

Article

The Relationship between Alumni Network and Exploratory Innovation: The Mediating Role of Enterprise Risk-Taking

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Abstract: In an increasingly open innovation environment, executives, as the core of corporate management and the main body of decision-making and execution, play a significant role in implementing innovation-driven development strategies. Based on executives' educational background, we constructed an executive alumni network platform using data from Chinese A-share listed companies from 2007 to 2019, and calculated the centrality indicators. The aim was to comprehensively explore the relationship between alumni networks and exploratory innovation in enterprises, and examine the mediating effect of enterprise risk-taking. Empirical results show that executive academic background networks can promote the development of exploratory innovation activities in enterprises. In other words, these networks provide the social relationships and trust foundation necessary to support innovation effectively. Enterprise risk-taking plays a mediating role in the relationship between alumni networks and exploratory innovation, underscoring the importance of risk-taking. Further research reveals that alumni networks have a significant positive impact on the sustainability of innovation, emphasizing the long-term value for corporate innovation. These findings demonstrate that alumni networks play a critical role in corporate innovation activities and provide theoretical support for advancing research in corporate innovation and sustained development.

Keywords: executive; executive alumni network; enterprise risk-taking; exploratory innovation; the mediating effect; innovation sustainability



Citation: Song, M.; Guo, L.; Shen, J. The Relationship between Alumni Network and Exploratory Innovation: The Mediating Role of Enterprise Risk-Taking. *Sustainability* **2023**, *15*, 15705. <https://doi.org/10.3390/su152215705>

Academic Editor: Alina Badulescu

Received: 10 September 2023

Revised: 31 October 2023

Accepted: 4 November 2023

Published: 7 November 2023



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1. Introduction

Enhancing independent innovation capabilities and building momentum for corporate development are crucial for sustaining business operations. This signifies that companies must consistently seek out new business models and introduce innovative products and services to adapt to the ever-evolving market landscape. Innovation represents a strategic pursuit, characterized by a blend of risk and reward, with exploratory innovation standing out as a highly promising form of practice. For the realization of exploratory innovation, companies need to foster an innovative-centric culture, allocate resources, and provide decision-making support, which means the willingness to take risks, experiment with novel concepts, and employ innovative approaches. The education background, social networks, and decision-making styles of executives hold pivotal roles in shaping corporate strategies and executing decisions, profoundly impacting a company's innovation endeavors. In a competitive marketplace, companies must adeptly navigate increasing levels of uncertainty and risk. Factors such as market volatility, technological advancements, and changes in the social environment constantly challenge business. Executives must possess the ability to address and manage risks to ensure the sustained growth of the organization. In light of the analysis, studying the relationship between executive alumni network and exploratory innovation, along with the mediating role of enterprise risk-taking, holds profound practical significance.

Executives assume a pivotal role in corporate management. They are tasked with the effective allocation of company resources, the identification and management of the

risks confronting the company, and the making of decisions that serve the company's best interests [1]. Executives must possess an innovative mindset, cultivate an environment that fosters the exploration of novel ideas, and provide the necessary resources and support to nurture innovation [2]. Current research on executives and innovation predominantly concentrates on factors such as executive social capital [3], the pressure of team performance [4], executive team restructuring [5], managerial competencies [6], board network positions [7], and executive's international backgrounds [8]. In contrast, there has been relatively limited attention devoted to the influence of executive alumni networks on corporate innovation activities. Risk constitutes an intrinsic element of innovation, and risk-taking is a resource-dependent prerequisite for innovative endeavors [9]. Companies can seek the necessary resources for risk-taking through social networks [10], which, in turn, can impact their innovation behavior. In line with this, this study employed executive alumni networks as an entry point to conduct a thorough investigation into their impact on exploratory innovation. It also examined the mediating role of enterprise risk-taking, with the objective of enhancing the body of research on the relationship between social networks and corporate innovation.

In summary, this study focused on the educational background of A-share listed companies between 2007 and 2019. It began by identifying the educational institutions attended by these executives and utilized this information to construct an executive alumni network, considering companies as nodes. The primary objective was to investigate the influence of executive alumni networks on exploratory innovation and analyze the mediating role of enterprise risk-taking. The research yielded the following findings: executive alumni networks positively facilitate the initiation of exploratory innovation activities within companies. Empirical tests have provided confirmation of the mediating influence of enterprise risk-taking. Moreover, additional investigation has unveiled the contribution of executive alumni networks to the sustainability of innovation. This underscores the critical support that executive alumni networks offer to a company's innovation endeavors, ultimately enhancing its long-term competitiveness and development potential.

This study offers several significant contributions. First, it departs from previous research that primarily examined the educational backgrounds or alma maters of top executives. Instead, it takes an innovative approach by investigating the impact of executive alumni networks on exploratory innovation. This enriches the body of research on the connection between executive background characteristics and corporate innovative networks. Second, in contrast to prior studies that often focused solely on centrality measures, this research delves deeper into the executive alumni network. It not only analyzes the network's topological structure but also considers small-world characteristics, network connectivity, and network positions. This comprehensive analysis provides a more holistic understanding of network features. Third, by incorporating variables such as enterprise risk-taking and innovation continuity into the research framework, this study offers a nuanced perspective on the influence of executive alumni networks on exploratory innovation. It provides empirical support from a micro-level standpoint, thereby enhancing and refining social capital theory. Lastly, this research holds practical implications for managers by guiding them on how to effectively utilize their resources and providing decision support for innovation activities.

2. Literature Review

Upper echelon theory suggests that the educational experiences and social relationships of executives can influence their cognitive patterns, risk preferences, and value orientations [11], thereby affecting a company's strategic decisions. Top management teams play a vital role in the selection of a company's innovation strategy and are a key driving force for exploratory innovation [6]. However, upper echelon theory primarily focuses on the individual characteristics of executives and gives less consideration to the social relationships and interactions among them. Social network theory emphasizes the exchange of information, cooperation, and trust among members. Executives, as decision-makers in a

company's innovation activities, greatly shape the network characteristics that influence the company's innovation pathways and strategies. These characteristics reflect the potential connections between companies and can provide valuable information, resources, and support, thus affecting a company's decision-making behavior.

Social network relationships provide companies with opportunities to access diverse external information, foster collaboration and communication with other businesses, establish trust and reputation, and enhance competitiveness and innovation capabilities through shared experiences and resources. They serve as a critical avenue for companies to overcome innovation challenges. Executive alumni networks, which are emotional bonds connecting top executives based on shared educational experiences, ensure mutual recognition and trust. As executive education experiences remain rooted in the past and unaffected by current market and environmental influences, they can effectively meet the demand for external information [12]. Cohen and colleagues suggested that the presence of network relationships increases the likelihood of information exchange between companies. Executive alumni networks serve as a channel for the transmission of confidential information [12,13] and can significantly reduce the social distance involved in information flow, thus reducing the cost of information acquisition for companies. Massa et al. argued that educational relationships make companies more similar, increase mutual trust, and enable companies to access resources and benefits that are challenging to obtain through their individual efforts [14]. Consequently, through social networks, companies can integrate various elements of innovation, diversify their innovation channels, establish trust foundations, and consequently, efficiently acquire additional resources [15].

In an increasingly open innovation environment, the quest for valuable knowledge and resources from external sources is paramount for exploratory innovation. Exploratory innovation extends beyond a company's knowledge boundaries, delves into new realms of knowledge, establishes sustainable competitive advantages, and continually seeks fresh development opportunities [16]. Vanhaverbeke et al. argued that cross-boundary exploration is an effective strategy for acquiring external technologies in corporate innovation [17], where companies establish partnerships between them. Venkataramani et al. proposed that companies require both external resource acquisition and internal knowledge integration capabilities [18]. Through social networks, they can more effectively integrate cross-boundary knowledge and resources into a framework, controlling and acquiring various strategic resources such as information, knowledge, technology, and management skills required for innovation. This, in turn, supports exploratory innovation activities.

Li et al.'s research indicated that social networks have a positive impact on innovation [19]. Yang et al. discovered that embedded inter-firm networks promote exploratory innovation [20]. Xing et al. argued that network relationships can reduce communication barriers between companies, enhance information exchange, resource sharing, collaboration willingness, and motivation among all parties, significantly facilitating the initiation of exploratory innovation activities [21]. Kuma et al. proposed that the networks in which companies are positioned possess value-creation capabilities, helping companies extract value from unique resources, thereby seeking competitive advantages [22].

The level of risk-taking is one of the crucial factors influencing a company's investment decisions. It is influenced by the decision preferences of executives, reflecting the attitudes of executives regarding the balance between expected returns and risks [23]. This factor is closely related to the future survival and development of the company [24–26]. Companies must adopt flexible and highly adaptive strategies to navigate complex and uncertain market environments to maintain their competitive edge. However, when taking on risks, companies face challenges stemming from uncertainty and resource dependency. Executive alumni networks broaden the avenues for companies to acquire external resources, helping them gain insights into market opportunities and trends, thus influencing their innovative behaviors.

In summary, executive alumni networks emerge as a pivotal factor impacting corporate innovation, providing us with a wide research perspective to explore essential variables

within the innovation process. By integrating enterprise risk-taking as an intermediary variable in our research framework, we will not only reveal the link between executive alumni networks and corporate innovation, but also facilitate a more comprehensive analysis of how this relationship is realized through the mechanism of risk-taking.

3. Theoretical Background and Hypotheses Development

3.1. Executive Alumni Network and Exploratory Innovation

The executive alumni network is a social relationship framework built upon the educational backgrounds of different top executives within the companies, with companies serving as nodes. In this study, the educational relationships among top executives were mainly limited to those formed based on their common educational experiences in listed companies. These connections capitalize on the executives' common educational backgrounds and similar knowledge bases, thus laying the foundation for trust [27]. This trust, in turn, fosters cooperation and the exchange of information, ultimately opening doors for businesses to acquire external resources. Furthermore, establishing network relationships with other enterprises serves as a robust avenue for businesses to tap into the essential knowledge and resources they need, solidifying its position as a dependable pathway for the pursuit of exploratory innovation [28,29].

Social capital theory suggests that the association between a company and other market entities in the economic society is an important channel for the company to obtain external resources [30]. This theory underscores the paramount importance of social networks and interpersonal relationships in the acquisition of resources and the flow of information. Executive alumni networks contribute to the cultivation of trust, simplifying the exchange of information and resource procurement, thereby diminishing the costs associated with resource transfers between companies and dismantling associated barriers. According to the principles of complex networks, if a company occupies a central position in the network, a higher network relationship strength indicates greater advantages in cooperation and resource acquisition [31]. Network centrality represents a company's position in the network. Enterprises positioned at the core of the network are more readily connected to enterprises with high centrality, thereby mitigating cooperation risks.

From the perspective of resource-based theory, companies located in the center position of the network have better opportunities to control and acquire various strategic resources (e.g., information, knowledge, technology, and management skills) [32]. This is because these companies can quickly access external resources and collect information about market trends, competition, and consumer demand, enabling them to transform the information into innovative products or services. In addition, enterprises with a high degree of centrality tend to be more proactive, actively engaging in frequent communication and collaboration with other businesses. Additionally, they can leverage collaborative partnerships to share resources, technology, and expertise, ultimately fortifying their competitive edge. This fosters exploratory innovation and ultimately enhances their market competitiveness and positioning. Therefore, companies should actively pursue and secure central network positions, thereby enhancing resource allocation to promote innovation.

Occupying a prominent position confers significant advantages upon companies in terms of information acquisition and resource procurement. High centrality within networks provides excellent opportunities for knowledge transfer and information exchange, enabling companies to reap enhanced innovation benefits by improving their network positions [33]. Simultaneously, it grants access to more diverse and heterogeneous information, promoting inter-enterprise knowledge flow and the acquisition of innovation resources [34]. With a company's network centrality on the rise, its range of associations continually expands, resulting in a broader array of information sources and channels. By continuously accumulating cooperative experience, companies can improve their knowledge absorption and learning ability, effectively integrating acquired knowledge and information to generate new insights and technologies [35]. This, in turn, bolsters their innovation prowess and competitiveness. Consequently, the executive alumni network can serve as a vital pillar for

fostering exploratory innovation, capitalizing on its resource and information advantages to facilitate such innovation endeavors.

Based on these insights, we proposed Hypothesis 1:

H1. *The executive alumni network has a positive impact on exploratory innovation.*

3.2. *The Mediating Effect of Enterprise Risk-Taking*

From the perspective of rational economic individuals, top executives are naturally driven to avoid risks. They tend to choose conservative investment strategies to evade the reputation loss caused by failed investments, which is not conducive to the long-term value addition of enterprises [36]. However, once executives have established an alumni network based on their educational resources, they can enrich the company's wellspring of knowledge sources and channels, absorb and integrate external knowledge and technology, enhance the capacity and frequency of information exchange between companies, alleviate the constraints and dependencies of their own resources, thereby reducing resource consumption. Simultaneously, the abundant and stable resource support provided by the network can significantly bolster the enterprise's risk-taking capacity. Studies by Florin et al. have suggested that executives' educational backgrounds not only influence their decision-making abilities, but also shape their risk tolerance [37]. The process of enterprise risk-taking is heavily dependent on resources. Zhang et al. postulated that the essence of risk-taking lies in providing companies with adequate resource support [38]. The alumni networks of top executives expand the array of investment opportunities. Li et al. argued that good investment opportunities make it easier for firms to obtain external financing, thus alleviating resource constraints [39]. Gómez and others considered the executive alumni networks as an informal institutional arrangement. The recognition and trust brought about by academic relationships reduce the obstacles to resource flow and promote the dissemination of tacit knowledge among network members [40]. The research results by Zhang et al. indicated that the more sufficient the executive incentives and the more investment opportunities faced a company encounters, the stronger the promotive effect of the social network on risk-taking [10].

Exploratory innovation is a typical high-risk investment activity. When the level of risk-taking in a business is high, it can proactively seize market opportunities; adapt to a fiercely competitive business environment; actively seek new knowledge, technology, and diverse resources within networks; continuously engage in exploratory innovation; and enhance its core competitiveness. Conversely, low-risk tolerance within a business significantly constrains various opportunities and resources, pushing the company to adopt a risk-averse investment stance and leading to numerous challenges in executing exploratory innovation activities. Studies by Liu et al. demonstrated that elevating the level of risk tolerance in businesses stimulates corporate R&D and fosters a demand for new technologies [41]. Dong believed that as the level of risk-taking increases, new businesses must allocate the necessary resources to develop and enhance innovative opportunities and capabilities for expanding into new markets [42]. Yan et al. maintained that the level of enterprise risk-taking significantly influences innovation; the higher the enterprise's risk-taking level, the more innovative investment the business makes, while the less risk-taking corresponds to reduced innovative investment [43]. Therefore, a higher level of risk-taking within a business indicates a greater propensity for pioneering initiatives and a higher likelihood of initiating innovative activities [44]. In addition, the dividends from innovative activities will continuously stimulate the business to maintain its innovativeness.

In sum, the executive alumni network accelerates information transmission, mitigates resource constraints, reduces the risks and uncertainties faced by companies, enhances their risk-taking level, and increases their investment in innovation activities, thereby driving innovation activity development continuously.

Based on these insights, we proposed Hypothesis 2:

H2. Enterprise risk-taking plays a mediating role in the impact of the executive alumni network on exploratory innovation.

4. Data Sources and Model Construction

4.1. Data Sources

We took A-share listed companies in China from 2007 to 2019 as the initial research sample, and collected the top executives' educational background information and the listed companies' relevant financial data from the CSMAR database. The data were preprocessed according to the following criteria, excluding financial, insurance, ST, and PT-listed companies, as well as companies with missing financial data, in the sample. After screening, we obtained 1832 "enterprise-year" observation samples. We adopted the method of truncating the top and bottom 1% for all continuous variables to ensure the model accuracy.

4.2. Variable Setting

4.2.1. Independent Variable—Alumni Network

In this article, the executive alumni network was defined as the relational network established among different executives who studied together at a specific university. Drawing inspiration from Freeman's centrality theory [45] and employing the research methodologies of Chen et al. [46] and Shen et al. [15], we constructed the "enterprise-school" bipartite matrix based on the bonds formed by executive educational background connections. We utilized Ucinet software version-6.560 to extract the "enterprise-enterprise" one-mode matrix from this bipartite matrix and then computed the centrality index for each company within the complex network. The eigenvector centrality (AN_{Eig}) was employed to gauge the strength of the alumni network relationship, measuring the degree of network significance. A higher AN_{Eig} value indicates that companies are more likely to obtain greater information and resources within the network, making it easier to discover and seize business opportunities. In addition, the degree centrality (AN_{Deg}) index was calculated, which represents the number of companies directly linked to a particular enterprise. The higher the degree centrality, the more heterogeneous resources the company possesses, along with a broader network of associative relationships. AN_{Deg} was employed for robustness testing in this study.

Eigenvector centrality is not only influenced by a node's degree value, but also depends on its neighboring nodes' importance. It is a function neighboring nodes' centrality, as shown in Equation (1):

$$\lambda x_i = \sum_{j=1}^n e_{ij} x_j \quad (1)$$

where n represents the number of nodes in the network, and e_{ij} represents the connection between adjacent enterprise nodes. If there is a relationship, it takes the value of 1; otherwise, it is 0. λ is the eigenvalue of the adjacency matrix, and i ranges from 1 to N .

The calculation process of degree centrality is shown in Equation (2):

$$AN_{Deg} = \frac{\sum_{i \neq j} X_{ij}}{N - 1} \quad (2)$$

where X_{ij} is the connection between the two nodes. If there is a relationship, it takes the value of 1; otherwise, it is 0. N represents the number of nodes in the network.

4.2.2. Dependent Variable-Exploratory Innovation

According to the Application Guidelines for Enterprise Accounting Standard No. 6—Intangible Assets issued by the Ministry of Finance in 2006 [47], research and development (R&D) expenditure during the research stage should be expensed. This is because the research stage is exploratory and requires companies to explore unfamiliar areas, which involves greater risk and higher uncertainty; therefore, the higher the research expenditure, the more inclined to exploratory spending. Drawing on the measurement

methods of Bi [48] and Ma [49,50], we measured exploratory innovation in companies using R&D expenses during the research stage divided by the total assets at the beginning of the period. This approach also eliminates the scale effect.

4.2.3. Mediating Variable-Enterprise Risk-Taking

Drawing on previous studies by scholars such as Li et al. [51] and He et al. [52], we used the earning volatility (Roa) to measure a company's level of risk-taking. Roa is the ratio of EBIT to total assets at the end of the year. To avoid the influence of industry heterogeneity, we adjusted the Roa for each year's company using the industry's mean level. For manufacturing companies, two-digit industry codes were used, and industries with only one company were excluded. The standard deviation of the Roa adjusted for the industry was calculated for each company in each year, and the result was multiplied by 100 for better visualization. A higher risk value (adjusted Roa) indicates a higher risk-taking level by the company. The observation period in this study was three years (where $t-t+2$ years was an observation interval), and the data collected covered the period from 2007 to 2021 to ensure that the research sample interval would be from 2007 to 2019. The specific calculation process was as follows:

$$AdjRoa_{in} = \frac{EBIT_{in}}{Assets_{in}} - \frac{1}{X} \sum_{k=1}^X \frac{EBIT_{kn}}{Assets_{kn}} \quad (3)$$

$$Risk_i = \sqrt{\frac{1}{N-1} \sum_{n=1}^N (AdjRoa_{in} - \frac{1}{N} \sum_{n=1}^N AdjRoa_{in})^2} \quad (4)$$

4.2.4. Control Variable

Executive alumni networks may mask the influence of variables such as competition or collaboration on innovation. Therefore, this paper includes the degree of competition (*Comp*) and collaboration (*Coll*) as control variables to mitigate omitted variable bias. Collaboration is a pivotal factor in fostering innovation [9]. Drawing from the study conducted by Zhou et al. [53], innovation collaboration is gauged by the number of jointly applied patents by companies. Recognizing competition as a significant factor impacting a company's innovation endeavors, industry competition levels (*Comp*) were measured using the Lerner's Index [54], in line with the research by Yu et al. [55]. Referring to the relevant research by Ma [49], we set up the variables of firm age (*FirAge*), asset-liability ratio (*Lev*), Tobin's Q (*Tb_q*), equity concentration (*Shrcr*), proportion of independent directors (*Ind*), and property rights nature (*SOE*). Annual and industry dummy variables were set to control for fixed effects of year (*Year*) and industry (*Industry*), respectively. The specific variable definitions are shown in Table 1.

Table 1. Variable definition.

Variable Classification	Variable Name	Variable Symbol	Variable Description
Dependent variable	Exploratory Innovation	EI	Ratio of R&D-expensed expenditures to total assets at the beginning of the period
Independent variable	Alumni network	AN _{Eig}	Eigenvector centrality: represents the strength of the alumni network relationship and, measures the quality of a company's network position
Mediating variable	Risk-Taking	RT	Standard deviation of the Roa adjusted for industry multiplied by 100 over three years ($t-t+2$)

Table 1. Cont.

Variable Classification	Variable Name	Variable Symbol	Variable Description
Control variable	Collaboration	Coll	The number of patents jointly applied for by companies
	Competition	Comp	The Lerner's Index of the industry where the company operates
	Firm Size	Size	Natural logarithm of total assets at the end of the period
	Firm Age	FirAge	Natural logarithm of the number of years listed on the stock exchange plus one
	Asset–Liability Ratio	Lev	End-of-period total liabilities divided by end-of-period total assets
	Tobin's Q	Tb_q	End-of-period market value of equity divided by end-of-period total assets
	Equity Concentration	Shrcr	The proportion of shares held by the largest shareholder
	Proportion of Independent Directors	Ind	The proportion of independent directors on the board
	Property Rights	SOE	Whether the company is state-owned. State-owned = 1, non-state-owned = 0
	Growth Ability Year	Growth Year	Sales revenue growth rate
	Industry	Industry	Classification follows the China Securities Regulatory Commission's Industry Classification Standards of 2012 [56]

4.3. Model Construction

We primarily investigated the impact of alumni networks on exploratory innovation and the mediating role of risk-taking. To test the hypotheses, we constructed the following empirical models:

$$EI = \alpha_0 + \alpha_1 \times AN_{Eig} + \alpha_i \times Controls + \varepsilon \quad (5)$$

$$RT = \alpha_0 + \alpha_1 \times AN_{Eig} + \alpha_i \times Controls + \varepsilon \quad (6)$$

$$EI = \alpha_0 + \alpha_1 \times AN_{Eig} + \alpha_2 \times RT + \alpha_i \times Controls + \varepsilon \quad (7)$$

where AN_{Eig} represents the alumni network, EI represents exploratory innovation, and RT represents risk-taking.

5. Analysis of Characteristics of Alumni Networks

5.1. Topological Analysis of Alumni Networks

Based on the “enterprise-enterprise” alumni network relationship matrix, we used the Netdraw tool in Ucinet software to draw the topological structure of alumni network relationships for three years, from 2017 to 2019. Network nodes represent companies, the node size represents centrality values, and the line thickness represents the strength of the relationship between companies [57], as shown in Figure 1. The network diagram for 2019 features 1446 nodes, with an average degree centrality of 165.25, a degree centrality of over 353 for the top 10% of companies, and a maximum degree centrality of 846 (owing to the numerous nodes and high degree values, to make the network diagram clearer, we selected the top 10% of nodes with high degree values to draw the network diagram, and we used the data of 2019 as an example). The results indicate that these companies have a significant influence on the alumni network and are hubs for resource and information exchange between companies.

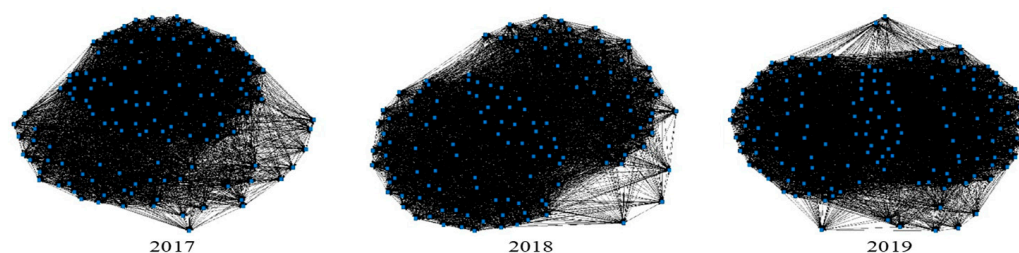


Figure 1. Topological structure of the alumni network relationship.

5.2. Analysis of Small-World Characteristics and Relationships

The small-world characteristics and relationships are important analysis tools for measuring the relationship features between nodes in social network analysis. The calculation results of related indicators are shown in Table 2. The shortest average distance represents the average length of the shortest path between the two nodes. The shorter the length, the stronger the reachability between nodes and the faster the information transmission in the network. The alumni network has the shortest distance of 1.971, meaning that only 1.971 edges are needed to connect two companies, and that the network has a tight topological structure and exhibits small-world network characteristics. The clustering coefficient of the alumni network is 0.845, indicating that the nodes in the network are highly clustered and have a high degree of association, creating a good environment for the aggregation and diffusion of resources among companies and providing an objective basis for the flow of innovative resources. The network connectivity is 0.9972, indicating that the number of unreachable pairs of points in the network is close to 0, and that companies in the network can directly or indirectly form connections. The efficiency of the network diagram is 0.8929, indicating that the redundancy of links in the network is large, ensuring the stability of innovation associations between companies. The maximum nearest neighbor is 1, indicating that there are common neighboring nodes between companies in the network, facilitating the flow of innovative elements. The small-world characteristics and relationships of the network confirm the connectivity of the alumni network and its significant topological features, providing security for the flow of resources and information between companies.

Table 2. The small-world characteristics and relationships indicators.

The Shortest Distance	Clustering Coefficient	Connectivity	Efficiency	The Maximum Nearest Neighbor
1.971	0.845	0.9972	0.8929	1.0000

6. Empirical Testing and Analysis

6.1. Descriptive Statistics of Key Variables

Descriptive statistics of key variables are shown in Table 3. The mean of exploratory innovation (EI) is 0.020, the median is 0.015, and the upper quartile was 0.029, indicating that the exploratory innovation level of most companies is below the market average, with significant room for improvement in innovation capabilities. The mean of risk-taking (RT) is 2.941, the median is 1.857, the minimum is 0.184, and the maximum is 28.497. The median is close to the lower quartile, indicating that most companies have a low tolerance for risk, and that there is a significant difference in risk preferences among different companies. The mean of AN_{Eig} is 0.023, the median is 0.012, and the distance to the lower quartile is close to 0.005, indicating that there are alumni network relationships between most companies, and that the network quality of different companies varies, with most companies having a low network quality.

Table 3. Descriptive statistics of key variables.

Variable	N	Mean	Sd	Min	Lower Quartile	Median	Upper Quartile	Max
EI	1832	0.020	0.022	0.000	0.003	0.015	0.029	0.125
RT	1832	2.941	3.485	0.184	1.053	1.857	3.497	28.497
AN _{Eig}	1832	0.023	0.025	0.000	0.005	0.012	0.038	0.101
Coll	1832	6.810	21.782	0.000	0.000	0.000	2.000	133.000
Comp	1832	0.110	0.061	0.022	0.067	0.099	0.134	0.318
Size	1832	22.778	1.593	19.957	21.643	22.526	23.720	26.352
FirAge	1832	2.074	0.881	0.000	1.386	2.303	2.833	3.219
Lev	1832	0.468	0.194	0.051	0.326	0.468	0.616	0.847
Tb _q	1832	1.843	1.111	0.903	1.154	1.493	2.115	8.270
Shrcr	1832	0.371	0.158	0.083	0.247	0.361	0.482	0.728
Ind	1832	0.376	0.055	0.333	0.333	0.364	0.429	0.571
SOE	1832	0.470	0.499	0.000	0.000	0.000	1.000	1.000

6.2. Regression Analysis

To test the impact of alumni networks on exploratory innovation and the mediating role of risk-taking, we used a fixed-effects model for analysis. The empirical results are shown in Table 4. Column (1) shows the results of the univariate regression analysis, where the regression coefficient of alumni networks on exploratory innovation is 0.0472, significant at the 5% level, indicating that alumni networks have a promoting effect on exploratory innovation and preliminarily support Hypothesis 1. That is, companies can obtain the resources and information needed for exploratory innovation through alumni networks. Columns (2) to (4) represent the stepwise empirical testing process for the relationship between alumni networks, risk-taking, and exploratory innovation. The coefficient of AN_{Eig} in column (2) is 0.0666, significant at the 1% level, which is larger than that in the univariate regression, indicating that the explanatory power of the model is stronger after adding control variables. In this regard, enterprises located at the center of the network have a comparative advantage in accessing external resources and effectively integrating internal and external resources, thereby fostering the development of exploratory innovation activities, confirming Hypothesis 1. This discovery highlights the significance of executive social relationships in corporate innovation. The coefficient of AN_{Eig} in column (4) is 0.0649, significant at the 1% level, indicating that the direct effect of alumni networks is significant. The coefficient of AN_{Eig} in column (3) is −5.3209, significant at the 10% level, indicating that alumni networks reduce the risk-taking level of companies. The coefficient of RT in column (4) is −0.0003, significant at the 5% level. Since the product of the coefficients of AN_{Eig} in column (3) and RT in column (4) is positive, the indirect effect is significant, thereby confirming Hypothesis 2. The findings demonstrate a significant mediating effect between the alumni network and exploratory innovation. This implies that enterprise risk-taking plays a crucial role on the impact of executive alumni networks on innovation activities. Executive alumni networks influence how executives assess and evaluate risks, indirectly affecting the initiation of exploratory innovation activities. This underscores the significance of executive decision-making and risk preferences in innovation activities.

Table 4. Mediation analysis.

Variable	(1)	(2)	(3)	(4)
	EI	EI	RT	EI
AN _{Eig}	0.0472 ** (2.15)	0.0666 *** (3.03)	−5.3209 * (−1.70)	0.0649 *** (2.96)
RT				−0.0003 ** (−2.24)

Table 4. *Cont.*

Variable	(1)	(2)	(3)	(4)
	EI	EI	RT	EI
Coll		0.0001 *** (6.22)	0.002 (0.66)	0.0001 *** (6.22)
Comp		0.0554 *** (4.84)	−3.7746 (−1.10)	0.0542 *** (4.71)
Size		−0.0008 (−1.62)	−0.5274 *** (−6.61)	−0.0009 ** (−1.96)
FirAge		−0.0040 *** (−5.39)	0.6831 *** (4.62)	−0.0038 *** (−5.02)
Lev		−0.0022 (−0.77)	1.3082 * (1.90)	−0.0018 (−0.63)
Tb_q		0.0029 *** (3.71)	0.0946 (0.99)	0.0029 *** (3.77)
Shrcr		−0.0007 (−0.18)	−0.8998 (−1.26)	−0.001 (−0.25)
Ind		−0.0121 (−1.46)	1.7037 (1.01)	−0.0115 (−1.40)
SOE		−0.0022 * (−1.83)	−0.6271 *** (−2.99)	−0.0024 ** (−1.99)
Cons	0.0193 *** (31.26)	0.0398 *** (3.91)	13.2623 *** (8.11)	0.0440 *** (4.33)
Year/Industry	Yes	Yes	Yes	Yes
Adj_R ²	0.3131	0.3832	0.1208	0.385
N	1832	1832	1832	1832

Note: Significance level (*—10%, **—5%, ***—1%); the numbers in parentheses represent t-values.

7. Robustness Analysis

7.1. Robustness Analysis of Mediation Effect

To verify the robustness of the mediating effect of risk-taking, we used the bootstrap method to conduct 500 and 1000 repeated sampling tests, and the results are shown in Table 5. The error-corrected 95% confidence intervals do not include 0, indicating that the mediating effect is robust, which further supports Hypothesis 2.

Table 5. Robustness analysis of the mediation effect.

		500 repeated sampling	1000 repeated sampling
Confidence Intervals (−95%)	Upper limit	0.0051431	0.0050349
	Lower limit	0.0001512	0.0000792

7.2. Robustness Test of Alternative Variables

Alumni networks are a unique form of social capital for companies that help build bridges for resource sharing and information exchange between them. They can help reduce information asymmetry between companies, and those companies that occupy a central position in the network are more likely to obtain the necessary innovative resources. Therefore, we conducted a robustness check using AN_{Deg} as an alternative variable for the independent variable. The results of the regression analysis of AN_{Deg} and the mediating effect of risk-taking on exploratory innovation are consistent with those of previous analyses, indicating that the results of this study are robust. The findings are shown in Table 6.

Table 6. Robustness test.

Variable	(1)	(2)	(3)	(4)
	EI	EI	RT	EI
AN _{Deg}	0.0144 *** (2.77)	0.0190 *** (3.65)	−1.3261 * (−1.83)	0.0185 *** (3.57)
RT				−0.0003 ** (−2.21)
Coll		0.0001 *** (6.11)	0.0022 (0.72)	0.0001 *** (6.12)
Comp		0.0557 *** (4.87)	−3.7771 (−1.10)	0.0545 *** (4.75)
Size		−0.0009 * (−1.90)	−0.5222 *** (−6.54)	−0.0011 ** (−2.23)
FirAge		−0.0040 *** (−5.40)	0.6845 *** (4.64)	−0.0038 *** (−5.04)
Lev		−0.0020 (−0.68)	1.2901 * (1.88)	−0.0016 (−0.54)
Tb _q		0.0028 *** (3.71)	0.0960 (1.00)	0.0028 *** (3.77)
Shrcr		−0.0006 (−0.15)	−0.9041 (−1.26)	−0.0009 (−0.22)
Ind		−0.0116 (−1.41)	1.6722 (1.00)	−0.0111 (−1.35)
SOE		−0.0021 * (−1.74)	−0.6320 *** (−3.01)	−0.0023 * (−1.90)
Cons	0.0186 *** (25.89)	0.0416 *** (4.12)	13.2056 *** (8.06)	0.0458 *** (4.54)
Year/Industry	Yes	Yes	Yes	Yes
Adj_R ²	0.3149	0.3854	0.1210	0.3872
N	1832	1832	1832	1832

Note: Significance level (*—10%, **—5%, ***—1%); the numbers in parentheses represent t-values.

7.3. PSM

When executives have extensive alumni network relationships, they may actively choose companies with strong innovation capabilities and higher risk-taking levels, which can lead to endogeneity problems due to self-selection bias in the sample. To ensure the reliability of the study, we used the propensity score matching PSM method for matching treatment. The dummy variable (AN_{Eig_dum}) of eigenvector centrality was used as the independent variable, and AN_{Eig} was ranked from small to large according to the three quartiles. The largest three quartiles were defined as the high-centrality group, marked 1, and the remaining two parts were defined as the low-centrality group, marked 0. Enterprise age, debt-to-asset ratio, Tobin's Q, property rights, growth ability, and degree of competition and collaboration were selected as matching variables, and a logistic regression model was used for matching. The kernel matching method was selected to match the two centrality groups, and the matched samples were used for regression analysis. The results of the regression analysis are shown in Table 7. In column (1), the coefficient of AN_{Eig_dum} is significantly positive at the 5% level, indicating that occupying a central position in the network is more conducive to exploratory innovation by companies, thus supporting Hypothesis 1. The coefficients in columns (2) and (3) are significant, thereby confirming Hypothesis 2; that is, risk-taking plays a mediating role in the impact of alumni networks on exploratory innovation.

Table 7. PSM regression analysis.

Variable	(1)	(2)	(3)
	EI	RT	EI
AN _{Eig_dum}	0.0024 ** (2.3466)	−0.3411 ** (−2.0182)	0.0023 ** (2.2597)
RT			−0.0003 * (−1.8529)
Coll	0.0001 *** (5.7586)	−0.0036 (−1.1637)	0.0001 *** (5.6975)
Comp	0.0562 *** (4.8473)	−3.0376 (−0.8734)	0.0553 *** (4.7527)
FirAge	−0.0042 *** (−6.2731)	0.6559 *** (4.9388)	−0.0040 *** (−5.9479)
Lev	−0.0031 (−1.1369)	0.1364 (0.2019)	−0.0031 (−1.1322)
Tb_q	0.0030 ** (4.1051)	0.3384 *** (3.1994)	0.0031 ** (4.2293)
SOE	−0.0033 *** (−2.9567)	−1.1081 *** (−5.3685)	−0.0036 *** (−3.1817)
Growth	0.0029 ** (2.0668)	−0.2766 (−1.4758)	0.0029 ** (2.0092)
Cons	0.0181 *** (6.8096)	1.9659 *** (3.8227)	0.0187 *** (7.0956)
Year/Industry	Yes	Yes	Yes
Adj_R ²	0.383	0.098	0.385
N	1818	1818	1818

Note: Significance level (*—10%, **—5%, ***—1%); the numbers in parentheses represent t-values.

8. Further Analysis

Enterprise innovation activities necessitate sustained, long-term investment in innovation and knowledge accumulation. The intricacy of innovation demands resource inputs that are developmental, organizational, and strategic in nature. Executives wield profound influence within the company as they possess the authority to make strategic decisions and judgments, ultimately determining the long-term allocation of company resources. This positions them as key drivers of corporate innovation. Within the constraints of bounded rationality, executives make innovative decisions by perceiving, processing, preserving, and selectively interpreting internal and external information.

Simultaneously, alumni networks provide sufficient resources crucial for corporate innovation activities. They ensure the availability of knowledge accumulation and information sources essential for innovative endeavors. Moreover, executive endorsement of corporate innovation activities fosters an innovative atmosphere within the company, engendering long-term incentivizing effects. This, in turn, guides employees in implementing research and development ideas and alleviates the negative impact of financial or technological constraints on innovation activities. Building on the foregoing analysis, we delved deeper into the impact of alumni networks on the sustainability of corporate innovation.

We referred to the methods of Chen et al. [58] and Yu et al. [59], who considered the current period and the lagging first and second periods of research and development investment, and used the ratio of innovation input in the pre- and post-periods to describe the sustainability of corporate innovation. The specific calculation formula is as follows:

$$IIP = \frac{RI_t + RI_{t-1}}{RI_{t-2} + RI_{t-1}} \times (RI_t + RI_{t-1}) \quad (8)$$

In the formula, R&D investments in the current period, lagging first period, and lagging second period are represented by RI_t , RI_{t-1} , and RI_{t-2} , respectively. The variable IIP represents the sustainability of innovation in the current period for the company.

In this study, innovation sustainability was employed as the dependent variable, while AN_{Eig} and AN_{Deg} , along with the previously mentioned control variables, served as independent variables. A step-by-step method was conducted to test the mediating effect of risk-taking on innovation sustainability. The results of the regression analysis are shown in Table 8. The regression coefficients of AN_{Eig} and AN_{Deg} on enterprise innovation sustainability are both significantly positive at the 1% level. This implies that alumni networks contribute to the enhancement of corporate innovation sustainability by providing diverse resources and information sources. They also assist companies in better understanding the opportunities and challenges posed by external environmental changes, ultimately fostering the sustainable development of innovation activities. However, in columns (3) and (8), the coefficients of AN_{Eig} and AN_{Deg} were found to be insignificant, and this result remains consistent even after conducting bootstrap testing. Consequently, it is evident that no significant mediating effect of risk-taking on innovation sustainability exists. This indicates that the mediating effect of risk-taking is not statistically significant.

Table 8. The impact of alumni networks on innovation sustainability.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	IIP	IIP	RT	IIP	IIP	IIP	RT	IIP
AN_{Eig}	11.3572 *** (14.15)	2.8037 *** (4.96)	−0.4937 (−0.18)	2.7983 *** (4.95)				
AN_{Deg}					2.8497 *** (15.66)	0.6667 *** (5.18)	−0.5845 (−0.97)	0.6605 *** (5.13)
RT				−0.0108 *** (−4.20)				−0.0107 *** (−4.16)
Coll		0.0053 *** (9.58)	−0.0066 ** (−2.35)	0.0052 *** (9.43)		0.0052 *** (9.39)	−0.0063 ** (−2.26)	0.0052 *** (9.25)
Comp		1.2503 ** (2.02)	−13.4130 *** (−4.33)	1.1049 * (1.78)		1.2443 ** (2.02)	−13.4153 *** (−4.33)	1.1006 * (1.77)
Size		0.8887 *** (56.08)	−0.4930 *** (−6.79)	0.8833 *** (55.98)		0.8867 *** (55.80)	−0.4827 *** (−6.64)	0.8815 *** (55.70)
FirAge		−0.1426 *** (−5.57)	0.5238 *** (4.31)	−0.1370 *** (−5.35)		−0.1440 *** (−5.63)	0.5232 *** (4.30)	−0.1384 *** (−5.41)
Lev		−0.3095 *** (−3.81)	2.9674 *** (6.04)	−0.2773 *** (−3.41)		−0.3088 *** (−3.80)	2.9638 *** (6.03)	−0.2771 *** (−3.41)
Tb_q		0.0853 *** (7.32)	0.1388 ** (2.30)	0.0868 *** (7.47)		0.0847 *** (7.28)	0.1405 ** (2.33)	0.0862 *** (7.44)
Shrcr		−0.2742 *** (−3.07)	−3.4469 *** (−7.86)	−0.3116 *** (−3.49)		−0.2779 *** (−3.11)	−3.4458 *** (−7.85)	−0.3148 *** (−3.52)
Ind		0.0047 (0.02)	0.7007 (0.58)	0.0123 (0.06)		−0.0069 (−0.03)	0.7154 (0.59)	0.0008 (0.00)
SOE		−0.0237 (−0.66)	−1.4255 *** (−10.50)	−0.0392 (−1.08)		−0.0215 (−0.60)	−1.4359 *** (−10.56)	−0.0369 (−1.02)
Cons	18.6655 *** (830.64)	−0.6600 * (−1.89)	14.9128 *** (9.67)	−0.4984 (−1.43)	18.5644 *** (710.17)	−0.6265 * (−1.79)	14.7371 *** (9.55)	−0.4686 (−1.34)
Year/Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj_R ²	0.1954	0.6179	0.1526	0.6191	0.2031	0.6181	0.1528	0.6193
N	5771	5771	5771	5771	5771	5771	5771	5771

Note: Significance level (*—10%, **—5%, ***—1%); the numbers in parentheses represent t-values.

In addition, referring to the grouping method used for eigenvector centrality above, we divided degree centrality into three groups according to quartiles, and we tested the impact on innovation sustainability separately. The results of the regression analysis are shown in Table 9. The regression coefficients of both eigenvector centrality and degree centrality are significantly positive at the 1% level, indicating that companies occupying a high position in the network are more likely to improve the sustainability of innovation activities. Being in a central position in an alumni network often provides access to more information, resources, and opportunities, thus ensuring the stability and long-term nature of innovation investments, promoting the sustainable development of innovation activities, enabling better adaptation to changes in internal and external environments, enhancing

corporate competitiveness, and making enterprises more adaptable to changing market demands and technological trends.

Table 9. Results of testing by grouping according to centrality.

Variable	(1)	(2)
	IIP	IIP
Eig_dum	0.1014 *** (4.20)	
Deg_dum		0.1212 *** (5.05)
Coll	0.0054 *** (9.75)	0.0054 *** (9.67)
ILI	1.2475 ** (2.01)	1.2528 ** (2.02)
Size	0.8934 *** (56.48)	0.8914 *** (56.14)
FirAge	−0.1439 *** (−5.62)	−0.1442 *** (−5.63)
Lev	−0.3122 *** (−3.84)	−0.3081 *** (−3.79)
Tb_q	0.0857 *** (7.35)	0.0847 *** (7.27)
Shrcr	−0.2876 *** (−3.22)	−0.2922 *** (−3.27)
Ind	0.0147 (0.07)	−0.0105 (−0.05)
SOE	−0.0262 (−0.73)	−0.0242 (−0.67)
Cons	−0.7358 ** (−2.11)	−0.6861 * (−1.96)
Year/Industry	Yes	Yes
Adj_R ²	0.6172	0.6177
N	5771	5771

Note: Significance level (*—10%, **—5%, ***—1%); the numbers in parentheses represent t-values.

9. Discussion and Implications

Current research underscores the compelling nature of investigating the influence of executive alumni networks on corporate innovation. By introducing enterprise risk-taking as an intermediary variable in the research framework and delving more profoundly into the correlation between executive educational backgrounds and exploratory innovation, we provide valuable insights and inspire future studies. Advancements in this field will enhance our comprehension of the dynamic processes of corporate innovation, thereby assisting companies in strategic planning, bolstering competitiveness, and ultimately attaining success.

This study used Chinese A-share listed companies from 2007 to 2019 as research samples and used theoretical foundations such as upper echelons theory, and complex network principles to construct alumni networks and empirically examine their impact on exploratory innovation, as well as the mediating effect of corporate risk-taking. The results indicate that, first, alumni networks can promote the development of exploratory innovation activities in companies, and the higher the centrality in the network, the more significant the improvement in exploratory innovation. It is evident that executive alumni networks have a positive impact on corporate exploratory innovation. These networks serve as important channels for companies to access resources and information, providing them with a broader and more diverse range of heterogeneous resources and knowledge.

Second, corporate risk-taking plays a mediating role in the impact of alumni networks on exploratory innovation. Because of the dependency of companies on enterprise

risk-taking for resources and information, executive alumni networks also influence it, consequently affecting the initiation of exploratory innovation activities within the company.

Third, based on our additional research, alumni networks have a positive impact on innovation sustainability, but the mediating effect of corporate risk-taking disappears in this process. While enterprise risk-taking acts as an intermediary in the early stages of innovation activities, executive alumni networks play a more significant role in sustaining the continuity of these activities.

Fourth, the innovation process is complex and influenced by numerous factors. The inclusion of control variables, competition, and collaboration enhances the paper's ability to thoroughly and comprehensively investigate the impact of executive alumni networks on innovation while ensuring the research results' reliability.

The research findings in this paper have significant practical implications for businesses and organizations:

First, companies should acknowledge the importance of executive social relationships. Recognizing the pivotal role of top management teams as innovation drivers, companies should actively explore the social relationships and information-sharing capabilities within these teams.

Second, companies should prioritize the development of executive alumni networks as a crucial long-term strategic objective. They should consistently nurture and strengthen the social connections of top executives to ensure the sustained and continuous nature of innovation.

Third, executives should fully comprehend the importance of their social network resources in innovation activities. They should seize and leverage the opportunities offered by their social networks, sift through valuable and critical information, and effectively manage risks, making innovative decisions that support the company's long-term development.

This study had some limitations. First, it only considered corporate risk-taking as a mediating variable and transmitted the impact of alumni networks on corporate risk-taking to exploratory innovation. In the future, it may be necessary to enrich the mechanism research of alumni networks on corporate exploratory innovation from other perspectives. Second, this study only examined alumni networks from the perspective of network centrality. In the future, it can be extended to investigate other characteristics of complex networks, such as structural holes and network density.

Author Contributions: Writing: M.S.; providing idea: L.G.; revising and editing: L.G. and J.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by National Natural Science Foundation of China (12272135) and Basic Research Project of Universities in Henan Province (21zx009).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data can mostly be obtained from China Stock Market and Accounting Research (CSMAR) Databases are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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