EXPLORING KNOWLEDGE INTEGRATION CAPABILITY, COLLABORATIVE R&D NETWORKS AND REDUNDANT RESOURCES TO INFLUENCE THE HIGH-TECH ENTERPRISE PERFORMANCE

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Abstract

Driven by the global scientific and technological revolution and industrial change, innovation has become the main driving force for development, and China regards it as an important support for its national strategy. As the key to enhancing China's global competitiveness, high-tech enterprises need to be closely aligned with national strategic needs. This study examines the effects of Knowledge Integration Capability, Collaborative R&D Network and Redundant Resources on Chinese High-Tech Enterprise Performance. Based on the dual innovation theory, the study finds that Knowledge Integration Capability affects Enterprise Performance through direct and indirect paths, with Collaborative R&D Network and Redundant Resources acting as mediating variables. The study adopts a mixed research methodology, combining explanatory sequential design, questionnaire survey and semi-structured interviews as research tools. The results show that Knowledge Integration Capability has a significant positive effect on Redundant Resources, Collaborative R&D Network and Enterprise Performance, and Redundant Resources and Collaborative R&D Network play an important mediating role in the effect of Knowledge Integration Capability on Enterprise Performance. This study provides new theoretical support for high-tech Enterprise Performance enhancement through resource integration in a dynamic environment.

Keywords: Knowledge Integration Capability, Collaborative R&D Networks, Redundant Resources, High-Tech Enterprise Performance

Introduction

Against the backdrop of the global scientific and technological revolution and industrial change, innovation has become the main driving force for development. In the face of the epidemic and the uncertainty of economic recovery, enterprises must strengthen independent innovation, master key technologies and improve the quality of science and technology innovation in order to promote high-quality development. High-tech enterprises play an important role in industrial restructuring and economic transformation, and need to focus on key technologies around national strategic needs in order to enhance global competitiveness.

Knowledge is a core element of innovation and a source of core resources and competitive advantages for enterprises. For high-tech enterprises, knowledge integration is crucial, which determines the quality of technological innovation and Enterprise Performance. High-tech enterprises promote patent innovation through knowledge integration and utilize the dual innovation theory to find a balance between existing and new knowledge to cope with competitive pressure.

Knowledge integration promotes technological invention and performance improvement by recombining existing knowledge elements. High-tech firms need to efficiently utilize internal Redundant Resources and external Collaborative R&D Networks to accelerate

the innovation process. This paper explores the relationship between Knowledge Integration, Dual Innovation, Open Innovation and Enterprise Performance, analyzes the roles of Redundant Resources and Collaborative R&D Network, and empirically examines the impact of Knowledge Integration Capability on the performance of high-tech enterprises.

The questions of this study are：

RQ1: What is the relationship between Knowledge Integration Capability, Redundant Resources, Collaborative R&D Network and Enterprise Performance?

RQ2: What is the role of Redundant Resources and Collaborative R&D Network between Knowledge Integration Capability and High-Tech Enterprise Performance?

RQ3: How to explain the model which contains Knowledge Integration Capability, Redundant Resources, Collaborative R&D Network and Enterprise Performance?

The research objectives of this study are:

RO1: To construct the relationship between Knowledge Integration Capability, Redundant Resources, Collaborative R&D Network and Enterprise Performance;

RO2: In order to explore the mediating role of Redundant Resources and Collaborative R&D Network between Knowledge Integration Capability and Enterprise Performance;

RO3: In order to explain the relationship model containing Knowledge Integration Capability, Redundant Resources, Collaborative R&D Network and Enterprise Performance.

Literature Review

1. Dual Innovation Theory

Dual innovation theory originated in the 1970s by Duncan, R. B. (1976) to address how firms can simultaneously manage conflicts and synergies between existing and new businesses, and March, J. G. (1991) further proposed two types of innovation, “exploration” and “utilization”. “two types of innovation, which represent driving fundamental change through experimentation and discovery of new knowledge, and improving efficiency by refining existing knowledge, respectively. With deeper research, scholars have found that these two types of innovation may either compete for resources or be mutually reinforcing through knowledge integration. Dual innovation theory requires enterprises to find a balance between utilizing existing knowledge and exploring new knowledge, and through rational innovation strategies and effective knowledge integration, enterprises can achieve short-term financial performance and long-term competitive advantage.

According to this theory, firms need to balance exploratory and exploitative innovation to achieve sustained competitive advantage. Knowledge Integration Capability is key in this process because it supports firms to effectively allocate internal resources and explore external innovation collaborations to ultimately achieve dual innovation goals. Through this theory, we can reveal how Knowledge Integration Capability directly and indirectly affects High-Tech Enterprise Performance through Redundant Resources and Collaborative R&D Network.

2. Knowledge Integration Capability

Henderson and Clark first proposed the concept of knowledge integration in the 1990s, emphasizing the need to integrate component knowledge and architectural knowledge for new product development in enterprises. Wu, H. et al. (2018) view Knowledge Integration Capability as a dynamic process that includes screening, acquiring, deconstructing, fusing and reconstructing knowledge. Scholars such as Martini, A. et al. (2017) and Song, M. et al. (2018) further explore the process and importance of knowledge integration. In a narrow sense, Knowledge Integration Capability is a key aspect of knowledge management; in a broader

sense, it covers the whole process from knowledge search to application. Through effective Knowledge Integration, enterprises not only enhance their innovation ability and competitiveness, but also can quickly adapt to market changes and meet different needs, therefore, enterprises need to place Knowledge Integration Capability at the core of the innovation system as the foundation to support their knowledge and technological innovation.

3. Redundant Resources

The concept of Redundant Resources was first introduced by March, J. G. et al. (1958) in Organizations to refer to the resources that an organization has in excess of what is needed to maintain the status quo. Cyert, R. M. et al. (1963) further defined Redundant Resources as the gap between a firm's available resources and its actual needs, emphasizing its buffering role in helping the firm to cope with internal pressures and external changes. Child, J. (1972) explains Redundant Resources from a strategic perspective as an indication of Enterprise Performance exceeding expectations.

Bromiley, P. (1991) defines Redundant Resources as excess resources over the planning cycle, usually in the form of cash flow, inventory, accounts receivable, or machinery and equipment. In recent years, scholars have refined the definition of Redundant Resources as internally under-deployed resources that can be used for innovation or strategic adjustments. Redundant Resources not only help maintain day-to-day operations, but also serve as an important source of innovation and strategic adjustments, helping firms maintain a competitive advantage in complex markets.

4. Collaborative R&D Network

In 1971, German scholar Haken first introduced the concept of "collaboration," defining it as the cooperation and coordination among subsystems within a system to achieve a synergistic effect where 1+1>2. Collaborative R&D networks, composed of enterprises and multiple innovation entities, are designed for cooperative innovation. Different scholars have defined these networks from various perspectives, such as strategic alliance theory and resource-based theory, referring to them as innovation networks, collaborative innovation networks, and industry-university-research collaboration networks.

Collaborative R&D networks play a critical role in technological innovation, characterized by the virtual aggregation of enterprises. Scholars like Gkypali, A. et al. (2018) consider them an essential strategy for enterprises to acquire knowledge. Xu, S. et al. (2019) view them as a strategy for acquiring and learning external knowledge, while Kobarg, S. et al. (2019) emphasize the importance of alliances and cooperation. Li, Z. et al. (2019) describe these networks as cooperative relationships for completing technological projects. Wang, H. (2020) and Wang, M. (2022) highlight their role in integrating and sharing R&D resources and increasing knowledge diversity.

Collaborative R&D offers advantages such as resource sharing, avoiding redundant research and development, improving efficiency, enhancing competitiveness, and diversifying risks. Heil, S. et al. (2018) believe that it provides high-tech enterprises with opportunities for outward exploration. Belderbos, R. et al. (2018) argue that it effectively facilitates the acquisition of external knowledge. Hurtado-Torres, N. E. et al. (2018) suggests that it brings complementary capabilities. Li, M. et al. (2019) emphasize that its positive impact requires reaching a threshold. Yu, G. et al. (2020) believe that it realizes the complementary advantages of technology and capabilities. Zou, S. et al. (2020) argue that it ensures the continued competitive advantage of technological innovation.

Collaborative R&D networks are an essential mechanism for enhancing a company's technological innovation capabilities and competitiveness. Through cross-organizational cooperation, they enable resource sharing and knowledge integration, driving technological

progress and maintaining a sustained competitive advantage.

5. Enterprise Performance

Enterprise Performance is a core concept in management, covering both achievement and effectiveness, and is an indicator of the behavior, manner, and results of an enterprise's work over a certain period of time and the objective impact it produces. Academics are divided on the definition of Enterprise Performance, and there are three main views: the results theory considers performance as a direct result, such as Drucker, P. (2018) defined as a synthesis of work results in The Effective Executive, and Bernardin, H. J. (1992) also regarded it as a synthesis of customer satisfaction, return on investment, and strategic objectives, etc.; and the behavioral theory is defined as behavior that can be observed and is a collection of behaviors to achieve job goals, as defined by Campbell, J. P. (1990) and Murphy, K. R. (1991); and holistic theory combines related behaviors, competencies, and outcomes, as defined by Boyatzis, R. E. (1991) based on competency. Domestic scholars are similar, with Chen, B. (2017) arguing that performance is an operational outcome based on strategic objectives, and Laskovaia, A. et al. (2017) arguing for an integrated holistic concept. Taken together, the outcome and holistic theories have their own focuses, and for high-tech enterprises, an integrated perspective is more comprehensive to reflect the characteristics of their Enterprise Performance, as such enterprises may not be profitable at the initial stage but have great growth potential. Therefore, this paper defines Enterprise Performance as the operating efficiency and performance of an enterprise during a certain period of time, as an indicator of the effectiveness of enterprise development and innovation.

Theoretical Framework

1. Relationship Between Knowledge Integration Capability and Redundant Resources

Knowledge Integration Capability of an enterprise is crucial in the effective utilization of Redundant Resources, which not only enhances the efficiency of resource utilization, but also strengthens the innovation and resilience of the enterprise. By integrating internal and external knowledge, enterprises can optimize resource allocation, avoid waste, and maximize resource utilization. First, Knowledge Integration Capability helps firms accurately identify and integrate Redundant Resources to support innovation activities and reserve resources for future R&D. Second, knowledge integration transforms Redundant Resources into innovation drivers, facilitating technological exploration and market opportunities to ensure that firms remain competitive. Finally, knowledge integration enables firms to flexibly adjust resource allocation in response to market fluctuations and technological challenges, enhancing organizational resilience and adaptability.

Based on this, this study proposes the following hypotheses:

H1: Knowledge Integration Capability has a positive impact on Redundant Resources.

2. The Relationship Between Knowledge Integration Capability and Enterprise Performance

High-tech firms rely on knowledge and innovation to maintain competitiveness, and it has been shown in the literature that knowledge management capabilities are closely related to Enterprise Performance. Knowledge integration helps firms to realize innovation in a dynamic environment and enhance revenue and competitive advantage. Empirical studies have shown that knowledge integration can effectively improve firm operations and enhance performance, market share, and human resource performance. For example, Guo, R. et al. (2019) found that planned and contingent knowledge integration has a positive impact on

Enterprise Performance, Dhir, S. et al. (2020) showed that knowledge integration contributes to post-merger and acquisition (M&A) performance, and Yang, M. et al. (2020) found that it has an inverted "U" shaped relationship on sustainable Enterprise Competitive Advantage. Other studies also point out that knowledge integration plays an important mediating role between different innovation types and Enterprise Performance. These studies emphasize the positive impact of knowledge integration on Enterprise Performance and competitive advantage.

Based on this, this study proposes the following hypotheses:

H2: Knowledge Integration Capability has a positive impact on Enterprise Performance.

3. The Relationship Between Knowledge Integration Capability and Collaborative R&D Networks

High-tech firms are increasingly relying on Collaborative R&D Networks to maintain their competitive advantage, and Knowledge Integration Capability is critical to the construction and operation of these networks. Scholars have conducted in-depth studies from various aspects. Gkypali, A. et al. (2018) in terms of information sharing mechanism, argues that Knowledge Integration Capability enhances the coordination and cooperation of the subjects in the network by facilitating the sharing of information. Kobarg, S. et al. (2019) in terms of resource allocation mechanism, argues that efficient Knowledge Integration Capability optimizes the allocation of resources so that enterprises can more effectively use the human, technological and financial resources. Wu, H. et al. (2018) in terms of innovation capability enhancement mechanism, argued that Knowledge Integration Capability enhances firms' innovation capability by helping to quickly identify innovation opportunities and transform them into market applications. In conclusion, Knowledge Integration Capability has a profound impact on the operation of Collaborative R&D Network through information sharing, resource allocation and innovation capability enhancement mechanism, which enhances the market competitiveness and innovation performance of Enterprise Performance.

Based on this, this study proposes the following hypotheses:

H3: Knowledge Integration Capability has a Positive Impact on Collaborative R&D Networks.

3. The Relationship Between Collaborative R&D Networks and Enterprise Performance

Existing studies generally agree that collaborative R&D has a positive impact on High-Tech Enterprise Performance because it provides abundant external resources and enhances the production and innovation capabilities of enterprises. Scholars have investigated the impact of Collaborative R&D Network on Enterprise Performance through social network analysis, paying particular attention to the breadth and strength of network relationships. Zhu, G. et al. (2019) found that the breadth (number of partners) and intensity (frequency of collaboration) of collaborative R&D can improve Enterprise Performance. Gao, X. et al. (2019) and Sun, B. et al. (2021) also confirmed this positive effect. Li-Ying Wang (2021) studied patent collaboration networks and concluded that collaborative R&D breadth and intensity promote Enterprise Performance. Kobarg, S. et al. (2019) found that collaborative R&D breadth has an inverted "U"-shaped relationship with breakthrough innovation performance, and intensity has an inverted "U"-shaped relationship with incremental innovation performance. " type relationship. Yang, Z. et al. (2020) also pointed out that the breadth and intensity of open innovation have similar effects on innovation performance. Zhen, M. et al. (2020) showed that Network Centrality has an inverted U-shaped effect on exploratory innovation, but has a positive effect on utilization innovation. Wang, T. (2020) found that the centrality of Collaborative R&D Network enhances Enterprise Performance. Overall, the

effects of the breadth, intensity and centrality of Collaborative R&D Network on high-tech Enterprise Performance are complex and varied, and are influenced by different types of innovation and industry characteristics.

Based on this, this study proposes the following hypotheses:

H4: Collaborative R&D Networks Have a Positive Impact on Enterprise Performance.

5. The Relationship Between Redundant Resources and Enterprise Performance

Redundant resources refer to the actual or potential idle resources within an enterprise that help the organization cope with environmental changes. March, J. G. et al. (1958) introduced the concept of "redundancy" in their book 《Organizations》, describing these surplus resources as a mechanism for managing uncertainty and change. Cyert, R. M. et al. (1963) further defined redundant resources as the difference between the enterprise's resource stock and actual demand, highlighting their role in alleviating internal pressures and adapting to external changes. Islam, S. M. T. et al. (2021) argues that Organizational Redundant Resources can provide the necessary support to enhance the firm's ability to cope with environmental changes and thus improve performance. Redundant resources not only offer a buffer in the face of emergencies but also enhance flexibility and adaptability, ultimately driving sustained development and performance improvement.

Based on this, this study proposes the following hypotheses:

H5: Redundant Resources Have a Positive Impact on Enterprise Performance.

6. The Mediation Effect of Redundant Resources

The success of high-tech enterprises depends on the effective utilization of Redundant Resources. Redundant Resources are underutilized idle resources that help firms respond to environmental changes and increase flexibility. Liu, B. et al. (2020) argues that high levels of Redundant Resources enable firms to better capitalize on external opportunities and expand strategic options.

Yang, M. et al. (2009) argues that redundant resources as a buffer to help firms cope with innovation costs and external pressures, and reduce risk. Scholars categorize them into absorptive and non-absorptive redundant resources. Absorbed Redundant Resources are idle cost resources within an organization that are used to support innovation projects, while non-absorbed Redundant Resources are liquid resources that have not yet been deployed and can be used flexibly for new strategies and innovation activities. Dong, J. Q. et al. (2019) argues that effective knowledge integration requires rational deployment of these resources to support related activities.

Based on this, this study proposes the following hypotheses:

H6: Redundant Resources Mediate the Effect of Knowledge Integration Capability on Enterprise Performance.

7. The Mediation Effect of Collaborative R&D Networks

Since its introduction in 2003, open innovation has rapidly evolved into a key paradigm in the competitive strategies of firms. Chesbrough, H. W. (2006) suggests that open innovation focuses on enhancing firms' innovative capabilities through the introduction of external knowledge, and that it drives firms to continuously innovate by integrating internal and external resources and facilitating knowledge flows. This concept emphasizes the value of external knowledge, which is usually valued more than internal knowledge by enterprise managers because this open innovation model can significantly reduce innovation costs and risks.

Collaborative R&D, as an important form of open innovation, has received extensive academic attention. Through collaborative R&D, firms are able to access a variety of

heterogeneous resources, which not only broadens the channels of knowledge acquisition, but also improves the efficiency of knowledge integration. This form of R&D collaboration enables firms to better utilize external resources, enhance their innovation capabilities, and gain an edge in competition.

Based on this, this study proposes the following hypotheses:

H 7 : Collaborative R&D Networks Mediate the Effect of Knowledge Integration Capability on Enterprise Performance.

8. Conceptual Framework Proposed

This study examines the impact of Knowledge Integration Capability, Redundant Resources and Collaborative R&D Network on High-Tech Enterprise Performance based on Dual Innovation Theory. Different types of Knowledge Integration Capability and their relationship with Enterprise Performance are analyzed, and the boundary conditions of internal resource deployment and external resource acquisition are considered. Redundant Resources and Collaborative R&D Network are introduced as mediating variables to delve into the impact of Knowledge Integration Capability on Enterprise Performance. The research framework reveals the role of Knowledge Integration Capability in different contexts and provides important insights for understanding innovation and Enterprise Performance in high-tech firms.

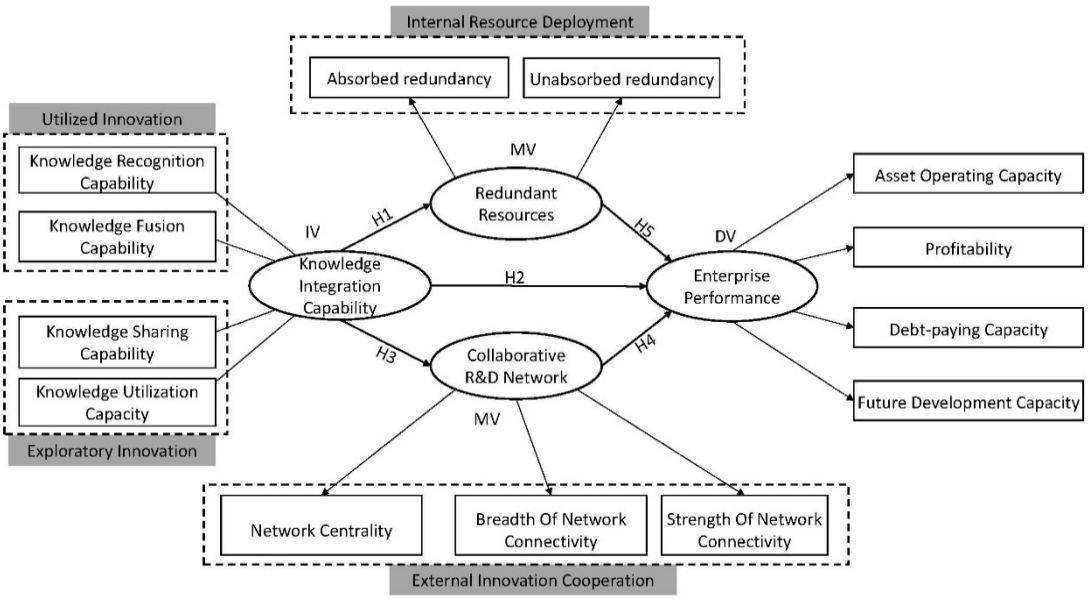

Figure 1 Research Theoretical Framework

Methodology

This study adopts a qualitative research method to analyze the literature review related to Knowledge Integration Capability, Redundant Resources, Collaborative R&D Network and Enterprise Performance by searching from databases. Reference sources include databases such as Web of Science, Scopus, and Science Direct, and only journal papers, dissertations, book chapters, and full-text documents are selected to ensure a comprehensive organization and systematic analysis of the literature in the relevant fields.

Conclusions

Based on the Dual Innovation Theory, this study constructs a theoretical framework covering Knowledge Integration, Redundant Resources, Collaborative R&D Network and Enterprise Performance, and explores the impact of Knowledge Integration Capability on the performance of high-tech enterprises. The main conclusions are as follows:

First, Knowledge Integration Capability has a significant positive impact on Redundant Resources, Enterprise Performance and Collaborative R&D Network. Effective knowledge integration optimizes internal resource utilization and enhances cooperation with external organizations, thus improving overall performance.

Second, Redundant Resources and Collaborative R&D Network played an important mediating role between Knowledge Integration Capability and Enterprise Performance, which further enhanced the competitiveness and innovation of the firm.

Overall, Knowledge Integration Capability is the key to enhancing the competitiveness of high-tech enterprises. By accumulating and effectively utilizing Redundant Resources and strengthening Collaborative R&D Networks, firms are able to achieve sustained innovation and growth in complex markets. This study provides theoretical and practical support for high-tech enterprises in their innovation-driven development strategy, enriches the research on Enterprise Performance from the perspective of knowledge management, and provides useful insights for understanding the knowledge integration process of high-tech enterprises and enhancing Enterprise Performance.

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