrate the knowledge and technologies related to production and environmental protection from both the acquiring and acquired parties after implementing M&A strategies. This strategy will simultaneously enhance the levels of general technological innovation and green technological innovation. To further validate the moderating effect of intellectual property protection on green technological innovation in new energy companies, this study constructs an interaction model represented by Equation (3).

$$innovation_{i,t} = \alpha_0 + \alpha_1 merge_{i,t} \times IPRP_{i,t} + \alpha_2 merge_{i,t} + \beta X_{i,t} + \mu_i + \eta_{p,t} + \varepsilon_{i,t} \quad (3)$$

$IPRP_{i,t}$ represents the level of intellectual property protection in the city where the new energy company is located. Considering Lv et al.'s measurement of intellectual property protection at the city level in China [37], and based on the Chinese government's pilot policy (i.e., to establish intellectual property demonstration cities), this study measures the intellectual property protection environment faced by enterprises. The larger the value of variable $IPRP_{i,t}$, the stronger the intellectual property protection; therefore, this study expects the estimated coefficient α_1 of the interaction term to be significantly positive. In other words, the stronger the intellectual property protection, the stronger the positive effect of implementing M&A strategies on technological innovation in new energy companies.

The estimation results of the interaction model are illustrated in Table 9, with the heteroscedasticity-robust standard errors reported in columns (1) and (2). Regardless of whether the dependent variable is a technological innovation or green technological innovation, the estimated coefficients of the interaction term are significantly positive at the 5% level, which is consistent with the expected result. Additionally, in columns (3) and (4), the estimation results cluster the standard errors at the industry level, which increases their magnitude and exhibits significant positive effects at the 10% level. This observation indicates that intellectual property protection is a crucial moderating variable. As the intellectual property protection environment improves for listed companies in the new energy industry, M&A can simultaneously promote the levels of technological innovation and green technological innovation. Thus, Hypothesis 3 is validated.

Table 9. Analysis of moderating mechanisms: intellectual property protection.

	(1)	(2)	(3)	(4)
	ln*patent*	ln*gpatent*	ln*patent*	ln*gpatent*
merge × *IPRP*	0.0021 **	0.0015 **	0.0021 *	0.0015 *
	(0.0009)	(0.0007)	(0.0011)	(0.0009)
merge	1.0018	−1.0025	1.0018	−1.0025
	(1.5269)	(5.5678)	(2.0031)	(5.8478)
IPRP	−0.3807 **	−1.3842 ***	−0.3807 **	−1.3842 **
	(0.1892)	(0.4052)	(0.1658)	(0.5379)
size	−1.3584 **	0.6025	−1.3584 ***	0.6025
	(0.6235)	(1.5368)	(0.4528)	(0.8658)
roa	−0.3658	−12.35	−0.3658	−12.35
	(3.5869)	(8.6847)	(2.3896)	(7.3585)
lev	0.6258 ***	0.0385	0.6258 ***	0.0385
	(0.1486)	(0.2756)	(0.1052)	(0.3052)
growth	−0.3754 *	−0.5012	−0.3754	−0.5012
	(0.2186)	(0.5463)	(0.4685)	(0.2146)
tobin	−0.2975	0.1518	−0.2975	0.1518
	(0.2485)	(0.1845)	(0.3328)	(0.1651)
constant	41.8465 ***	7.2468	41.8465 ***	7.2468
	(9.3257)	(28.5645)	(9.2578)	(18.2565)
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	315	315	315	315
R^2	0.9731	0.9193	0.9731	0.9193

*, **, *** Significantly at the 10%, 5%, and 1% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses.

7. Heterogeneity Analysis

When listed companies in the lithium battery industry implement M&A strategies, they can opt for either technical mergers or non-technical M&A. Non-technical M&A mainly extend upstream through vertical M&A to ensure the supply of raw materials and reduce costs. To analyze the impact of M&A in the lithium battery industry on technological innovation, it is necessary to further elaborate on which type of M&A crucially facilitates the improvement of technological innovation levels of enterprises. Herein, based on whether the M&A activities of listed companies in the lithium battery industry entailed intellectual property M&A during the sample observation period, the 34 listed companies were divided into technology M&A sample groups and other M&A sample groups and re-estimated using the empirical model (1) in the sub-sample, and the results are depicted in Table 10. Items (1) and (2) represent the estimated results pertaining to the technology

M&A sub-sample. The explained variables are enterprise technology innovation and green technology innovation. The estimated coefficients of the core explanatory variable merge are 0.0258 and 0.0079, at least at the 10% level. The lower value is significant, which indicates that technology M&A has significantly enhanced the technological innovation capabilities of listed lithium battery-industry companies. Columns (3) and (4) are the estimated results of the non-technical M&A sample group, and the explained variables are corporate technology innovation and green technology innovation. Compared with the estimated results in columns (1) and (2), the core explanatory variables, the estimated coefficient of a merge is smaller, and the statistical significance is significantly reduced, which indicates that technology M&A are the main driving factor for the technological enhancement of listed companies in the lithium battery industry.

Table 10. Heterogeneity analysis.

	Technology M&A		**Nontechnology M&A**	
	(1) ***patent***	**(2)** ***gpatent***	**(3)** ***patent***	**(4)** ***gpatent***
merge	0.0258 **	0.0079 *	0.0068 *	−0.0005
	(0.0131)	(0.0046)	(0.0041)	(0.0082)
size	−1.7238	−4.4416	−0.7275	2.8596 *
	(0.7353)	(1.7373)	(1.2240)	(0.3808)
roa	12.0920	33.8063	−1.0144	−82.4669 **
	(6.8175)	(25.2271)	(17.1219)	(5.5301)
lev	0.5249	0.3896	0.2228	−0.7422
	(0.5497)	(1.2125)	(0.9017)	(0.2658)
growth	−0.4846	−1.7177	−0.3046	−3.2207
	(0.5378)	(2.6111)	(1.1739)	(0.5724)
tobin	−0.4005	−0.3804	0.7765	1.2259
	(0.6039)	(1.1031)	(1.4441)	(0.2418)
constant	37.4242	103.8420	13.3891	−57.9323 *
	(14.6908)	(39.5838)	(24.5550)	(8.6773)
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	95	95	168	168
R^2	0.9209	0.9982	0.6700	0.9999

*, ** Significantly at the 10%, 5% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses.

8. Further Research

For new companies, the implementation of M&A strategies can enhance technological innovation levels and promote green technological innovation under certain conditions. However, the improvement in technological innovation levels following the implementation of M&A strategies may yield unexpected implications for environmental governance. On the one hand, the enhancement of technological innovation levels can enhance production efficiency and energy efficiency in new energy enterprises, reduce fossil fuel consumption, and decrease emissions of pollutants such as carbon dioxide and sulfur dioxide, thereby generating positive effects on environmental governance. On the other hand, the improvement in energy efficiency can potentially stimulate increased energy consumption by lithium battery companies, which leads to rebound effects in energy usage. Green technological innovation mainly entails pollution control and prevention technologies, source reduction technologies, waste minimization technologies, recycling and regeneration technologies, ecological processes, green products, and purification technologies, which can reduce the emission of pollutants during the product manufacturing process. Based on the preceding analysis, this study proposes that the enhancement of technological innovation levels following the implementation of M&A strategies by new energy companies may not necessarily be beneficial for environmental governance. However, the improvement in green technological innovation levels occasioned by M&A can contribute to environmental governance.

$$pollution_{i,t} = \alpha_0 + \alpha_1 merge_{i,t} \times \ln patent_{i,t} + \alpha_2 patent_{i,t} + \alpha_3 merge_{i,t} + \beta X_{i,t} + \mu_i + \eta_{p,t} + \varepsilon_{i,t} \quad (4)$$

$$pollution_{i,t} = \alpha_0 + \alpha_1 merge_{i,t} \times \ln gpatent_{i,t} + \alpha_2 patent_{i,t} + \alpha_3 merge_{i,t} + \beta X_{i,t} + \mu_i + \eta_{p,t} + \varepsilon_{i,t} \quad (5)$$

This study constructs the interaction models represented by Equations (4) and (5) to validate the preceding analysis. In these models, $pollution_{i,t}$ represents the pollutant emissions of new energy companies, and it primarily includes sulfur dioxide and industrial wastewater emissions. The data are obtained from environmental pollutant emission disclosures contained in the annual reports of listed companies. $merge_{i,t} \times \ln patent_{i,t}$ and $merge_{i,t} \times \ln gpatent_{i,t}$ represent the interaction terms between M&A and technological innovation, as well as green technological innovation, respectively. The definitions of other variables remain constant. In the empirical analysis, the study primarily considers the estimated coefficients of the interaction terms $merge_{i,t} \times \ln patent_{i,t}$ and $merge_{i,t} \times \ln gpatent_{i,t}$. A negative coefficient indicates that the technological innovation effects resulting from M&A are beneficial for environmental governance. Conversely, a positive coefficient indicates that the technological innovation effects resulting from M&A are detrimental to environmental governance.

The estimation results of Model (4) are presented in columns (1) and (2) of Table 11. The estimated coefficients of the interaction terms are negative; however, they are not statistically significant. This lack of significance may be occasioned by the offsetting effects pertaining to the inhibitory effect of technological innovation and the rebound effect of energy consumption, which leads to insignificant estimation coefficients for the interaction terms.

Table 11. Further Research.

	(1)	(2)	(3)	(4)
	ln*Water*	**ln*SO*$_2$**	**ln*Water***	**ln*SO*$_2$**
merge × ln*patent*	−0.0021	−0.0015		
	(0.0019)	(0.0013)		
ln*patent*	0.0038 *	0.0059 **		
	(0.0021)	(0.0029)		
merge × ln*gpatent*			−0.0042 *	−0.0053 *
			(0.0025)	(0.0031)
ln*gpatent*			−0.0102 **	−0.0208 *
			(0.0047)	(0.0114)
merge	−1.0033	−1.0048	1.0439	1.0315
	(1.3568)	(2.8564)	(1.5746)	(2.0875)
size	−0.9487	−0.8456 *	−0.9875 **	−0.8754 *
	(0.6235)	(0.4382)	(0.4528)	(0.5234)
roa	−0.4256	−0.8546	−0.3546	−0.9784
	(0.9874)	(0.7452)	(0.3896)	(0.8645)
lev	0.5214 ***	0.4851	0.3257 ***	0.2586
	(0.1265)	(0.2012)	(0.1052)	(0.3052)
growth	−0.3856 *	−0.4965	−0.2851	−0.3019
	(0.2242)	(0.4862)	(0.2019)	(0.2859)
tobin	0.2835	0.1247	0.2975	0.1518
	(0.2485)	(0.1845)	(0.3328)	(0.1651)
constant	1.5216 ***	2.6528 ***	1.8745 ***	2.7451 ***
	(0.2145)	(0.1936)	(0.4026)	(0.2049)
corporate fix effect	Yes	Yes	Yes	Yes
year fix effect	Yes	Yes	Yes	Yes
N	301	305	298	300
R^2	0.3546	0.2814	0.3546	0.2814

*, **, *** Significantly at the 10%, 5%, and 1% levels, respectively. The robust standard error of heteroscedasticity is reported in parentheses.

The estimation results of the empirical model (5) are depicted in columns (3) and (4) of Table 10. The estimated coefficients of the interaction terms are −0.0042 and −0.0053, and they are significant at the 10% level. This observation indicates that the enhancement of green technological innovation levels following M&A can reduce pollutant emissions, which is consistent with the expected results.

9. Conclusions and Suggestions

Based on the background of promoting the high-quality development of the new energy industry, particularly the lithium battery industry, to achieve the "carbon peaking" goal, this study focuses on publicly listed companies in the Chinese lithium battery industry from 2012 to 2022. Using a multiple-period difference-in-differences approach, the study empirically examines the impact of M&A on technological innovation in lithium battery companies. The research findings indicate that the implementation of M&A strategies by new energy companies can enhance their technological innovation levels. However, M&A do not significantly improve the levels of green technological innovation in the listed lithium battery companies. These conclusions are robust against tests such as parallel trend tests, placebo tests, and core explanatory variable substitution tests.

Furthermore, the analysis of regulatory mechanisms reveals the following: after implementing M&A strategies, strengthening the absorptive capacity of knowledge and technology, as well as enhancing intellectual property protection, is more conducive to the improvement of technological innovation levels. Moreover, this strategy can stimulate new energy companies to actively engage in environmentally friendly green technological innovation. Using a heterogeneity analysis, it is revealed that technological M&A can simultaneously enhance both technological innovation and green technological innovation levels. Non-technological M&A, such as vertical mergers, do not significantly influence technological innovation in companies. Therefore, technological M&A are the main driving factors for enhancing technological innovation capabilities in the lithium battery industry.

Additionally, further studies reveal heterogeneity in the environmental effects of technological innovation occasioned by new energy company M&A. By implementing M&A strategies, which entails promoting green technological innovation, industrial wastewater and sulfur dioxide emissions can be effectively reduced. Therefore, this research bears clear policy implications:

(1) Lithium battery companies should develop comprehensive M&A strategies based on their own resource endowments. M&A should be perceived as a crucial lever for enhancing technological innovation capabilities. Adequate resource integration should be performed after M&A. In regard to the increasingly intense external competitive environment, lithium battery companies should not rely solely on closed innovation. They should exhaustively leverage their resource advantages and assess the technical knowledge and mineral resources of target companies. By conducting M&A, they can obtain open innovation resources and achieve high-quality development through the combination of internal and external efforts.

Furthermore, effective integration should be conducted for target companies after implementing the M&A strategy. This includes integrating knowledge, technology, personnel, and culture. Communication and collaboration between the R&D departments of both parties should be strengthened, and investment in research and development and in the training of R&D personnel should be increased. The joint research and development mode and the intensity of R&D investment will impact the re-innovative capability pertaining to new knowledge and technology. Companies should comprehensively utilize the R&D capabilities of the acquired party and implement proactive measures to integrate their research institutions and personnel. Internal research and development investment should be prioritized to retain key technical talent; thus, the enhancement of the company's ability in technology transfer and application is enabled. Cultural exchange between companies should be strengthened, and personnel integration should be achieved through training programs and fair reward mechanisms, ensuring that resource integration promotes technological innovation levels in new energy companies.

(2) To stimulate the green technological innovation effect occasioned by the implementation of M&A by new energy companies and to effectively reduce pollutant emissions, measures pertaining to the formulation and implementation of M&A strategies should be implemented, and the following two aspects should be considered:

First, in the process of implementing M&A strategies, new energy companies should focus on their research and development capabilities and technological reserves. This involves cultivating core technical talents, solidifying knowledge foundations, and enhancing knowledge absorption capabilities, which lay a crucial foundation for promoting green technological innovation through resource integration. Based on the M&A context, companies should also enhance their research and development capabilities, particularly in regard to their development and research abilities. Companies should focus on developing the development capabilities of the entire team, which requires prioritizing activities such as concept generation, design, research and development, and testing; thus, the creation of new products and the formation of new processes can be facilitated. A strong research and development capability enables companies to conserve internal resources and mitigate operational risks, and a rich technological reserve enhances the company's knowledge repository, which creates favorable conditions for M&A in the new energy sector. It also reduces the likelihood of post-merger technology integration and transformation failures, which provides a robust foundation for the innovation activities of new energy companies. Therefore, new energy companies should not only actively acquire external resources but also internally prioritize the cultivation of their research and development capabilities and the accumulation of technological resources by increasing research and development investment and expanding the breadth and depth of their knowledge base. Simultaneously, new energy companies should engage in planned and purposeful investigations and experimental activities; thus, they can acquire new knowledge, enhance absorption capabilities, and strengthen their innovation capabilities.

Second, when formulating merger and integration plans, new energy companies should prioritize the implementation of technology-focused M&A strategies. Through technology-driven M&A, new energy companies can quickly acquire assets such as target companies' technological resources and research and development teams, which can supplement, update, and expand the company's knowledge base; shorten the research and development process; overcome technological limitations; and enhance both technological innovation and green technological innovation levels. Therefore, for publicly listed companies in the lithium battery industry, M&A activities should not only focus on vertical integration with upstream suppliers to secure the supply of raw materials but also strongly emphasize M&A related to new materials and new technologies. In the long run, the innovation synergies achieved through technology-driven M&A are key to maintaining a company's market competitiveness. Lithium battery companies should closely monitor the latest technological trends within the industry and pursue collaborative innovation through technology-driven M&A.

(3) After implementing M&A strategies, the elevation of green technological innovation levels in new energy companies is more conducive to reducing pollutant emissions. To stimulate the green technological innovation effects of M&A, government departments should strengthen the protection of intellectual property rights and raise awareness through which new energy companies can defend their rights. The development of a new technology or patent requires substantial investment in research and development, and the process of technology commercialization often exhibits a long time span, which subjects it to various challenges and dilemmas. If new energy companies do not possess a robust mechanism for protecting intellectual property rights to support their research and development achievements, it not only diminishes their enthusiasm for innovation but also increases the risk of core technology leakage and escalates the cost of social rights protection. Frequent disputes over intellectual property rights can disrupt the economic market order. Therefore, on the one hand, the government should implement actions to protect intellectual property rights, intensify efforts to combat infringement and increase penalties for infringers. On the other hand, they should enhance society's overall awareness of intellectual property protection, expand and deepen educational campaigns, and stimulate the enthusiasm of the entire new energy industry for technological innovation and the development of green technologies.

This study exhibits certain limitations. The technological innovation level and green technological innovation level of new energy companies mainly encompass aspects such as novelty, value, and technicality. Merely utilizing the number of technological innovations and green technological innovations effected by companies to represent the innovation level does not facilitate a deeper investigation into the heterogeneous impact of M&A on the technological innovation levels of new energy companies. Additionally, due to the lack of data on M&A scale variables in the lithium battery industry, the "inverted U" relationship between M&A scale and technological innovation was not discussed herein, and further research is required in this research field. Furthermore, the decision-making process for technological innovation in new energy companies is highly complex, and it is influenced by various factors, including the government, the market, and the companies. This study mainly utilized fixed effects, the difference-in-differences models, and control variables to reveal the causal relationship between M&A and technological innovation, which provides credible empirical evidence. However, if natural experiments or instrumental variables, which exhibit critical utility for M&A, could be discovered, an empirical analysis could yield more reliable conclusions.

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