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The Sustainability of Technological Innovation in China: From the Perspective of Network Relationships

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Abstract: Sustainable technological innovation is a key factor for companies seeking competitive advantage. Against the backdrop of the Sino-US trade war, the US government has been severely impeding Chinese enterprises' technological innovation with its trade policies. Consequently, how to ensure the sustainability of technological innovation is a huge challenge for Chinese enterprises. In the Chinese context of a relationship-based society, network relationships have been instrumental in the process of technological innovation. This study constructs a theoretical model, with market dynamics as the moderator, exploring the impact of three dimensions of network relationships (network relationship selection, network relationship maintenance, and network relationship utilization) on sustainable technological innovation via an empirical analysis of 208 Chinese technology companies. The results of this study indicate that network relationship selection, network relationship maintenance, and network relationship utilization have a positive effect on sustainable technological innovation. Furthermore, the moderating effect of market dynamics on the association between network relationships and sustainable technological innovation is also confirmed. This study contributes to resource-based theory and dynamic capability theory by demonstrating how network relationships influence sustainable technological innovation in varying market dynamics. This study provides a better understanding of the role of network relationships in sustainable technological innovation and suggests that managers should pay attention to the selection, maintenance, and utilization of network relationships in order to achieve sustainable technological innovation. Additionally, managers should also consider market dynamics when making decisions related to network relationships, as they can have a significant impact on sustainable technological innovation.

Keywords: network relationship selection; network relationship maintenance; network relationship utilization; market dynamics; sustainable technological innovation

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1. Introduction

The trade-war conflict between the United States and China has had a significant impact on the global economy, including areas of technological development and improvement [1]. This trade friction has escalated into a technological competition, with both sides focusing on mid- to high-end manufacturing capability and technological innovation capability [2]. American companies have stopped exporting high-tech products, such as chips, to Chinese companies, which could lead to the disruption of some industrial production chains in China. This further highlights the fact that relying on the high-end manufacturing capacity and technological innovation ability of others is a huge potential risk. According to international market access conditions and the competitive situation, Chinese enterprises should strive to produce products with a high complexity of standards, high technical content, high value-added capability, and low substitutability. For this purpose, Chinese enterprises must break through in terms of core technologies and enhance their technological innovation capabilities, thus enabling them to transition away from their

current role as low-cost and low-tech manufacturers in the field of high-end chip design and manufacturing in the long run. Consequently, Chinese companies have increasingly paid attention to the sustainability and capability of technological innovation. Sustainable technological innovation emphasizes the judicious use of resources, ecological conservation, and socially responsible growth, in contrast to traditional technological advancement, in order to achieve balanced economic and social growth [3]. Sustainable technological innovation entails enterprises launching and executing innovative projects that meet the requirements of economic, social, and ecologically sustainable development over a relatively long period of time, thereby continuing to realize commercialization and gain economic benefits [4]. Consequently, sustainable technological innovation should be directed toward the continual enhancement of an organization's economic strength, technological prowess, and operational scope. The technological evolution process presents a cyclical pattern of alternating continuity and discontinuity. There are both competition-strengthening and competition-destroying discontinuities, the latter of which often has the "creative destruction" effect described by the economist, Joseph Schumpeter [5]. For enterprises to ensure their continued survival and development in the process of technological dynamic evolution, they must continuously invest in technological advancement [6]. Bogers et al. [7] argue that a firm's sustainable technological innovation is largely dependent on its resources and dynamic capacities (i.e., the capability to integrate and utilize existing resources and simultaneously develop new ones). According to resource-based theory, resources possess the following characteristics: (1) they are valuable; (2) they are scarce; (3) they are difficult to replicate; (4) they have causal ambiguity; (5) they are difficult to replace [8,9]. In the context of China's relationship-based society, network relationships, related to the use of the term 'guanxi', satisfy these characteristics, and can be seen as a crucial resource that determines whether or not a company can gain external resources that are beneficial to business development [10]. Some Hong Kong executives have argued that they perceived numerous advantages to having established good guanxi, such as the facilitation of routine business operations, access to information about government policies, and the expediting of administrative approvals [11]. This highlights the value and importance of guanxi in relation to commercial activities. From an economic standpoint, guanxi can be understood through the lens of social capital theory, which suggests that social capital is a resource derived from communal bonds and the cultures that prioritize such connections [12]. By leveraging existing social connections, individuals and businesses can gain access to valuable resources and networks that would otherwise be inaccessible due to a lack of ascribed relationships or natural affiliations [13]. According to social network theory, an enterprise's innovation activities are typically embedded in social networks and are heavily influenced by them [14]. Consequently, more and more enterprises are obtaining external network resources through network relationships, with the aim of gaining innovation advantages and achieving sustainable innovation by actively absorbing and utilizing external network resources. Network relationships provide firms with many resources, including money, investment, knowledge, information, cooperative opportunities, and other nonmaterial support [15]. The strength of a company's dynamic capabilities is reflected in its ability to efficiently integrate and utilize the resources of current partners and further develop new partners through network relationships [16]. According to the transaction cost theory, corporate managers must consider the make-or-buy decision with regard to resource acquisition [17]. For a company, developing a production chain can be time-consuming and costly. Utilizing network relationships to obtain complementary resources can quickly make up for certain technological shortcomings [18]. Studies have indicated that network relationships have a positive impact on sustainable innovation, as they promote companies' cooperation with customers, suppliers, research institutions, universities or colleges, and government departments [19]. Moreover, network relationships built during the early stages of a firm's life cycle are crucial in strengthening a small enterprise's ability for sustainable innovation [20]. Jiang et al. [21] proposed, based on social network theory and upper echelon theory, that inter-firm relationships could promote the form and develop-

ment of technological standards alliances. Managers' inability to obtain the right resources, due to their failure to pay attention to their network relationships, may limit technological innovation [22]. However, Chen et al. [23] argued that strong network relationships could result in over-reliance on partners, which could lead to potential technology leaks and the inefficiency of technological innovation. Zhang et al. [24] suggested that the relationship between the R&D alliance network and innovation performance may be characterized as an inverted U-shape. Nowadays, the link between network relationships and sustainable technological innovation is receiving widespread attention from researchers.

The competition for technological advantage between the United States and China reflects the current challenges of a highly competitive business environment, where innovative products are quickly imitated, technological and product innovation are accelerated, product life cycles are shortened, and the sustainable period of competitive advantage is becoming shorter [25]. Companies such as Motorola, Nokia, and Kodak, which were once successful in technological innovation and have created many significant market-value products, have suffered due to their lack of focus on network relationships and collaborative innovation, as well as because of their inability to generate new products quickly enough to meet market demand [26]. This suggests that market dynamics may be an essential factor influencing network relationships and sustainable technological innovation. However, few studies have focused on the effect of market dynamics when studying the association between network relationships and sustainable technological innovation. Therefore, it is important to investigate whether market dynamics affect this interaction. Additionally, Chinese and Western companies differ significantly in terms of their societal context, industrial environment, management strategy, and unwritten rules [27]. Most of the previous literature has used Western businesses as research samples. It is necessary to confirm whether these conclusions apply to the real situation in China. Based on the above analysis, there is a lack of theoretical and empirical studies on the interaction between network relationships and sustainable technological innovation, as well as the role of market dynamics using Chinese companies as samples. Therefore, this study incorporates network relationships, market dynamics, and sustainable technological innovation into a theoretical framework, based on resource-based theory and dynamic capability theory. We combine theoretical research and empirical analysis to reveal the relationships between the variables and to propose suggestions on how to deal with network relationships during different periods for the improvement and sustainability of technological innovation. The empirical findings of this paper demonstrate that network relationships significantly contribute to sustainable technological innovation. Additionally, we found that market dynamics have a positive moderating effect on the association between network relationships and sustainable technological innovation.

The following parts of this paper will discuss the theoretical basis of this study and the development of hypotheses. Subsequently, the research approach will be illustrated, and the outcomes of the data analysis will be presented. Finally, this paper concludes with a summary of the conclusions, discussions, and implications.

2. Theoretical Analysis and Hypotheses

2.1. Network Relationships

The term "network relationships" refers to the interaction between a company and its partners, including the connections and transactions among them [18,24]. Chen and Chen [28] argued that these relationships encompass a company's forward linkages and transactions (e.g., terminal sales), backward linkages and transactions (e.g., supply and logistics transportation), and collaborative linkages (e.g., strategic cooperation with competitors). From the perspective of resource-based theory, Gulati [29] argued that the intertwined relationships between organizations are an inimitable resource, known as network resources, and that the accumulation and use of social network resources are a guarantee for enterprises to create lasting competitive advantage. It is difficult for competitors to imitate network relationships over a short period due to their causal ambiguity, which

may involve enterprise history, cultural values, managers' preferences, etc. [30]. Relational capital is a type of social capital that is derived from the value of the relationships between individuals, organizations, and networks. It is characterized by trust, shared values, and mutual understanding, and is a key factor in enabling enterprises to gain a competitive edge in terms of market competition [31]. The management of an enterprise is an ongoing effort to achieve objectives while taking into account all forms of capital, including the often-overlooked relational and social capital, to ensure the sustainable success of the enterprise [32]. Granovetter [33] classified network relationships into four dimensions based on relationship strength, including communication time, emotional intensity, intimacy (mutual confiding), and reciprocal services. Cai and Pan [34] argued that the reliability and strength of network relationships can be demonstrated by the length of the cooperative period and the cooperative forms between partners. Mariotti and Delbridge [35] added potential relationships and dormant relationships to the content of network relationships, based on a study by Granovetter [33]. Dang and Xiao [36] considered network relationships as an organizational capability and identified three dimensions of network relationships, including relationship initiation, relationship development, and relationship termination. Building on the process of building and utilizing network relationships, Wang and Xiong [37] divided network relationships into three dimensions: network relationship selection, network relationship maintenance, and network relationship utilization. This study describes network relationships using the model proposed by Wang and Xiong [37].

2.2. Network Relationship Selection and Sustainable Technological Innovation

Network relationship selection is the process by which a firm selects partners based on its selection criteria for specific purposes, such as accessing complementary resources [38]. Criteria for selection include partners' R&D capabilities, reputation, credibility, development diversity, cultural alignment, strategic alignment, the complementarity of resources, etc. [39]. According to the structural hole theory, when a business occupies structural holes, it can successfully select wide and non-redundant network relationships, thereby leveraging these connections to acquire abundant innovative resources and effectively promote sustained technological innovation [40]. Alliance capabilities, such as alliance proactiveness and alliance portfolio coordination, can facilitate sustainable technological innovation [41]. Specifically, alliance proactiveness is mainly associated with the pre-formation stage of development, when firms are actively seeking out new alliance partners. Scherngell and Hu [42] emphasized the importance of selecting appropriate partners and argued that geographical and technological distance between partners influences the generation of interregional collaborative knowledge and technological innovation. Dang and Gong [43] argued that selecting partners with cognitive similarity, institutional affinity, and geographical proximity had a positive effect on interregional innovative cooperation. Sustainable technological innovations are important factors for organizations to achieve further growth that benefits not just the employees but also society [44]. However, selecting the right network relationships for sustainable technological innovation can be difficult, as it is not always possible to find a perfect match between resources [45]. Coviello and Munro [46] conducted a study to investigate the influence of network connections on internationalization processes, using small firms as their sample, and discovered that the appropriate network relationships could propel market growth and foster sustainable innovation. Moorthy and Polley [47] highlighted the finding that sustainable technological innovation is influenced by the breadth and depth of knowledge. To deepen knowledge in a certain field, firms should cooperate with other firms that have expertise in similar technology areas [48]. Mohannak [49] conducted a study of Melbourne firms and discovered that large firms fostered a clustering of professional expertise through their involvement in business activities, research, and teaching, which could create an innovative environment that could indirectly benefit small firms within the same relationship network. However, few studies have focused on the possible consequences of the wrong selection of network relationships. As partners are more likely to access the core technologies of a firm, this

practice may leave its critical knowledge and technology exposed, leading to opportunistic behavior by unscrupulous partners. If the partner firms are competitors in the final product market, this could result in the weakening of competitive advantage and even in the loss of the original market [50]. The choice of network relationships depends on the contrast between the gains from increased mutual trust and the risks posed by opportunistic behaviors [51]. Studies have found that the wrong selection of partners is one of the most significant causes of the failure of cooperative innovation and technology alliances, resulting in higher costs and risks for firms than if they were to proceed alone [52]. Based on the above analysis, this study proposes the following hypothesis:

H1: *Network relationship selection positively affects sustainable technological innovation.*

2.3. Network Relationship Maintenance and Sustainable Technological Innovation

Network relationship maintenance involves following contractual principles and incurring transaction costs to maintain long-term and stable relationships with external organizations [37]. Transaction costs are the costs paid by a firm to establish social relationships with other organizations, such as person-to-person or firm-to-firm relationship costs, which include the costs of disseminating information, negotiating, contracting, and executing contracts [53,54]. The cost of maintaining network relationships is a part of the overall transaction cost [55]. Enterprises' relational capital can help them gain the trust of other organizations, lowering transaction costs, promoting knowledge-sharing, and fostering sustainable innovation [32]. In order to maintain network relationships with outside organizations, a company must gain trust, interaction, and commitment from these organizations, which can provide potential opportunities for collaborative innovation [56]. Relationship ties are strengthened when interactions between companies are frequent, close, reciprocal, and private [33]. Such frequent interactions foster mutual understanding and deepen mutual trust between relationship firms [57]. Trust is known as a moderator of social behavior, as it can reduce opportunistic behavior and promote common standards of reciprocity among partners [58]. When partners have complete trust in each other, they are more likely to exploit entrepreneurial opportunities, as there is less need for monitoring or controlling potential opportunistic behavior and more chances for knowledge-sharing and knowledge transfer [59]. Based on the concept of relational embeddedness, enterprises can build strong social network ties through sustained engagement, thus avoiding isolation from external rivals and ensuring sustainable technological innovation [60]. Maintaining network relationships is beneficial for businesses, enabling them to become familiar with the information of potential trading partners or existing collaborators and helping them to identify opportunities and threats, thus enhancing the success rate of innovation and promoting sustained innovation [56]. It is evident that the maintenance of network relationships is essential for the achievement of sustainable innovation outcomes. This intricate process of forming alliances with external partners enables the integration of social and environmental objectives into the innovation process [61]. Maintaining or abandoning certain network relationships is a management strategy to reduce redundant relationship resources and improve the efficiency of resource utilization, which is a process for enhancing dynamic capability [62]. Enterprises possess non-redundant and heterogeneous network relationships, which can reduce the cost of maintaining redundant connections and help enterprises to efficiently maintain and fully utilize more valuable connections for sustainable technological innovation [63]. Based on the benefit-oriented principle, business managers decide whether to continue relationships with external organizations [64]. Companies tend to adjust their partner structure by retaining more strongly connected inner-circle members and fewer weakly connected network members, thus reducing the cost of maintaining weak and unnecessary relationships with other organizations. As the retained partners are highly compatible with a firm's innovation plan, the firm can learn from and absorb the advanced technology of relationship partners, which can be beneficial for technological and product innovation [65]. Firms have limited budgets to maintain

network relationships with external organizations, and, in order to maximize the benefits of such relationships, they allocate more maintenance costs to partners that contribute more to the network in return for resources enabling technological innovation [66]. Based on the above analysis, this study proposes the following hypothesis:

H2: *Network relationship maintenance positively affects sustainable technological innovation.*

2.4. Network Relationship Utilization and Sustainable Technological Innovation

Network relationship utilization involves companies utilizing the network relationships that they select and maintain to achieve a purpose, such as promoting sustainable technological innovation [37]. These relationships include those with business partners, suppliers, customers, competitors, governments, and agencies [67]. Resource-based theory suggests that resources are essential for firms to gain a competitive advantage [8]. In the context of open innovation, the complexity, uncertainty, and high risk of innovation make it difficult for enterprises to achieve sustained innovation when solely relying on their own knowledge and resources [68]. In the relationship-based system of Chinese society, managers must focus on how to integrate and leverage the resources of external organizations through network relationships [69]. The utilization of relational resources can help enterprises to acquire external network knowledge. Knowledge diversity, as an important indicator of an enterprise's ability to absorb heterogeneous resources, will affect the effectiveness of resource absorption and integration, and thus influence the sustainability of enterprise innovation [70]. Jukka Partanen [71] argues that network relationships help firms overcome the liabilities of newness and smallness and promote sustainable innovation, taking small, technologically innovative firms as examples. Markus Perkmann [72] contends that network relationships, such as research partnerships, contract research, and consulting, are highly valued by firms throughout the entire innovation cycle; firms' expectations for relationship-based collaboration are usually driven by capacity-building and learning motives. Information is an important factor in determining the success or failure of a company's development. By leveraging their network relationships, decision-makers can gain insight into the actions of major competitors, customers' potential needs, and market competition, which can inform the direction of innovation [73]. Sinkula et al. [74] posit that external network utilization can positively influence firms' commitment to learning and the implementation of regular market intelligence activities. This emphasizes the vital role that external networks play in the development of knowledge and the maintenance of sustainable technological innovation within the company, as the acquisition of market information is one of the most extensively researched knowledge-creation mechanisms in the enterprise [75,76]. Baker et al. [77] indicate that companies with fewer and more limited internal resources gain even more from utilizing strong external networks, thus emphasizing the importance of external networks in aiding internal capabilities during the sustainable innovation process. Managers can increase the likelihood of innovation success by exploiting relationships with government officials and becoming familiar with new government policies promptly, enabling them to take advantage of tax benefits and subsidy policies [78]. A popular model of technological development is relationship-based cooperation between enterprises, governments, and research institutions. These entities provide resources, such as investments, laboratories, and data for research institutions to engage in risky innovation behaviors, and sign contracts to purchase the outcomes of their innovation. As an example, the U.S. Food and Drug Administration collaborated with 11 universities to develop a rapid COVID-19 antigen test [79]. Based on the above analysis, this study proposes the following hypothesis:

H3: *Network relationship utilization positively affects sustainable technological innovation.*

2.5. Moderating Effect of Market Dynamics between Network Relationships and Sustainable Technological Innovation

Market dynamics refer to the rate and extent of market demand shifts, the level of market competition, and the difficulty of forecasting the market, including alterations in customer preferences, the emergence of new customers, changes in customer composition, unpredictable customer demand, unpredictable competitors' strategies, increased industry opportunities, changes in government policies, and fluctuations in raw material supply [80]. When markets are dynamic, firms must contend with a fluctuating and unpredictable environment of rapidly advancing technology, varying customer demand, and unstable market structures. This makes it challenging to distinguish the market boundaries, create functional business models, and recognize market participants, including competitors, customers, and suppliers [81]. In such cases, there is an urgent need for firms to continuously innovate their products or services in order to respond to market change, which requires them to identify and meet changing customer needs, expand the boundary of information, and collaborate with other organizations [81]. Studies have demonstrated that sustainable technological innovation is related to network relationships and market dynamics [82,83]. However, few studies have indicated the effect of the interaction between network relationships and market dynamics on sustainable technological innovation. In a stable market environment, firms focus on the continuous use of established technologies and simply maintain their current business operations [84]. At that point, the advantages generated by network relationships in which a firm has invested significantly are not significant compared to those of its competitors [85]. Superfluous network relationships can incur high transaction costs that often outweigh the potential benefits of alliances [86]. It is unwise to over-maintain network relationships with redundant organizations when they have little value. In highly dynamic markets, a company's existing market advantages may vanish as new products emerge [87]. Firms that adopt innovative activities before their competitors do so can adjust their products and services early, thus preserving or strengthening their competitive advantage. In dynamic environments, firms can gain greater advantages from network relationships than from stable ones [88]. Controlling resources gives a company the opportunity to control the market or alter the competitive landscape [89]. The selection of network relationships can determine whether a company can acquire and integrate external resources in dynamic market environments [69]. Complementary partners can make up for resource deficiencies and enable the rapid production of new products to capture the market [90]. In the process of maintaining network relationships, partner firms build mutual trust and come to an agreement on corporate values. When facing highly dynamic market environments, they can quickly form stable business alliances to respond to market challenges, thus improving the efficiency of collaborative innovation [91]. Leveraging network relationships to gain financial support, faster information, and technological cooperation from outside organizations can give a company a significant advantage in terms of sustainable technological innovation and competition in dynamic markets [92]. As new competitors enter the market, monopolies are increasingly valuing customer needs and product creativity, fostering inter-firm cooperation, and encouraging innovative behaviors [93]. Firms with strong network relationships are more likely to engage in knowledge-sharing, exchange, and integration, which boosts their chances of innovating and gaining a competitive edge [94]. Zhang et al. [95] hypothesized that the indirect effects of business and political ties on innovation performance are more pronounced in dynamic environments, and their results supported this hypothesis. Bai and Ding [96] conducted an empirical analysis with a sample of high-tech firms in eastern China and found that market dynamics positively moderated the relationship between network capabilities and exploratory innovation. The highly dynamic market environment effectively stimulates enterprises to actively seek out relationship-based cooperation to research and develop new technologies [88]. However, some studies have come to different conclusions. To cope with this dynamic market environment, companies leverage network relationships to undertake more innovative, forward-looking, and risky activities; however,

dispersed resources make it more difficult for these companies to implement exploitative innovation and maintain their existing business [97]. The resource consumption resulting from maintaining network relationships weakens the regeneration and adjustment capability of the organizational structure, thus negatively impacting sustainable technological innovation [98]. In conclusion, most studies have shown that the more dynamic the market, the greater the impact of network relationships on sustainable technological innovation. Based on the above analysis, the following hypotheses are proposed:

H4: *Market dynamics strengthen the positive association between network relationship selection and sustainable technological innovation*.

H5: *Market dynamics strengthen the positive association between network relationship maintenance and sustainable technological innovation*.

H6: *Market dynamics strengthen the positive association between network relationship utilization and sustainable technological innovation*.

3. Methodology

3.1. Sample and Data Collection

China's technology industry is a knowledge- and technology-intensive sector with high product-added value and great growth potential, which is concentrated in urban cities. This study focuses on sustainable technological innovation; thus, we use China's technology firms as a representation of empirical research, as they are based on significant technological advancements and development requirements. In China, the majority of technology companies, such as those in the machinery and equipment manufacturing, electronics, biopharmaceuticals, and new materials industries, are knowledge- and technology-intensive and possess strong growth potential and all-around advantages. These companies create products and offer services with high levels of added value and technology and play a significant role in the country's long-term economic and social development. We used a purposive sampling method to select sample companies for this study from technology companies in urban cities in China. We estimated the population of technology enterprises, using the data collected from the China Stock Market and Accounting Research Database. Additionally, this database provided us with details about each firm's location, main business, income, financial performance, firm size, and age. Approximately 400 companies were identified through a broad range of research processes. We eliminated micro-businesses that lacked innovation activities, in accordance with the final goal of our study and the suggestions from our panel of experts, resulting in a final list of 320 companies. The questionnaire was mainly completed by members of the executive board, heads of R&D, and R&D project leaders who had worked in technology companies for more than two years. They had a clear understanding of company operations, technological innovation, organizational behaviors, and market dynamics, as well as a full awareness of the variables involved in the questionnaire, which ensured that the data collected was reliable. In this study, questionnaires were distributed through three channels: distributing them to companies at product exhibitions, contacting managers through social relationships or following recommendations from friends, and inviting managers to fill out the questionnaires online via invitations using emails found on the companies' official websites. From June to December 2022, 320 copies of the questionnaire were distributed and 273 completed surveys were returned, representing a response rate of 85.31%. After evaluating the statistical accuracy of the completed surveys and discarding those deemed invalid (due to a considerable amount of missing data or invalid patterns of response), a total of 208 valid responses were obtained, yielding an efficiency rate of 76.19%. Of the enterprises surveyed, 33.65% were small (fewer than 300 employees), 53.37% were medium (301–2000 employees), and 12.99% were large (more than 2000 employees). In total, 93.75% of the enterprises were over three years old, and 50.96% were state-owned. The cities

where the sample companies were located mainly included Shanghai, Nanning, Huizhou, Taizhou, and Guangzhou. The majority of respondents (81.25%) were R&D project leaders, 13.94% were heads of R&D, and 4.81% were members of the executive board. To examine non-response bias, a comparison of early and late responders was conducted, with the results of the *t*-tests revealing no systematic differences between the two groups ($p > 0.05$). Additionally, Harman's single-factor test was used to test for common method variance, with the total explanatory power of the factors reaching 73.41%. The first factor explained only 32.68% (less than 40%) of the variance, suggesting that there was no major common method bias issue in the sample. The demographic characteristics of the respondents are outlined in Table 1.

Table 1. Sample characteristics distribution of the respondents who returned questionnaires.

	Sample	**Percentage**		**Sample**	**Percentage**
Firm size			Firm age (years)		
≤300	70	33.65%	1∼2	13	6.25%
301∼2000	111	53.37%	3∼5	61	29.33%
≥2001	27	12.98%	6∼10	62	29.80%
Position of respondent			11∼20	39	18.75%
Member of executive board	10	4.81%	≥21	33	15.87%
Head of R&D	29	13.94%	Age of respondent		
R&D project leader	169	81.25%	≤30	97	46.63%
City			31∼40	83	39.90%
Shanghai	53	25.48%	41∼50	23	11.07%
Nanning	51	24.52%	51∼60	5	2.40%
Huizhou	46	22.12%	≥61	0	0.00%
Taizhou	40	19.23%	Ownership		
Guangzhou	12	5.77%	State-owned	106	50.96%
Other	6	2.88%	Non-state-owned	102	49.04%

3.2. Measurement

Survey items were derived from existing mature scales, both domestically and internationally, and were slightly modified based on feedback and expert opinions (as shown in Table 2).

The scale of network relationship selection mainly draws on the research results of Tsou et al. [99], which were measured using five items. The test items for each respondent include: (1) we choose business partners based on their capacity to sustainably manage working conditions; (2) we choose business partners for their proficiency in conducting competitive analysis, formulating strategies, and collaborating on the development of new products or services; (3) we select business partners because they have cooperative exchange behaviors for mutual gain; (4) we choose business partners based on their alignment with our goals; (5) we choose business partners that are compatible with our technical capabilities.

The scale of network relationship maintenance, measured using five items, draws heavily on the findings of Mu et al. [57] and Wang and Xiong [37]. The test items for each respondent include: (1) my company and partners both have faith in each other's capacity to meet contractual obligations; (2) my company and partners will not exploit each other's vulnerabilities to gain unfair advantages; (3) my company and partners have jointly invested a considerable amount of R&D funds, technologies, and personnel in the course of collaboration; (4) when a disagreement between my company and partners arises, senior executives take part in resolving the dispute, and both sides are devoted to enhancing the cooperative relationship; (5) my company and partners often communicate with each other in both formal and informal ways, and both sides can precisely transmit and comprehend information.

The scale of network relationship utilization draws heavily on the findings of Park and Luo [91] and Long [100] and was measured using six items. The test items for each respondent include: (1) my firm has utilized network relationships with buyers; (2) my firm has utilized network relationships with suppliers; (3) my firm has utilized network relationships with competitors; (4) my firm has utilized network relationships with various levels of political governments; (5) my firm has utilized network relationships with industrial authorities; (6) my firm has leveraged its network of connections with various government entities, including taxation offices, banks, industrial and commercial administrative offices, and similar organizations.

The scale of market dynamics mainly refers to the research results of Pae et al. [101] and was measured by four items. The test items for each respondent include: (1) the product preferences of our customers are subject to frequent changes; (2) new customers often have distinct product-related requirements compared to our existing customers; (3) our customers are constantly seeking out new products; (4) we are witnessing demand for our products and services from customers who have not previously purchased them.

Despite the fact that research on the indicator system of sustainable technological innovation has attracted the attention of many scholars, there is currently no unified standard for the indicator system of sustainable technological innovation. Most studies are constructed on the basis of the researchers' personal comprehension of sustainable technological advancement. Some researchers have proposed that sustainable technological innovation is a dynamic process that involves multiple stages [102]. They have suggested that the process can be broken down into distinct stages, each of which can be evaluated for its capacity to contribute to the overall process. The proponents of the process view typically employ production capability, technology capability, innovation efficiency, continuity, marketing capability, and output capability indicators as the primary metrics for assessing sustainable technological innovation [103–106]. Scholars have explored the driving forces of sustainable technological innovation, based on the motivation of achieving sustainable development goals. It has been suggested that the potential for increased profits and sustained growth were the primary drivers for businesses to invest in sustainable technological innovation. Some researchers have identified knowledge sustainability, production sustainability, and market sustainability as the key indicators of sustainable technological innovation [107]. This study mainly measures sustainable technological innovation in terms of technology capability, innovation efficiency, and output capability. The scale of sustainable technological innovation, comprising four items, is primarily based on the research findings of Donbesuur et al. [108], Shao Chunyan [104], Vacchi et al. [103], Chen [106], and Xu et al. [109]. The test items for each respondent include: (1) compared to other enterprises in the same industry, my company has developed a greater number of new products and services over an extended period of time; (2) compared to other enterprises in the same industry, my company has developed a greater number of new technologies over an extended period of time; (3) compared to other enterprises in the same industry, my company has had a larger proportion of sales of new products (or services) to total sales over an extended period of time; (4) compared to other enterprises in the same industry, my company has been launching new products (or services) more quickly over an extended period of time.

The variables in this study were analyzed and measured using a five-point Likert scale, with numbers ranging from "1" (strongly dissatisfied) to "5" (strongly satisfied), indicating the respondent's level of acceptance of a particular item. Previous studies have demonstrated that multiple factors have a comprehensive effect on sustainable technological innovation. Company size and age are important control variables that can influence a firm's innovation performance, potentially leading to different outcomes. For instance, larger companies may have more resources and greater experience than smaller ones, while older companies may have greater experience and more resources than newer ones. Controlling for these variables can help researchers better understand the effects of other factors on outcomes [110]. Therefore, company age and size were taken into account as control variables to reduce their influence on the findings and to emphasize the various variables

affecting sustainable technological innovation in the proposed theoretical model. Company age was measured based on the period since the firm's establishment, and company size was measured according to the current number of employees, which is a common approach used in existing studies [111].

Table 2. Measurement scales.

	Factor Loading	CR	AVE	Cronbach's α
Network relationship selection				
We choose business partners based on their capacity to sustainably manage working conditions	0.874	0.918	0.691	0.917
We choose business partners for their proficiency in conducting competitive analysis, formulating strategies, and collaborating on the development of new products or services	0.802			
We select business partners because they have cooperative exchange behaviors for mutual gain	0.785			
We choose business partners based on their alignment with our goals	0.864			
We choose business partners that are compatible with our technical capabilities	0.828			
Network relationship maintenance				
My company and partners both have faith in each other's capacity to meet contractual obligations	0.786	0.910	0.669	0.910
My company and partners will not exploit each other's vulnerabilities to gain unfair advantages	0.817			
My company and partners have jointly invested a considerable amount of R&D funds, technologies, and personnel in the course of collaboration	0.832			
When a disagreement between my company and partners arises, senior executives take part in resolving the dispute, and both sides are devoted to enhancing the cooperative relationship	0.841			
My company and partners often communicate with each other in both formal and informal ways, and both sides can precisely transmit and comprehend information	0.813			
Network relationship utilization				
My firm has utilized network relationships with buyers	0.789	0.894	0.584	0.894
My firm has utilized network relationships with suppliers	0.744			
My firm has utilized network relationships with competitors	0.792			
My firm has utilized network relationships with various levels of political governments	0.782			
My firm has utilized network relationships with industrial authorities	0.742			
My firm has leveraged its network of connections with various government entities, including taxation offices, banks, industrial and commercial administrative offices, and similar organizations	0.734			
Market dynamics				
The product preferences of our customers are subject to frequent changes	0.793	0.891	0.673	0.891
New customers often have distinct product-related requirements compared to our existing customers	0.823			
Our customers are constantly seeking out new products	0.860			
We are witnessing demand for our products and services from customers who have not previously purchased them	0.803			
Sustainable technological innovation				
Compared to other enterprises in the same industry, my company has developed a greater number of new products and services over an extended period of time	0.941	0.959	0.852	0.957

Table 2. *Cont.*

	Factor Loading	CR	AVE	Cronbach's α
Compared to other enterprises in the same industry, my company has developed a greater number of new technologies over an extended period of time	0.951			
Compared to other enterprises in the same industry, my company has had a larger proportion of sales of new products (or services) to total sales over an extended period of time	0.936			
Compared to other enterprises in the same industry, my company has been launching new products (or services) more quickly over an extended period of time	0.863			

3.3. Reliability and Validity

This study used the statistical analysis software SPSS20.0 and AMOS24.0 to measure the reliability and validity of each item for the variables in the theoretical model (Table 2). The results showed that Cronbach's α of all scales exceeded 0.8 and the CITC values of all items were greater than 0.35, indicating that the reliability of the scales was good. Furthermore, the validity of each item was tested, and the variance contribution of each item was examined via principal component analysis. Confirmatory factor analysis (CFA), based on a pre-test for small-sample data, was conducted on the large-sample data for validity testing. The loadings of items of each variable ranged from 0.734 to 0.951. The composite reliability (CR) of the scales of network relationship selection, network relationship maintenance, and network relationship utilization was 0.918, 0.910, and 0.894, respectively, with the average variance extracted (AVE) being 0.691, 0.669, and 0.584, respectively. The composite reliability and the average variance extracted from the market dynamics scale were 0.891 and 0.673, respectively. The composite reliability and the average variance extracted from the sustainable technological innovation scale were 0.959 and 0.852, respectively. The results demonstrated that the items had good convergent validity [112]. The AVE method was employed to evaluate the discriminant validity of the model (Table 3). The results indicated that the square root values of the average variance extracted for each variable were higher than the Pearson correlation coefficient, suggesting that the model had good discriminant validity [113].

Table 3. Descriptive statistics and correlation coefficients.

Variables	Mean	SD	Correlation				
			1	2	3	4	5
Network relationship selection	3.242	0.529	**0.831**				
Network relationship maintenance	3.231	0.399	0.133	**0.818**			
Network relationship utilization	3.255	0.396	0.315 **	0.078	**0.764**		
Market dynamics	3.022	0.562	0.016	−0.004	0.046	**0.820**	
Sustainable technological innovation	2.157	0.848	0.459 **	0.495 **	0.489 **	0.551 **	**0.923**

** $p < 0.01$; The bold number in the diagonal position is the square root of average variance extracted (AVE), and the others are the Pearson correlation coefficients.

4. Analysis and Results

This study examined several commonly used indicators of fit ($\chi 2/df = 1.149 < 3$, NFI = 0.911 > 0.9, IFI = 0.987 > 0.9, TLI = 0.984 > 0.9, CFI = 0.987 > 0.9, and EMSEA = 0.027 < 0.05), which demonstrated an acceptable model fit.

Hierarchical regression analysis is a powerful tool for understanding the relationships between variables. It enables researchers to identify the relative importance of each predictor variable and to determine the overall effect of the predictors on the outcome. Moreover, it allows researchers to control for the effects of other variables, and to detect interactions between variables. Hierarchical regression analysis was then conducted to further examine

the hypotheses; the results are reported in Table 4. Model 1 showed the effects of control variables on the dependent variable (sustainable technological innovation). The main predictors (network relationship selection, network relationship maintenance, and network relationship utilization) were entered in Model 2, while the moderator (market dynamics) was entered in Model 3. The interactions between the independent variables (network relationship selection, network relationship maintenance, and network relationship utilization) and the moderator (market dynamics) were entered in Model 4, and the interactions were mean-centered to reduce multicollinearity. The variance inflation factors were calculated to assess the possibility of multicollinearity, and the results were within the acceptable range (1.045 to 1.243, < 10), thus indicating that no multicollinearity among the variables.

Model 1 showed that company age had a significantly positive impact on sustainable technological innovation, whereas company size did not. Hypotheses 1, 2, and 3 predicted that network relationship selection, network relationship maintenance, and network relationship utilization would have a positive relationship with sustainable technological innovation, respectively. Model 2 supported these hypotheses, revealing that network relationship selection, network relationship maintenance, and network relationship utilization had a positive relationship with sustainable technological innovation ($\beta1 = 0.287$, $p < 0.01$; $\beta2 = 0.429$, $p < 0.01$; $\beta3 = 0.365$, $p < 0.01$). Compared to Model 1, R^2 of Model 2 increased ($\Delta R^2 = 0.501$, $p < 0.01$), indicating that the total variance explained was improved and the fitting effect was better after adding the independent variables. According to the *t*-values in the results, network relationship maintenance had the most significant positive effect on sustainable technological innovation, followed by network relationship utilization, and finally, network relationship selection. Model 3 showed the change of R^2 after adding market dynamics. Compared to Model 2, R^2 of Model 3 increased ($\Delta R^2 = 0.287$, $p < 0.01$), indicating that the total variance explained was improved and the fitting effect was better after adding the moderating variable. Hypotheses 4, 5, and 6 predicted that market dynamics would strengthen the positive association between sustainable technological innovation and network relationship selection, network relationship maintenance, and network relationship utilization. Based on Model 3, Model 4 was augmented with the interaction terms of network relationship selection and market dynamics, network relationship maintenance and market dynamics, and network relationship utilization and market dynamics. Compared to Model 3, R^2 of Model 4 increased ($\Delta R^2 = 0.031$, $p < 0.05$), indicating that the total variance explained was improved and the fitting effect was better after adding the interaction terms. The results of Model 4 supported Hypotheses 4, 5, and 6, showing that market dynamics strengthened the positive association between network relationship selection and sustainable technological innovation, strengthened the positive association between network relationship maintenance and sustainable technological innovation, and strengthened the positive association between network relationship utilization and sustainable technological innovation ($\beta1 = 0.080$, $p < 0.05$; $\beta2 = 0.069$, $p < 0.05$; $\beta3 = 0.105$, $p < 0.05$). Furthermore, our results also showed that the impact of network relationships on sustainable technological innovation varied at different levels of market dynamics. To visually demonstrate the roles of different levels of market dynamics, we plotted the results based on the results. As shown in Figures 1–3, when the level of market dynamics is high (one standard deviation above the mean), network relationship selection (simple slope = 1.112, $p < 0.001$), network relationship maintenance (simple slope = 1.584, $p < 0.001$), and network relationship utilization (simple slope = 1.615, $p < 0.001$) have a significant positive predictive effect on sustainable technological innovation. However, when the level of market dynamics is low (one standard deviation below the mean), network relationship selection (simple slope = 0.713, $p < 0.001$), network relationship maintenance (simple slope = 1.020, $p < 0.001$) and network relationship utilization (simple slope = 0.956, $p < 0.001$) also have a positive predictive effect on sustainable technological innovation, but the predictive effect is smaller. To ensure the accuracy of the results, this research conducted an analysis of the marginal effect of network relationships across the range of values of market dynamics to assess its statistical significance [114]. As shown in Figure 4, market dynamics positively

moderate the association between network relationship selection and sustainable technological innovation. The marginal effect of network relationship selection on sustainable technological innovation reveals that as the intensity of market dynamics increases, the positive predictive effect of network relationship selection on sustainable technological innovation also increases. The results of Figure 5 indicate that market dynamics have a positive influence on the association between network relationship maintenance and sustainable technological innovation. The marginal effect of network relationship maintenance on sustainable technological innovation reveals that as the intensity of market dynamics increases, the positive predictive effect of network relationship maintenance on sustainable technological innovation also increases. According to the results of Figure 6, it can be concluded that, in general, market dynamics have a positive effect on the association between network relationship utilization and sustainable technological innovation. However, when the level of market dynamics is relatively low (less than 2.5), the positive effect of network relationship utilization on sustainable technological innovation is not statistically significant. When the level of market dynamics is relatively high (greater than or equal to 2.5), the positive effect of network relationship utilization on sustainable technological innovation increases with the increasing intensity of market dynamics.

Table 4. Results of hierarchical linear regression analysis for sustainable technological innovation.

Dependent Variable Sustainable Technological Innovation	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Control variables				
Company size	−0.034(−0.457)	0.004(0.076)	0.041(1.233)	0.060(1.910) *
Company age	0.154(2.062) **	−0.002(−0.030)	0.037(1.082)	0.022(0.700)
Independent variables				
Network relationship selection		0.287(5.545) ***	0.281(8.570) ***	0.297(9.751) ***
Network relationship maintenance		0.429(8.685) ***	0.433(13.850) ***	0.414(14.262) ***
Network relationship utilization		0.365(7.045) ***	0.332(10.097) ***	0.326(10.708) ***
Market dynamics			0.540(17.394) ***	0.547(18.823) ***
Interaction between variables				
Network relationship selection × Market dynamics				0.080(2.604) **
Network relationship maintenance × Market dynamics				0.069(2.328) **
Network relationship utilization × Market dynamics				0.105(3.433) **
Adjusted R^2	0.011	0.511	0.804	0.833
$\triangle R^2$	0.021	0.501	0.287	0.031
$\triangle F$	2.187	70.683 ***	302.540 ***	12.73 ***

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, ***$p < 0.01$.

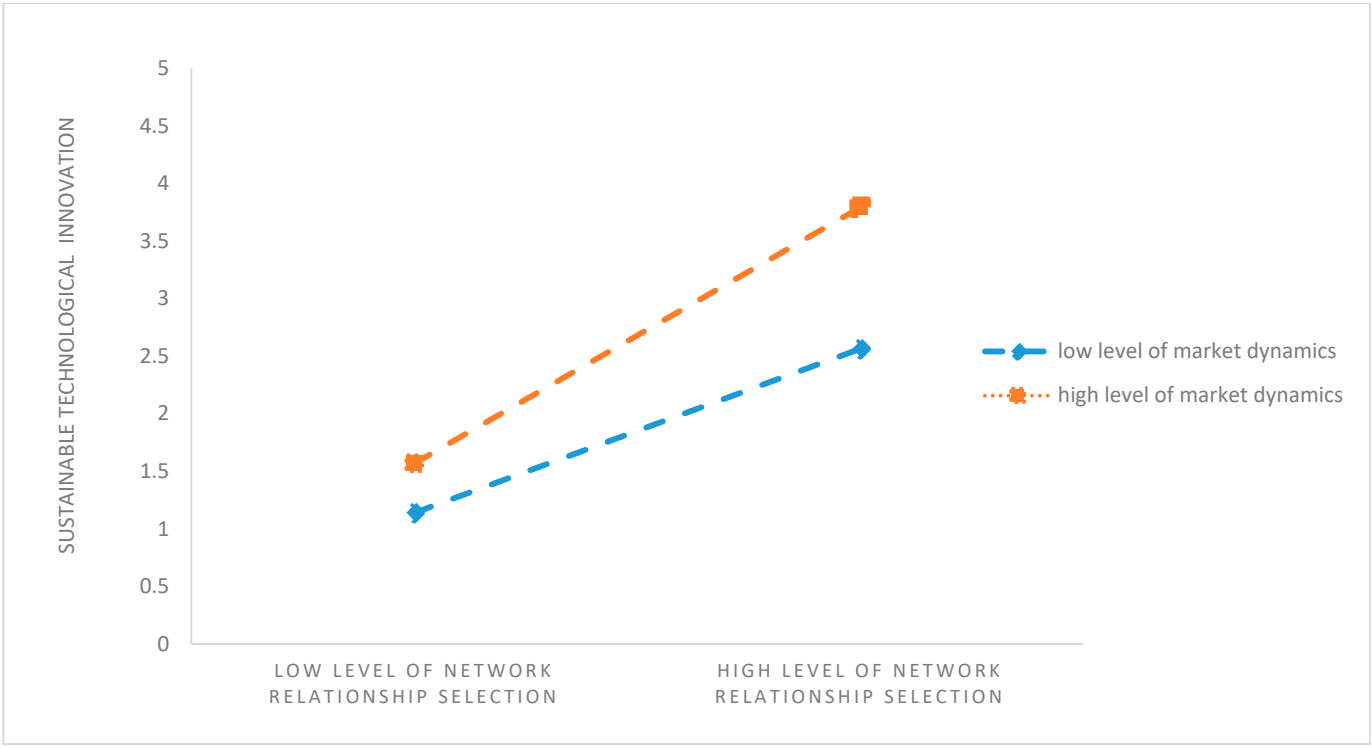

Figure 1. The moderating effect of market dynamics on the association between network relationship selection and sustainable technological innovation.

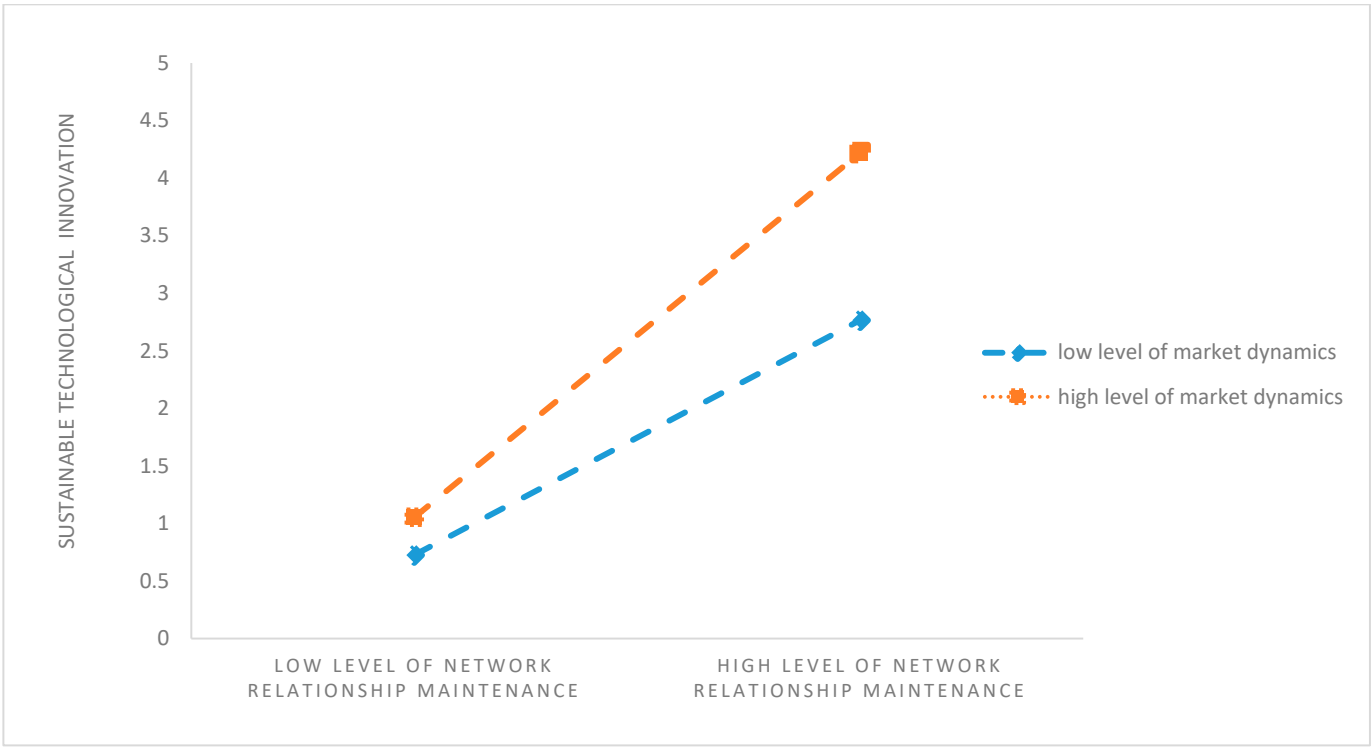

Figure 2. The moderating effect of market dynamics on the association between network relationship maintenance and sustainable technological innovation.

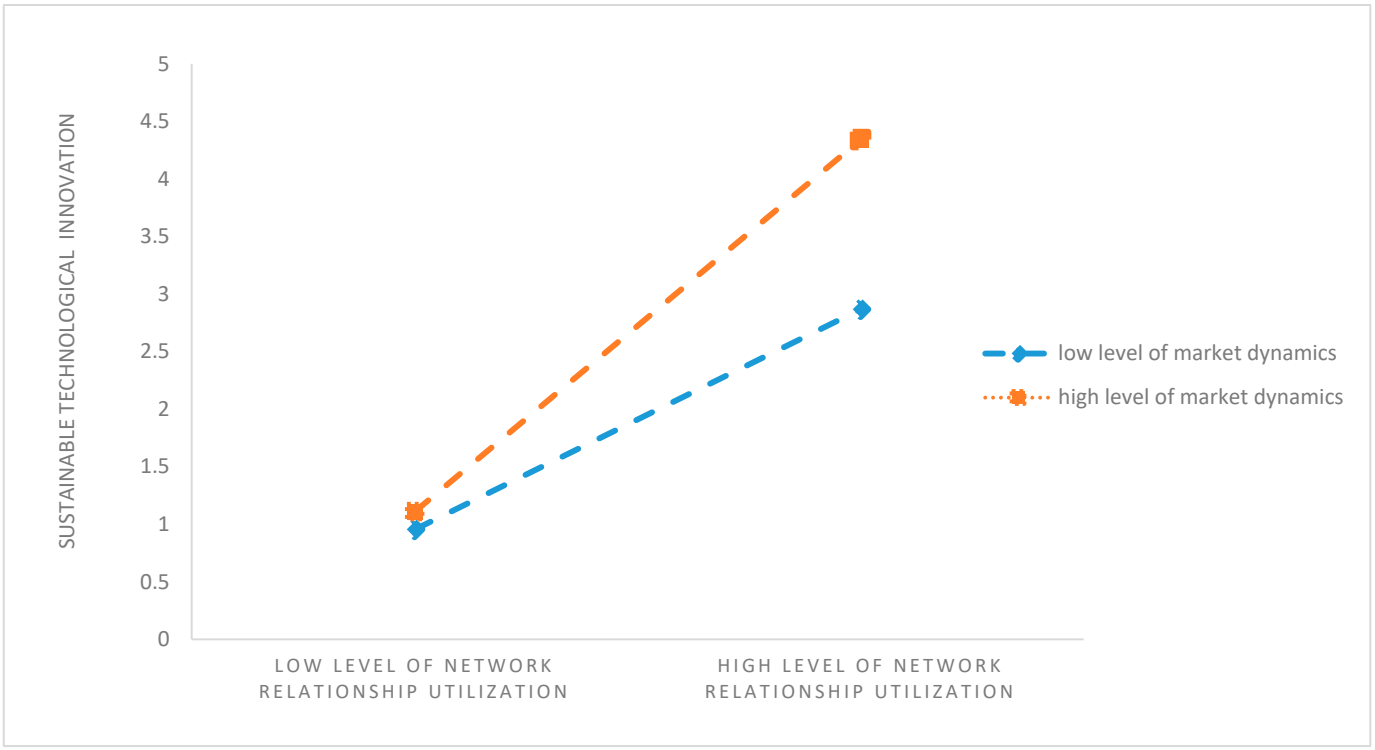

Figure 3. The moderating effect of market dynamics on the association between network relationship utilization and sustainable technological innovation.

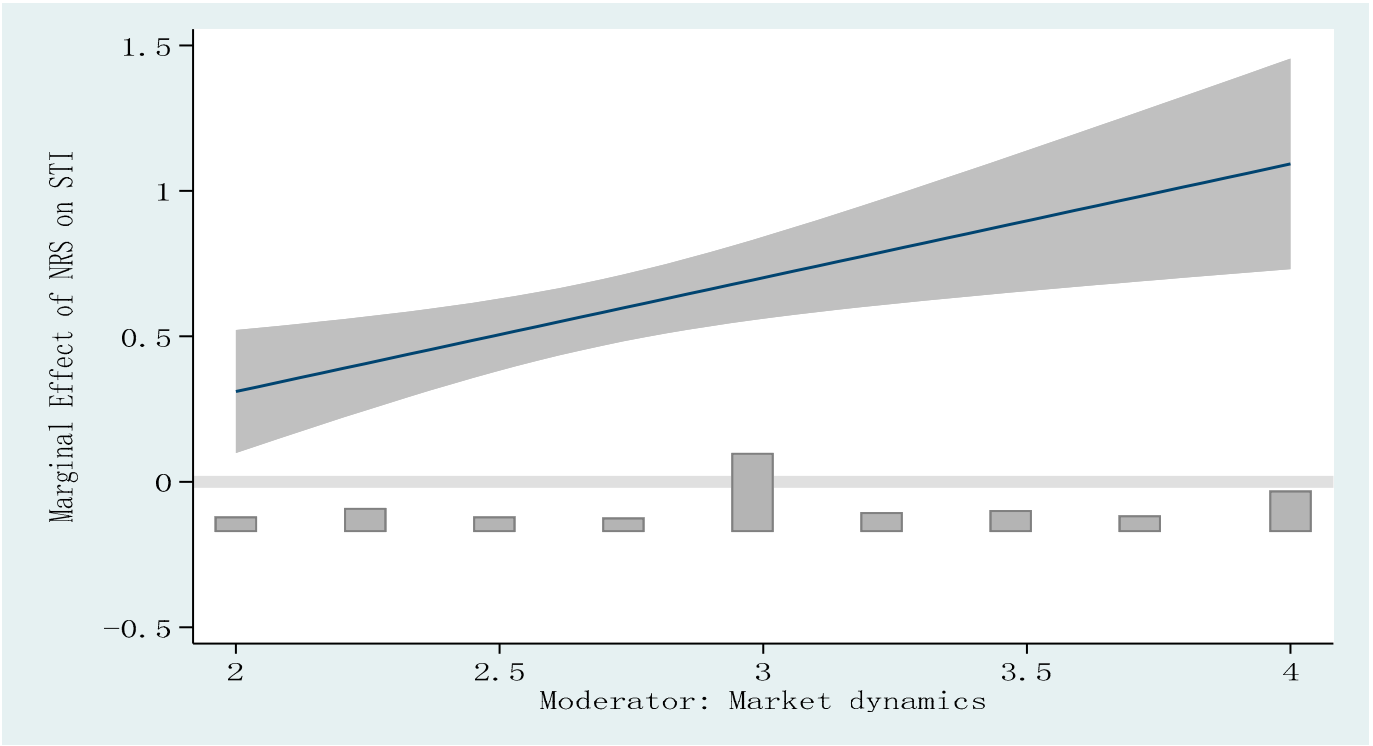

Figure 4. The marginal effect of NRS on STI at different levels of market dynamics. Note: NRS: network relationship selection; STI: sustainable technological innovation.

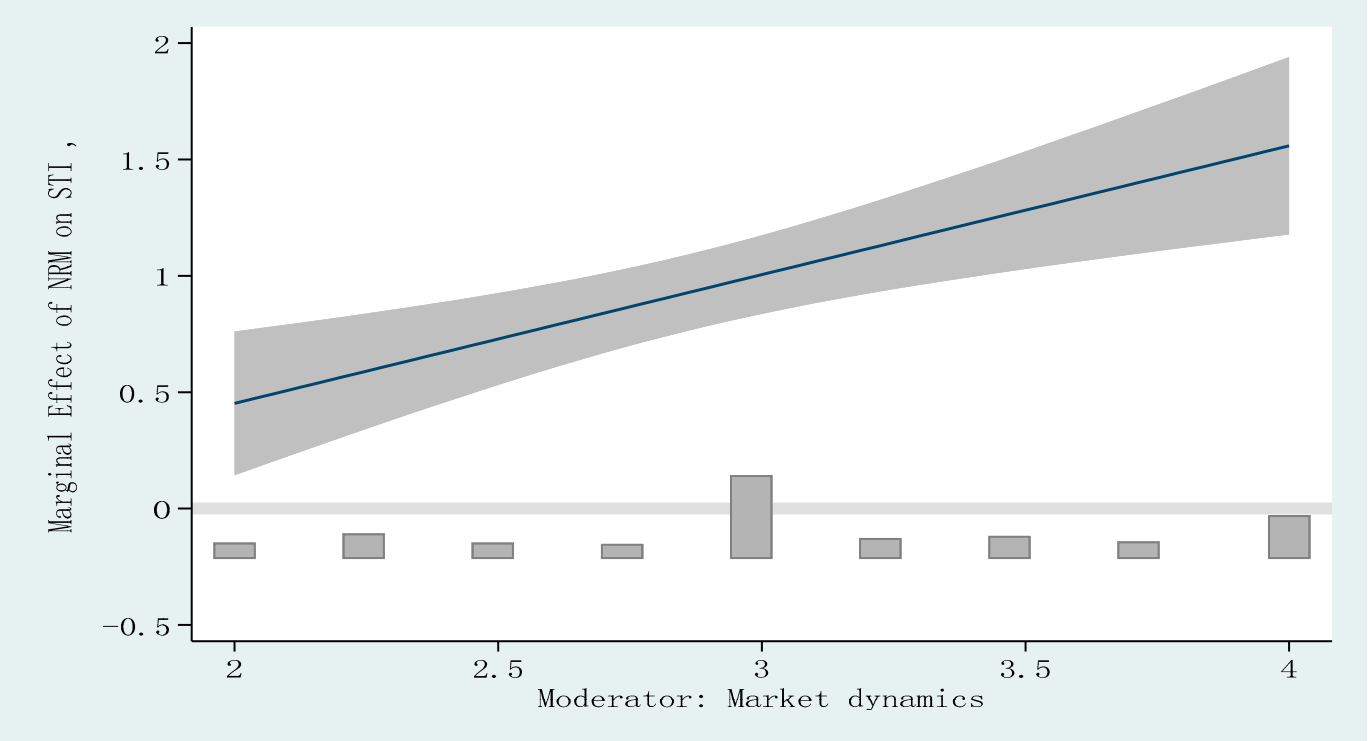

Figure 5. The marginal effect of NRM on STI at different levels of market dynamics. Note: NRM: network relationship maintenance; STI: sustainable technological innovation.

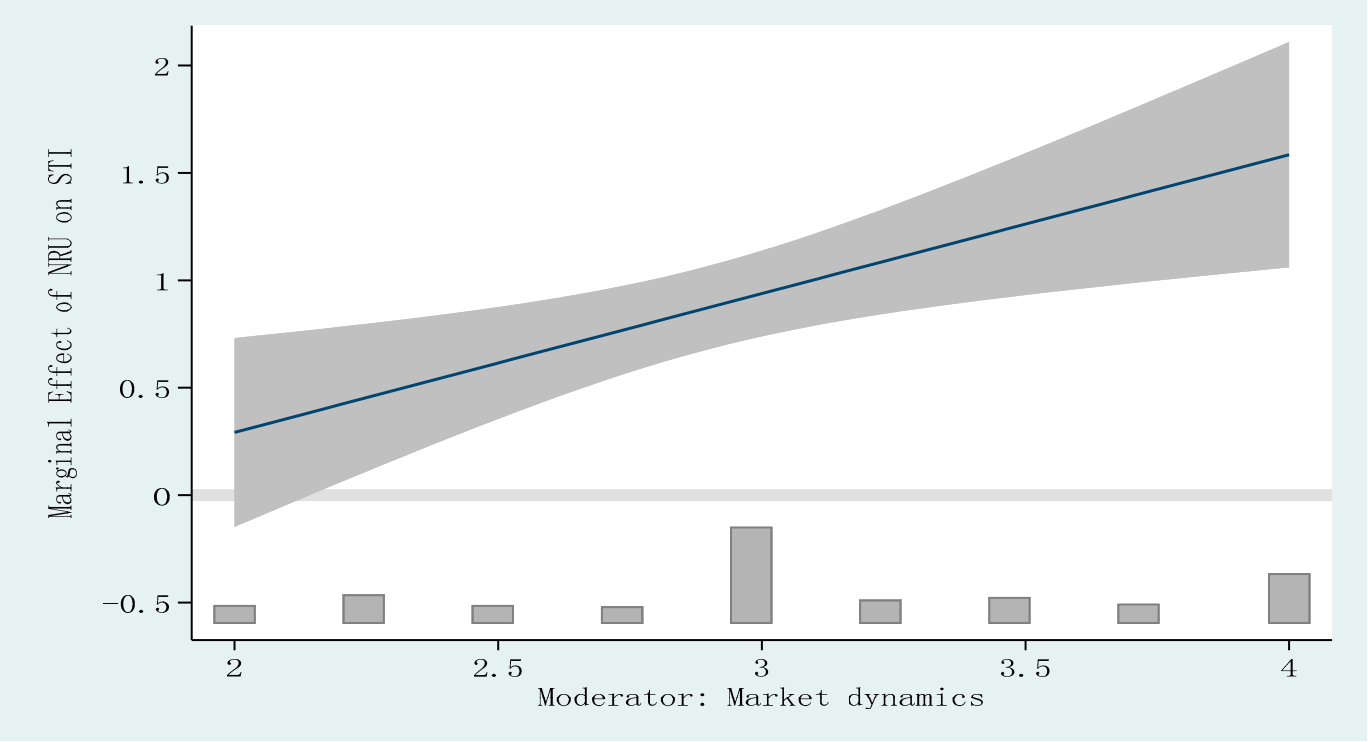

Figure 6. The marginal effect of NRU on STI at different levels of market dynamics. Note: NRU: network relationship utilization; STI: sustainable technological innovation.

5. Discussion

In recent years, network relationships have become increasingly important for businesses in order to accelerate innovation and bolster competitiveness. However, there is still debate as to whether network relationships have a positive effect on sustainable technological innovation. Additionally, some studies have suggested that market dynamics may be a significant factor influencing network relationships and sustainable technological innovation [82,115]. Our results indicate that network relationship selection, network relationship maintenance, and network relationship utilization have a positive correlation with sustainable technological innovation ($\beta 1 = 0.287$, $p < 0.01$; $\beta 2 = 0.429$, $p < 0.01$; $\beta 3 = 0.365$, $p < 0.01$). This is in line with the findings of other studies [37,116]. Network relationship selection is a process of adjusting external organization structures to acquire resources [51]. Expanding corporate networks and accessing complementary resources are the key objectives of network relationship selection [117]. After forming network relationships with the right partners, firms incur relatively low costs to maintain partnerships and to save the costs of seeking new partner firms and trial costs [118]. Network relationship maintenance increases the likelihood of firms gaining the commitment and trust of other firms, which lays the groundwork for collaborative innovation [119]. However, maintaining redundant and unnecessary network relationships may require companies to invest a great deal of money and time for little reward, so discretion in terms of the management of network relationships is essential. Network relationship utilization means that a firm can use its network relationships to acquire needed resources, such as investment, information, knowledge, and technology. The effective use of network relationships to access, integrate, and leverage external resources is one of the key drivers of sustainable technological innovation [120].

The results of this study show that the interaction coefficients between network relationship selection, maintenance, and utilization and market dynamics regarding sustainable technological innovation are 0.080 ($p < 0.05$), 0.069 ($p < 0.05$), and 0.105 ($p < 0.05$), respectively, indicating that market dynamics strengthen the positive effect of network relationships in terms of sustainable technological innovation. In highly dynamic markets, firms encounter both opportunities, such as launching new products and monopolizing the market, and also challenges, such as the entry of new rivals and technological bottlenecks [120]. Network relationships can be of great value during such periods, providing firms with the opportunity to gain the required resources to ensure the sustainability of technological innovation and thus alter the competitive landscape [89]. Thus, managers should pay sufficient attention to network relationships in highly dynamic markets, particularly when seeking new partners that match a company's development direction [88]. However, managers should be wary of selecting new network relationships with an eagerness for quick success and instant benefits, as this usually leads to bad results and high costs [91]. Long-term and trust-based network relationships are more conducive to cooperative innovation development than short-term and unstable ones. Maintaining or relinquishing certain network relationships implies that a firm can implement revised enterprise strategies and reconfigure existing resources and technologies, which could be beneficial to sustainable technological innovation [121]. By utilizing network relationships, firms can break away from their knowledge and experience inertia, gaining access to advanced knowledge and technology from outside organizations [122]. The more highly dynamic the market is, the more effectively network relationships can reduce the complexity and uncertainty inherent in innovation [123].

In summary, when a market is less dynamic, it is wise for a firm to maintain its original network relationships and technologies to support existing business operations. However, when a market is highly dynamic, rich network relationships can promote sustainable technological innovation through knowledge exchange, information transfer, the provision of cooperation opportunities, etc. Corporate decision-makers with limited time and effort should prioritize network relationship maintenance and utilization, balancing partner selection and cost control to improve resource utilization and ensure the sustainability of technological innovation.

6. Conclusions

This study clarifies the role that the network relationship has regarding the impact of sustainable technological innovations. Further studies can implement such research in their own regions to further improve overall sustainable technological innovations. This study highlights not only the effect of network relationships and market dynamics but also their significant contributions to sustainable technological innovation. Drawing from the perspectives of resource-based theory and dynamic capability theory, this study examines the impact of network relationship selection, network relationship maintenance, and network relationship utilization on sustainable technological innovation, as well as the role of market dynamics in the interaction between network relationships and sustainable technological innovation. The main findings are as follows.

Firstly, the results show that network relationship selection, network relationship maintenance, and network relationship utilization, as the three dimensions of network relationships, have a significant positive impact on sustainable technological innovation, which is in line with previous research findings [33,95]. Based on our own findings, when competing with foreign companies in the field of high-tech products, especially when encountering technological blockades, Chinese enterprises should prioritize seeking cooperation from organizations based on network relationships. For example, in the face of a chip shortage, the Chinese Academy of Sciences, Ali, and ZTE leveraged the advantages of their respective resources (talents, funding, and machine tools) to break through the technological bottleneck in the development of chips and achieved sustainable technological innovation [124]. There are also many successful cases of university-enterprise and government-enterprise cooperation, such as the development of the COVID-19 vaccine by the Chinese government and Sinopharm [125] and the cultivation of new energy talents by the Shanghai University of Electric Power and Tesla [126]. When dealing with various network relationships, managers should carefully assess and screen network relationships that are beneficial to enterprise innovation [88]. Based on our findings, managers should focus on selecting partners with strong R&D capabilities, as indicated by the number of R&D talents, the number of new technologies, and R&D investment. From the perspectives of R&D cost and urgency, it is wise to choose a partner with complementary technology to improve the efficiency of technology utilization and reduce technology cooperation costs. Collaborative alliances between a variety of stakeholders can supply the essential complementary knowledge and capabilities to integrate social and environmental objectives into the sustainable innovation process. As these partnerships often bring together conflicting interests in the value-creation process, network relationships have the potential to promote sustainability [127]. To maintain network relationships, managers should regularly organize formal or informal communication activities with partners, such as joint training, business exchange, organizational learning, and corporate culture exchange, to create a good inter-firm relationship. Network relationship utilization is an issue for managers; our findings suggest that they should maximize these relationships to gain resources for sustainable technological innovation, which is consistent with the findings of Mu and di Benedetto [128]. For example, managers should arrange for publicists to monitor the policies issued by government departments (e.g., the tax bureau, administrative bureau, and finance bureau) and apply for financial subsidies or tax exemptions as soon as possible through network relationships.

Secondly, market dynamics have a positive impact on the association between network relationships and sustainable technological innovation. In a highly dynamic market, customers tend to seek out new products and their product preferences can change significantly over time [101]. This study shows that the heterogeneity of market dynamics ultimately affects the association between network relationships and sustainable technological innovation through differences in management strategy, knowledge exchange, resource integration, organizational learning, information transfer, and cooperation opportunities, among others. Based on our findings, managers should adopt forward-looking organizational behaviors to respond to increasingly volatile market environments, such as

monitoring and anticipating changes in the market environment via customer feedback, market research, and information tracking, as well as identifying opportunities and threats in the market with the help of patent analysis, text mining, market intelligence, and market prediction [129]. Additionally, enterprises should improve their system of information capture and delivery. For example, managers may capture information through the processes of information search, collection, classification, screening, storage, and retrieval, and establish broad channels of communication to enhance the breadth and depth of market information searches [130].

Thirdly, the intensity of the moderation of market dynamics on the association between network relationships and sustainable technological innovation varies greatly, depending on the level of market dynamics. Thus, corporate decision-makers should adopt different attitudes toward network relationships and partners, depending on the level of market dynamics. The results lead us to the conclusion that, in less dynamic markets, firms should primarily maintain network relationships with existing partners and develop some network relationships that are very beneficial to business development [84]. On the other hand, in highly dynamic markets, network relationships have a more significant positive effect on sustainable technological innovation; thus, companies should pay high attention to the selection, maintenance, and utilization of network relationships in order to achieve success in terms of sustainable technological innovation capability.

7. Theoretical Implications

This study makes the following theoretical contributions. Firstly, it provides one of the few empirical studies of network relationships on sustainable technological innovation, validating the assumption that network relationship selection, maintenance, and utilization have a positive effect on sustainable technological innovation. Additionally, it shows that different levels of market dynamics have different degrees of influence on the association between network relationships and sustainable technological innovation. These findings respond to research on the market dynamics and network relationships in developed countries, while also contributing to the social network theory and dynamic capacity theory by examining and describing the capability growth path of Chinese enterprises [131,132]. Secondly, this study contributes to resource-based theory in several ways. It enriches our understanding of the underlying mechanisms by which network relationships influence the resource reconstruction process in China and reveals possible mechanisms by which differences in sustainable technological innovation arise at different levels of market dynamics [81]. Furthermore, it provides new research ideas for resource integration and capability reconstruction in the future [133]. Thirdly, the existing literature is limited in terms of demonstrating how to alter a firm's dynamic capability by selecting, maintaining, and exploiting its network relationships. Market dynamics are viewed as a catalyst that influences managers' attitudes toward the extent and urgency of changing companies' dynamic capability [134]. Our research makes an effort to reveal that the process of selecting and maintaining network relationships is not only a factor that determines the dynamic capability construction of enterprises but also offers an opportunity to alter their capability to acquire necessary resources and maintain the sustainability of technological innovation.

8. Practical Implications

The findings of this study have important practical implications for business management practices. Network relationships are seen as a key factor in driving technological innovation, and this study proves that enterprises can sustain their technological innovation by developing network relationships. It is unlikely that an enterprise has all the internal resources needed for sustainable technological innovation, thus requiring them to actively build network relationships to obtain external resources [135]. Therefore, corporate managers should change their traditional and closed management ideas, actively seek external network relationships, and integrate external resources to compensate for the lack of internal innovation resources. As technology changes rapidly and market competition

intensifies, firms should continuously improve their technological innovation capabilities and dynamic capabilities to adapt to the turbulent external environment. In the open innovation paradigm, firms should dynamically integrate and reconfigure the network resources required for the sustainability of technological innovation in response to changes in the market environment and internal resources [136]. Moreover, in the different degrees of market dynamics, the strategy-makers of enterprises should weigh the advantages of expanding new relationships and maintaining existing relationships based on the urgency of technological innovation, adjusting business management strategies accordingly [137]. It is worth noting that when managers have only limited time and energy, it is wise to focus on maintaining valuable network relationships and making the most of them, rather than on paying huge costs to choose partners.

9. Limitations and Further Research

Firstly, the association between network relationships and sustainable technological innovation may be moderated by other factors, such as a firm's strategic positioning, executives' perceptions, organizational resources, and the external technological environment. To further explore this association, future research should investigate whether multiple factors simultaneously moderate this relationship. Secondly, the sample companies in this study were technology companies in China's urban cities; further research should expand the sample size to determine if the same conclusions apply to other companies. Thirdly, network relationships and the technological innovation of a firm are dynamic and may change continuously over time; thus, it is not ideal to study the impact of network relationships on sustainable technological innovation from a static perspective. Future research should explore the association between network relationships and sustainable technological innovation from a dynamic perspective, using panel data.

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