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The Impact of Scientific and Technological Information Resource Utilization on Breakthrough Innovation in Enterprises: The Moderating Role of Strategic Aggressiveness

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Abstract: This study aims to explore the relationship between the utilization of scientific and technological information resources and breakthrough innovation in enterprises, examining the moderating role of strategic aggressiveness in this relationship. Based on an investigation of 438,228 patent data from 2616 Chinese enterprises, we construct a theoretical framework of "strategy–capability–performance" and conduct an empirical study using a mixed-effects model. The results indicate that both the intensity and imbalance of scientific and technological information resource utilization have significant positive effects on breakthrough innovation in enterprises. Further analysis reveals that strategic aggressiveness plays a moderating role in the relationship between the utilization of scientific and technological information resources and breakthrough innovation. Additionally, heterogeneity analysis shows differences in the impact of scientific and technological information resource utilization on breakthrough innovation across different regions and ownership types. Specifically, the imbalance of scientific and technological information resource utilization in coastal areas has a greater impact on breakthrough innovation than in non-coastal areas, and the intensity of scientific and technological information resource utilization in state-owned enterprises has a greater impact on breakthrough innovation than in non-state-owned enterprises. The findings of this study provide important insights for enterprise innovation management, helping enterprises to more effectively utilize scientific and technological information resources to drive breakthrough innovation and promote sustainable and healthy development.

Keywords: scientific and technological information resources; breakthrough innovation; strategic aggressiveness; disruptive innovation

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1. Introduction

Breakthrough innovation has become a crucial engine driving the sustainable development of enterprises. Not only can breakthrough innovation help enterprises maintain a competitive edge in a fiercely competitive market, but it can also disrupt traditional industry models and explore new market spaces [1]. Therefore, understanding and promoting breakthrough innovation in enterprises is vital for their development. According to resource dependence theory, enterprises are influenced by their external environment in acquiring and utilizing key resources, and they undertake strategic actions to reduce dependency on these critical resources. Scientific and technological information resources are crucial for enterprise innovation. Scientific and technological information resources refer to the carriers of scientific and technological activities or knowledge [2–4]. These resources encompass a wide range of technical knowledge and industry trends, including but not limited to books, scientific papers, patents, technical reports, and standard documents (national standards, industry standards) [5,6]. Therefore, scientific and technological information resources provide opportunities for enterprises to access advanced technologies and broaden their innovation horizons. The effective utilization of internal and external scientific and technological information resources is of significant value for the technological research and development and innovative growth of enterprises [7,8]. The Chinese government has repeatedly emphasized the need to enhance the openness of national scientific and technological information resources to enterprises, enabling them to integrate and optimize these resources to break through more disruptive and frontier technologies. Although previous studies have found that scientific and technological information resources significantly impact patent innovation performance [9,10] and patent quality [11,12], how the effective utilization of these resources influences breakthrough innovation in enterprises remains unclear. Breakthrough innovation in enterprises often transcends traditional boundaries and paradigms, representing a disruptive and leapfrogging form of innovation with an influence and challenge far beyond conventional innovation. Therefore, understanding how the utilization of scientific and technological information resources affects breakthrough innovation in enterprises is crucial for exploring the mechanisms and pathways of enterprise innovation development.

Moreover, the impact of effective utilization of scientific and technological information resources on breakthrough innovation in enterprises may be influenced by the strategic aggressiveness of enterprises. Strategic aggressiveness is one of the key driving factors of an enterprise's innovation capability [13]. According to strategic choice theory, an enterprise's strategic choices influence its resource allocation and innovation activities [14]. To achieve breakthrough innovation in the market, enterprises need to acquire and effectively utilize various scientific and technological information resources in a timely manner. Enterprises with high strategic aggressiveness demonstrate greater proactivity and adaptability in acquiring and utilizing scientific and technological information resources, thereby more effectively promoting breakthrough innovation [15]. Therefore, in-depth research on how strategic aggressiveness affects the impact of effective utilization of scientific and technological information resources on breakthrough innovation in enterprises can help identify new pathways and mechanisms for enterprise innovation development, promoting the sustainable and healthy development of enterprises. Based on this, the key questions this study aims to address are:

(1) How can Chinese enterprises effectively utilize scientific and technological information resources to enhance breakthrough innovation performance?
(2) How does strategic aggressiveness moderate the relationship between the utilization of scientific and technological information resources and breakthrough innovation in enterprises?

The main contributions of this study are: (1) Systematically exploring the impact of the intensity and imbalance of scientific and technological information resource utilization on breakthrough innovation in enterprises, enriching the existing literature on the theoretical discussion of the relationship between scientific and technological information resource utilization and breakthrough innovation in enterprises. Specifically, this study provides an in-depth exploration of how strategic aggressiveness moderates the relationship between the utilization of scientific and technological information resources and breakthrough innovation, offering new perspectives and theoretical support for understanding the mechanisms of enterprise innovation development. (2) Through empirical analysis, this study verifies that the intensity and imbalance of scientific and technological information resource utilization have significant positive effects on breakthrough innovation. Additionally, the study finds that strategic aggressiveness plays an important moderating role in this relationship. These empirical results not only enrich the empirical research in the field of enterprise innovation management but also provide practical guidance for enterprise managers, helping them more effectively utilize scientific and technological information resources to promote breakthrough innovation. (3) The results of this study have important implications for enterprise innovation management practices. Enterprises should focus on enhancing their capability to integrate and utilize scientific and technological information resources to promote the occurrence of breakthrough innovation. When formulating strategies, enterprises should consider the moderating effect of strategic aggressiveness on the relationship between the utilization of scientific and technological information resources and breakthrough innovation to achieve more effective innovation management and strategic planning. Enterprises in different regions and with different ownership structures should flexibly adjust their strategies for utilizing scientific and technological information resources to adapt to the local resource environment and market demand, thereby enhancing their capability and level of breakthrough innovation.

2. Literature Review

2.1. Research on Scientific and Technological Information Resources

Scientific and technological information resources play a crucial role in today's society. Their value is not only reflected in promoting scientific and technological innovation and development but also in fostering economic growth and enhancing enterprise competitiveness [16]. Despite being one of the core elements of technological resources, scientific and technological information resources have not received sufficient attention. In addition to the factors extensively discussed in existing research, such as technological manpower resources, technological financial resources, technological material resources, and technological market resources [9,17,18], technological manpower resources refer to personnel directly engaged in scientific and technological activities or providing direct services for such activities. Technological financial resources pertain to funds allocated for research and development activities, sourced primarily from government allocations and enterprise self-financing. Technological material resources encompass various research instruments, equipment, and pilot plants necessary for scientific and technological activities. Technological market resources mainly include markets for scientific talents, scientific finance, and technological materials. In contrast, scientific and technological information resources primarily consist of books, scientific papers, patents, technical reports, and standard documents (national and industry standards) [19,20], focusing more on information acquisition, dissemination, and application [21]. These resources cover a wide range of disciplines and technical fields, forming the basis of scientific research and technological innovation. With the continuous advancement of the "Digital China" initiative, the importance of scientific and technological information resources is increasingly recognized by all sectors of society. Moreover, these resources have become the core of digital intelligence development.

In the innovation process of enterprises, the foundational resources such as human, financial, and market resources have received extensive attention and discussion. However, the utilization and role of scientific and technological information resources by enterprises have not been sufficiently emphasized and understood. In the digital era, the importance of these resources is highlighted by the fact that the transmission speed of scientific and technological information far exceeds that of technological entities [22,23]. By timely acquiring and application of scientific and technological information resources, enterprises can enhance their capabilities in technology research and development, product innovation, adapt more flexibly to market changes [24], and improve the efficiency of scientific and technological achievements transformation [25,26], thereby achieving sustainable development.

Existing research on scientific and technological information resources mainly focuses on two aspects. On one hand, it involves the development and platform construction of the resources themselves [27–30]. For example, Ezinwa Nwagwu (2007) discussed the significance of local scientific and technological information databases in the development and sustainability of indigenous knowledge in Africa [27]. Lypak et al. (2018) explored the possibility of constructing a social memory and media institution-integrated information resource platform using cloud services, taking Zboriv city as an example [28]. Mikhaylova et al. (2019) used scientific and technological information resources to comparatively assess the scientific and technological potential of Russia (Northwest Federal District) and the Baltic region EU countries, revealing new patterns of innovation development [31]. On the other hand, it concerns the impact of these resources on social and economic development [32–34]. Jonscher (1983) analyzed the role of scientific and technological information resources on U.S. economic development, particularly in determining productivity levels, revealing the information sector labor force's past growth, productivity trends, and their impact on future economic performance [32]. Zhao and Zhang (2011) studied the information resource allocation mechanism in an industry–university–research collaboration based on a system dynamics model and proposed an optimization scheme for information resource allocation to improve input–output efficiency in R&D cooperation [33]. Sutrisno (2023) systematically reviewed the impact of information technology on enterprise innovation performance [35].

While past studies have extensively explored the role of scientific and technological information resources in promoting technological progress and economic growth, their specific impact on radical innovation in enterprises remains insufficiently elucidated. Enterprises engaging in radical innovation must navigate highly competitive markets and rapidly evolving technological environments. The timely acquisition and application of scientific and technological information resources provides crucial technological insights and market trend analyses, enabling enterprises to more accurately seize innovation opportunities. Unlike traditional resources, scientific and technological information resources are characterized by their higher speed of information acquisition and update frequency, facilitating rapid dissemination of cutting-edge technological advancements and changes in market demands. Consequently, these resources not only enhance a company's technological research and development capabilities but also improve its flexibility and responsiveness in competitive markets. Future research should delve deeper into the specific mechanisms through which scientific and technological information resources promote radical innovation in different industries and across various scales of enterprises. Additionally, exploring how optimizing the acquisition and management of these resources can further enhance a company's innovation competitiveness in the global market is essential.

2.2. Research on Breakthrough Innovation

Enterprise breakthrough innovation refers to the innovation form whereby enterprises introduce entirely new products, technologies, services, or business models that disrupt traditional industry patterns and achieve market leadership [36]. Compared to incremental innovation, breakthrough innovation is more disruptive and revolutionary, capable of fundamentally altering industry patterns and creating new business value. Existing research shows that enterprise breakthrough innovation has several notable characteristics: (1) High risk and high reward: Breakthrough innovation is often accompanied by high risks, but successful implementation usually leads to substantial rewards and market share growth [37]. (2) Leapfrog progress: Breakthrough innovation is not just an improvement of existing products or technologies but a disruptive change that brings leapfrog progress to the entire industry pattern [38]. (3) Multi-faceted impact: Breakthrough innovation affects not only the enterprise itself but also the entire industry ecosystem and related stakeholders [39].

Factors influencing breakthrough innovation in enterprises mainly include: (1) Technological factors: The emergence and application of new technologies are important drivers of breakthrough innovation in enterprises, such as artificial intelligence, the Internet of Things, blockchain, etc. [40]. (2) Market factors: Changes in market demand and the emergence of new markets provide opportunities for enterprise breakthrough innovation, and understanding market trends is crucial for innovation direction [41]. (3) Organizational factors: An enterprise's organizational culture, innovation mechanisms, and team capabilities play key roles in the implementation of breakthrough innovation [41,42]. Organizations with innovative consciousness and flexibility are more likely to achieve breakthrough innovation. Although scholars have conducted extensive research on management strategies, organizational structure, and incentive mechanisms for enterprise breakthrough innovation [40,41,43,44], no studies have explored how scientific and technological information resources, with gradually enhanced openness in China, drive enterprise breakthrough innovation.

2.3. Research on Strategic Aggressiveness

Enterprise strategic aggressiveness refers to the degree of risk-taking and innovation strategies adopted by enterprises in market competition. Research on strategic aggressiveness can be divided into two main aspects. On the one hand, researchers focus on the impact of strategic aggressiveness on enterprise performance, exploring how decision-making boldness and decisiveness in formulating and executing strategies affect long-term competitive advantage and market performance [45]. Some studies have found a positive correlation between strategic aggressiveness and long-term performance and market value of enterprises [46]. Aggressive enterprises are often more willing to take risks and more open to adopting new technologies and business models, thus achieving higher returns and competitive advantages in the market [47]. This proactive behavior is reflected not only in investments in innovative research and development resources but also in actively exploring new markets and technological fields [48,49], laying the foundation for the future growth and innovation of enterprises. Other studies focus on the relationship between strategic aggressiveness and financial performance, finding that aggressive enterprises usually have higher revenue growth rates and market shares [13], as well as greater financial stability and profitability [50]. These studies provide important insights for enterprise strategic formulation and management practices, emphasizing the critical role of strategic aggressiveness in long-term enterprise development.

On the other hand, researchers look at the role of strategic aggressiveness in enterprise innovation, exploring how aggressive decision-making by enterprise leadership promotes innovation activities [47], thereby driving sustainable development and growth of enterprises. Enterprise innovation is a key driver for continuous development and competitive advantage, and strategic aggressiveness is considered a critical factor in promoting innovation activities. Some studies suggest that aggressive enterprises are more willing to invest resources in R&D and more actively explore new markets and technological fields, thereby gaining a leading position in innovation competition [51]. Other studies explore the impact mechanisms of strategic aggressiveness on innovation activities from the perspectives of organizational learning and innovation culture, finding that aggressive enterprises often have more open and inclusive innovation environments, better attracting and retaining outstanding innovative talents, thereby driving continuous innovation and progress in the enterprise [13,52]. In the current era of digitalization and informatization, the rapid change and continuous updating of scientific and technological information resources make them a crucial support for enterprise strategic aggressiveness. Enterprises with high aggressiveness can effectively utilize these resources to accurately identify and seize new technological and market opportunities, thereby maintaining a sharp competitive edge in innovation. Scientific and technological information resources not only provide essential knowledge and technical support for enterprise innovation but also expand their innovation boundaries, promoting the exploration of cross-domain integration and innovation models. Therefore, a deeper exploration of how strategic aggressiveness enables enterprises to effectively integrate and utilize scientific and technological information resources for breakthrough innovation mechanisms and pathways is of significant theoretical and practical importance in driving sustained leadership in global competition.

3. Theoretical Analysis and Hypotheses

3.1. Analysis of the Impact of Scientific and Technological Information Resource Utilization on Enterprise Breakthrough Innovation

According to resource dependence theory, scientific and technological information resources are critical drivers of organizational innovation and development, playing a key role in the knowledge diffusion process [53,54]. Based on an in-depth consideration of enterprise scientific and technological information management, this study divides the utilization of these resources into two key dimensions: the intensity of utilization and the imbalance of utilization. The intensity of utilization refers to the depth of integration and application of scientific and technological information resources by enterprises, focusing on the full utilization of these resources and reflecting the organization's level of knowledge acquisition and application capability [55]. On the other hand, the imbalance of utilization highlights the uneven distribution of resources across different fields, revealing the organization's specialization in specific areas and relative dependency on certain domains [56,57]. By introducing these two dimensions, we can comprehensively understand the behavioral characteristics of organizations in the utilization of scientific and technological information resources, providing a more refined and multi-layered perspective to explain their impact on patent knowledge diffusion.

Scientific and technological information resources encompass various forms of technological assets, industry knowledge, and market information, providing essential support for enterprise innovation activities. On the one hand, high-intensity utilization of these resources allows enterprises to acquire and absorb the latest scientific achievements and market information in a timely manner, offering continuous momentum and inspiration for innovation activities [58]. Through in-depth research on technological trends and market demands, enterprises can better seize innovation opportunities and gain market dominance, thereby achieving breakthrough product or service innovation. On the other hand, high-intensity utilization can accelerate the innovation process [59], reduce innovation costs, and improve innovation efficiency. By leveraging advanced technological tools and innovative methods, enterprises can quickly transform innovative ideas into market practices, swiftly responding to market demand changes and achieving market leadership. Therefore, this study hypothesizes:

H1a. *The increase in the intensity of scientific and technological information resource utilization may directly promote enterprise breakthrough innovation, facilitating sustainable development*.

Due to disparities in capabilities to access scientific and technological information resources, organizational structures, and management abilities, different enterprises exhibit varying levels of inequity in utilizing these resources. However, it is precisely this imbalance that can stimulate innovation activities and drive breakthrough innovations within companies. The inequity of scientific and technological information resources affects breakthrough innovation in three main ways regarding knowledge supply. Firstly, differential knowledge and innovation demand matching: The uneven distribution of scientific and technological information resources means that some enterprises may possess in-depth knowledge in specific fields or cutting-edge technologies, while others may lack such resources [60]. This differentiated knowledge supply better aligns with specific innovation project needs, as different types of innovation often require specialized knowledge support [61]. For instance, some enterprises may focus on developing cutting-edge technologies, while others concentrate on applying existing technologies to new markets or products [62]. This differentiated knowledge supply helps enterprises meet innovation needs more accurately, thereby fostering breakthrough innovations. Secondly, efficiency and speed enhancement of innovation: Enterprises with diversified knowledge supply can often respond more swiftly to market changes and technological advancements [63,64]. By fully leveraging in-depth knowledge in specific areas, these enterprises can advance more efficiently in technology development and product innovation processes. For example, having unique knowledge reserves in critical technology domains enables enterprises to swiftly address technical challenges and expedite the development and commercialization of innovation projects. Thirdly, resource integration and formation of innovation ecosystems: Inequities in scientific and technological information resources facilitate resource integration and cooperation among enterprises and industries, particularly the differentiation in knowledge supply that drives the formation of industrial innovation ecosystems [65]. Companies can achieve knowledge complementarity and optimize resource allocation by sharing specialized knowledge in specific fields with other enterprises [66]. This integration and cooperation not only accelerate technological innovation processes but also promote the commercial application and market expansion of new technologies, thereby achieving breakthrough innovations in fiercely competitive market environments. Therefore, this study hypothesizes:

H1b. *The imbalance in scientific and technological information resource utilization may positively affect enterprise breakthrough innovation, providing new momentum and opportunities for innovation.*

3.2. The Moderating Role of Strategic Aggressiveness

Strategic aggressiveness is widely regarded as a key factor for enterprise success in the modern business environment. Aggressive strategic decisions typically involve significant investment in new technologies and the high utilization of information resources to gain market share and innovation advantages [67]. However, despite the full utilization of scientific and technological information resources being generally seen as crucial for promoting enterprise innovation and competitive advantage, strategic aggressiveness may influence this relationship. According to strategic choice theory, on the one hand, high strategic aggressiveness may lead to a lack of depth and stability in the utilization of scientific and technological information resources, thereby weakening the enterprise's ability to achieve breakthrough innovation. In other words, if enterprises excessively pursue short-term innovation goals while neglecting the long-term accumulation and deep application of scientific and technological information resources, their innovation capability may be limited. Therefore, this study hypothesizes:

H2a. *Strategic aggressiveness may weaken the positive impact of the intensity of scientific and technological information resource utilization on enterprise breakthrough innovation.*

Strategic aggressiveness may lead to an imbalance in resource allocation during the utilization of scientific and technological information resources, affecting the effectiveness of innovation. Overly aggressive enterprises might overinvest in certain fields or projects while neglecting other potential innovation opportunities [68]. This imbalance in resource utilization may result in breakthrough innovation in some areas but significant lag or deficiencies in others. Thus, even if enterprises achieve innovation breakthroughs in some aspects, the overall innovation level may not reach an optimal state due to imbalanced resource utilization. Therefore, this study hypothesizes:

H2b. *Strategic aggressiveness may weaken the positive impact of the imbalance in scientific and technological information resource utilization on enterprise breakthrough innovation.*

Based on the above discussion, this study constructs a theoretical framework of "strategic aggressiveness (strategy)—scientific and technological information resource utilization (capability)—breakthrough innovation (performance)". Figure 1 illustrates the structure of this theoretical framework, emphasizing the relationships and mutual influences among the elements, providing a clear guiding model for further research. This framework not only helps to understand the intrinsic relationships among strategic aggressiveness, scientific and technological information resources, and breakthrough innovation but also provides a strong theoretical foundation for future research.

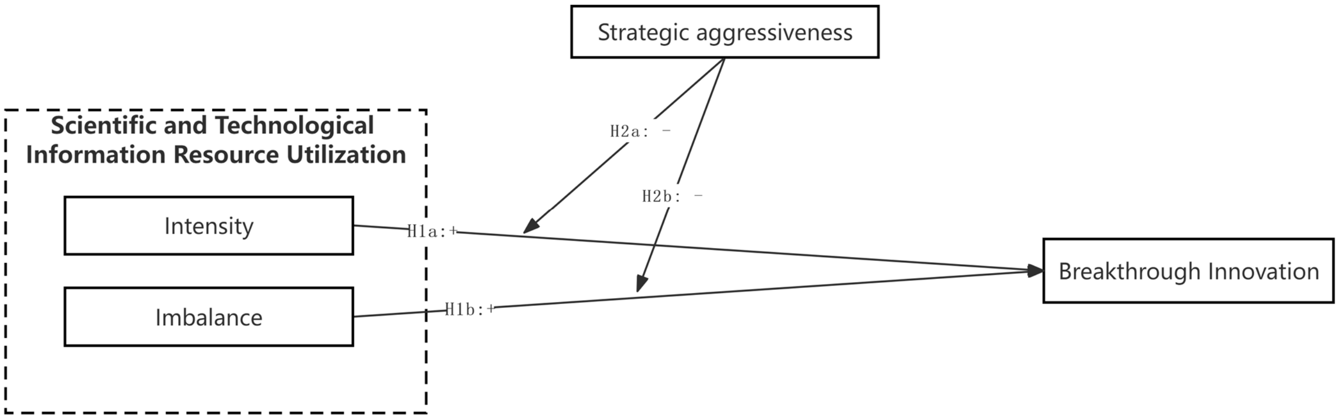

Figure 1. Framework diagram of the study.

4. Data Sources and Research Methods

4.1. Data Sources and Processing

The data for this study primarily comes from Clarivate's IncoPat patent database and the Wind business database. The empirical research focuses on listed manufacturing enterprises in China. As the main body of the real economy, the manufacturing sector is the foundation of China's economic development and a critical factor in gaining an advantage in international economic competition. Listed manufacturing enterprises, being the most significant and outstanding entities within the manufacturing sector, play a crucial role in advancing modern economic development and market resource allocation. Therefore, conducting an empirical study using patent data from listed manufacturing enterprises in China is of significant importance for the continuous healthy development of the Chinese economy and for enhancing international competitiveness. The specific data acquisition and processing steps are as follows:

Step One: Retrieve a list of 2616 Chinese listed manufacturing enterprises from the Wind database, including information such as stock codes, company names, listing dates, annual enterprise scale, and annual R&D investment.

Step Two: Based on the obtained company list, use the IncoPat patent database to search for invention patents filed by these 2616 listed manufacturing enterprises between 2011 and 2020. The search criterion used was "(Applicant = (Company Name)) AND (Application Date = (20110101 to 20201231))," resulting in a total of 438,228 patents (Figure 2). Extract information such as the patent application number, publication number, title, application date, publication date, applicants, inventors, and International Patent Classification (IPC) codes.

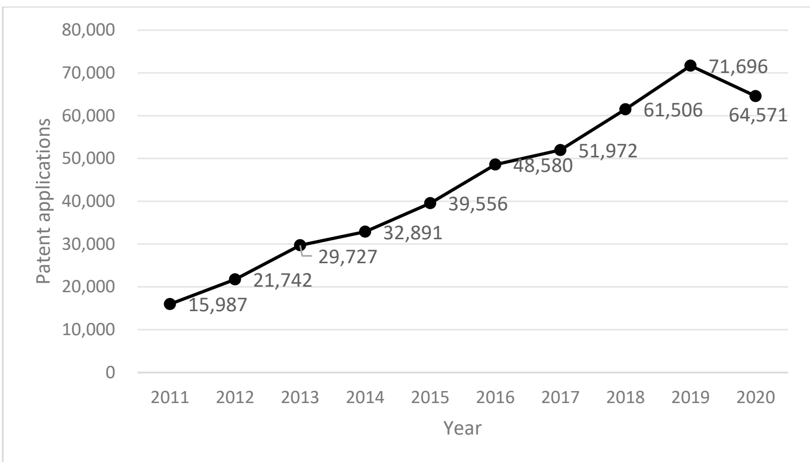

Figure 2. Patent distribution trend year by year.

Step Three: Integrate the data obtained from the previous two steps based on stock codes and yearly information. Use Python tools to calculate each enterprise's utilization of scientific and technological information resources, strategic aggressiveness, and breakthrough innovation indicators. This process yields relevant values for various indicators for each enterprise over different time periods, resulting in a dataset of 14,632 samples for subsequent analysis.

4.2. Main Research Variables

(1) Independent Variable—Enterprise Scientific and Technological Information Resource Utilization (STIRA)

Based on the definitions provided by scholars in existing research, citations of patents and scientific papers are considered an intuitive and robust indicator of scientific and technological information resources. They reflect the extent to which enterprises depend on and actively utilize external scientific and technological information in their R&D and innovation activities [69,70]. Therefore, in this study, the utilization of scientific and technological information resources by enterprises is measured based on the number of patents and scientific papers cited during the innovation process. Patent citations include both inventor citations and examiner citations. Existing research indicates that examiner citations significantly complement applicant citations [71,72], as examiner citations typically reflect a deep understanding and independent judgment of the relevant technological field during the professional examination process. Compared to inventor citations, examiner citations are more authoritative because they are made by experienced examiners within the professional field during the evaluation of patent applications. These citations not only mitigate the potential limitations of inventor citations but also provide a more comprehensive perspective for assessing the innovativeness and technological contribution of the patents. Therefore, when measuring patent citation information, this study considers both types of citations to comprehensively and accurately understand the technological background and evaluation basis behind the citations. The utilization of scientific and technological information resources is measured from two key dimensions: the intensity (STIRA_In) and the imbalance (STIRA_Im) of utilization. This approach provides a more comprehensive assessment of how enterprises utilize scientific and technological information resources in their innovation processes.

The intensity of utilization of scientific and technological information resources is primarily measured by the ratio of the total number of scientific and technological information resources cited in the patent innovation process to the number of invention patents each year. The formula is as follows:

$$\text{STIRA\_In}_{i,t} = \text{TotalCitation}_{i,t} / \text{Application}_{i,t} \quad (1)$$

where i represents the enterprise; t represents the year; $\text{STIRA\_In}_{i,t}$ represents the intensity of scientific and technological information resource utilization of enterprise i in year t; $\text{Application}_{i,t}$ represents the total number of invention patents published by enterprise i in year t; and $\text{TotalCitation}_{i,t}$ represents the total number of scientific papers and patents cited by enterprise i when applying for invention patents in year t.

For the imbalance of utilization of scientific and technological information resources, this study measures it by the variation in the number of scientific papers and patents cited per patent applied by the enterprise each year. The specific calculation formula is:

$$\text{STIRA\_Im}_{i,t} = \sqrt{\sum_{j=1}^{n} \left(\text{Citation}_{i,t,j} - \overline{\text{Citation}_{i,t}}\right)^2 / \text{Application}_{i,t}} \quad (2)$$

where i represents the enterprise; t represents the year; j represents the j-th invention patent applied by enterprise i in year t; $\text{Citation}_{i,t,j}$ represents the number of scientific papers and patents cited by enterprise i in the j-th invention patent application in year t; $\overline{\text{Citation}_{i,t}}$ represents the average number of scientific papers and patents cited by enterprise i in invention patent applications in year t; and $STIRA\_Im_{i,t}$ represents the imbalance of scientific and technological information resource utilization of enterprise i in year t.

(2) Dependent Variable—Enterprise Breakthrough Innovation Performance (BI)

Patent data can reflect the innovation outcomes of enterprises to some extent, with different types of patents indicating various levels of innovation. Compared to utility models and design patents, invention patents emphasize originality and technological breakthroughs as they typically involve deeper technological innovation rather than merely improvements to existing technologies [73]. Therefore, invention patents better demonstrate an enterprise's innovation capabilities and the extent of technological breakthroughs. Following the studies of Jiang (2021) [74] and Lin (2023) [73], this paper uses the number of invention patent applications during the sample period to measure the breakthrough innovation output of enterprises. For robustness checks, the study refers to Ahuja (2001) [75] and other research, utilizing the number of newly added IPC subcategories in the innovation process to measure breakthrough innovation [41]. Since scholars have found that the depreciation cycle of technological knowledge is generally around five years, the specific method involves using a five-year rolling time window. In Python, the Networkx module is employed to calculate the number of new IPC subcategories for each enterprise within the time interval.

(3) Moderating Variable—Enterprise Strategic Aggressiveness (SA)

Referring to the study by Bentley (2013) [76] and others, this research uses six key dimensions to measure strategic aggressiveness: the ratio of R&D expenditure to operating revenue, the ratio of the number of employees to operating revenue, the proportion of sales and administrative expenses to operating revenue, sales revenue growth rate, employee turnover, and capital intensity. These dimensions reflect the enterprise's input and operating conditions in various aspects. By calculating the rolling average of these indicators over the past five years and grouping the samples by "year-industry", the first five indicators are ranked from largest to smallest, and the sixth indicator is ranked from smallest to largest, each assigned values from 4 to 0. Finally, the values of these six indicators are summed to form a variable ranging from 0 to 24, with higher scores indicating greater strategic aggressiveness [77].

(4) Control Variables

Additionally, to accurately identify the relationships between different variable indicators, this study controls for the following variables based on existing research—Enterprise age: The time elapsed since the enterprise's establishment, indicating the length of the enterprise's existence. Enterprise profitability: The ability of the enterprise to generate profit within a certain period, measured by the ratio of annual total profit to total operating revenue; the higher the profit margin, the stronger the profitability. Ownership nature: State-owned enterprises are assigned a value of 1, while other enterprises are assigned a value of 0. Number of R&D Staff: Natural logarithm of the number of R&D personnel disclosed annually in the company's annual report. Investment in R&D: Natural logarithm of the expenditure spent annually on R&D by the enterprise. Time dummy variables and industry dummy variables. Table 1 provides a detailed list of the main variables.

Table 1. Detailed list of main variables.

Variable Type	Variable Name	Variable Breakdown Name	Symbol
Independent variable	Utilization of enterprise scientific and technological information resources	Intensity of utilization of enterprise S&T information resources	STIRA_In
		Imbalance of utilization of enterprise S&T information resources	STIRA_Im
Moderating variable	Strategic aggressiveness	Strategic aggressiveness	SA

Table 1. *Cont.*

Variable Type	Variable Name	Variable Breakdown Name	Symbol
Dependent variable	Breakthrough innovation	Enterprise breakthrough innovation performance	BI
Control variable	Control variables	Enterprise age Enterprise profitability Nature of property rights Number of R&D Staff Investment in R&D Time dummy Industry dummy	Ea Ep Npr R&Dsn R&Di Year Ind

4.3. Research Methods

Due to the use of panel data in this study and the application of the Hausman test, the null hypothesis "Difference in coefficients not systematic" was tested. The Hausman test resulted in a p-value of 0.0000, rejecting the null hypothesis (Table 2). Therefore, opting for a fixed effects model for analysis is more appropriate.

(1) In the study of the impact of the utilization of enterprise scientific and technological information resources on the breakthrough innovation of enterprises, the model is:

$$\text{BI}_{\text{i,t}} = \beta_0 + \beta_1 STIRA\_In_{i,t} + \beta_2 Control_{i,t} + \beta_3 \text{Year} + \beta_4 \text{Ind} + \varepsilon_{i,t} \quad (3)$$

$$\text{BI}_{\text{i,t}} = \beta_5 + \beta_6 STIRA\_\text{Im}_{i,t} + \beta_7 Control_{i,t} + \beta_8 \text{Year} + \beta_9 \text{Ind} + \varepsilon_{i,t} \quad (4)$$

where BI denotes the breakthrough innovation performance of enterprises, STIRA_In denotes the intensity of the utilization of scientific and technological information resources of enterprises, STIRA_Im denotes the imbalance of the utilization of scientific and technological information resources of enterprises, i denotes an enterprise, t denotes a year. Control denotes the control variable, which contains the variables of the age of the enterprise, profitability of the enterprise, number of R&D staff, investment in R&D and the nature of the property right, etc.; Year denotes the control of time dummy variable, Ind denotes control industry dummy variable, and $\varepsilon_{\text{i,t}}$ are residual terms.

Table 2. Hausman test results.

	Coefficients			
	(b) FE	**(B) RE**	**(b-B) Difference**	**Sqrt (Diag(V_b-V_B)) Std. Err.**
Stira_In	−0.031944	−0.0329217	0.0009777	0.0005199
Stira_Im	0.1151972	0.1242172	−0.00902	0.0008367
Ea	−0.0099359	−0.0160318	0.0060959	0.0034465
Ep	-2.20×10^{-6}	1.07×10^{-6}	-3.27×10^{-6}	1.73×10^{-6}
R&Dsn	0.0219173	0.01065	0.0112673	0.0020405
R&Di	0.1543455	0.2717775	−0.117432	0.008623

(2) In exploring the moderating effect of enterprise strategic aggressiveness on the relationship between the utilization of scientific and technological information resources and breakthrough innovation, the specific model is as follows:

$$\text{BI}_{\text{i,t}} = \beta_{10} + \beta_{11} STIRA\_In_{i,t} + \beta_{12} STIRA\_In_{i,t} * SA_{i,t} + \beta_{13} Control_{i,t} + \beta_{14} \text{Year} + \beta_{15} Ind + \varepsilon_{i,t} \quad (5)$$

$$\text{BI}_{\text{i,t}} = \beta_{16} + \beta_{17} STIRA\_\text{Im}_{i,t} + \beta_{18} STIRA\_\text{Im}_{i,t} * SA_{i,t} + \beta_{19} Control_{i,t} + \beta_{20} \text{Year} + \beta_{21} Ind + \varepsilon_{i,t} \quad (6)$$

where SA is the moderating variable enterprise strategy aggressiveness and the other variables are the same as above.

5. Research Results

5.1. Descriptive Statistical Analysis of Enterprise Indicators

Based on the research data from 14,632 samples, a series of interesting results were found. Firstly, regarding the utilization of scientific and technological information resources by enterprises, the average value is 6.008, indicating that most enterprises are somewhat active in utilizing these resources. However, the minimum value of 0 suggests that some enterprises do not sufficiently utilize scientific and technological information resources. In contrast, the maximum value of 34 shows that some enterprises have achieved remarkable success in this area, demonstrating their leading position in technological application. For the imbalance of scientific and technological information resource utilization, the average value is 2.714, with a minimum of 0 and a maximum of 23.784 (Table 3). This indicates significant differences among enterprises in their utilization of scientific and technological information resources; some may focus more on specific resources while neglecting others.

Table 3. Distribution of main variables.

Variable	N	Mean	p50	SD	Min	Max
STIRA_In	14,632	6.008	6	2.549	0	34
STIRA_Im	14,632	2.714	2.51	2.144	0	23.784
BI	14,632	2.135	1.946	1.147	0.693	9.028
SA	6611	11.683	12	3.835	0	23
Ea	14,632	17.352	17	6.042	1	63
Ep	14,632	−13.843	11.198	1612.435	−160,034.734	4805.529
R&Dsn	14,632	3.19	4.382	2.897	0	10.485
R&Di	14,150	17.855	17.726	1.311	8.007	23.491

In terms of enterprise breakthrough innovation, the average value is 2.135, with a minimum of 0.693 and a maximum of 9.028. This suggests that while most enterprises are making efforts in innovation, some are at a lower innovation level, possibly lacking sufficient resources or innovation awareness. As for enterprise strategic aggressiveness, the average value is 11.683, with a minimum of 0 and a maximum of 23. This indicates that most enterprises tend to be conservative in their strategic planning, but there are some that adopt more aggressive strategies, potentially taking on greater risks. Overall, these data reveal the diversity among Chinese listed manufacturing enterprises in terms of scientific and technological information resource utilization, innovation, and strategic planning. These differences provide useful clues for further causal exploration and contribute to a deeper understanding of the success factors of different enterprises and their impact on industry development.

5.2. Correlation Analysis of Indicators

This study first conducted a correlation analysis of the variables to determine whether the dataset is suitable for multiple linear regression analysis. Correlation analysis is crucial for assessing the degree of association between variables and is essential for establishing an accurate predictive model. We utilized the Pearson correlation coefficient for this analysis, and the results are shown in Table 4. The study found a positive correlation between the intensity and imbalance of scientific and technological information resource utilization and enterprise breakthrough innovation. This indicates that effective utilization and increased imbalance of scientific and technological information resources significantly impact achieving breakthrough innovation in enterprises. This finding is highly relevant in the current environment of rapid technological advancement, highlighting the critical role of technology resource management in enterprise innovation. Conversely, the study observed a negative correlation between strategic aggressiveness and breakthrough innovation. This result is insightful for enterprise strategists, suggesting the need to make appropriate decisions in balancing risk and innovation.

Table 4. Distribution of Pearson correlation coefficients and VIF test for main variables.

Variable	BI	STIRA_In	STIRA_Im	SA	Ea	Ep	Npr	R&Dsn	R&Di	Mean VIF
BI	1									
STIRA_In	0.036 ***	1								
STIRA_Im	0.375 ***	0.353 ***	1							
SA	−0.059 ***	−0.023 *	−0.002	1						
Ea	0.097 ***	0.028 ***	0.128 ***	−0.137 ***	1					
Ep	0.001	0.01	−0.003	0.018	0.012	1				
Npr	0.134 ***	0.020 **	0.017 **	−0.189 ***	0.178 ***	0.005	1			
R&Dsn	0.244 ***	0.057 ***	0.265 ***	−0.042 ***	0.386 ***	0.003	0.085 ***	1		
R&Di	0.525 ***	0.044 ***	0.225 ***	−0.165 ***	0.246 ***	−0.027 ***	0.216 ***	0.482 ***	1	
VIF	-	1.17	1.27	1.08	1.12	1.01	1.08	1.36	1.27	1.17
1/VIF	-	0.857186	0.789739	0.926606	0.894439	0.989701	0.924842	0.734387	0.787834	-

t statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In addition to the correlation analysis, we also conducted a Variance inflation factor (VIF) test to assess whether there is a multicollinearity problem among the independent variables. Multicollinearity can lead to inaccurate or distorted estimates of model parameters, so it must be effectively controlled. Our findings indicate that the maximum VIF value for the main variables, including independent and control variables, is 1.36, with a mean of 1.17, which is well below 10. This suggests that there is no severe multicollinearity problem in this study. This result enhances the robustness and reliability of the model validation.

5.3. The Impact of Enterprise Scientific and Technological Information Resource Utilization on Breakthrough Innovation

The study found that both the intensity and imbalance of enterprise scientific and technological information resource utilization have a significant positive impact on breakthrough innovation. Without any control variables, the regression coefficient between the intensity of scientific and technological information resource utilization and breakthrough innovation is 0.0164 ***, while the regression coefficient between the imbalance of scientific and technological information resource utilization and breakthrough innovation is 0.201 *** (Table 5). These findings provide important insights into the drivers behind enterprise innovation behavior.

Table 5. Impact of Enterprise Scientific and Technological Information Resource utilization on breakthrough innovation.

	(1) BI	(2) BI	(3) BI	(4) BI	(5) BI	(6) BI
STIRA_In	0.0164 *** (4.40)	0.00634 ** (1.98)	0.00757 ** (2.37)			
STIRA_Im				0.201 *** (49.00)	0.150 *** (39.87)	0.160 *** (41.72)
Ea		−0.00928 *** (−6.20)	−0.00377 ** (−2.48)		−0.0107 *** (−7.51)	−0.00305 ** (−2.13)
Ep		0.0000114 ** (2.25)	0.00000699 (1.41)		0.0000113 ** (2.37)	0.00000561 (1.20)
Npr		0.0816 *** (4.03)	0.0684 *** (3.26)		0.110 *** (5.72)	0.0676 *** (3.42)
R&Dsn		0.000926 (0.27)	0.00216 (0.46)		−0.0194 *** (−5.92)	0.00213 (0.48)
R&Di		0.463 *** (63.53)	0.459 *** (59.92)		0.429 *** (61.65)	0.417 *** (57.01)
_cons	2.037 *** (83.97)	−6.021 *** (−47.51)	−6.001 *** (−40.30)	1.590 *** (112.21)	−5.706 *** (−47.82)	−5.476 *** (−38.96)
N	14,632	14,150	14,150	14,632	14,150	14,150
Year	No	No	Yes	No	No	Yes
Ind	No	No	Yes	No	No	Yes
R^2	0.001	0.279	0.309	0.141	0.352	0.385
adj. R^2	0.001	0.279	0.307	0.141	0.352	0.383

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

Firstly, the active utilization of scientific and technological information resources is crucial for promoting breakthrough innovation in enterprises. This finding not only underscores the strategic importance of scientific and technological information resources in today's business environment but also highlights the key factors enterprises should focus on when utilizing these resources. Secondly, the concept of imbalance prompts us to consider the internal resource allocation and utilization patterns within enterprises. In this study, we observed that enterprises with a higher imbalance are more likely to achieve breakthrough innovation, which may indicate the importance of flexibility and differentiated strategies in resource allocation.

When control variables such as enterprise age, profitability, and ownership nature are added, the impact of the intensity and imbalance of scientific and technological information resource utilization on breakthrough innovation remains significant. This demonstrates the independence and persistence of these influencing factors. Specifically, the regression coefficient between the intensity of scientific and technological information resource utilization and breakthrough innovation is 0.00634 **, and the regression coefficient between the imbalance of scientific and technological information resource utilization and breakthrough innovation is 0.150 ***. When time and industry dummy variables are further included, the regression coefficient between the intensity of scientific and technological information resource utilization and breakthrough innovation is 0.00757 **, and the regression coefficient between the imbalance of scientific and technological information resource utilization and breakthrough innovation is 0.160 ***. This indicates that the utilization patterns of scientific and technological information resources have a robust and sustained impact on promoting breakthrough innovation in enterprises, regardless of different time periods or industrial environments. These results fully support hypotheses H1a and H1b.

5.4. Testing the Moderating Role of Strategic Aggressiveness

To examine the moderating role of strategic aggressiveness, this study constructed interaction terms between the utilization of scientific and technological information resources and strategic aggressiveness. The findings indicate that the regression coefficient of the interaction term between the intensity of scientific and technological information resource utilization and strategic aggressiveness on breakthrough innovation is −0.00201 *** (Table 6 and Figure 3). This suggests that as enterprise strategic aggressiveness increases, the positive impact of the intensity of scientific and technological information resource utilization on breakthrough innovation weakens, thus validating hypothesis H2a. Furthermore, the regression coefficient of the interaction term between the imbalance of scientific and technological information resource utilization and strategic aggressiveness on breakthrough innovation is −0.00503 ***. This result indicates that increased strategic aggressiveness diminishes the positive impact of the imbalance of scientific and technological information resource utilization on breakthrough innovation, supporting hypothesis H2b.

Table 6. The moderating role of strategic aggressiveness.

	(1) BI	(2) BI	(3) BI	(4) BI
STIRA_In	0.00757 ** (2.37)	0.0522 *** (5.61)		
STIRA_Im			0.160 *** (41.72)	0.264 *** (18.40)
Ea	−0.00377 ** (−2.48)	0.0134 *** (4.14)	−0.00305 ** (−2.13)	0.0125 *** (4.10)
Ep	0.00000699 (1.41)	0.00311 *** (4.48)	0.00000561 (1.20)	0.00244 *** (3.73)
Npr	0.0684 *** (3.26)	0.300 *** (8.91)	0.0676 *** (3.42)	0.261 *** (8.25)
R&Dsn	0.00216 (0.46)		0.00213 (0.48)	
R&Di	0.459 *** (59.92)		0.417 *** (57.01)	
STIRA_In * SA		−0.00201 *** (−3.31)		
STIRA_Im * SA				−0.00503 *** (−4.75)
_cons	−6.001 *** (−40.30)	1.405 *** (8.71)	−5.476 *** (−38.96)	1.338 *** (8.98)

Table 6. *Cont.*

	(1) BI	(2) BI	(3) BI	(4) BI
N	14,150	6611	14,150	6611
Year	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes
R^2	0.309	0.122	0.385	0.223
adj. R^2	0.307	0.115	0.383	0.218

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

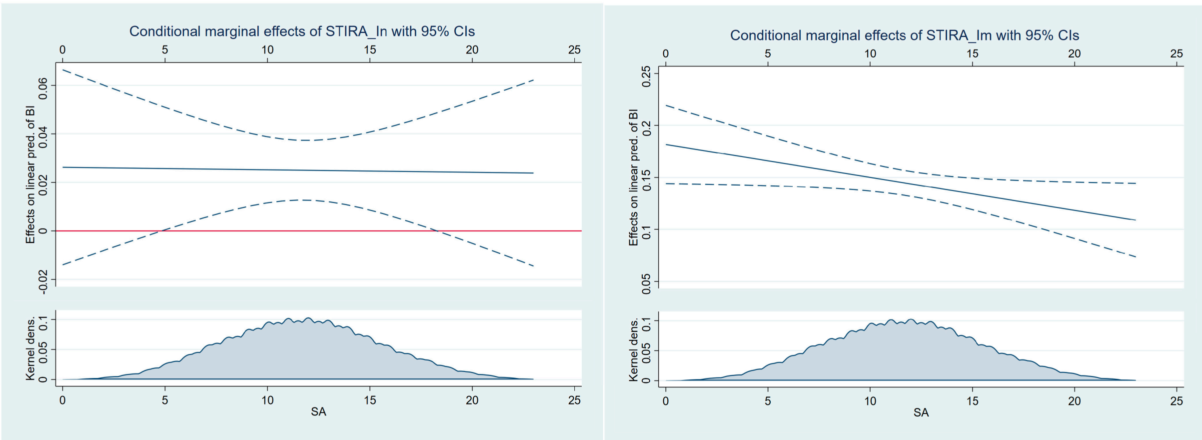

Figure 3. The moderating effect diagram.

5.5. Endogeneity and Robustness Tests

To prevent potential endogeneity between technological information resource utilization and radical innovation, this study conducted an endogeneity test using the two-stage least squares (2SLS) method with instrumental variables. We chose "Top Management Team Innovation Participation (TMTIP)" as the instrumental variable. TMTIP typically reflects the top management team's focus on environmental management and sustainable development within the enterprise, without directly influencing radical innovation outcomes. Therefore, it meets the exogeneity requirements of instrumental variables. Additionally, TMTIP may be correlated to some extent with the enterprise's investment in and strategic formulation of innovation activities. Companies driven by their top management teams in innovation may indirectly influence the utilization of technological information resources, thereby impacting radical innovation outcomes. This study matched executive information disclosed in enterprise annual reports with inventor information from patents related to innovation processes. It further quantified the varying degrees of top management team involvement in innovation across different enterprises. According to the two-stage least squares (2SLS) regression results in Table 7, the effectiveness of "Top Management Team Innovation Participation" as an instrumental variable was validated. The findings indicate that there is no endogeneity issue between technological information resource utilization and radical innovation.

Table 7. 2SLS Endogeneity test results.

			Phase I			
Variant	STIRA_In	t-Value	*p*-Value	STIRA_Im	t-Value	*p*-Value
TMTIP	23.22846	1.70	0.09	74.77208	6.5	<0.01
Constant Term	6.001367	280.14	<0.01	2.692901	149.6	<0.01
N	14,632			14,632		
R^2	0.000			0.0028		

Table 7. *Cont.*

		Phase II	
Variant	**BI**	**t-Value**	***p*-Value**
STIRA_In	0.0164	4.40	<0.01
STIRA_Im	0.201	49.00	<0.01
Constant Term	2.037	83.97	<0.01
N	14,632		
R^2	0.001		

To ensure the robustness and reliability of the research results, this study conducted several robustness tests using lagged independent variables, changing the sample size, including dummy variables, and replacing variables. Lagged independent variables: When the independent variables were lagged by one period, the relationship between the utilization of scientific and technological information resources and breakthrough innovation remained significant (Table 8). At this point, the robustness test for the moderating effect is also significant (Table 9). Changing sample size: By excluding data from 2011 to 2015 and using data from 2016 to 2020, the robustness test results remained consistent. Including dummy variables: Province dummy variables were considered because although most enterprises do not change provinces, some might. Including important omitted variables at the province level that do not change over time helps prevent biased and inconsistent estimation results. The regression analysis, including province dummy variables, showed that the results remained robust, and the conclusions were still valid. Replacing dependent variable: When the method for calculating breakthrough innovation was changed, the relationship between the utilization of scientific and technological information resources and breakthrough innovation remained significant, strategic aggressiveness remains negatively moderated (Tables 8 and 9). This indicates that the conclusions are not affected by the calculation method of the dependent variable, further validating the robustness of the research results. Overall, through the application of multiple robustness test methods, the research results have been further validated and supported, enhancing the credibility and generalizability of the study's conclusions.

Table 8. Main effects robustness test.

	One Period Lag		Change Sample Size		Add Regional Dummy Variables		Replace Dependent Variable	
	BI	BI	BI	BI	BI	BI	BI	BI
L.STIRA_In	0.00824 **							
	(2.02)							
L.STIRA_Im		0.0968 ***						
		(19.36)						
STIRA_In			0.0134 ***		0.00731 **		0.0645 ***	
			(3.73)		(2.29)		(4.31)	
STIRA_Im				0.141 ***		0.160 ***		0.326 ***
				(32.31)		(41.68)		(17.28)
Ea	−0.00504 ***	−0.00485 ***	−0.00476 **	−0.00417 **	−0.00368 **	−0.00301 **	−0.0114	−0.00995
	(−2.90)	(−2.84)	(−2.50)	(−2.32)	(−2.42)	(−2.10)	(−1.60)	(−1.41)
Ep	0.00000717	0.00000665	0.00000682	0.00000603	0.00000688	0.00000556	0.0000232	0.0000215
	(1.35)	(1.27)	(1.35)	(1.26)	(1.39)	(1.19)	(1.00)	(0.93)
Npr	0.0609 **	0.0679 ***	0.0338	0.0323	0.0611 ***	0.0643 ***	0.474 ***	0.475 ***
	(2.55)	(2.90)	(1.22)	(1.23)	(2.85)	(3.18)	(4.82)	(4.88)
R&Dsn	−0.00367	−0.00582	−0.00206	0.000857	0.00194	0.00203	−0.0608 ***	−0.0604 ***
	(−0.67)	(−1.08)	(−0.36)	(0.16)	(0.41)	(0.46)	(−2.76)	(−2.77)
R&Di	0.495 ***	0.475 ***	0.481 ***	0.435 ***	0.460 ***	0.417 ***	1.264 ***	1.181 ***
	(55.19)	(53.58)	(45.76)	(43.25)	(59.94)	(57.01)	(35.14)	(32.83)
_cons	−6.448 ***	−6.229 ***	−6.346 ***	−5.755 ***	−5.988 ***	−5.471 ***	−18.32 ***	−17.06 ***
	(−36.30)	(−35.78)	(−33.30)	(−31.81)	(−40.16)	(−38.88)	(−26.22)	(−24.65)
N	10,945	10,945	9028	9028	14,150	14,150	14,150	14,150
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province	No	No	No	No	Yes	Yes	No	No
R2	0.329	0.351	0.313	0.384	0.310	0.385	0.165	0.181
adj. R2	0.325	0.348	0.310	0.381	0.307	0.383	0.162	0.178

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

Table 9. Robustness test for moderating effects.

	One Period Lag		Change Sample Size		Add Regional Dummy Variables		Replace Dependent Variable	
	BI	BI	BI	BI	BI	BI	BI	BI
L.STIRA_In	0.00542 *							
	(1.83)							
L.STIRA_Im		0.0859 ***						
		(11.15)						
STIRA_In			0.00268 *		0.0116 *		0.0864 **	
			(1.28)		(1.44)		(2.12)	
STIRA_Im				0.133 ***		0.148 ***		0.409 ***
				(9.47)		(11.59)		(6.13)
Ea	0.00623 **	0.00845 ***	0.00779 **	0.00652 **	0.00704 **	0.00627 **	0.0417 ***	0.0402 ***
	(2.08)	(2.95)	(2.36)	(2.06)	(2.52)	(2.36)	(2.98)	(2.89)
Ep	0.000780	0.000379	0.00141 *	0.000904	0.000610	0.000299	0.00367	0.00314
	(1.20)	(0.61)	(1.79)	(1.20)	(1.00)	(0.51)	(1.19)	(1.03)
Npr	0.153 ***	0.175 ***	0.127 ***	0.102 ***	0.170 ***	0.143 ***	0.734 ***	0.687 ***
	(4.85)	(5.76)	(3.53)	(2.97)	(5.70)	(5.05)	(5.01)	(4.73)
R&Dsn	0.0778 ***	0.0586 ***	0.0953 ***	0.0850 ***	0.100 ***	0.0826 ***	0.412 ***	0.379 ***
	(4.71)	(3.69)	(4.96)	(4.61)	(6.69)	(5.77)	(5.47)	(5.05)
R&Di	0.484 ***	0.464 ***	0.451 ***	0.416 ***	0.441 ***	0.406 ***	1.105 ***	1.041 ***
	(31.83)	(31.76)	(23.16)	(22.28)	(33.22)	(31.99)	(16.55)	(15.69)
STIRA_In*SA	−0.00134 ***		−0.00137 **		−0.00192 ***		−0.000944 *	
	(−3.47)		(−2.14)		(−3.62)		(−1.35)	
STIRA_Im*SA		−0.00840 ***		−0.000192 *		−0.000787 *		−0.00788 *
		(−16.74)		(1.19)		(−1.84)		(−1.62)
_cons	−6.569 ***	−6.423 ***	−6.878 ***	−6.242 ***	−6.014 ***	−5.490 ***	−16.57 ***	−15.39 ***
	(−20.39)	(−21.01)	(−21.49)	(−20.36)	(−22.55)	(−21.67)	(−12.37)	(−11.61)
N	5420	5420	4448	4448	6539	6539	14,632	14,632
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province	No	No	No	No	Yes	Yes	No	No
R2	0.366	0.416	0.359	0.411	0.349	0.408	0.078	0.107
adj. R2	0.360	0.410	0.353	0.405	0.344	0.403	0.075	0.104

t statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.6. Heterogeneity Analysis

To gain a deeper understanding of the relationship between the utilization of scientific and technological information resources and breakthrough innovation across different regions and ownership types, this study conducted a series of heterogeneity tests. Regional heterogeneity analysis helps us better understand how different regional backgrounds impact enterprise innovation capabilities. Due to differences in economic development levels, industrial structures, and policy environments across regions, enterprises may face different resource allocations and market environments [78], leading to significant variations in the utilization of scientific and technological information resources and innovation models. Drawing on the existing research, listed enterprises are categorized into coastal and non-coastal cities. Previous studies have found that, compared to non-coastal areas, coastal regions generally have a more developed economic base and more resource advantages, as well as easier access to international markets and foreign investment [79]. Therefore, coastal regions may possess certain advantages in obtaining scientific and technological information resources, technological innovation capabilities, and market competitiveness. Additionally, coastal areas may more easily form industrial clusters and technological innovation ecosystems, facilitating information exchange and cooperation among enterprises and promoting the sharing and interaction of innovation resources, which is conducive to enhancing innovation capabilities.

In this study, the analysis found that both coastal and non-coastal regions show a positive impact of the intensity of scientific and technological information resource utilization on breakthrough innovation. The coefficient difference test between the groups for the independent variables showed a *p*-value of 0.398, which is greater than 0.1 (Table 10), indicating no significant difference in the intensity of scientific and technological information resource utilization between coastal and non-coastal regions. Notably, although the imbalance in scientific and technological information resource utilization positively affects breakthrough innovation in both coastal and non-coastal regions, the coefficient difference test for the independent variables revealed a *p*-value of 0.0408, which is less than 0.1. This suggests that the regression coefficients can be directly compared, showing a significant difference in the impact of the imbalance of scientific and technological information resource utilization on breakthrough innovation between coastal and non-coastal regions. Specifically, the imbalance in scientific and technological information resource utilization has a greater impact on breakthrough innovation in coastal regions compared to non-coastal regions.

Table 10. Results of regional heterogeneity test.

	Non-Coastal BI	Coastal BI	Non-Coastal BI	Coastal BI
STIRA_In	0.0179 ***	0.00288 *		
	(3.01)	(1.76)		
STIRA_Im			0.143 ***	0.167 ***
			(20.46)	(36.54)
Ea	−0.00584 *	−0.00183	−0.00424	−0.00139
	(−1.77)	(−1.09)	(−1.35)	(−0.88)
Ep	−0.000125	0.00000834 *	−0.000127 *	0.00000672
	(−1.61)	(1.71)	(−1.70)	(1.47)
Npr	0.00133	0.00141	0.00122	0.00157
	(0.14)	(0.26)	(0.14)	(0.31)
R&Dsn	0.418 ***	0.489 ***	0.391 ***	0.437 ***
	(31.21)	(52.31)	(30.47)	(49.19)
R&Di	−5.114 ***	−6.610 ***	−4.819 ***	−5.923 ***
	(−19.91)	(−35.76)	(−19.79)	(−33.99)
_cons	0.0179 ***	0.00288 *		
	(3.01)	(1.76)		
N	4122	10,028	4122	10,028
Year	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes
R2	0.319	0.317	0.381	0.398
adj. R2	0.312	0.314	0.374	0.395
Inter-group differences	$p = 0.398 > 0.1$		$p = 0.0408 < 0.1$	

t statistics in parentheses. * $p < 0.1$, *** $p < 0.01$.

Ownership nature is a crucial component of enterprise governance structure, significantly influencing decision-making behavior, resource allocation, and innovation motivation. There are distinct differences in ownership nature between state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs). SOEs are typically fully or partially invested or controlled by the government or government agencies, with ownership and control primarily exercised by the government. This grants SOEs a unique operating environment and behavioral characteristics [80]. In contrast, non-SOEs are primarily invested by private entities or other non-governmental entities, with ownership and control exercised by private or non-governmental entities, making their operations more influenced by market mechanisms and competitive environments [81]. This study categorizes enterprises into SOEs and non-SOEs for heterogeneity analysis based on their ownership structure. The analysis reveals that both SOEs and non-SOEs show a positive impact of the intensity of scientific and technological information resource utilization on breakthrough innovation. However, the p-value between the two groups is 0.0317, which is less than 0.1, indicating that the regression coefficients can be directly compared, and there is a significant difference in the intensity of scientific and technological information resource utilization between SOEs and non-SOEs (Table 11). Specifically, the intensity of scientific and technological information resource utilization has a greater impact on breakthrough innovation in SOEs compared to non-SOEs. Furthermore, both SOEs and non-SOEs show a positive impact of the imbalance of scientific and technological information resource utilization on breakthrough innovation. The coefficient difference test for the independent variables between the groups shows a p-value of 0.4417, which is greater than 0.1, indicating no significant difference in the imbalance of scientific and technological information resource utilization between SOEs and non-SOEs.

Table 11. Results of ownership nature heterogeneity test.

	Non-State BI	Nationalized BI	Non-State BI	Nationalized BI
STIRA_In	0.00381 *	0.0235 ***		
	(1.13)	(2.79)		
STIRA_Im			0.158 ***	0.169 ***
			(38.61)	(17.37)
Ea	−0.00541 ***	0.00573	−0.00463 ***	0.00655 *
	(−3.36)	(1.38)	(−3.07)	(1.65)
Ep	0.00000734	0.000506	0.00000571	0.000348
	(1.54)	(0.70)	(1.28)	(0.50)
R&Dsn	0.00185	0.0214	0.00322	0.0129
	(0.37)	(1.47)	(0.69)	(0.93)
R&Di	0.456 ***	0.448 ***	0.409 ***	0.415 ***
	(49.72)	(28.86)	(47.12)	(27.78)
_cons	−5.889 ***	−6.044 ***	−5.318 ***	−5.621 ***
	(−33.80)	(−18.72)	(−32.52)	(−18.24)
N	10,952	3198	10,952	3198
Year	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes
R2	0.268	0.379	0.356	0.431
adj. R2	0.265	0.371	0.353	0.424
Inter-group differences	$p = 0.0317 < 0.1$		$p = 0.4417 > 0.1$	

t statistics in parentheses. * $p < 0.1$, *** $p < 0.01$.

6. Discussion

Theoretical studies indicate that effective utilization of scientific and technological information resources is crucial for enhancing innovation capabilities within enterprises. This paper provides an in-depth analysis of the relationship between enterprise utilization of scientific and technological information resources and breakthrough innovation, discussing three main directions and deepening and expanding upon existing research findings.

6.1. Relationship between Enterprise Utilization of Scientific and Technological Information Resources and Breakthrough Innovation

Effective utilization of scientific and technological information resources is one of the core drivers for enterprise innovation. In this study, we observe a significant positive relationship between the intensity of scientific and technological information resource utilization and breakthrough innovation within enterprises. Specifically, enterprises that fully leverage external scientific and technological information, strengthen internal R&D capabilities, and rapidly transform technological achievements are more likely to stand out in market competition. For instance, by continuously updating technologies and making market-oriented innovation investments, enterprises can quickly respond to changes in consumer demand and introduce competitive new products and services. This proactive strategy of utilizing scientific and technological information resources not only enhances market share and profitability but also establishes innovation leadership within their industries. Existing research highlights that enterprises can accelerate the application and commercialization of new technologies by establishing open innovation platforms, enhancing technology transfer, and collaboration [82,83]. Particularly in high-tech and knowledge-intensive industries, efficient utilization of scientific and technological information resources is not only a key factor for enterprises to maintain competitive advantages but also directly promotes technological progress and industrial upgrading [84].

On the other hand, the imbalance in the utilization of scientific and technological information resources also significantly influences breakthrough innovation within enterprises. Imbalance refers to differences in resources and capabilities among enterprises when acquiring and applying technological information, which can lead to imbalance and uncertainty in innovation activities. However, this study finds that moderate imbalance can encourage enterprises to actively engage in technological innovation and market exploration. For example, some enterprises with higher costs of information acquisition or technological thresholds successfully overcome technical challenges and achieve innovative breakthroughs in new products and services through cooperation with universities, research institutions, cross-border innovation, and international collaboration. Existing studies indicate that enterprises facing uncertain external environments and resource constraints can achieve dual breakthroughs in technology and market through flexible responses and innovative combinations [85,86]. Especially in the increasingly competitive global context, enterprises that effectively manage and utilize imbalance in scientific and technological information resources often adapt and lead in different markets and technological fields.

6.2. Moderating Role of Strategic Aggressiveness in the Relationship between Utilization of Scientific and Technological Information Resources and Breakthrough Innovation

Strategic aggressiveness in enterprises typically refers to proactive strategic behaviors adopted in response to market competition and technological change. This behavior is manifested not only in enterprises pursuing technological innovation and product leadership but also in expanding market share, entering new markets, and developing new products. In this study, we observe that increased strategic aggressiveness in enterprises significantly moderates the relationship between the utilization of scientific and technological information resources and breakthrough innovation. Firstly, the enhancement of strategic aggressiveness in enterprises may weaken the positive impact of scientific and technological information resource utilization intensity on breakthrough innovation. Strategically aggressive enterprises often have strong internal innovation capabilities and resource integration abilities [87], preferring to acquire and apply the latest technologies through internal R&D and strategic alliances [88] rather than relying on externally open scientific and technological information resources. Therefore, although these enterprises still utilize external information, their paths to innovation may rely more on internal R&D and core technology accumulation, thus reducing the driving effect of scientific and technological information resource utilization intensity on innovation.

Secondly, the enhancement of strategic aggressiveness in enterprises may also weaken the positive impact of imbalance in the utilization of scientific and technological information resources on breakthrough innovation. The imbalance in the utilization of scientific and technological information resources typically reflects differences in enterprises' capabilities in acquiring and applying technological information. However, in enterprises with high strategic aggressiveness, these capabilities may be more effectively utilized or compensated through strategic cooperation. For example, these enterprises may promote integration and exchange of internal and external resources through establishing open innovation platforms, thereby enhancing innovation efficiency and outcomes. Existing literature indicates that enterprises with high strategic aggressiveness in high-tech and knowledge-intensive industries can respond more quickly to market demands and technological changes through internal innovation and strategic alliances [89], achieving leadership in innovation [90]. These enterprises, relying on internal resources and core technology accumulation, have lower dependence on external scientific and technological information resources, thereby reducing the positive impact of the intensity of scientific and technological information resource utilization on innovation. This suggests that, in the context of increasingly fierce globalization competition, adjusting strategic aggressiveness can help enterprises better adapt to and lead the changes in markets and technologies.

6.3. Regional and Ownership Differences in the Utilization of Scientific and Technological Information Resources and Breakthrough Innovation

When studying the impact of regional differences and ownership nature on the utilization of scientific and technological information resources and breakthrough innovation within enterprises, we explored the specific effects of coastal and non-coastal regions, state-owned enterprises (SOEs), and non-state-owned enterprises (NSOEs) on the intensity and imbalance of scientific and technological information resource utilization. Firstly, from the perspective of regional differences, both coastal and non-coastal regions positively influence breakthrough innovation through the intensity of scientific and technological information resource utilization. However, there is no significant difference between them. Coastal regions, due to geographical and economic advantages, typically have easier access to cutting-edge scientific and technological information resources, supporting enterprises in technological innovation and market applications. However, non-coastal regions may face challenges in acquiring scientific and technological information resources, but through technology transfer and policy support, they can also promote innovation activities. Existing studies have shown that regional differences in innovation capabilities are not only influenced by geographical factors but also closely related to local government innovation policies and investments [78,91,92]. Therefore, for enterprises, the intensity of scientific and technological information resource utilization is influenced to some extent by local government innovation environments and policy support, which may exhibit different characteristics in different regions.

Secondly, regarding the impact of imbalance in the utilization of scientific and technological information resources, research finds that compared to non-coastal regions, coastal regions demonstrate a more significant impact of imbalance in the utilization of scientific and technological information resources on breakthrough innovation. This is mainly reflected in coastal enterprises being able to effectively address technological challenges and market competition through more proactive technological innovation strategies and efficient resource allocation, promoting the transformation and application of innovation outcomes. In contrast, enterprises in non-coastal regions may need to overcome shortages of technical resources through enhanced cooperation with external innovation entities and policy guidance to enhance innovation capabilities. Existing research indicates that differences in regional innovation capabilities are not only related to the ability to acquire technological resources but also closely related to local economic structures [93], industrial foundations [94], and effective implementation of science and technology policies [79]. Therefore, when enterprises conduct innovation activities in different regions, it is necessary to fully consider the characteristics of local innovation ecosystems and resource allocation strategies to optimize the efficiency of scientific and technological information resource utilization and achieve innovation outcomes.

Finally, regarding the impact of different ownership natures on the utilization of scientific and technological information resources and breakthrough innovation, both state-owned enterprises (SOEs) and non-state-owned enterprises (NSOEs) significantly positively influence breakthrough innovation through the intensity and imbalance of scientific and technological information resource utilization. However, the impact of scientific and technological information resource utilization intensity on breakthrough innovation is higher for state-owned enterprises (SOEs) than for non-state-owned enterprises (NSOEs). This may be related to the advantages that SOEs have in resource allocation, such as government support, financial advantages, and technological reserves in key areas. However, in terms of the imbalance in the utilization of scientific and technological information resources, there is no significant difference in influence between state-owned enterprises (SOEs) and non-state-owned enterprises (NSOEs). This suggests that regardless of the ownership nature of enterprises, effective management and utilization of scientific and technological information resources can promote the enhancement of innovation capabilities and competitive strength in the market. Existing research also emphasizes the important role of government in the innovation activities of state-owned enterprises, particularly in policy support and coordination in technology introduction and market development [95].

In summary, significant differences exist in the utilization of scientific and technological information resources and breakthrough innovation among enterprises in different regions and with different ownership natures. These differences are influenced not only by local innovation environments and policy support but also closely related to enterprises' own technological innovation strategies and resource allocation capabilities. Future research can further explore how to promote balanced development of scientific and technological information resource utilization across different regions and types of enterprises through optimizing innovation policies and resource allocation, thereby promoting sustainable economic growth and industrial upgrading.

7. Conclusions and Implications

7.1. Conclusions

With the accelerating global digitization process, scientific and technological information resources play a crucial role in the development of high-quality innovation in enterprises. This study constructs a theoretical framework of "strategy-capability-performance" and utilizes a mixed-effects model to analyze data from listed manufacturing enterprises in China from 2011 to 2020, deeply exploring the role of scientific and technological information resources in fostering breakthrough innovation. The research findings indicate that, firstly, there is a significant positive relationship between the intensity of scientific and technological information resource utilization and breakthrough innovation in enterprises, highlighting their critical role in driving innovation, particularly through flexible resource allocation and differentiated strategies. Secondly, enterprise strategic aggressiveness significantly moderates the relationship between scientific and technological information resource utilization and breakthrough innovation, emphasizing the importance of considering strategic aggressiveness in innovation management and strategic formulation. Finally, the impact of scientific and technological information resource utilization on breakthrough innovation varies across different regions and types of enterprises, particularly in terms of resource utilization asymmetry. These findings provide empirical support and theoretical guidance for enterprises in formulating innovation strategies and resource allocation.

7.2. Implications

7.2.1. Theoretical Contributions

This study contributes significantly to academic theory in several aspects. Firstly, by introducing strategic aggressiveness into the analysis of scientific and technological information resource utilization and its relationship with enterprise innovation, this study deepens the understanding of strategic factors in enterprise innovation activities. Through quantitative analysis of how strategic aggressiveness influences the effectiveness of scientific and technological information resource utilization, it enriches the theoretical framework of external resource management and strategic formulation in the process of enterprise innovation, providing a new perspective and methodology for further research in strategic management.

Secondly, while exploring the impact of scientific and technological information resource utilization on breakthrough innovation in enterprises, this study also analyzes in depth the mechanisms through which resource utilization intensity and asymmetry affect innovation activities, expanding the theoretical boundaries of resource management and enterprise innovation relationships. By revealing the differences in the effects of resource utilization under different strategic environments, the study provides empirical evidence and theoretical guidance for enterprises in resource allocation and strategic decision-making.

7.2.2. Managerial Implications

Based on the research findings, several managerial recommendations are proposed:

Firstly, it is recommended that enterprise managers fully consider the strategic value of scientific and technological information resources and the role of strategic aggressiveness when formulating innovation strategies and resource allocation policies. By strengthening the integrated management and optimized allocation of scientific and technological information resources, enterprises can enhance the efficiency and effectiveness of innovation activities, effectively addressing market competition pressures.

Secondly, enterprises are encouraged to enhance the cultivation and enhancement of strategic aggressiveness in strategic planning. By improving organizational flexibility and adaptability, enterprises can better adjust and utilize scientific and technological information resources to achieve innovation-driven development. Especially in environments characterized by frequent technological changes and rapid shifts in market demands, enhancing strategic aggressiveness can effectively mitigate the uncertainty of resource allocation effects and promote continuous enhancement of enterprise innovation capabilities.

Lastly, governments and industry associations can promote cooperation and sharing of scientific and technological information resources among enterprises through policy support and resource integration, thereby building an innovation ecosystem. By establishing open innovation platforms and shared resource repositories, they can provide broader development space and collaboration opportunities for SMEs and innovative enterprises, thereby driving technological progress and economic development. Through comprehensive discussions on theoretical contributions and managerial implications, this study provides profound theoretical guidance and empirical support for the practice of enterprise scientific and technological information resource management and innovation strategies, offering significant theoretical insights and practical application value.

8. Research Limitations

This study provides a deep analysis of the relationship between the utilization of scientific and technological information resources, strategic aggressiveness, and breakthrough innovation in enterprises, offering profound insights for firms in crafting innovation strategies, knowledge management, and industrial policy. However, there are several limitations that need to be addressed in future research. Firstly, the sample is limited to Chinese enterprises, thus limiting the generalizability of the findings to other countries and economic systems. The significant differences in innovation ecosystems across different countries and regions may lead to notable variations in innovation strategies and behaviors among enterprises. For instance, substantial disparities in marketization levels and policy support between China and other countries could directly influence the effectiveness of innovation behaviors and outcomes. Additionally, these differences are closely tied to ownership issues, as various forms of ownership in other countries can strongly impact management styles and decision-making processes.

Secondly, the study's scope of moderating variables is limited, failing to encompass all potential factors that could influence the relationship between the utilization of scientific and technological information resources and breakthrough innovation comprehensively. Future research should also consider the significant role of market position in shaping innovation activities within enterprises. In the context of globalization and external competition, a company's market position can significantly influence its innovation behaviors. This is particularly evident in cross-national comparative studies. For example, multinational corporations positioned at the center of global markets may possess greater resources and technological advantages, enabling them to pursue more audacious innovation strategies and investments. In contrast, state-owned enterprises may be constrained by policy restrictions and internal decision-making mechanisms, resulting in more conservative innovation behaviors reliant on policy support. Therefore, a company's market position not only determines its competitiveness in global markets but also directly affects the selection and execution of its innovation strategies. Future research endeavors should strive to overcome these limitations by employing broader international samples and considering a wider array of potential moderating factors to delve deeper into the relationship between the utilization of scientific and technological information resources and breakthrough innovation.

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