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Research on the Effect of Intellectual Capital on Enterprise Innovation Capability: Focused on Chinese Firms

by

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(지적 자본이 기업 혁신 역량에 미치는 영향 : 중국 기업을 중심으로)

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요 약

신속하게 변화하는 비즈니스 환경과 향상된 과학기술 수준에 직면한 현실에서 혁신은 기업이 경쟁의 우위를 유지할 수 있는 관건 요소이며, 지적 자본의 실물 자본 대체는 기업 창조력의 주요 원천으로 자리잡고 있다. 그렇다면 지적 자본은 과연 어떠한 경우에 기업의 혁신을 촉진할 수 있는 것인가? 특히 지적 자본은 인적 자본, 구조 자본, 관계 자본 등 여러 가지 측도를 포함하며 개인적 측면과 더불어 조직적 측면도 함께 다루고 있다. 그렇다면, 이러한 차원이 혁신에 미치는 영향에 충돌 존재하는가? 각 차원의 작용은 어떻게 구별되는가? 이러한 차원들은 어떤 메커니즘으로 기업 혁신에 영향을 미칠 수 있는 것인가? 이러한 질문들은 학계와 실무계가 절박한 마음으로 해결해야 할 당면 과제이다. 유감스럽게도 기존의 연구들은 결론의 차이가 커서 관리실천에 대한 지도적인 통일논리를 형성하기 어려웠고 기타 주변 이론과 명확한 연계를 구축하기에는 더욱 어려웠다. 이를 감안하여 지적 자본의 구성 차원을 명확히 밝히고 각 차원이 혁신에 미치는 영향에 대한 탐구를 통해 이 과정의 메커니즘을 밝혀낸다. 또한 이에 관련 개념이론을 접목해 유기적인 틀을 구축하고 기업의 실천을 지도할 수 있는 이론 및 논리 체계를 구축하는 것이 매우 중요하다.

따라서, 본 논문에서는 위에 언급한 이론과 실천에 존재하는 각종 문제에 대해 지적 자본이 기업 혁신에 어떻게 영향을 미치는지에 대한 핵심적인 문제를 둘러싸고 연구를 전개한다. 우리는 기업혁신 이론과 더불어 지적 자본 이론을 이론적 기초로 삼아 다른 관련변수를 도입함으로써 본 논문 연구의 틀을 설계 설계하는 이러한 과정 속에서 그 작용 메커니즘에 대해 깊이 있는 탐구를 진행했다. 이에 더해 우리는 다양한 실증 연구 방법을 적용해 다음과 같은 4 가지 문제를 형성하였다. (1) 지적 자본

및 서로 다른 각각의 요소가 어떻게 기업의 기술 혁신에 영향을 미치는가? (2) 기업의 사회적 책임 이행이 지적 자본과 기술 혁신의 영향 관계 속에서 과연 어떤 작용을 일으키는가? (3) 기업 혁신을 촉진하고자 하는 목적의 지식 공유가 어떻게 지적 자본의 서로 다른 각각의 요소에 영향을 미치는가? (4) 지적 자본의 서로 다른 각각의 요소가 기업 혁신의 양면적 특징 (탐험적 및 활용적 혁신) 에 어떻게 차별적인 영향을 미치고 있는가?

본 논문에서는 문헌 및 이론 연구, 문헌 계량 및 과학 지식 도감, 간접 데이터 기반 다중 회귀 모델, 설문 기반 구조 방정식 모델 등과 같은 연구 방법을 종합적으로 적용하였다. Stata, SPSS, Amos, CiteSpace 등과 같은 과학적인 소프트웨어 프로그램을 빌어 지적 자본과 기업 혁신 간 관계에 관한 연구를 보다 풍부하게 추진함으로써 기업의 사회적 책임 및 지식 공유가 양자 관계에서 담당하는 역할을 탐구하고 제시하였으며, 주로 다음과 같은 결론을 얻었다. (1) 지적 자본과 그 요소 (인적 자본과 구조 자본) 는 기술 혁신에 U 자형의 영향을 나타낸다. (2) 기업의 사회적 책임 이행은 지적 자본이 기술 혁신에 미치는 영향 및 그 관계를 조절하고 있다. (3) 지식 공유는 지적 자본과 그 요소에 현저하게 긍정적인 영향을 미치지만, 탐험적 혁신 및 활용적 혁신에는 직접적인 영향을 미치지 않는다. (4) 대체적으로 지적 자본과 그 요소는 탐험적 혁신 및 활용적 혁신에 현저하게 긍정적인 영향을 끼치며 지식 공유와 양면적 혁신 활동 사이에서 완전한 중개 역할을 담당한다.

키워드: 지적 자본, 기술 혁신, 기업의 사회적 책임, 기업의 소유권, 지식 공유, 양면성 혁신

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Abstract

In the face of a rapidly changing business environment and rapidly advancing technology, innovation has become the key to maintaining a competitive advantage for enterprises, and intellectual capital has replaced physical capital as the primary source of enterprise creativity. However, can intellectual capital promote enterprise innovation in all circumstances? In particular, intellectual capital includes multiple dimensions such as human capital, structural capital, and relational capital, involving both individual and organizational levels. Are there conflicts between the effects of these dimensions on enterprise innovation? What is the role of each dimension? What mechanisms are needed for them to have an impact on enterprise innovation? This is an urgent question for academics and practitioners. Unfortunately, the current research findings are widely divergent, making it difficult to form a unified theory with guiding significance for management practice. It is even more difficult to establish clear links with other peripheral theories. Given this, it is essential to clarify the constitutive dimensions of intellectual capital, explore the impact of each dimension on innovation, reveal the mechanism in this process, form an organic framework by combining relevant conceptual theories, and build a theoretical logic system that can guide enterprise practice.

Therefore, in this thesis, we focus on the core issue of how intellectual capital affects enterprise innovation in response to the various problems in theory and practice mentioned above. We design the research framework of this paper based on the theoretical foundation of enterprise innovation theory and intellectual capital theory and gradually explore the mechanism of action in this process in depth by introducing other relevant variables. On this basis, we used various empirical research methods to develop the following four sub-questions: (1) How do intellectual capital and its different elements affect technological innovation? (2) What role does the fulfillment of CSR play in the relationship between intellectual capital and technological innovation? (3) How does knowledge sharing for the purpose of promoting enterprise innovation affect different elements of intellectual capital? (4) What are the differential effects of intellectual capital and its different elements on the ambidexterity characteristics (exploratory and exploitative) of enterprise innovation?

With comprehensively applies research methods such as literature and theoretical research, bibliometric and mapping knowledge domains, multiple regression model based on secondary data, and structural equation model (SEM) based on survey questionnaire, and with the help of scientific software such as Stata, SPSS, Amos, and CiteSpace, this thesis promotes and enriches the research on the relationship between intellectual capital and corporate innovation, and explores and reveals the role of corporate social responsibility (CSR) and knowledge sharing in the relationship. The main research conclusions are as follows. (1) Intellectual capital and its elements (human and structural capital) show a U-shaped effect on technological innovation. (2) The fulfillment of corporate social responsibility positively moderates the relationship between the effect of intellectual capital on technological innovation. (3) Knowledge sharing has a significant positive effect on intellectual capital and its elements, but no direct effect on exploratory and exploitative innovation. (4) By and large, intellectual capital and its elements have significant positive effects on exploratory and exploitative innovation, acting as complete mediators between knowledge sharing and ambidextrous innovation.

Keywords: Intellectual Capital; Technological Innovation; Corporate Social Responsibility; Enterprise Ownership; Knowledge Sharing; Ambidextrous Innovation

I. Introduction

1.1 Research Background

Over the past few decades, knowledge has gradually become one of the essential factors of production. As a result, a new form of economy called the knowledge economy has emerged. This means that the production of goods and services in this era is based on knowledge-intensive activities. This has led to a great deal of academic interest in knowledge management (Powell & Snellman, 2004). The turbulent business environment and fierce competition in the marketplace have driven firms to seek new knowledge and use it to promote innovation, achieve superior performance, and thereby gain an edge over other firm. However, knowledge management in China is still in its infancy. The lack of attention to knowledge by many entrepreneurs who grew up in a closed and rigid period, as well as the insurmountable institutional barriers, have made the practice of knowledge management in Chinese firms very different from that in other countries (Liu et al., 2018; Zhao et al., 2012).

Knowledge management is inseparable from technology management. Bowonder and Miyake (2000) believe that technology management is predicated on knowledge management. The process of technology management in a firm aims to scan, select, learn, and adapt to new opportunities. It is essentially a process of constantly accepting and integrating new knowledge. Due to a range of knowledge management practices, firms could sustain themselves in the tide of the knowledge economy. While interest in knowledge management is ignited, attention must also be paid to the continued mining and development of the vast and vital literature on technology management topics (Teece, 1998). Effective knowledge management has become the key to business success, especially in knowledge-based industries. Much evidence suggests that the market value of knowledge-intensive firms is between two and nine times their book value, as most of the value of such firms is intangible. This part of the difference is usually considered to be created by the intellectual capital (Cabrita et al., 2017).

Numerous empirical studies confirm the importance of intellectual capital. Only those firms that manage their intellectual capital and knowledge creation processes effectively can grow and survive, while those that do not do so have difficulty innovating and are therefore destined for decline and failure (Bradley, 1997a; Cabrita et al., 2017). Economic growth in developing countries is necessarily the joint product of those intellectual capitals that represent ideas, skills and experience contained in a multitude of firms (Bradley, 1997b). This process has happened in all of today's many developed countries, as innovation is like a seed that spreads through a variety of actors to improve the productivity and performance of firms, which in turn contributes to social change and the accumulation of national wealth (Fu et al., 2018).

1.1.1 Practical Background

(1) Innovation-driven High-quality Development

Since the reform and opening up, China's development has mainly benefited from a long period of high-speed economic growth. But due to the rapidly changing external situation and the international realities that is difficult to assess properly, China's economy is in a critical transition period. The Chinese government believes China has shifted from its previous high-speed growth phase to a high-quality development phase. This statement hints at the dialectical relationship between speed and quality, as well as the future thinking of policymaking under downward economic pressure. It is generally believed that, in addition to export trade, which accounts for a decreasing share of GDP, China's past development was mainly factor-driven and investment-driven, including relatively cheap labor costs and large-scale infrastructure investment. However, the experience of many developed countries shows that high-quality economic development is necessarily innovation-driven (Zhou et al., 2020).

In a narrow sense, innovation-driven can be interpreted as technology-driven. From this perspective, innovation activities are mainly expressed as R&D inputs and outputs, reflecting the changes in various specific indicators, such as R&D expenditures, number of patents, and new product sales revenue, focusing on the discussion of knowledge creation and diffusion, technology protection, and commercialization. In a broad sense, innovation-driven refers to the development model that a country needs to adopt once its economic situation reaches a particular stage. It is similar to the transition from resource-driven and factor-driven to innovation-driven and wealth-driven as proposed by Michael E. Porter in the theory of national competitive advantage, or from factor-driven and efficiency-driven to innovation-driven as proposed by the World Economic Forum. In the innovation-driven period, national economic growth relies on the accumulation of innovation and knowledge factors, as well as a solid institutional system designed to support innovation (Tian, 2019).

(2) Human is the Key to Successful Innovation

It is generally accepted that innovation is both a spirit and a practice, and that any specific practice necessarily requires human involvement. As Rothwell (1992) states, the success of innovation is human-centered. Innovation is essentially a “human process,” and no management technique or tool can exist without humans. Although appropriate decision-making processes and organizational structures appear to be particularly important in many cases, scholars have long recognized that individuals, not organizations, are the key to successful innovation. The innovation practices of individuals (whether entrepreneurs or ordinary employees) often play a critical role in developing a project (Rubenstein et al., 1976). In this sense, not all entrepreneurs have the entrepreneurship to innovate, and not only entrepreneurs possess entrepreneurship. Ordinary employees may also be its carriers. Therefore, while management practices that focus on entrepreneurs may increase the likelihood of innovation success, it is also vital to manage creative people effectively (Mumford, 2000).

As the sum of economically valuable factors such as knowledge, skills, and physical strength of all individuals in the firm, human capital is the main raw material for knowledge innovation. Unlike physical capital, it is owned by individuals but is invested in the firm because of contractual relationships and usually has a higher rate of return. The emergence of knowledge-based firms has led to a deeper understanding of human capital and a rapid change in the way firms manage human resources. Human capital is increasingly becoming the essential capital of firms, and its carrier "human" has also become the core resource that firms compete with each other. In the traditional concept, firms only focus on physical capital but ignore that their human capital may not meet the actual needs of human-centered firms in the knowledge economy. Firms should give human capital owners the rights and benefits commensurate with their contributions to motivate them to create greater value (Tong et al., 2008).

(3) Intellectual Capital is the Nourishment of Innovation

In the new market and economic conditions, the essential factors of production in the business process have been transformed into intellectual resources, which include creative knowledge and creative people, highlighting the importance of human capital. However, if theories such as human capital and social capital are a revolution of general capital theory, the intellectual capital theory is another far-reaching expansion on this basis. Modern firms (especially knowledge-intensive firms) increasingly rely on the investment and development of intellectual resources to obtain economic benefits through the production, dissemination, and application of knowledge. The concept of intellectual capital has only served as an appendage and extension of human capital for a long time. It is based on human capital, complemented by relational / social capital, and guaranteed by structural / organizational capital (Stewart, 1997; Sveiby, 1997). Multiple dimensions synergistically promote individual knowledge creation and sharing, enhancing the firm's economic returns and value.

Although most studies support the positive role of intellectual capital, it is still often found that certain dimensions of intellectual capital have a negative impact on firm development (Zhang & Lv, 2015). This may be because firms over-invest their limited resources in specific areas, for example, by consuming large amounts of financial resources in maintaining relationships with external stakeholders, resulting in a severe shortage of resources that can be invested in innovative activities. It is also possible that the layout of intellectual capital does not match the firm's innovation model. For example, once a firm decides to adopt an open innovation strategy with user participation, it needs to consider increasing its spending on relational capital, reducing its spending on human capital, and adjusting its organizational structure appropriately. It can be seen that to gain competitive advantage through innovation, enterprises no longer have to allocate only physical capital such as machinery, equipment, and raw materials but must also pay attention to the reasonable layout of intellectual capital (Subramaniam & Youndt, 2005; Ren & Song, 2021).

1.1.2 Theoretical Background

(1) The Proper Meaning of Sustainable Management: CSR

Corporate Social Responsibility (CSR) is one of the topics of lively discussion in the international community. It is a fundamental condition for China's firms to enter the international market and a critical factor in creating value and achieving sustainable development. According to Carroll's (1979) CSR pyramid model, from bottom to top are economic, legal, ethical, and discretionary responsibilities. Milton Friedman, a Nobel Prize winner in economics, once pointed out that "the business of a business is business," which explains the fundamental purpose of establishing a firm and striving for going concern. However, with time, this development model of making profits as the highest morality of firms has become unsustainable. Corporate responsibility has gradually expanded to a comprehensive CSR encompassing the balanced development of social economy, ecological environment, people's livelihood, and human life rights, etc. Although fulfilling social responsibility seems to be a self-disciplinary act of firms, in recent years, it has essentially become an obligation, but there is still some flexibility in the extent to which firms fulfill their social responsibilities.

As Porter and Kramer (2006) argued, mandatory international norms can guide firms to implement CSR awareness into their business strategies and maximize their value to society and community. Overall, it seems that the international community generally agrees that CSR fulfillment can help firms improve their competitiveness and performance. Although in the short term, it may lead to a temporary increase in costs, in the medium or long term, CSR fulfillment can help firms reduce operating costs, improve employee motivation, and enhance the ability to manage crises, innovate, and apply new knowledge (Utting, 2005). In other words, if China's firms want to achieve their sustainability goals and promote sustainable innovation, they need to balance economic, environmental, and social responsibility at the same time, and pay attention to the needs of a broader range of stakeholders (Liu et al., 2016).

(2) The Key Path to Knowledge Management: Knowledge Sharing

Promoting knowledge sharing has been the core of research in knowledge management. The most severe difficulty of knowledge management is “changing human behavior.” If firms want to implement innovation successfully, they need to change the low willingness of employees to share and then encourage knowledge-sharing behavior (Ruggles, 1998). Knowledge sharing aims to enable each member of the sharing system to access and utilize the knowledge results created by others fully. This sharing relationship can promote the existing knowledge to bring its maximum value and emerge new knowledge. However, with the continuous improvement of knowledge collection and storage methods, the efficiency and effectiveness of knowledge sharing have become the main problems plaguing firms’ knowledge management. The modern organizational theory even proposes to replace “knowledge is power” proposed by Francis Bacon with “sharing knowledge is power.” Knowledge transforms from individual ownership to collective ownership through knowledge sharing, and each participant can benefit from this process (Fong & Chu, 2006).

In August 2020, the Suzhou Bureau of Statistics had released a survey report on the employment situation involving 491 enterprises, which showed that the number of employees who left in the first half of 2020 accounted for 24.4% of the number of employees at the end of the previous year. Nearly half of the surveyed firms reported difficulties in recruiting employees and a lack of technical staff. Most firms did not believe that employee turnover was directly related to the epidemic. The departure of employees means the loss of human capital. If the tacit knowledge possessed by individuals can be transformed into explicit knowledge that employees can generally use before then, the actual loss will be significantly reduced. However, knowledge sharing does not happen automatically. A reasonable sharing system cannot be built on selfless dedication, nor can it be built on external coercion. Firms are increasingly emphasizing the role of information technology for knowledge management and investing heavily in it. But it is not easy to demonstrate a positive relationship between the complexity of technology and the quality of knowledge sharing (De Long & Fahey, 2000). Information technology is only an auxiliary tool for knowledge sharing. If the role of people, the main subject of knowledge sharing, is ignored, the firm's knowledge management will lose its direction (Qin & Ding, 2007).

1.2 Research Objectives, Questions, and Significance

1.2.1 Research Objectives and Questions

As mentioned earlier, both intellectual capital and innovation are critical factors for firms to maintain competitive advantage, and their relationship has been the focus of academic research. However, intellectual capital includes many dimensions, such as human capital, structural capital, and relational capital. Different studies have not precisely divided them in the same way, which has given rise to very different measurement methods. At the same time, innovation contains many different types, and different firms usually need to adopt different strategies when pursuing different types of enterprise innovation. So, do different dimensions of intellectual capital have the exact mechanisms of influence on different types of innovation? Are all dimensions of intellectual capital able to positively affect different types of innovation in any given situation? Unfortunately, the reality of management practice is so complex that attempts to develop a unified theory always end up in vain. The only way to reveal the general principles behind the phenomenon is to analyze it case-by-case. In this study, to better fit the actual situation of the knowledge management field in China, we emphasize the role of humans or employees and the social responsibility that firms should take the initiative. Based on intellectual capital theory and innovation theory, we take the impact of intellectual capital on innovation as the mainline and form the following four specific sub-questions by introducing relevant variables.

(1) Sub-Question 1: How do intellectual capital and its different elements affect technological innovation?

Promoting technological innovation is essential for firms to maintain sustainable growth in a highly competitive environment. Although many existing studies have explored this issue, they have mainly focused on the linear relationship between intellectual capital and technological innovation, ignoring the possibility of a nonlinear relationship between them. In this sub-question, we use the VAIC method to divide intellectual capital into two dimensions: human capital and structural capital. Based on factor endowment theory, this study explores the nonlinear relationship between intellectual capital and technological innovation through OLS regressions using data from Chinese A-share listed firms from 2014-2019 as a sample.

(2) Sub-Question 2: What role does the fulfillment of CSR play in the relationship between intellectual capital and technological innovation?

Since CSR has essentially become an obligation that firms must undertake, consumes their limited resources, and influences stakeholders' perceptions and decisions about the firm, CSR fulfillment inevitably impacts many performance-related outcome variables. There have been many studies that have confirmed the positive or negative effects of CSR. However, there is not much current evidence of a direct causal relationship between intellectual capital and CSR; therefore, this study treats CSR as a moderating variable rather than a mediating variable for the effect of intellectual capital on technological innovation. In addition, we also explore whether firms with different ownership systems produce inconsistent findings for the above question.

(3) Sub-Question 3: How does knowledge sharing for the purpose of promoting enterprise innovation affect different elements of intellectual capital?

There is no doubt that the primary purpose of firms to encourage knowledge sharing is to drive innovation, and many studies have confirmed the influence relationship between them. However, as nutrients for enterprise innovation, what role do the different elements of intellectual capital play in this relationship? Are the effects of knowledge sharing on the different elements of intellectual capital all positive and significant? This study used a triadic perspective to classify intellectual capital into human, structural, and relational capital to explore this sub-question. Using the structural equation model and questionnaire survey method, we analyzed the impact of knowledge sharing on the three elements of intellectual capital by collecting questionnaire data from high-tech enterprises in Jiangsu Province.

(4) Sub-Question 4: What are the differential effects of intellectual capital and its different elements on the ambidexterity characteristics (exploratory and exploitative) of enterprise innovation?

Scholars have long recognized that no one innovation model can make all firms successful and that the models behind successful firms are often very different. Firms must choose the model that best suits their capabilities and development goals. Following on from the previous sub-question, when we consider the ambidexterity of innovation and divide it into exploratory and exploitative innovation, how do different elements of intellectual capital differentially affect the relationship between knowledge sharing and different types of innovation? To this end, we test whether different elements of intellectual capital both play a mediating role between knowledge sharing and enterprise innovation and whether they are fully or partially mediating.

1.2.2 Significance of the Research

Since the concept of intellectual capital was introduced, it has been one of the critical topics of interest in both theoretical and practical circles. Although many scholars have researched related issues, many valuable results have been formed. However, there is still no unified conclusion on many vital topics because of the many research points and comprehensive coverage. Moreover, both intellectual capital theory and innovation theory are not static but dynamic and should provide new evidence based on new realities. Therefore, this thesis can enrich the relevant theories to a certain extent and expand the research perspective of knowledge management.

On the one hand, adhering to the core topic of knowledge management, this thesis explores the role of knowledge sharing in promoting the accumulation of intellectual capital and enterprise innovation in more detail. Most firms have very limited resources to invest in knowledge sharing. Firms expect to maximize knowledge sharing with a minor investment, thus introducing many emerging management tools. In the new situation, this thesis further analyzes the role of different dimensions of intellectual capital in bridging knowledge sharing and different types of innovation by constructing a new research framework. We hope to help firms select more suitable management tools to facilitate knowledge sharing to match their innovation models.

On the other hand, this thesis is also oriented to corporate social responsibility, emphasizing that more attention should be paid to human values in the production and operation process and contributions to the environment, consumers, and society. This thesis does not limit our attention to the linear relationship between intellectual capital and technological innovation. We try to use the VAIC method to explore the possibility of a nonlinear U-shaped relationship between intellectual capital and technological innovation in two dimensions: human capital and structural capital, in order to provide a new direction for other scholars to conduct further research on intellectual capital, and at the same time, to provide a theoretical basis for firms to fulfill their social responsibility proactively, moderately, and effectively. In addition, we use secondary data and questionnaire survey methods, respectively. The findings of these two research methods complement and corroborate each other, further deepening our understanding of the relationship between intellectual capital and innovation.

1.3 Research Ideas and Methodology

1.3.1 Structure of the Thesis

This thesis is divided into 5 chapters and contains 2 sub-studies. The specific technical roadmap is shown in Figure 1-1, and the thesis is structured as follows.

Chapter 1: Introduction. This chapter first introduces the current practical background and theoretical background regarding intellectual capital, enterprise innovation, and their relationship. Then, we discuss the necessity of raising relevant questions and describe the specific research structure, significance of the research, and technical roadmap. Finally, we elaborate on the research methodology, and potential contribution points one by one.

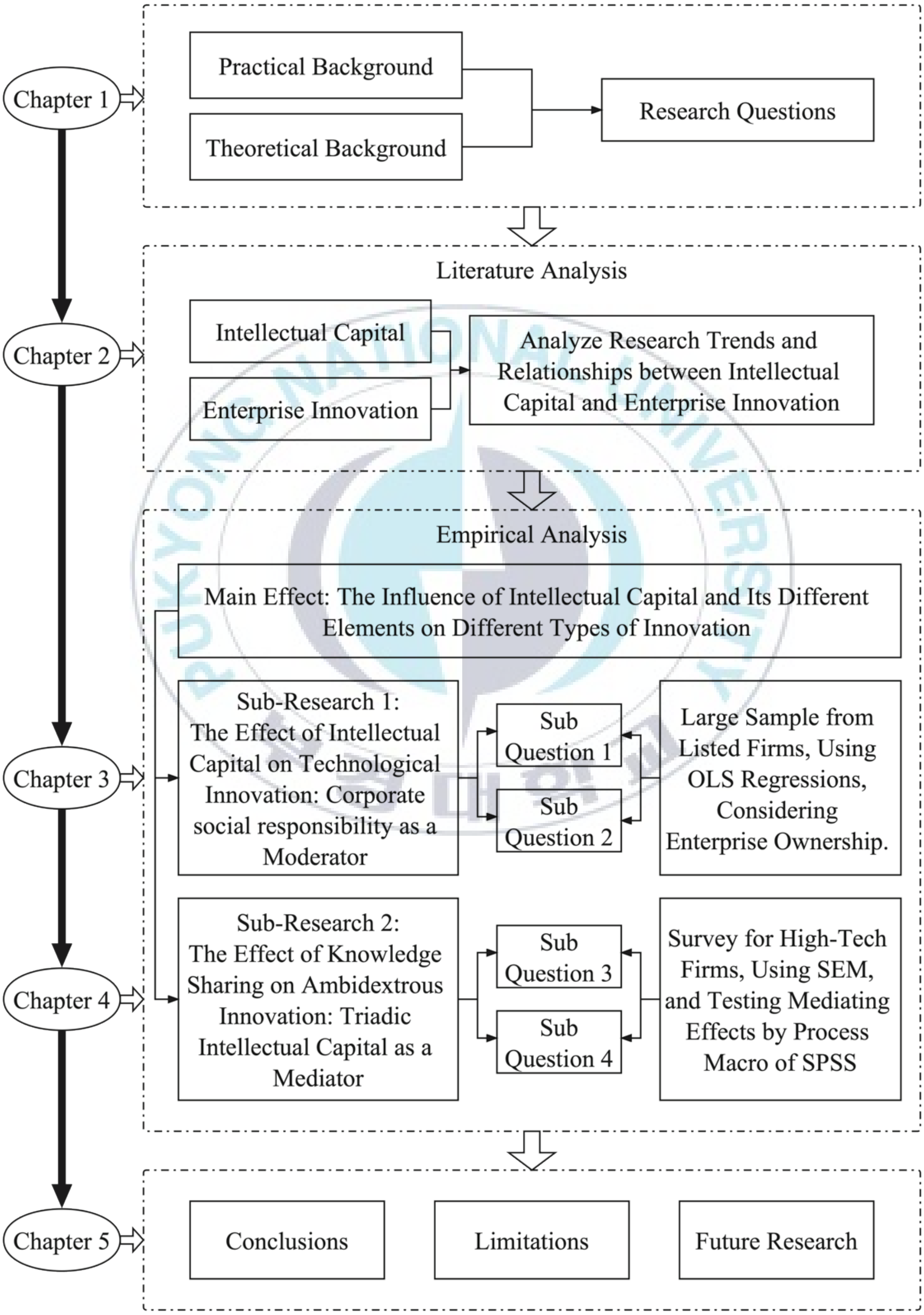
Chapter 2: Literature review. This chapter provides a more systematic organization and review of intellectual capital and enterprise innovation theories and clarifies each concept's theoretical basis and mainstream views. It also uses bibliometrics to summarize the research frontiers and hot issues on the relationship between intellectual capital and innovation. It provides appropriate comments to build a theoretical framework for subsequent research.

Chapter 3: A study of the relationship between intellectual capital, corporate social responsibility, and technological innovation. As the first sub-study of this thesis, this chapter explores the possibility of a nonlinear relationship between intellectual capital and technological innovation based on a review of the literature on the two. We then include CSR in the study to examine whether it may play a moderating role in the relationship between the impact of intellectual capital on technological innovation. In addition, we do further group tests (state-owned and private firms) to clarify whether the impact of intellectual capital on technological innovation differs significantly depending on the ownership nature of the firm. Finally, we make some managerial recommendations and respond to some current controversies regarding how intellectual capital is measured (especially the VAIC method).

Chapter 4: A study of the relationship between knowledge sharing, intellectual capital, and ambidextrous innovation. As the second sub-study of this thesis, this chapter takes knowledge sharing as the antecedent variable of intellectual capital. Based on the theoretical logic of "knowledge sharing - triadic intellectual capital - ambidextrous innovation," we further explore the complex relationship between the three dimensions of intellectual capital and the two dimensions of ambidextrous innovation and the mediating role of intellectual capital. This chapter refers to the mature scales in the classical literature and obtains data by distributing questionnaires to employees of high-tech firms. Then, we use the structural equation model to analyze the data and discuss some unexpected results.

Chapter 5: Conclusions. This chapter concludes the results of this thesis with a holistic view based on the empirical test results of the two sub-studies. Then, we present some management implications and suggestions from the perspective of long-term corporate sustainability, analyze the shortcomings of this thesis, and provide an outlook on future research directions worth tapping.

<Figure 1-1> Structure of this Thesis



1.3.2 Research Methodology

For the needs of the empirical study, this thesis used software such as Stata, SPSS, Amos and CiteSpace for data processing and analysis. The main research methods applied in this thesis are as follows.

(1) Literature Analysis and Mapping Knowledge Domains

Literature analysis is an analytical method to collect, identify, and organize the existing literature related to the proposed research and obtain the required information through systematic analysis to form a more comprehensive scientific understanding. It can help us clarify the current research status, identify research gaps, determine more appropriate research directions, and propose research questions and hypotheses accordingly. Chapters 2 to 4 of this thesis extensively use the literature analysis method for research. Knowledge mapping refers to a class of graphics that shows the development process and structural relationship of knowledge with the knowledge domain as the object. Through data mining, information processing, knowledge measurement, and graph drawing, complex knowledge domains are visualized, revealing the dynamic development patterns of knowledge domains, and providing practical and valuable references for research. Mapping knowledge domains has been increasingly used in literature reviews in recent years. Chapter 2 of this thesis analyzes research trends and frontier topics on intellectual capital and enterprise innovation using CiteSpace and knowledge mapping.

(2) Secondary Data and Multiple Regression Model

Secondary data, as opposed to primary data (first-hand data), refers to statistics that have been collected not for the ongoing study but other purposes. This data type is characterized by low cost, large sample size, and expertise, making the resulting research conclusions appear more objective. As a result, an increasing proportion of studies are using secondary data. However, not all questions that one wants to study can be supported by secondary data. Even when similar data are available, they usually fail to answer the researcher's specific research questions due to biases in operational definitions or collection methods. In general, regression analysis involves analyzing the causal relationship between the independent and dependent variables to be studied by building a mathematical model, solving for each model parameter based on the measured data, and assessing whether the regression model fits the measured data well. The regression model that contains only one independent variable is called a univariate regression model, while the one that contains multiple independent variables is called a multiple regression model. If the relationship between the independent and dependent variable is linear, it is a linear regression model; if it is nonlinear, it is a nonlinear regression model, and usually requires the inclusion of a quadratic term in the regression model. All the data used in Chapter 3 of this thesis are secondary data and are analyzed using a nonlinear multiple regression model.

(3) Questionnaire Survey and Structural Equation Model

The questionnaire survey is commonly used to obtain primary data, mainly measuring individuals' behaviors and attitudes, usually using closed-ended scale tests. The most common form of scale is the Likert scale. In contrast to secondary data, the use of primary data must consider issues of reliability and validity. For the sake of the scientific nature of the study, the questionnaire should be designed so that the items are not beyond the knowledge and ability of the respondents, are consistent with the research hypothesis, and are not ambiguous or suggestive. The structural equation model (SEM) is a multivariate statistical method that integrates factor analysis and path analysis. It simultaneously tests the relationship between the manifest, latent, and disturbance / error variables and thus obtains the direct effects, indirect effects, or total effects of the independent variables on the dependent variable (Fan et al., 2016). A complete structural equation model consists of two parts: a measurement model and a structural model. The former describes how the latent variables are measured or conceptualized by the manifest indicators. The latter describes the relationship between the latent variables, and the amount of variation that other variables in the model cannot explain. Cepeda-Carrion et al. (2019) analyzed the rationality of using SEM to study knowledge management issues. They argue that variables and data in knowledge management are mainly obtained directly from surveys and interviews, and that management issues affecting organizational performance can only be operationalized based on unobserved variables, while SEM is a data analysis technique designed to explain unobserved variables with latent variables. Therefore, Chapter 4 of this thesis uses questionnaires to collect data and AMOS to conduct SEM analysis.

1.4 Potential Research Contributions

All research questions in this thesis are grounded in the Chinese context. We focus on the core topic of the impact of intellectual capital on innovation, as they are among the factors that are currently most capable of adding value to firms, generating competitive advantage, and improving performance. Our discussion revolves around the relationship between multiple dimensions of intellectual capital and different types of innovation. Then, on top of that, some new research frameworks are constructed by introducing other variables to explore their relationship with innovation one by one. Specifically, this thesis makes a reasonable attempt in several aspects, and the main potential contributions and advances are reflected in the following points.

(1) Expanded the boundaries of related research. By integrating corporate social

responsibility and knowledge sharing into the research framework, this thesis further analyzes the influence mechanism of intellectual capital on enterprise innovation from the dualistic and triadic viewpoints of intellectual capital, respectively. Our research results reconfirm the importance of intellectual capital to the sustainable development of firms and the need for firms to pay attention to knowledge sharing and social responsibility in the new situation.

(2) Discovered new research findings. This thesis breaks through the mindset that the relationship between intellectual capital and enterprise innovation can only be linear. By measuring intellectual capital with a VAIC formula more commonly used in China, we confirm the non-linear U-shaped relationship between intellectual capital and technological innovation. To some extent, this explains why certain elements of intellectual capital negatively affect enterprise innovation or performance in some studies. Our research also shows that knowledge sharing does not directly promote innovation and that its effect on innovation is mediated by intellectual capital. Therefore, we must first consider whether tools designed to encourage knowledge sharing actually help accumulate intellectual capital.

(3) Used a composite research approach. This thesis uses two research methods, "secondary data + multiple regression model" and "questionnaire survey + structural equation model," to compensate for the shortcomings of using a single research method. The findings of both empirical approaches suggest that, in general, intellectual capital ultimately promotes innovation. However, the secondary data with a vast sample size show that intellectual capital needs to cross a "threshold" and accumulate to a certain amount before promoting innovation. The primary data with a smaller sample size suggest that while intellectual capital can foster innovation, not all elements are compatible with a firm's innovation strategy.

II. Literature Review

2.1 Intellectual Capital Theory

With the advent of the knowledge-based economy, traditional tangible assets, such as plants and equipment, can no longer fully explain the competitive advantage of firms (Bayraktaroglu et al., 2019). Increasing attention has been given to discovering other potential capabilities of all kinds of enterprises. Early on, scholars tended to discuss intellectual capital in the field of accounting. However, its importance in the process of enterprise value creation has gradually been widely recognized by entrepreneurs. In this context, scholars have given unprecedented attention to intellectual capital and expanded it into the discussion of management, economics, and other disciplines. This section discusses the definition of intellectual capital, compares several theories that delineate the internal structure of intellectual capital, and introduces the commonly used measures of intellectual capital.

2.1.1 Definition of Intellectual Capital

Intellectual capital, in a narrow sense, can be traced back to 1836. In *An Outline of the Science of Political Economy*, Nassau W. Senior regarded intellectual capital as a synonym for human capital, referring to the knowledge and skills possessed by each worker, and considered it an essential productivity factor. Currently, however, scholars generally agree that the concept of intellectual capital in a broad sense was first introduced by Canadian-born economist Galbraith in 1969 (Bontis, 2001). He tried to use intellectual capital to explain the difference between the market value and the book value of a firm (Hsu & Fang, 2009). Since then, it has been widely accepted that intellectual capital is not only a static stock of knowledge but also a dynamic process of value creation using knowledge in the brain (Edvinsson & Sullivan, 1996). It is not limited to technological innovation, nor to forms of intellectual property recognized by law, such as patents, copyrights, trademarks, and business secrets. Stewart (1994) published many articles in *Fortune* magazine in the 1990s that contributed significantly to the development and refinement of intellectual capital theory. For example, Stewart (1997) argued that all knowledge and capabilities that provide a competitive advantage to a firm, or that enable a firm's real value to exceed its book value, including information, experiences, intellectual property rights (IPR), and customer relationships, could be broadly referred to as intellectual capital. Meanwhile, other scholars have also contributed their own definitions of intellectual capital. One of the more unusual definitions is that of Ulrih (1998), who compares intellectual capital to the product of an employee's competence and commitment.

Since intellectual capital has become very multidisciplinary, developing a uniform and clear definition is not easy. Some scholars believe that intangible assets, intellectual assets, and intellectual capital have the same or similar meanings (e.g., Guthrie, 2001). For example, Lev (2000) summarizes that, in accounting, the concept of intangible assets is commonly used. In economics, the concept of intellectual assets is generally used. In management and legal instruments, the concept of intellectual capital is more commonly used. However, Itami and Roehl (1991) also pointed out that intellectual capital is actually a special kind of intangible asset. Intellectual capital includes both traditional intangible assets that can be recorded in accounting books, such as IPR, and goodwill, and new intangible assets that cannot be recorded in accounting books because they cannot be accurately identified, such as the knowledge and skills of employees and the management culture of the firm. Dumay and Garanina (2013) call for scholars to move away from the dominant accounting paradigm in the study of intellectual capital. From practical experience, although there are many significant commonalities among intangible assets, intellectual assets and intellectual capital, especially in that they all provide a competitive advantage to the enterprise (Petty & Guthrie, 2000), in the available literature, the meanings of intellectual assets and intellectual capital are closer, while the meanings of intangible assets and intellectual capital are more different, because intangible assets do not always exist in the form of knowledge. Therefore, intellectual capital should not be arbitrarily equated with intangible assets.

Some other scholars analyze intellectual capital in terms of both value creation and value extraction. Firms that focus on value creation tend to focus their management efforts on how human capital is organized and directed, and how knowledge is created and provides value to the business. Firms that focus on value extraction tend to focus their management efforts on their intellectual assets (e.g., IPR and commercializable intangible assets) and make more money from them (Edvinsson & Sullivan, 1996). Hall (1992) argued that intellectual capital is the value driver that transforms productive resources into value-added assets and classifies intellectual capital as both human-dependent and human-independent. Both categories of intellectual capital create value but differ in the way and ability to drive value creation. Bradley (1997a; 1997b) argued, similar to Hall (1992), that firm's intellectual capital has the ability to transform knowledge and other intangible assets into resources that could create wealth. It is this intellectual capital that allows the use value of the firm's physical assets to be enhanced and brings additional profits to the firm. Edvinsson and Sullivan (1996) pointed out that many knowledge-based firms in the market have high valuations, but the mere presence of high intellectual capital does not seem to be sufficient to explain this phenomenon. In fact, from the point of view of firm profitability, it is perhaps more crucial to try to improve the firm’s ability to exploit its intellectual capital.

From this, we can see that intellectual capital, no matter from which perspective it is understood, is essentially a special type of resource based on intelligence (or knowledge) that has no physical form. Intellectual capital is owned or controlled by firms, brings competitive advantage to firms, and generates benefits to firms in the future period, which may be either in the traditional monetary or physical form, or in the form of intellectual capital itself.

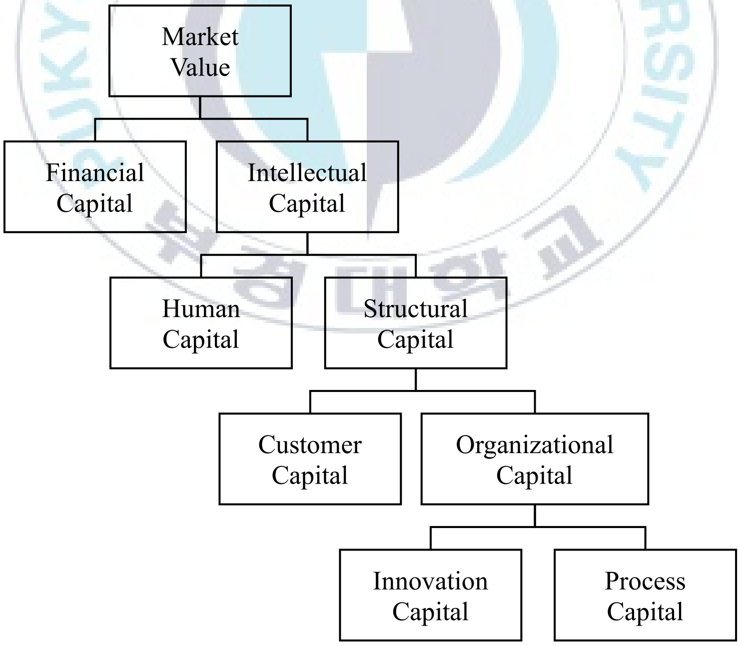
2.1.2 Dimensions of Intellectual Capital

Scholars currently have different opinions about the dimensional classification of intellectual capital, forming different views such as dualism, triadism, and pluralism. However, these views do not differ much in essence, and often just make further subdivisions based on other classifications, or recategorize them, and some even simply change the names of the classifications. In practice, researchers often decide which classification to adopt based on the research methods or data sources. Because certain dimensions are difficult to measure using financial data, scholars who focus on using financial data may prefer to use dualism. In contrast, scholars who focus on using survey data may prefer to use triadism or pluralism.

(1) Dualism

In 1993, Edvinsson (1997) first used the term “intellectual capital” in place of the accounting term “intangible assets” in the annual report of the Swedish financial and insurance firm *Skandia*, meaning that market value = intellectual capital + financial capital. A few years later, Edvinsson and Malone (1997) developed a *Skandia Value Scheme*, where intellectual capital is first divided into human capital and structural capital as a whole, as shown in Figure 2-1. Human capital refers to the level of knowledge, experience, skills, and problem-solving abilities of each member of the firm, while structural capital is a set of knowledge and skills that reflect the firm's infrastructure and the processes that sustain the normal operation of the organization. Then, they further divided structural capital into customer capital and organizational capital. Organizational capital refers to the connections within the firm, while customer capital refers to the connections to the outside of the firm and the value of customer relationships. Organizational capital can be further subdivided into innovation capital, which represents how the firm operates, and process capital, which contains the firm's intellectual property and other intangible assets.

<Figure 2-1> Skandia Value Scheme



In 1999, the Organization for Economic Cooperation and Development (OECD) held an international symposium on intellectual capital in Amsterdam, the Netherlands. The conference described intellectual capital as the economic value of two types of intangible assets: organizational (structural) capital and human capital. More precisely, structural capital refers to elements such as proprietary software systems, distribution networks, and supply chains. Human capital includes human resources within the organization (i.e., employee resources) and resources outside the organization (i.e., customer and supplier resources) (Guthrie, 2001).

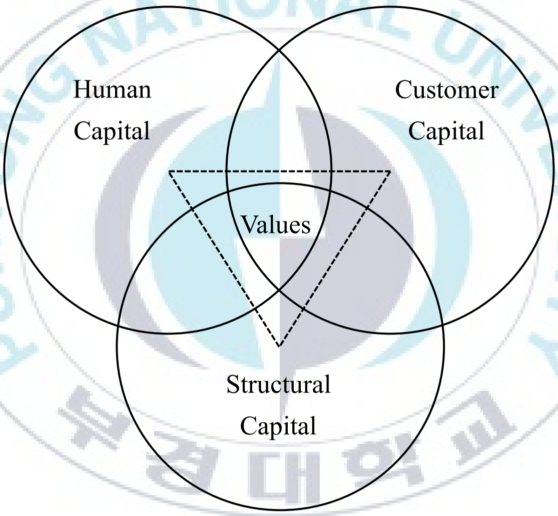
Besides, many other scholars have also enriched the dualistic intellectual capital to some extent. For example, Nahapiet and Ghoshal (1998) divide intellectual capital into human capital and social capital. They argued that social capital facilitates the creation of new intellectual capital. It is also the availability of more intensive social capital that, to a certain extent, gives firms an advantage over other market agents in creating and sharing intellectual capital. However, this view is not adopted in the study of Leitner (2015), who argues that relationships and collaborative networks with various types of partners (e.g., customers, suppliers, and research institutions) are important for firm's innovation activities. Not only within the innovation team, but also when communicating with external participants, it enables firms to integrate new forms of knowledge in a unique way.

(2) Triadism

Based on the dualism, some scholars have continued to expand the triadism of intellectual capital. Stewart (1997) splits structural capital into a new type of structural capital that represents the internal resources of the organization and customer capital that represents the external resources of the organization. At this point, intellectual capital is composed of three elements: human capital, structural capital, and customer capital, respectively. It measures human capital in terms of employee attitude, turnover rate, and new product output; structural capital in terms of sales ratio, overhead, and working capital turnover; and customer capital in terms of customer satisfaction, brand,

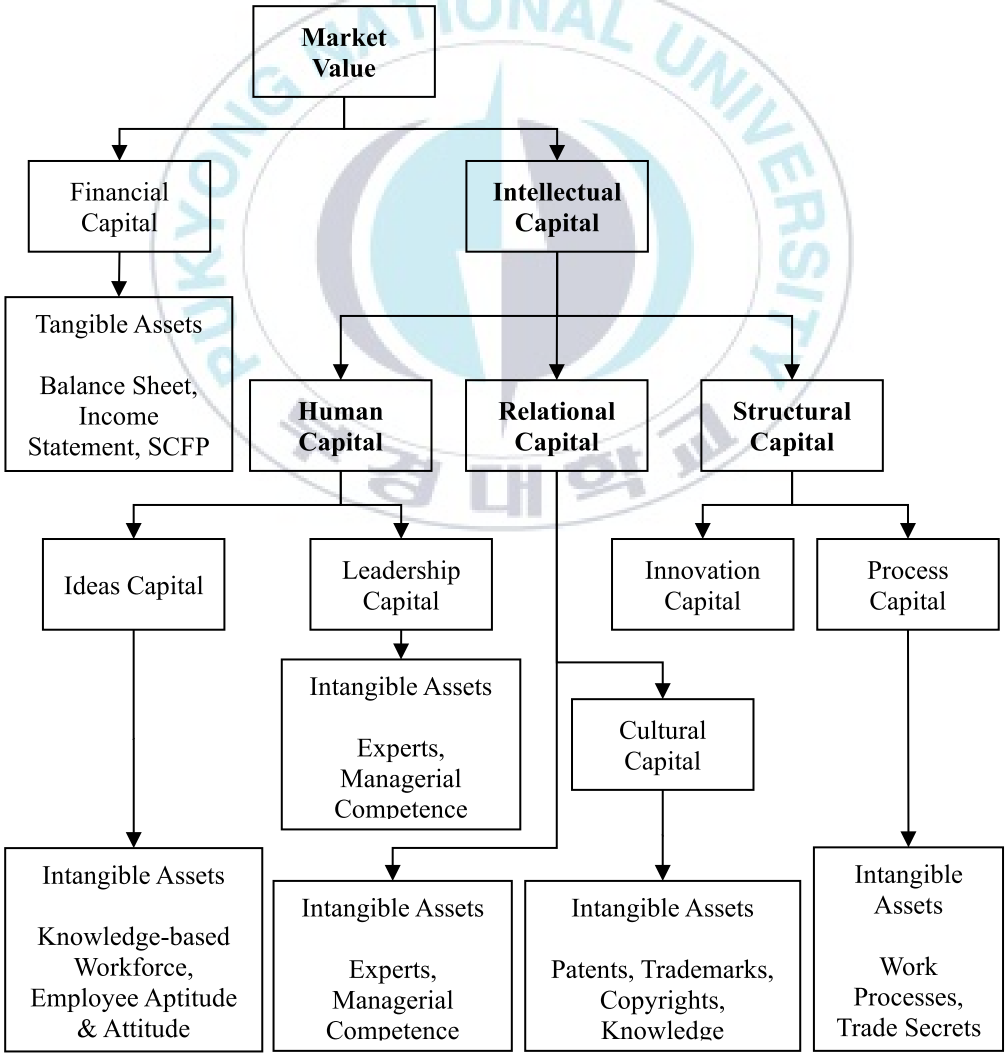
and customer retention rate. This classification has also been adopted by many scholars such as Bontis (1998). Figure 2-2 depicts the process by which these three elements interact and work together to create firm value. In this case, the dotted line represents the knowledge management process of the enterprise, the goal of which is to maximize the value area of the center. It is easy to find that the closer the connection between the three elements, the larger the space of value created for the enterprise.

<Figure 2-2> Stewart's Intellectual Capital Framework



In addition, Johnson (1999) further divided and described the model of triadic intellectual capital in detail. As shown in Figure 2-3, he divides intellectual capital into human capital, structural capital, and relational capital. The relational capital component includes intangible assets such as customer or supplier relationships and relationship networks. Li and Huang (2003) pointed out that the connotation of relational capital is much larger than that of customer capital, which is limited to the value derived from customer-related relationships. An organization's external relationships should not only be with customers but also with suppliers, government departments, and other stakeholders. Only when other kinds of external relationships are taken into account, could a more comprehensive and systematic picture of an organization's external relationship circle be presented. Therefore, it may be more appropriate to use relational capital rather than customer capital to express the external relationships of a firm. At present, when Chinese scholars conduct studies related to intellectual capital, most of them adopt this triadic model consisting of human capital, structural capital, and relational capital (e.g., Wang et al., 2014).

<Figure 2-3> Johnson's Intellectual Capital Framework



(3) Pluralism

With the increasing complexity of the business environment, scholars have further expanded the connotation of intellectual capital on the basis of the original triadic theory by incorporating concepts such as market capital, intellectual property capital, innovation capital, and social capital, creating a pluralistic theory of intellectual capital. Brooking (1998), one of the early proponents of pluralistic theory, defines intellectual capital mainly from the perspective of intangible assets. He considers intellectual capital as the sum of intangible assets of a firm, including market assets, human-centered assets, intellectual property assets and infrastructure assets. Johannessen et al. (2005) classify intellectual capital into human capital, structural capital, network capital, and system capital from the perspective of enterprise value creation. Network capital reflects the social relationships between internal and external aspects of the enterprise, and its purpose is to achieve organizational goals and improve the bottom line. They argued that network capital facilitates the establishment and development of trust relationships, strengthens the quality of trust relationships, and enhances the closeness of interpersonal network connections. Systemic capital refers to the ability of a firm to adapt to environmental changes caused by changes in social institutions and to create its own future.

The five-factor theory is represented by Bassi (1999), who classifies intellectual capital into human capital, structural capital, innovation capital, process capital, and customer capital. After that, Bueno et al. (2006) also considered that intellectual capital should be divided into five dimensions, namely human capital, organizational capital, technological capital, business capital and social capital. Among them, technological capital includes the firm's technological R&D investment, technological equipment, and industrial intellectual property. Business capital includes relationships with customers; relationships with competitors and allies; and relationships with suppliers, investors, and institutions. Social capital includes a firm's reputation, social image, social behavior, and social relationships. Andreou and Bontis (2007) categorize intellectual capital as market capital, human capital, decision effectiveness, organizational capital, and innovation capital. Decision Effectiveness refers to the extent to which a firm's decision-making process should be responsible for failed business practices. Innovation capital refers to the success rate of new products and services and the resulting revenue.

Throughout the abovementioned divisions, we could see that, regardless of the value standpoint, there is a great deal of consistency in what intellectual capital encompasses, differing only in the fineness of the division and the deeper logical relationships. It should be noted that in this study, we did not try to create or improve a new intellectual capital structure on our own but rather borrowed and inherited from existing research. Our basic view is that intellectual capital should be divided into at least two parts: human capital and structural capital. Regarding how they should continue to be divided, especially structural capital, different classifications should be adopted in due course, based on the actual research questions and the supporting findings of existing studies. We have avoided the expression "social capital" and advocate using the term "relational capital." Pierre Bourdieu pioneered the concept of capital based on his rationalist methodology. He divided capital into economic, cultural, and social capital and argued that social capital exists in the form of a network of relationships (Tamer et al., 2014). Compared to relational capital, social capital has a broader connotation, and its status is no less than that of intellectual capital. It may not be appropriate to place it under intellectual capital.

2.1.3 Measurement of Intellectual Capital

As academic research on the concept, components and mechanisms of intellectual capital continues to intensify, especially the quantitative research has gradually taken the absolute dominant position in the field of knowledge management, and how to measure intellectual capital more accurately has become an increasingly important research topic. Many current empirical studies are inseparable from the accurate evaluation of research objects. Only through reasonable measurement could the specific composition and size of intellectual capital be correctly assessed, and a series of subsequent studies be conducted (Liebowitz & Suen, 2000).

Due to the nonphysical nature of intellectual capital, as well as the lack of information in traditional corporate financial statements and the shortcomings of accounting methods, it is currently impossible to find a method that could accurately and unambiguously measure the intellectual capital of a firm. However, scholars have contributed a wide range of measurement methods, which can be tentatively divided into monetary and nonmonetary measurement methods depending on how closely they are related to corporate financial statements. Monetary measurement methods are a way to assess intellectual capital using specific financial data that can be accurately measured in a firm's financial statements. Nonmonetary measurement methods are more subjective and focus on measuring and managing intellectual capital through nonfinancial indicators.

(1) Monetary Measurement Methods

a. Market to Book Ratio

The *Market to Book Ratio (MBR)* is usually used in investment analysis. When the market value is higher than the book value, it indicates that the quality of the assets is good and has growth potential. Conversely, it indicates that the firm has limited growth prospects. The basic assumption of the MBR is that the market value of an enterprise is equal to the sum of its net assets and intellectual capital. A firm uses the assets it owns or controls to generate revenue in a variety of ways, i.e., in effect, intellectual capital reflects the utilization of the firm's assets. In this case, the market value of the firm is the product of the market value of each share of the enterprise and the number of outstanding shares. The advantage of this method is that it is very simple, and it intuitively reflects the value premium of the firm (Saenz, 2005).

However, because there are more noneconomic factors affecting the market value of an enterprise's stock and the book value of a firm is greatly influenced by accounting policies, there are huge differences in the book value of enterprises under different accounting standards, the comparability between enterprises is poor, and there are major limitations. Therefore, the Market to Book Ratio is not a rigorous intellectual capital measurement method (Tan et al., 2008).

b. Tobin's Q

The *Tobin's Q* is widely known in the financial field and was proposed by Tobin (1969), a Nobel laureate in economics, long before intellectual capital in the broad sense was formally introduced. It is calculated as the ratio of the market value of a firm to the replacement cost of the firm's assets. A Tobin's Q value greater than 1 usually indicates that the market value of the firm is higher than the replacement cost and that the firm could earn excess profits and is therefore worth investing in. Tobin's Q could be used as a proxy variable for intellectual capital mainly because it reflects the excess of a firm's market value over its book value, and this difference could be approximated as intellectual capital (Youndt & Snell, 2004).

This approach is a good indicator of the effectiveness of the firm's internal management or strategic operations, but it still suffers from an overly one-sided interpretation of intellectual capital. For example, Linderberg and Ross (1981) show in their study that a higher Tobin's Q value indicates that the firm's goodwill, operating capacity, and growth opportunities are at a higher level. However, its main drawback is that it is subject to capital market cycles and only reflects the total amount of intellectual capital in a general way, making it difficult to extract information about the main components of intellectual capital (Tan et al., 2008). Therefore, this method is less frequently used in the field of management.

c. Economic Value Added

The *Economic Value Added (EVA)* is a method of measuring the residual value of a firm proposed by *Stern Stewart & Company* in New York city, the U.S.A. It is also a comprehensive financial management evaluation system that combines capital budgeting, financial planning, goal setting, performance evaluation, and employee compensation into consideration. The Economic Value Added is calculated as shown in equation 2.1.

$$EVA = Sales - Cost - Tax - Interest \tag{2.1}$$

where *Sales* represents the operating revenue, *Cost* represents the operating cost and expense, *Tax* represents the tax borne by the enterprise, and *Interest* represents the financial expense. According to Marchant and Barsky (1997), the effective management of intangible assets could improve the EVA of a firm, and the essence of intellectual capital is the sum of the intangible assets of a firm, so EVA could be used as a measure of the intellectual capital of a firm.

EVA has a high correlation with the firm's stock price and could be used in conjunction with the firm's budget to prepare financial planning and target setting. Moreover, the data required for EVA is relatively easy to obtain, which facilitates academic research. The premise of EVA assumes that a firm's economic growth is derived from asset management alone. Asset management positively affects corporate performance, so strengthening the management of intellectual capital could effectively improve corporate performance. However, its complex adjustment process and weak additional explanatory power make it difficult to form clear guidance on how to manage the intellectual capital of enterprises (Tan et al., 2008).

d. Value-Added Intellectual Coefficient

The *Value-Added Intellectual Coefficient (VAIC)* is a model proposed by Pulic (2000), an Austrian scholar, to measure the value creation efficiency of intellectual capital. The value-added efficiency calculated by the VAIC method consists of two components, capital employed efficient (CEE) and intellectual capital efficient (ICE). The model considers value added as the key to measure the performance of a firm. The improvement of enterprise performance depends on the input and output efficiency of physical and intellectual capital, and the larger the value of VAIC is, the better the enterprise performance. Value Added refers to the difference between the input and output of a firm. Here, inputs refer to all inputs except labor costs, and outputs include all operating revenues. VAIC is calculated as shown in Equation 2.2.

$$\begin{aligned} VAIC &= HCE + SCE + CEE = ICE + CEE \\ HCE &= \frac{VA}{HC} \\ SCE &= \frac{VA - HC}{VA} = \frac{SC}{VA} \\ CEE &= \frac{VA}{CE} \end{aligned} \tag{2.2}$$

where HCE represents human capital efficiency, SCE represents structural capital efficiency, and the sum of HCE and SCE is ICE. HCE is equal to the ratio of VA to human capital (HC). HC is expressed in terms of the firm's payroll costs (cash paid to and for employees in the cash flow statement). SCE is equal to the ratio of structural capital (SC) to VA, with SC is equal to VA minus HC. CEE is equal to the ratio of VA to capital employed (CE), and CE is expressed as the book value of the firm's year-end net assets. It is important to note that different studies have adopted different criteria for measuring indicators such as VA. For example, Li and Zhang (2017) chose to express VA as the sum of profit before tax, payroll cost, and interest cost after considering the actual disclosure of information by Chinese listed firms.

The VAIC model for the first time uses human cost instead of the firm's expense to represent human capital, thus making the measure between human capital and structural capital clearer and the results relatively fair and objective. Moreover, as far as the data of a large number of listed firms are concerned, all the data that need to be used in the VAIC model could be found in various types of financial information publicly released by listed firms, which is more operable and thus widely used in academic and business activities.

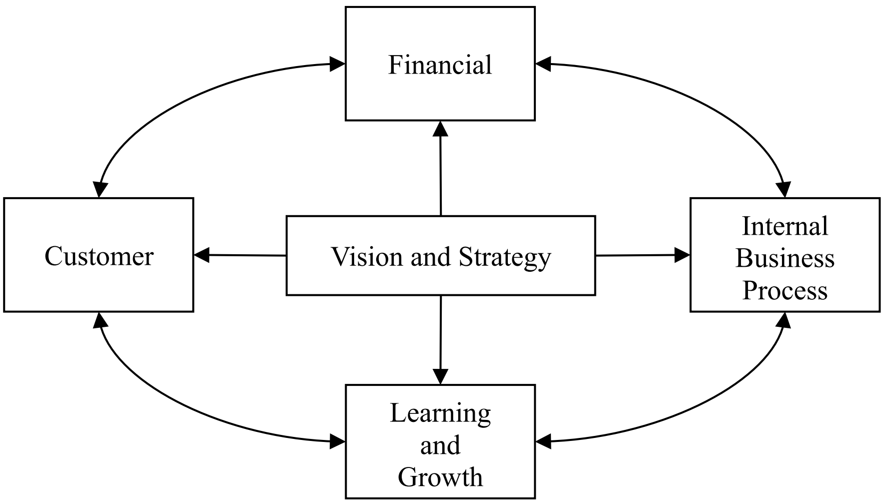
However, because the VAIC model treats all the difference between value-added minus human capital as structural capital, while highlighting the creative ability of human capital, it makes the definition of structural capital too vague and generalized. Moreover, in essence, what the VAIC model measures is actually the value creation efficiency of intellectual capital rather than intellectual capital itself. Therefore, although the value-added efficiency of intellectual capital is often treated as a proxy variable for intellectual capital in practice, they should not be simply equated.

(2) Nonmonetary Measurement Methods

a. Balanced Scorecard

The *Balanced Scorecard* was developed by Kaplan and Norton (1996). It was originally applied to business performance evaluation, breaking the traditional paradigm of overreliance on financial indicators for performance evaluation. The core idea of the balanced scorecard is to focus on the strategy and vision of an enterprise in addition to its financial performance. It breaks down corporate strategy into multiple perspectives such as financial, customer, internal process, learning and development, and combines long-term corporate goals and visions to achieve comprehensive analysis and balanced development (Kaplan & Norton, 1996). Although this model was not developed specifically for intellectual capital, the approach has also been used by many scholars to measure intellectual capital because its core concepts are very similar to the dimensions of intellectual capital and have a strong logic. The structure of the balanced scorecard is shown in Figure 2-4.

<Figure 2-4> The Framework of the Balanced Scorecard



It is important to note that intellectual capital emphasizes the dynamic mode of application of knowledge, whereas the balanced scorecard considers the balance of the system (Allee, 1999). Intellectual capital focuses on the process of managing and transforming knowledge, while the balanced scorecard emphasizes the results of managing knowledge transformation activities. This makes the balanced scorecard may ignore the importance of the firm's employees, managers, and the knowledge of these people, and does not truly view the firm from a knowledge perspective.

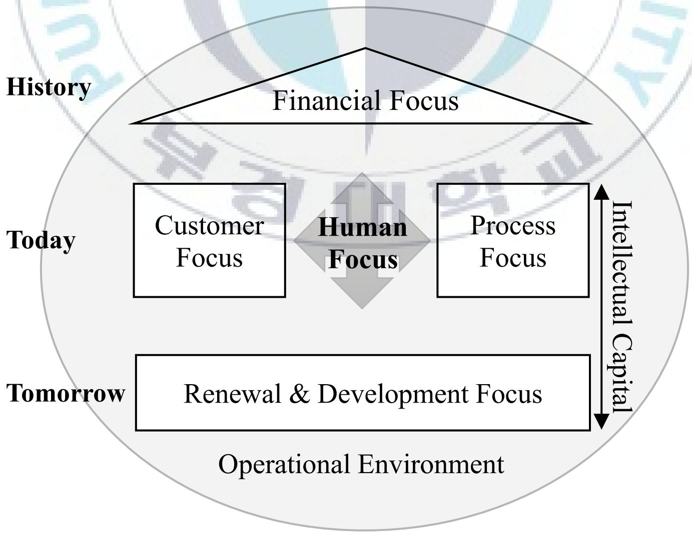
b. Skandia Navigator

The *Skandia Navigator* was developed by Skandia Corporation as a further refinement of the balanced scorecard approach (Edvinsson & Malone, 1997). Skandia Navigator is divided into five dimensions: financial, operational processes, innovation and development, customers, and human capital, which makes it possible to reflect both external and internal relationships as well as financial and nonfinancial information of the firm. It is important to note that the financial dimension here is the result of the firm's various activities and is the most valued part of the model, but it is not a dimension of intellectual capital. Intellectual capital is composed of four other dimensions (Edvinsson, 1997).

The model is structured like an edifice, where the most important financial results are the roof of the building, and innovation and development are the foundation of the building, which is the potential for the long-term health development of the firm. Customers and operational processes are the outer walls of the building, the barriers that keep the business running. Human capital is the heart of the edifice, serving to channel service capabilities, skills, and knowledge. Skandia Navigator captures hundreds of metrics to measure the level of these five dimensions. To facilitate the practical implementation of the model, Edvinsson and Malone (1997) processed these indicators and selected more than 20 indicators that could be measured in monetary terms and nine indicators that were measured in terms of efficiency.

The advantage of Skandia Navigator is that it could provide much information that cannot be presented in a firm's financial statements, giving a more comprehensive picture of the firm's true competitiveness. However, the weakness of Skandia Navigator is also obvious: it uses too much internal information, and the indicators are very complicated, making it almost impossible for researchers outside the firm to use it for empirical research and only for internal reporting (Tan et al., 2008). The structure of Skandia Navigator is shown in Figure 2-5.

<Figure 2-5> The Skandia Navigator



c. Intangible Asset Monitor

The *Intangible Asset Monitor* (IAM) was proposed by Sveiby (1997), who considered intangible assets to consist of three components: employee capabilities, internal structure, and external structure. The model uses more nonfinancial indicators and takes into account both renewal and growth as well as the efficiency and stability of the firm, with more comprehensive measures. The intangible asset monitor assumes that people are the only profit creators in the business and that each intangible asset can be evaluated in terms of growth / renewal, efficiency and stability and forms a matrix with three rows and three columns.

For each row, the IAM approach provides many alternative metrics. Each firm has the flexibility to select metrics based on specific strategic objectives. However, this flexibility is also a double-edged sword, as it makes the results obtained by using the IAM not comparable across firms, only reflecting the strength of intellectual capital in each dimension in a disaggregated manner (Andriessen, 2004), and has the disadvantage of being highly subjective and easily manipulated by managers. The IAM relies on information mostly from within the firm and is not suitable for empirical research by general researchers (Bontis, 2001).

d. Questionnaire Method

Since intellectual capital is highly "intangible", its measurement methods are almost impossible to standardize. Some of the previously mentioned measurement methods not only have difficulty showing the specific internal structure of intellectual capital but also have difficulty reflecting the interactive and synergistic effects. In addition, in the face of large samples and cross-industry empirical studies, these methods are not only difficult to obtain intrafirm data but also difficult to compare if those methods are used for research. Therefore, in recent years, for the measurement of intellectual capital, scholars have tended to collect primary data for research by distributing questionnaires or developing scales.

Although the questionnaire method has difficulty escaping from the problem of subjectivity of primary data, it does not depart from the definition and structure of intellectual capital previously defined by scholars. Moreover, the researcher could newly develop or select scales from the existing research results and make appropriate adjustments according to the specific conditions of the research subjects. Unlike the use of secondary data such as financial statements, which measure intellectual capital by constructing proxy variables, the questionnaire not only reflects the specific situation of intellectual capital in depth and clearly, but also, the development or selection of the scale itself is a theoretical deduction process, and the information derived from it could better serve the management and decision-making of the firm. This is the reason why most scholars currently adopt this method.

2.2 Enterprise Innovation Theory

As a source of economic growth and competitive advantage, innovation has long been of great interest to scholars and entrepreneurs (Dess & Picken, 2000; Ibrahim & Fallah, 2005). With the advent of economic globalization and the increasing speed of technological change, innovation is no longer only an important determinant of firm performance, but also a key to survival, growth, and sustained competitive advantage (Teece et al., 1997; Mone et al., 1998). With the existing market almost carved up, competitors must innovate in order to successfully enter the market and shake the position of the established firms. Likewise, established firms must maintain or even increase their investment in innovation to prevent their dominance from being overtaken by disruptive innovation from competitors (Cefis & Marsili, 2005). In this section, we first review the concept and origins of the term innovation, then introduce the current mainstream academic approach to innovation classification, and finally briefly summarize some common ways of measuring innovation.

2.2.1 The Concept and Origin of Innovation

It is generally accepted that Joseph A. Schumpeter, an Austro-Hungarian-born economist, first systematically explained the nature and meaning of innovation (Hansén & Wakonen, 1997). In his 1912 book *Theory of Economic Development*, he suggested that innovation is essentially the creation of a new production function, also a recombination of the factors of production. In his opinion, innovation is driven by entrepreneurship, and the entrepreneur's responsibility is to realize innovation and introduce this "new combination" into the production system to maximize the excess profit. Thus, in his 1942 book *Capitalism, Socialism, and Democracy*, he argued that innovation was the driving force behind the growth and development of the capitalist economy. Without innovation, there could be no capitalist development.

What Schumpeter calls innovation encompasses at least five situations. Among them, introducing new products and applying new production methods are technical innovation activities, while opening up new sales markets, finding new sources of raw material supply, and building new organizational forms are nontechnical innovation activities. Thus, Schumpeter's innovation theory has a very broad connotation and is not limited to technological innovation. Both technological and nontechnological innovations are integral parts of a firm's innovation activities, and they basically cover the whole process of production and business activities (Ziemnowicz, 2013).

Furthermore, before Schumpeter, especially the rapid increase in productivity brought about by the Industrial Revolution led to a focus on the role of technological progress. Adam Smith, for example, argued as early as 1776 in *An Inquiry into the Nature and Causes of the Wealth of Nations* that the division of labor could improve the skills of laborers, promote technological progress, and increase labor productivity, leading to rapid economic growth and the general affluence of citizens. Shortly after Smith's passing away, Thomas R. Malthus and his Malthusians argued that population growth had grown much faster than the resources needed to survive, which inevitably led to hunger, war, and disease. That birth rate had to be decisively curbed.

However, many later scholars argued that Malthus clearly failed to anticipate the role of technological progress in increasing food production. For this reason, David Ricardo, who was heavily influenced by Malthus, argues in his book *On the Principles of Political Economy and Taxation* that the prospects for a country's economic development are bleak when even technological advances struggle to offset the diminishing returns caused by growing populations and increasingly infertile land. After that, Karl H. Marx pointed out in *Capital: A Critique of Political Economy* that capitalists could solve the problem of declining profitability by introducing new methods of production in order to make excess profits. Although these early economists did not explicitly coin the term innovation, their focus on technological progress clearly provided a source of ideas for Schumpeter and subsequent scholars.

Unlike the idea of innovation, which Schumpeter developed only a hundred years ago, scholars have a very long history of analyzing phrases such as "technological progress" or "new ways of production." It stands to reason that innovation does not have the same connotations as they do, but rather is a sublimation of them. However, some scholars argue that Schumpeter's innovation theory focuses more on the novelty of things and can be summarized as "doing things differently." But, in reality, it is almost impossible for different subjects to do things in exactly the same way. According to this common and simple definition, making any slight change is an innovation, which is obviously doubtful. Therefore, they tried to explain the contemporary meaning of innovation by emphasizing the difference between innovation and invention (Utterback, 1974; Hansen & Wakonen, 1997).

However, Utterback (1974) held a process-based view and argued that coming up with a new idea is not innovation. He argued that only the process by which a new idea, technology, or creativity is first actually applied in production could be called a true innovation. On the other hand, Hansen & Wakonen (1997) take an outcome-based view in which they argued that the major difference between an innovation and an invention is the presence or absence of commercial success. That is, a true invention may not be an innovation because it may never be commercially successful; an innovation may not be scientifically significant, but it must be commercially successful.

It should be noted that Hansen & Wakonen's (1997) view not only overemphasizes scientific and technological progress, but also exalts the requirements for innovation and invention at the same time. If achieving commercial success is the proper meaning of innovation, then those "innovations" that have not yet achieved success will have no place, and derivative concepts based on processes such as innovative behavior and innovative capabilities will be out of the question. To assume that an invention must achieve some significant advantage in science and technology is, first, to narrowly equate invention with technological progress; second, even if it is limited to the field of science and technology, it seems to confuse the difference between invention in the general sense and patent for invention.

Our basic view of innovation is similar to that of Crossan and Apaydin (2010). Enterprise innovation should be an ongoing tense rather than a future tense, and it is both a process and an outcome. The novelty requirement in innovation should be relative rather than absolute novelty. That is, something may be commonplace in other firms, but if it is new to the firm that will implement it, then its application process and outcome should still be considered an innovation. Moreover, innovation itself is difficult to detect when it starts and ends because it never stops, just like changes in the socioeconomic structure. If someone insists that only achievements that occur at a specific time point in the future qualify as innovation, that is just an artificial severing of the timeline, but innovation will continue.

As Joseph A. Schumpeter said, an innovation is truly a recombination of thing A with thing B. When we talk about patents for inventions, this recombination should be nonobvious to those skilled in the field. However, for innovation in the general sense, this additional condition is not necessary. In deciding whether a scientific or technical invention should be granted a patent, there is often also a comprehensive consideration of whether it is commercially successful, which is also not necessary for innovation in the ordinary sense. It is essential to clarify that while we reject the confusion between inventions and patents for inventions, this does not detract from the fact that they are highly theoretically homologous.

The origins of the patent system far predate the origins of innovation theory. Already in 1474, Venice enacted the first patent law with modern characteristics. The year after Schumpeter's birth (1884), *the Paris Convention on the Protection of Industrial Property*, which underpins modern intellectual property right theory, was born and is still in use today. The core of the patent system is "disclosure for protection," which means that the patentee discloses the details of the technology to the world to a certain extent in exchange for a license from the state to exclusively implement the technology for a certain period.

In Schumpeter's theory of innovation, entrepreneurs are constantly pushing for innovation in order to pursue excessive profits under monopoly. To disrupt other market players and change the structure of the market, competitors reach creative destruction through three stages: new ideas, new technologies, and commercialization. It could be seen that the purpose of the patent system is highly consistent with the purpose of enterprise innovation, and the development of the patent system is complementary to the development of innovation theory. For example, in recent years, academics have paid more and more attention to the innovation of business models. Before April 1, 2017, business model innovation was not patentable in Mainland China. With the revision of the *Patent Examination Guidelines*, some business model innovations have been able to be protected through patents (Still need to include technical features, the specific details will not be stated).

2.2.2 Dimensions of Enterprise Innovation

Enterprise innovation is a complex and systematic concept, and scholars have classified enterprise innovation from different perspectives and coined many academic terms. However, according to our understanding of innovation and based on the summaries of previous scholars, enterprise innovation should be naturally divided into innovation as a process and innovation as an outcome. The former answers the question of how a firm innovates, while the latter answers the question of what kind of innovation a firm does. Moreover, innovation as a process always comes before innovation as an outcome (Crossan & Apaydin, 2010).

Innovation as a process could be further subdivided in terms of organizational level (individual, team, firm), drivers (internal drivers such as existing knowledge and resources, external drivers such as market opportunities and policy changes), direction of transmission (initiated from the top, initiated from the bottom), source of novelty (incubated internally, introduced externally), and openness of the process (open innovation, closed innovation). Innovation as an outcome could be further subdivided in terms of the object (product, service, process, business model), intensity (incremental innovation, radical innovation), breadth (firm, market, industry), and means of innovation (technological innovation, management innovation). In addition, whether based on the viewpoint of process or outcome, enterprise innovation could be divided into explicit and implicit innovation based on its nature.

(1) Open and Closed Innovation

Depending on the degree of openness of the innovation process, enterprise innovation could be classified as open innovation or closed innovation. Before the 1980s, although government or university-led laboratories produced many results in research focused on basic science, these results were difficult for firms to use directly for commercial purposes. As a result, many large firms tended to set up in-house laboratories to focus on R&D projects that required long-term, large investments. In this highly centralized, closed model, the process of idea generation, development, manufacturing, and marketing is done by the firm itself, also known as closed innovation (Chesbrough, 2003). This model has produced many amazing products to date and has made some firms very profitable.

However, due to the size, capital, knowledge base, and other objective conditions, firms have had to try to join with other organizations to complement their resources in the face of increasing technological sophistication. As a result, various kinds of strategic alliances and joint ventures for the purpose of collaborative R&D have started to emerge. At the same time, in the field of management, more and more scholars have begun to pay attention to the influence of factors such as social networks on enterprise innovation (Gulati, 1998). By the end of the 1980s, users began to show stronger demand for the diversity and individualization of goods. Some firms realized that instead of listening to users' complaints, they should involve users themselves in the R&D process and provide free ideas for new product development or improvement, a model that came to be known as "user innovation" (Urban & Von Hippel, 1988).

With the birth of the new model, open innovation is further defined as a purposeful knowledge management and innovation activity that crosses organizational boundaries. It has both monetary and nonmonetary models (Chesbrough & Bogers, 2014). At this point, the firm is no longer considered the sole subject of innovation; the customer and user communities become equally the source of ideas. Ideas can be easily transferred from firm to firm and from customer to firm (Bogers et al., 2017).

However, some scholars do not consider user innovation to be open innovation because it challenges traditional firm-centered innovation theory, although some scholars have called for people to break out of this mindset and instead begin to embrace the user as the center of innovation (Von Hippel, 2009). Of course, user innovation also poses a challenge for firms in terms of intellectual property protection. Users are often not sufficiently aware of intellectual property protection, and their ideas may contain innovations that belong to others, without the firm knowing about them. The user may also become aware of his legal right to claim remuneration only after his idea has been successfully marketed by the firm, and this may lead to disputes (Jeppesen & Frederiksen, 2006).

As an advocate of the term open innovation, Chesbrough (2003) summarizes previous research and argues that open innovation is a new paradigm. According to this paradigm, firms could use both internal and external resources for innovation and commercialization. This means that firms could use both internal and external sources of novelty in their R&D activities, and then use both their own internal and external channels to bring new products to the market (West & Gallagher, 2006).

Open innovation is not limited to collecting external resources for internal R&D, but also includes exporting internal resources for external use by other firms through licensing (Chesbrough & Crowther, 2006). The former is referred to as inbound open innovation, and the latter is referred to outbound open innovation. Only, scholars seem to be more enthusiastic about the former and tend to overlook the importance of the latter (West & Bogers, 2014). Some scholars suggest that this phenomenon may be due to the fact that inbound open innovation focuses more on how to source knowledge externally (Boudreau & Lakhani, 2013), while the majority of SMEs lack the ability to conduct their own R&D. However, a more likely reason is that many management scientists themselves are not knowledgeable about technology and therefore avoid research involving topics such as technology licensing and intellectual property.

Inbound open innovation typically consists of three stages: acquiring external innovation resources, integrating them into a firm's products or services, and finally commercializing them. However, the vast majority of early studies only stopped at the first stage (West & Bogers, 2014). Fortunately, with the promotion of cross-border integration between disciplines, today, there is an unprecedented focus on research related to the commercialization of technologies. Outbound open innovation initially focused on how to protect innovation achievements with exclusive rights such as intellectual property rights (Chesbrough, 2003).

Exclusive rights in this context refer to the possibility for firms to use their intellectual capital to obtain consideration paid by external users, for example, by lending or ceding it (Ceccagnoli, 2009). However, there are a growing number of examples where firms are sometimes willing to give up their exclusive rights. For example, Google selectively opened the Android source code to the public for other enterprises to use for free, gaining huge external support for the whole project both creatively and technically. This not only strengthened Google's market position but also enabled it to reap huge benefits in other areas, a typical open collaborative innovation (Baldwin & Von Hippel, 2011; Henkel et al., 2014).

(2) Product or Service, Process, and Business Model Innovation

According to the different objects of innovation, enterprise innovation can be divided into product or service innovation, process innovation, and business model innovation. As the name suggests, product innovation is the improvement of the function, performance, or appearance of an existing product, or the development of a new product (Rennings et al., 2013). It is highly correlated with the commercial success of firms, providing opportunities for continued growth and expansion into new areas for dominant firms, as well as opportunities for new entrants to gain a foothold in existing markets (Henard & Szymanski, 2001; Wang & Ahmed, 2004). If a product is considered a system composed of many individual components, then product innovation can be further divided into component innovation, architectural innovation, and complex product system innovation (Davies, 1997; Hobday, 1998).

The most straightforward and effective way to describe such a system is to list the names of the components, their functions, and the structure of the system (how the components are arranged and connected) (Hughes, 1983). It is generally accepted that an innovation is a component innovation if it leads to a change in one or more parts of the product but does not affect the structure of the system (Teece, 1988). In contrast, if the innovation results in a change in the system structure, it is an architectural innovation (Henderson & Clark, 1990).

However, architectural innovations usually not only change the arrangement and connection of components but also change the components themselves. As the number of components and their connections grows, the complexity of the system increases, giving birth to the concept of complex product systems (CoPS) (Magnusson et al., 2003). CoPS are generally considered to be large products, systems, or infrastructures with high R&D investment, high technology content, and often requiring single-piece or low-volume customized production (Hobday & Rush, 1999). The dominant firm tends to limit the number of CoPS transactions by closely cooperating with other upstream and downstream firms, creating a market pattern of limited competition and oligopoly (Miller et al., 1995).

Although it is difficult to disagree that the terms *product* and *service* have clear and different definitions, in recent years, an increasing number of firms have referred to their nonphysical service offerings as products as well (Harkonen et al., 2017), especially for firms in knowledge-intensive business services (KIBS) such as legal, tax, financial and IT services (Gallouj & Savona, 2009). The productization of services may help in marketing and promotion, reduce the perception of risk, and make it easier for customers to understand the features and specifics of the service and to make choices and purchase decisions (Wirtz et al., 2021). Some scholars have called for treating services as tangible objects to achieve marketing differentiation from other firms offering similar services (Grönroos, 2020; Wirtz, 2021). Although some scholars say that product innovation includes service innovation, there are significant differences between product innovation and service innovation. For example, in labor-intensive services, employees who actually provide services to customers may themselves be part of the innovation (Berry, 2006).

Academics generally credit Barras (1986) from the United Kingdom with pioneering research on service innovation. However, his direct use of product innovation and process innovation to explain the different stages of the service product life cycle made his explanation of service innovation too “technical” (Miles, 2001). As the research progresses, the unique attributes of service innovation are uncovered, and it is inappropriate to continue to simply apply the ideas of product innovation or technological innovation (Sirilli & Evangelista, 1998). In addition to the productization of services, the servitization of manufacturing has been widely discussed in recent years. This means that firms have shifted their focus from producing products to providing services (Reiskin et al., 1999) and that they have begun to shift their thinking from selling the goods themselves to selling the functions of the goods or the services they provide (Stoughton & Votta, 2003).

Process innovation is the application of new or significantly improved technology, equipment, or software to a production or delivery process to reduce unit costs, improve quality, or increase profitability (OECD, 2005). It often occurs late in the product life cycle (Utterback & Abernathy, 1975). A distinctive feature of process innovation is the ability to achieve the same or even higher output with less labor input (Lachenmaier & Rottmann, 2011). Moreover, process innovation may not have a negative impact on employment because it increases market demand (Dachs & Peters, 2014). Product and process innovations are closely related and sometimes difficult to distinguish. For example, if a firm develops a new device, which is a product innovation, and then the new device is used in the production and development of other products, it is a process innovation (Rennings et al., 2013). Some researchers argue that process innovation is more difficult for competitors to imitate and replicate than product innovation, creates higher value for firms (James et al., 2013) and is more effective.

Process innovation is usually implicit, systematic, and complex, and is also more costly to implement than product innovation (Gopalakrishnan & Bierly, 2001). Thus, Cohen and Klepper (1996) suggest that it may be for these reasons that large, financially strong firms exhibit a greater advantage in process innovation. Yin and Zuscovitch (1998) further argued that large firms prefer process innovation and small firms prefer product innovation. While large firms dominate the original product, small firms are more likely to be the market leaders for new products.

However, Callois (2008) disagrees, arguing that the closer the ties between small firms, the more they could share risk and reduce costs, making them more inclined to process innovation than product innovation. Of course, some studies have shown that large firms are more sustainable in both product and process innovation (Roper & Hewitt-Dundas, 2008). In addition, some other scholars have argued from a competitive perspective that firms tend to escape from intense market competition by introducing new products. When competition is relatively moderate, firms will be more inclined to process innovation (Weiss, 2003).

There is no uniform definition of what a business model is in academic circles. For example, Morris et al. (2005) argued that a business model aims to illustrate how firms position and integrate a set of internally related factors at the economic, operational, and strategic levels to build a competitive advantage in a specific market. Osterwalder et al. (2005) argued that a business model is a tool that is based on many constituent elements and their relationships and is used to describe the business logic of a particular firm. In essence, however, describing a firm's business model is explaining how the firm works (Magretta, 2002). Thus, literally, business model innovation is the replacement or improvement of a firm's original mode of operation.

However, according to Mitchell and Coles (2003), a simple or small improvement is not a true business model innovation. It is only when four or more components are changed relative to other competitors that the business model could be successfully replaced, i.e., business model innovation. While there is some truth in this view, the way of setting hard and fast indicators makes it too narrow, and difficult for many scholars to agree. What is more, scholars disagree far more on what constitutes a business model than on what is a business model.

For example, Chesbrough and Rosenbloom (2002) argued that a business model consists of six elements: market, value chain, value proposition, cost and profit, value network, and competitive strategy; while Hwang and Christensen (2008) divide the business model into four parts: profit formula, process, resources, and value proposition. But, regardless of how business models and their components are interpreted, in terms of their ultimate purpose, business model innovation is the search for a new business logic and a new operating model in order to obtain higher profits and create new values for stakeholders (Casadesus-Masanell & Zhu, 2013). What is certain is that business model innovation is becoming a more popular choice for firms than product innovation and process innovation, which is time-consuming and has an unpredictable return on investment (Amit & Zott, 2012).

(3) Radical and Incremental Innovation

Depending on the intensity of innovation, although scholars have proposed many different ways to classify it, most of them agree that at least two categories should be distinguished from it: incremental innovation and radical innovation (some scholars also refer to it as disruptive innovation) (Utterback & Abernathy, 1975; Gopalakrishnan & Damanpour, 1997). From the existing studies, there is a convergence in the academic understanding of incremental innovation as an improvement within the existing paradigm and technological trajectory, which aims to maintain or strengthen the existing market rules and competitive dynamics (Zhang & Chen, 2011).

The cycle of incremental innovation is generally longer because it is composed of numerous small innovations (Garcia et al., 2003). Although incremental innovation may bring qualitative changes to a firm or product when it accumulates to a certain level, it is difficult to be perceived by customers in a short period, so some managers are reluctant to consider it as a real innovation (Crossan & Apaydin, 2010). Incremental innovation is mainly the modification, enhancement and improvement of existing products, production methods, and distribution systems (Song & Montoya-Weiss, 1998). This innovation process may be difficult and complex, and the results may be great and groundbreaking, but incremental innovation remains as long as it continues the established technological trajectory, meets the existing needs of mainstream users, and exhibits a greater degree of continuity (Christensen & Bower, 1996).

Scholars' definition of radical innovation stems from Schumpeter's theory of creative destruction, which allows entrepreneurs to shift their attention from competing through price to competing through innovation. Each large-scale innovation uses a very different technological and business model, eliminating old technologies and production systems, and creating a new production system (Ziemnowicz, 2013). Thus, Dosi (1982) argues that radical innovation is a paradigm shift, a leap in the technological trajectory. This leads to discontinuities at the macro and micro levels that are significant, which is of great significance. Radical innovations that cause disruptions at the world, industry or market level would automatically cause disruptions at the enterprise and customer levels.

The goal of radical innovation is often not to satisfy an established need of the mainstream customer but to create a new need that the customer is not yet aware of (Garcia & Calantone, 2002). To achieve this goal, radical innovation should include radically different technologies or combinations of technologies (Ganguly et al., 2010) that significantly improve the technology level. Moreover, it should provide a higher customer value than the industry's previous products (Sorescu et al., 2003). This value could be either unprecedented functionality or similar functionality but with significant performance improvements. For example, a study by Leifer et al. (2000) states bluntly that radical innovation could directly or indirectly lead to a fivefold or more improvement in product performance or a significant cost reduction of 30% or more. Bizarrely, this hard and fast standard is accepted by many scholars.

Some other scholars have tried to carve out new areas beyond incremental innovation and radical innovation. Creating too many concepts seems completely unnecessary. For example, Garcia and Calantone (2002) have realized in their study that what some scholars call "really new innovation" is in fact what other scholars call radical innovation or discontinuous innovation. Although this new term does not convince most scholars, they still refer to the fuzzy zone between incremental and radical innovation as "really new innovation". Interestingly, for Kleinschmidt and Cooper (1991), a "really new innovation" product is new to the firm but not to the market. Song and Montoya-Weiss (1998), on the other hand, argued that "really new innovation" products are not only new to the market but also the first of their kind. While a binary taxonomy focusing on "continuity" is sufficient to explain existing problems, where ambiguity is often only a matter of time or degree, some scholars are keen to "open up a third way" to give the academic community more fields for debate. In particular, in some studies, scholars have the habit of turning otherwise not-so-macro management topics into economics topics, blurring the focus even more.

While both inventors and entrepreneurs have tried to create epoch-making products that bring huge profits to their firms, the reality is that the majority of new products on the market rely on incremental innovation to improve on existing products (Veryzer, 1998). However, whether they are prepared to adopt incremental innovation or radical innovation, entrepreneurs should focus more on methodological diversity and less on technological path dependence (Wuyts et al., 2004). This is important for the long-term sustainability of the firm.

On a purely technological level, the counterpart to radical innovation is disruptive technology, while the counterpart to incremental innovation is sustaining technology. The goal of the former is to replace existing mainstream technologies by changing the existing technology paradigm to create new products or services. The latter aims to continuously improve the performance of existing products or add new features to them (Christensen & Bower, 1996). On this basis, Nagy et al. (2016) argued that radical innovation is a type of innovation model that provides entirely new functionality, has new forms of ownership, and generates discontinuous technological standards or consumer expectations. However, radical innovation is not limited to technology. Markides (2006) expands the meaning of radical innovation by dividing it into disruptive technological innovation and disruptive business model innovation. Both types of innovation threaten dominant firms and require managers to adopt a completely different management model.

It is worth mentioning that some scholars consider exploratory innovation as a kind of radical innovation and exploitative innovation as a kind of incremental innovation, and some studies even consider these two ways of classifying enterprise innovation as exactly equivalent, while academics generally refer to exploratory innovation and exploitative innovation together as ambidextrous innovation (Popadić & Černe, 2016). The interest in the term "ambidexterity" originated from March's (1991) study. He believes that "exploration," which aims to build new capabilities, refers to a firm's behavior in searching for new knowledge, experimenting with new technologies, changing new directions, and usually implies a more significant risk and more prolonged investment. In contrast, "exploitation," which aims to use and improve existing capabilities, refers to an organization's new combination and reinvention of existing knowledge and technologies, usually implying a more negligible risk and more positive return (Levinthal & March, 1993).

March (1991) was highly concerned with the issue of resource constraints in organizations and how to make trade-offs between these two different ways of organizational learning. A single-minded exploratory innovation can easily lead a firm into a failure trap, and excessive exploitative innovation can lead a firm into a success trap, so it is difficult for a firm to gain sustainable competitive advantage through only one innovation mode (Andriopoulos & Lewis, 2009). Because of the incompatibility of the capabilities and organizational resources required for exploitative and exploratory innovation, companies that focus on both innovation modes will form tensions or contradictions due to competition for limited resources within the organization (He & Wong, 2004). Thus, the main challenge in managing enterprise innovation may be to manage the tension between exploration and exploitation.

(4) Technological and Management Innovation

When we talk about enterprise innovation, many times, we mean technological innovation. Even though we know that there are other categories of innovation beyond technological innovation, when we define innovation as a whole, it is always more like technological innovation. In fact, many of the aforementioned categories and definitions of innovation could be applied to technological innovation without dispute. However, in the face of an increasingly complex market environment, firms must deal not only with technical and economic issues but also with internal coordination, cost control and staff management (Benghozi, 1990). Scholars have realized that management innovation is one of the main reasons for restricting the development of modern enterprises and have begun to distinguish management innovation from product and process innovation (Stata, 1989).

Research has shown that management innovation could play a central role in the process of organizational change, both in helping to adapt to the external environment and in improving the efficiency and effectiveness of internal processes (Walker et al., 2011). According to Gopalakrishnan and Damanpour (1997), innovation can be divided into technological innovation and management innovation. Among them, technological innovation includes new products, new processes and new technologies directly related to basic work, while management innovation mainly includes innovation in organizational structure, administrative process and human resources that are indirectly related to basic work but directly related to organizational management. Another significant difference between the two is that management innovation is difficult to protect through patents, and when innovation is measured with patents, it almost always refers to technological innovation. Additionally, because managerial innovation is often implicit and difficult to define or observe explicitly, it is difficult to determine the boundary between it and technological innovation (Birkinshaw et al., 2008).

In different studies of different scholars, management innovation is sometimes referred to as organizational innovation or administrative innovation (Damanpour, 2014). For example, Tether and Tajar (2008) argued that technological innovation and organizational innovation will lead to changes in physical technologies and social technologies within an organization, respectively. Physical technology here refers to technology in the usual sense and to specific operating procedures in the production process, while social technology refers to the division of labor and their modes of collaboration (Nelson, 2002). However, according to Kimberly and Evanisko (1981), the important difference between technological innovation and administrative innovation may not be that they provide different functions but that they imply different decision-making processes.

Some scholars have defined the decision-making process of management innovation as a new practice, process, structure, or technology that the organization has introduced to achieve its objectives, leading to significant changes in management activities (Birkinshaw et al., 2008). They identified four main stages of management innovation: dissatisfaction with the status quo, inspiration from other sources, inventions, and internal and external validation (Birkinshaw & Mol, 2006). Later, these four stages are further described as motivation, invention, implementation, theorization & labeling. However, this way of phasing too much emphasis on innovation by the enterprise itself. As stated by Walker et al. (2011), it is not uncommon for an organization to generate, adopt and implement innovation, and it is common for innovation to be generated by one organization and adopted by another. They divide management innovation into two dimensions: information technology and administration. The information technology dimension refers to the use of new management information systems to improve operational efficiency. The administrative dimension refers to the introduction of new management regimes and processes to make management more effective (Damanpour et al., 2009).

With the development of information technology, many entrepreneurs and scholars realized that it is possible to try to make computer systems manage the information held by the firm like a human brain (Demarest, 1997). In order to innovate or develop new technologies, various learning processes within the firm are constantly exporting knowledge. However, information (explicit knowledge) accounts for only a small part of it, and more of it is the so-called tacit knowledge, such as technology (Nieto, 2003; Gupta et al., 2000). Therefore, a more profound topic is how to manage knowledge than how to manage information. Obviously, the discipline of knowledge management is a typical product of the coordinated development of technological innovation and management innovation. On the one hand, the implementation of knowledge management is itself a management innovation (Rasmussen & Hall, 2016), as it exhibits four main characteristics of management innovation: it is novel; it is implemented in practice; it aims to contribute to organizational goals; and it has an impact on the management of the organization (Birkinshaw et al., 2008). On the other hand, numerous studies have shown that knowledge management is significantly associated with technological innovation (e.g., Tan & Nasurdin, 2011).

Enterprises' knowledge management not only helps to create, share, and utilize tacit knowledge but also helps to transform tacit knowledge into explicit knowledge, promote collaboration and knowledge flow among employees, and achieve stable growth of the enterprise knowledge base (Du Plessis, 2007). Therefore, when enterprise managers realize the importance of knowledge management, they are likely to use it to create greater value and greatly improve technological innovation (Lee et al., 2013). Research has shown that in many cases, knowledge management could facilitate complementary technological and managerial innovations (Mothe et al., 2015). It reduces the risk of technological innovation associated with R&D while increasing the enterprise’s control over the technology, allowing the firm to reap the benefits of sharing technological knowledge (Lu et al., 2007).

2.2.3 Measurement of Enterprise Innovation

It is essential to measure innovation using observable quantitative indicators for academic research and decision-making. Scholars usually use data such as patents, papers, number of researchers, or R&D funding for the measurement of innovation depending on the research object (Zhang et al., 2018). However, innovation itself is extremely complex and uncertain, especially with the development of technology, connotation, nature, and type of innovation are constantly changing, making it increasingly difficult to measure (Yan et al., 2021). The most important concern when measuring innovation is the accuracy of the results; if there are significant errors, then the decisions based on these measurements will also be misleading. In particular, these indicators have proven to be inadequate over time (Becheikh et al., 2006).

The results of innovation measurement will inevitably be influenced not only by physical factors such as measurers and measurement tools but also by factors involving value choices such as innovation theory. Many scholars have worked to continuously improve innovation theory so that it can better serve enterprise innovation practices. However, the complexity of innovation practices and the ambiguity of the boundaries of innovation types make it impossible for any innovation theory to reflect innovation practices perfectly, thus generating errors that cannot be eliminated. Therefore, Yan et al. (2021) argued that errors in innovation measurement are characterized by pervasiveness, controllability, complexity, and variability. Moreover, according to Becheikh et al. (2006), indicators for measuring innovation can be divided into two types: direct (innovation count and firm-based surveys) and indirect (R&D and patents) measurements, and although the former compensates for some of the shortcomings of the latter, it still has many shortcomings. Just as there are no perfect indicators when evaluating socioeconomic phenomena, no one indicator can perfectly or completely measure innovation (Mendonça et al., 2004). This section mainly introduces the advantages and disadvantages of several common measurement methods.

(1) Patents

There is no doubt that when talking about the use of the number of patent applications or grants to measure innovation, it actually refers to the measurement of technological innovation. As one of the most used measures, its robustness has been proven in numerous empirical studies (Katila, 2000). Scholars have demonstrated the importance of innovation in economic growth and that increased patent activity could contribute to labor productivity and economic growth; therefore, patent data can, to some extent, reflect the strength of innovation activity (Crosby, 2000). The output process of patents is usually the process of developing new products and technologies, and such output undergoes rigorous examination by patent examiners representing executive power. Even if the administrative authority does not ultimately grant a patent application, the corresponding patent application document is still a concentrated expression of the inventor's or applicant's creative labor (Zhang et al., 2018).

Patent data are very easy to obtain, and the patent granting standards remain uniform over a certain period and space, facilitating cross-company comparisons. Many scholars insist that innovation must be predicated on commercial success and that patents should clearly be a prerequisite for the commercialization of technology. Therefore, despite the various drawbacks of this measurement method and the fact that some scholars openly oppose the use of patents as indicators for measuring innovation, in practice, most scholars are still accustomed to using patents as a proxy variable for innovation or technological progress (Jalles, 2010).

Scholars' criticisms of using patents to measure innovation focus on the following points. First, they argued that patents measure invention rather than innovation. Even though patents could represent innovation in some ways, not all innovations require a patent (Hitt & Hoskisson, 1991; Pakes & Griliches, 198). Different firms also have different perceptions of the need for patents (Becheikh et al., 2006). Even within the same firm, the quality of patents varies considerably (Scherer, 1965). However, the fact is that, regardless of the type of firm, it is vital to file patent applications whenever possible for new achievements that have a chance of being patented. The ability to file patent applications quickly and accurately reflects a firm's innovation management capability. For those biases that differences between firms or industries may cause, academics have also developed a series of proven empirical practices to improve the comparability of results (Griliches, 1990).

Second, critics usually pay attention to whether these patents have yielded commercial results. They believed that many firms' motives for filing patents are not innovation but rather enhancing their reputation, increasing bargaining power, or creating obstacles for competitors (Archibugi & Planta, 1996; Torrisi, 2016). However, is it not the purpose of firms to invest large amounts of money in R&D to achieve these criticized motives? Innovation is called one of the sources of competitive advantage because firms need to rely on it to compete with other market players. Patent law is a competition law, and the patent system is designed to protect competition. As stated in the previous section, the patent system and innovation theory have developed in tandem, and this criticism rather justifies the use of patents to measure innovation.

Finally, some scholars have tried to assess the commercialization potential of patents through some weighting algorithms to evaluate innovation better (Zhang et al., 2017). It is more common to adjust the indicators using the number of citations of patents (Hall & Jaffe, 2005) or the average number of applications in the industry (Ahuja, 2000). But, as Reeb and Zhao (2020) said, patents reflect the nature of innovation, not the success of R&D. These algorithms assess the success of innovation, not the innovation itself. In addition, attitudes toward patents may indeed vary across industries, regions, and sizes of firms (Archibugi & Planta, 1996). For example, some cities have incentives or funding for firms to apply for patents, while others do not. However, these differences are not insurmountable. In addition to using them as control variables, group comparison is also common in empirical studies. Thus, patents remain an ideal indicator that can be used to measure innovation.

(2) Surveys

While patents are not the perfect measure of innovation, the question that deserves to be asked is, is there a better way to measure innovation than patents? Becheikh et al. (2006) believed that a firm-based survey is such a better and more direct way to measure innovation. It can be used to measure not only technological innovation but also other kinds of innovation. Unlike other measurement approaches, firm-based surveys cover the firms that generate innovations and those that simply use them, which means that innovation research extends from manufacturing to services (Archibugi & Planta, 1996). In addition to reflecting innovation as an outcome, as patents do, surveys allow us to discover what factors hinder firms from innovating and what factors sustain their incentive to innovate. In particular, they help reveal those non-R&D input factors hidden behind financial data. This makes scholars no longer limit their research to the outcome of innovation but also focus on the process of innovation and study innovation as a long-term activity (Salazar & Holbrook, 2004).

However, although the questionnaire survey method seems to provide a more comprehensive evaluation of enterprise innovation, it avoids many of the problems that exist in other methods and has been widely used in academic research. But it is important to realize that most of those innovation surveys that have been praised by scholars and used in case studies are initiated by governments or large organizations. This type of survey requires a significant monetary investment, is more rigorous at all stages, and usually yields more credible conclusions (Walker et al., 2002). It is difficult for average research teams to afford such high costs, and most scholars can distribute survey questionnaires only to an extremely limited extent. This may lead to underrepresentation of the samples they collect, and the scientific rigor of the research design is questionable by peers.

Scholars have generally focused on the following points in questioning the use of survey questionnaire methods in innovation research. First, the data obtained from the survey may lack comparability, which includes incomparability between countries and incomparability between industries or firms. Developing countries are more likely to adopt incremental innovation strategies, while developed countries are more likely to focus on radical innovation. As a result, some scale items designed for developing countries may not be applicable to developed countries and vice versa (Cirera & Muzi, 2020). Additionally, it may be inappropriate to use the same survey for different industries or firms, and it may be challenging to detect innovations in general business or low-tech sectors. Some scholars have suggested that the sample should be limited to one or a few similar industries in a single survey. If necessary, the heterogeneity of the sample can also be reduced by setting control variables or group treatment.

The second is the shortcomings of the questionnaire survey as a research method itself. In the design stage of scales and questionnaires, the type of enterprise innovation to be measured must be clarified in advance due to the diversity of innovation theories. The design of the scales and questionnaires should follow the scientific principles and set the items reasonably to avoid the phenomenon that the respondents are tired of stating, refuse to state, or state incorrectly, which will affect the quality of the final survey (Bertrand & Mullainathan, 2001). In the implementation stage of the questionnaire survey, it is crucial to avoid interviewing the same respondent multiple times or giving too long a recall period. For example, Cirera and Muzi (2020), through a large-scale empirical analysis, found that the longer the recall period set by the questionnaire, the greater the error in innovation measurement. In addition, in face-to-face surveys, the attitude and behavior of the surveyors may influence the responses. Therefore, it is necessary to use modern information technology tools to conduct the survey and minimize human intervention.

Finally, there is the problem of subjectivity in the questionnaire survey. Several studies have found that many potential respondents do not understand what innovation is or have misconceptions about the specific type of innovation to which an innovative activity belongs (Acosta et al., 2016). To compress the subjective interpretation space of the enterprise innovation survey, it is essential to ensure that the respondents of the questionnaire have a certain level of knowledge and technology and are those who are involved in innovation activities in the firm and try to select R&D personnel as subjects (Cirera & Muzi, 2020). At the same time, it is crucial to avoid too many words in the questionnaire items that are commonly used in academic research but not in life, such as “significant” or “robust”, to ensure that the items’ intent is appropriately understood and judged (Yan et al., 2021).

(3) R&D Expenditure

Some scholars believe that R&D expenditure, a kind of data expressed directly in monetary terms, could better solve the problem of comparability in measuring innovation, as mentioned several times earlier (Yan et al., 2021). In concrete practice, R&D expenditure can be further divided into indicators such as R&D spending, R&D intensity, and R&D per employee. Among them, R&D Spending is the total amount of a firm's R&D investment throughout the year, and sometimes its natural logarithm is used (Rodríguez & Nieto, 2016). This method does not really eliminate the industry differences. Some scholars have suggested subtracting the industry's mean value from the R&D spending of a firm and then dividing it by the industry's standard deviation (Barker & Mueller, 2002). However, since the firm's size strongly influences R&D spending, it is also usually divided by its annual operating revenue to convert it into a ratio (Kogan et al., 2017), or called R&D intensity.

R&D Intensity is biased toward characterizing the extent to which firms are willing or able to support innovative activities. However, it remains highly volatile, especially for start-ups or high-tech firms, where R&D Intensity is generally large (Baysinger & Hoskisson, 1989). In the existing literature, the average value of R&D intensity for three consecutive years is generally used for measurement (Daellenbach et al., 1999). Some scholars have argued that there is no alternative relationship between R&D spending and R&D intensity. For example, Barker et al. (2002) pointed out that the two indicators are not significantly correlated, reflecting different levels of innovation investment issues. In addition, some scholars recommended using R&D Per Employee and believed that it is less influenced by internal or external factors such as economic cycles, accounting manipulation, and asset sales (Graves, 1988).

The use of R&D expenditure as an indicator of enterprise innovation continues to have many obvious drawbacks. First, although increasing R&D investment positively impacts firms' innovative activities, the relationship between R&D investment and innovative performance is not necessarily linear. When R&D investment exceeds a certain intensity, the contribution to the growth of firm performance will be weakened (Dai & Cheng, 2013). R&D expenditure also covers those activities that are stopped in the middle of the process and are not eventually translated into innovation. Second, some scholars have pointed out that R&D expenditure does not reflect the entire investment of enterprises in innovation activities. For example, it is more common that the cost of purchasing new equipment and industrial software packages is often not included in R&D expenditures (Yan et al., 2021).

In some earlier studies, scholars found that non-R&D inputs could account for up to two-thirds of the cost of innovation activities (Mansfield & Rapoport, 1975). Moreover, in practice, R&D expenditure data are often used to measure the efficiency of inputs and outputs. The main research methods are stochastic frontier analysis (SFA) and data envelopment analysis (DEA), which have some conceptual gaps with what we call "measuring innovation." In addition, the use of R&D expenditure as an indicator to measure innovation is more favorable to large firms, as R&D activities in SMEs tend to be informal or irregular. As a result, R&D expenditure is less and less used as an indicator of innovation (Becheikh et al., 2006).

(4) Others

In addition to the most used indicators of patents, surveys, and R&D expenditure, scholars also often use indicators such as new product sales revenue, technical personnel, and papers to measure innovation (Zhang et al., 2018).

a. New Product Sales Revenue

Some scholars argued that a measure based on new product sales revenue could better represent the importance and market acceptance of innovation outcomes than patents (Hambrick & MacMillan, 1985). Therefore, it is also a standard underlying indicator when assessing innovation performance or input–output efficiency (Kamien & Schwartz, 1975). However, the same heterogeneity exists among new products. The process of identifying new products is more influenced by subjective factors. Patents are granted by statutory authorities, and qualified papers are usually subject to peer review. However, the innovation size of new products is difficult to evaluate with a standardized system and can be influenced by factors such as industry or firm size (Cirera & Muzi, 2020; Protogerou et al., 2017). In addition, data on new products are usually collected in a decentralized manner by multiple departments, and the classification criteria, statistical caliber, and calculation methods of each department may differ significantly. This makes the metadata collection standards about new products in the database inconsistent and makes it challenging to accurately reflect the status of innovation (Chen & Zhen, 2020).

b. Technical Personnel

In addition to investment in R&D, investment in technical personnel is often used to measure innovation, as the knowledge that exists in the minds of individuals is vital for innovation. In particular, technical personnel are a significant source of human capital for firms and play a pivotal role in their innovation. Similar to R&D expenditure, technical personnel are often used to measure input–output efficiency, mainly by SFA and DEA. In addition to the number of personnel, full-time equivalent (FTE) of R&D personnel is also often used (Zhang, 2020). However, the quality of technical personnel varies widely among individuals, and the existing quantitative evaluation criteria are difficult to measure and less operational. Few scholars have introduced the quality of technical personnel into their studies. Existing studies have shown that technical personnel's education and professional level have essential effects on innovation, and attention must be paid to improving both the quantity and quality of technology personnel (Amador et al., 2018). Therefore, using technical personnel alone for innovation evaluation will inevitably result in errors.

c. Papers

The rationale for using papers as an indicator to measure innovation is similar to that of patents. Existing studies show that innovative subjects engaged in basic research are much less willing to apply for patents than to publish papers (Archibugi & Planta, 1996). As a result, papers are usually used only to evaluate the innovation performance of universities, research institutes, and other institutions. This approach also has similar drawbacks to patents. For example, patents are affected by industry differences, while papers are affected by disciplinary differences. However, the shortcomings of papers are obvious in comparison because the peer review mechanism for papers is not as rigorous and uniform as that for patent review. In academia, it is generally accepted that papers published in higher-level journals represent more advanced research, and a variety of citation indexes have been created for this purpose. As a result, scholars also often weight papers at different levels when using the number of papers to evaluate innovation, sometimes in conjunction with patents (Yan et al., 2021).

2.3 Intellectual Capital and Enterprise Innovation

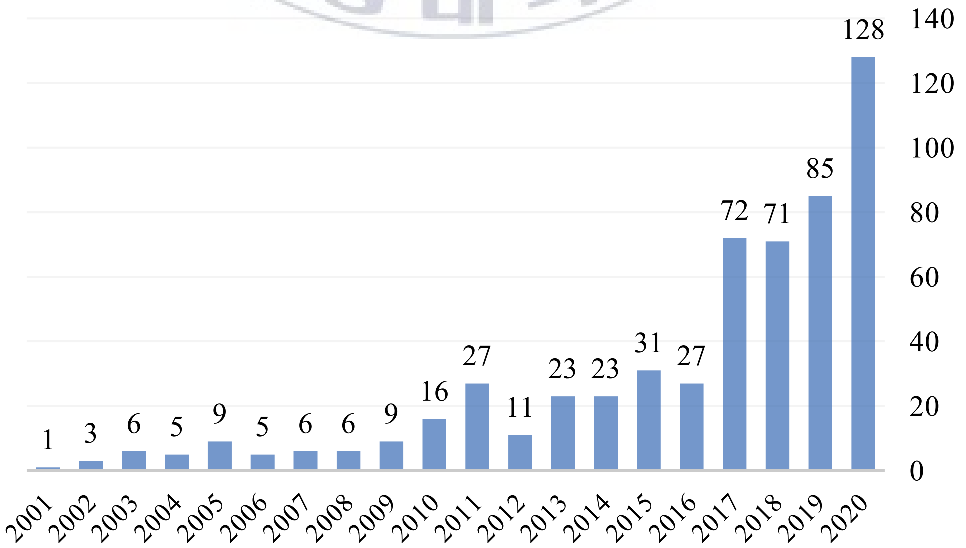
There seems to be a consensus that intellectual capital could influence enterprise innovation without much justification (Carmona-Lavado et al., 2010). But does intellectual capital and its various dimensions positively contribute to enterprise innovation for any type of firm at any stage of development? For example, for some firms, the role of intellectual capital is to create innovations that will become their new products or services in the future. However, for other firms, the role of intellectual capital may be to integrate innovations from other firms and create value by reducing the cost of manufacturing or distribution (Harrison & Sullivan, 2000). Different business forms and values will inevitably lead to different research results, and a great deal of detail remains to be clarified. The high complexity of intellectual capital and enterprise innovation has left ample room for other scholars to further investigate. In particular, the relationship between various dimensions of intellectual capital and different types of enterprise innovation remains worthy of study. Therefore, to find a better entry point for academic research, it is necessary to directly analyze the papers on the relationship between intellectual capital and innovation over the years.

To visualize the current state of research on the relationship between intellectual capital and enterprise innovation in recent years, in this section, we used CiteSpace to conduct a bibliometric analysis. CiteSpace is a powerful software developed by Dr. Chaomei Chen and his team. It can take a massive amount of disorganized literature and generate a visual knowledge graph through keyword analysis, citation analysis and many other features, facilitating the mining of research hotspots, knowledge frontiers, and development trends in a specific field (Zhang & Chun, 2021). Since we are not performing a detailed bibliometric study, we have used only a few features. The data source is the Web of Science Core Collection. Web of Science is a world-renowned literature database, and its core collection contains prestigious citation indexes such as SCIE/SSCI/ESCI/CPCI, representing the most advanced academic research results. The query is "TS = ("intellectual capital") AND TS= (innovati*)." The document type is restricted to Article, the language is restricted to English, and the search date is December 31, 2021, resulting in 717 papers for the analysis. When using CiteSpace for literature analysis, the year range was set to 1994 to 2021.

2.3.1 Literature Overview

The number of literature and the frequency of citations are important indicators of the development of a discipline or topic. Since Web of Science may have a lag of half a year or more, according to incomplete statistics, the times cited of the retrieved papers totaled 18695, and the total number of citing papers totaled 13307, indicating a high level of activity in the relevant research topics. The number of publications from 2001 to 2020 is shown in Figure 2-6. At least 134 papers were included in the Core Collection in 2021, which is higher than the number of papers published in the whole year of 2020. By and large, the number of publications related to intellectual capital and innovation maintains a growing trend.

<Figure 2-6> Number of Publications from 2000 to 2020 by Year



Specifically, before 2010, the number of papers in this academic area was low, indicating that academic research on intellectual capital was in its infancy at that time. While the number of papers increased slightly from 2010 to 2016, the growth trend was insignificant and even decreased in some years. It is noteworthy that the number of papers jumped threefold in 2017 and has maintained a faster growth rate since then. This is a good indication that academics have paid increasing attention to studying the relationship between intellectual capital and innovation in recent years.

<Figure 2-7> National Cooperation Network Map

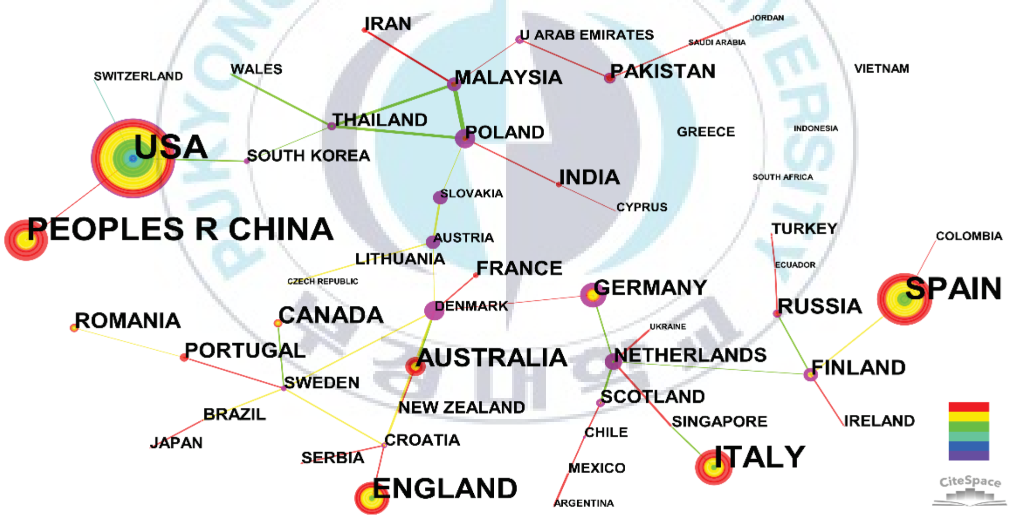


Figure 2-7 shows the cooperation between countries in this research topic, where each node represents a country. The larger the radius of the circle of the node is, the greater the volume of publications from that country. The thicker the connecting line between the two nodes, the closer the cooperation between the two countries. In addition, centrality is also an important indicator, represented in the figure as the purple circular outer ring of the node. The thicker the purple circular outer ring is, the higher the node centrality, which reflects the importance or influence size of the corresponding country in this academic area (Meng et al., 2021).

As can be seen from the above figure, five countries, the United States (Number: 143, Centrality: 0.14), China (106, 0), Spain (98, 0.07), Italy (82, 0), and England (63, 0), have the highest number of publications, indicating that more scholars in these countries are concerned with this topic. However, the centrality of all five countries is very low, with three countries having a centrality of 0, which is at the edge of the figure, indicating a lack of international cooperation in this research topic. This may be related to the significant differences in commercial systems across countries, making it difficult to obtain comparable data for cross-country studies. Although the number of publications is low, Denmark (6, 1.22), Austria (5, 0.93), Poland (12, 0.84), the Netherlands (14, 0.83), Slovakia (4, 0.82), and Germany (20, 0.77) have a high centrality and are in the middle of the figure, indicating the high importance of the papers published in these countries. These countries are geographically close to Germany, and the years of important papers are 2010 and 2011. This indicates that these countries may have formed a closer collaboration on the topic.

2.3.2 Reference Analysis

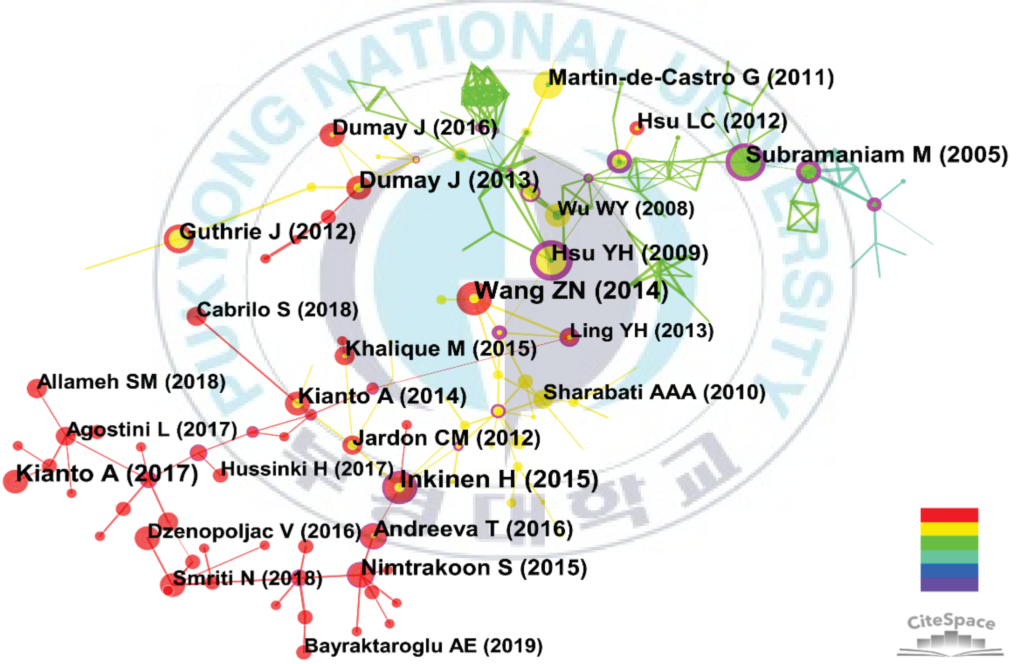
Citation bursts help to identify the most influential references in an academic area over a specific time. A citation burst may occur when there is a sudden spike in citations of a particular reference (Díez-Martín et al., 2021). Table 2-1 shows the burst period and strength of the 20 references that attracted the most attention from other scholars among these 717 papers. This indicator reflects, to some extent, the evolutionary trend of hotspots within this research topic. By combining this with keyword analysis, we were also able to identify the impact relationships that this area focused on.

<Table 2-1> **Top 20 References with the Strongest Citation Bursts**

References	Strength	Begin	End
Stewart (1997)	6.19	1999	2008
Subramaniam & Youndt (2005)	13.48	2005	2013
Hsu & Fang (2009)	12.14	2009	2018
Martín-de-Castro et al. (2011)	9.12	2011	2018
Wu et al. (2008)	7.88	2009	2018
Youndt et al. (2004)	7.64	2009	2013
Reed et al. (2006)	7.63	2009	2018
Kang & Snell (2009)	5.92	2009	2018
Sharabati et al. (2010)	9.2	2014	2018
Kianto et al. (2010)	6.99	2014	2018
Yang & Lin (2009)	6.58	2014	2018
Guthrie et al. (2012)	6.42	2014	202
Cabrita & Bontis (2008)	6.17	2014	2018
Inkinen (2015)	6.11	2015	2021
Dumay (2014)	5.76	2014	2018
Cabello-Medina et al. (2011)	5.66	2014	2018
Hsu & Sabherwal (2012)	5.66	2014	2018
Kianto et al. (2017)	10.22	2019	2021
Nimtrakoon (2015)	7.04	2019	2021
Smriti & Das (2018)	5.61	2019	2021

When another paper simultaneously cites paper A and paper B, a co-citation relationship is formed between paper A and paper B. The larger the number of co-citations of the two papers, the stronger their correlation. Thus, literature co-citation is often used to determine the frontier issues in a specific research field (Boyack & Klavans, 2010). As shown in Figure 2-8, each node represents a cited paper, and the line between the nodes represents the co-citation of these cited papers. The larger the radius of the nodes, the more influential the paper is, and the closer the nodes are to each other, the more frequently the paper is co-cited.

<Figure 2-8> Literature Co-citation



The results of citation bursts and literature co-citations partially overlap, but there are some differences. For example, Wang and Wang (2014) examined the relationship between knowledge sharing, innovation, and performance with 89 high-tech firms. This paper does not directly study intellectual capital, it is therefore not included in the 717 papers. However, it reaps many co-citations from the literature studying intellectual capital and innovation, reflecting the research trends in the subsequent period.

In papers published after 2015, Nimtrakoon (2015) critiqued previous methods of calculating VAIC and proposed a new calculation whereby the relationship between intellectual capital, market value and financial performance was investigated. Inkinen (2015) reviewed empirical studies related to intellectual capital and firm performance and found that intellectual capital not only directly affects firm performance but also indirectly affects firm performance through other factors. At the same time, the interaction or combination effect between the various elements of intellectual capital will affect performance. Dženopoljac et al. (2016) measured the impact of intellectual capital on financial performance in the ICT industry using the VAIC method. Dumay (2016) provided a critique of the way intellectual capital is reported in the form of financial statements by reflecting on the value of intellectual capital. He advocates that more information should be disclosed to help stakeholders think more about corporate ethics and social responsibility. Andreeva and Garanina (2016) found that developing structural capital is the most beneficial for improving organizational performance among the elements of intellectual capital.

Kianto et al. (2017) defined knowledge-based HRM practices as a key driver of intellectual capital and innovation, in addition to human capital being a cornerstone. Agostini et al. (2017) found that SMEs with higher levels of intellectual capital have good performance in both radical and incremental innovation. Hussinki et al. (2017) examined the effect of intellectual capital on firm performance using knowledge management practices as a mediating variable. Smriti and Das (2018) assessed the impact of intellectual capital on performance, where intellectual capital and elements were measured using VAIC and analyzed the relationship between Tobin’s Q and them. Allameh (2018) found that social capital positively affects knowledge sharing, which in turn positively affects the three dimensions of intellectual capital and ultimately innovation. Bayraktaroglu et al. (2019) proposed an extended VAIC model and used it to validate the relationship between intellectual capital and firm performance.

2.3.3 Keyword Analysis

Similar to citation bursts, a keyword burst is a sudden increase in the frequency of words or phrases contained in the cited literature at a given time. Table 2-2 presents the 20 burst words and their beginning and ending years. It can be found that these keywords are divided into four main time periods.

(1) From 1999 to 2008. With the introduction of the concept of intellectual capital in the business world in the 1990s and the launch of the *Journal of Intellectual Capital* in 2000, the discussion of intellectual capital gradually began to take the form of academic research. At this stage, scholars in the field of knowledge management focused more on intellectual capital itself, especially the internal knowledge base and collaborative relationships are an important source of intellectual capital for firms. Meanwhile, studies on the relationship between intellectual capital and innovation were relatively simple. For example, Subramaniam and Youndt (2005) explored the positive effects of organizational capital on incremental innovative capability and human capital on radical innovative capability, as well as the positive moderating role of social capital. Wu et al. (2008) examined the positive effects of social capital and entrepreneurial orientation on intellectual capital and intellectual capital on innovation, as well as the positive moderating effects of social capital and entrepreneurial orientation.

(2) From 2009 to 2013. During this period, while strengthening basic theoretical research, the study of this topic began to extend to its outer edges, such as how intellectual capital facilitates technology transfer and investment by firms and ultimately stimulates economic growth. In addition, scholars in this field have shown

great interest in biotechnology, spanning two stages, from 1999 until 2013. For example, Sharabati et al. (2010), using the pharmaceutical sector as an example, argue that human capital is positively affected by factors such as education and experience, structural capital is positively affected by factors such as systems and R&D, inversely affected by IPR, and relational capital is affected by factors such as relationships with customers and suppliers. Yang and Lin (2009) also studied the mediating role of intellectual capital in the relationship between HRM practices and organizational performance, using the healthcare industry as an example.

(3) From 2014 to 2018. At this time, scholars began to pay more attention to the intangible asset properties of intellectual capital and its antecedent and outcome variables, such as the impact of knowledge transfer on intellectual capital and how intellectual capital promotes different types of innovation. For example, Kianto and Aramburu (2017) analyzed the positive mediating role of human capital in the effects of knowledge-based HRM practices on structural and relational capital, and the positive moderating role of structural and relational capital in the effects of human capital, knowledge-based HRM practices on innovation performance. Smriti and Das (2018) studied the positive impact of intellectual capital, human capital, structural capital, and capital employed on firm productivity, profitability, sales growth, and market value using the VAIC method with a sample of Indian listed firms.

(4) From 2019 to the present. In recent years, the relationship between intellectual capital and enterprise innovation has started to become more pragmatic, and scholars have begun to try to find more empirical evidence to explain many phenomena in management practices, especially how they improve the financial performance of firms and contribute to the growth of market value. For example, through an extended VAIC model, Bayraktaroglu et al. (2019) found that innovation capital moderates structural

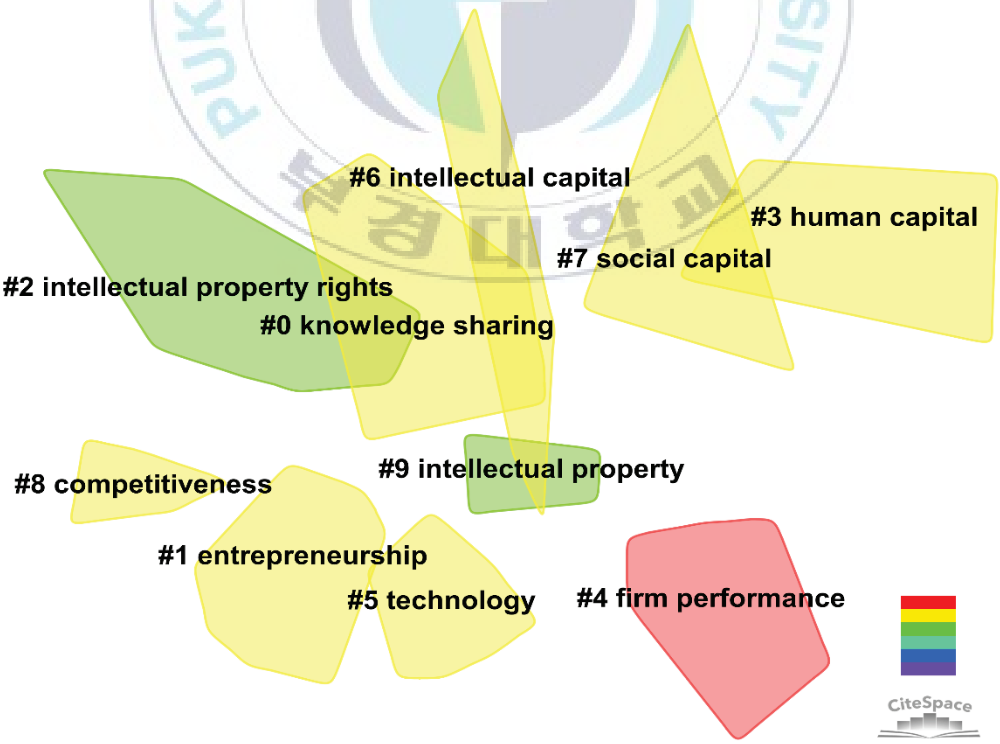
capital and profitability, intellectual capital elements moderate capital employed and profitability, while innovation capital positively affects productivity.

<Table 2-2> Top 20 Keywords with the Strongest Citation Bursts

Keywords	Strength	Begin	End
biotechnology	7.31	1999	2013
collaboration	5.02	1999	2008
knowledge	3.38	1999	2008
economics	3.83	2004	2013
technology transfer	3.41	2004	2013
right	3.94	2009	2013
organizational knowledge	3.56	2009	2013
investment	3.54	2009	2018
intangible asset	4.53	2014	2018
radical innovation	4.48	2014	2018
product innovation	3.59	2014	2018
economic growth	3.59	2014	2018
knowledge transfer	3.48	2014	2018
financial performance	10.79	2019	2021
impact	6.27	2019	2021
empirical evidence	6.08	2019	2021
quality	3.80	2019	2021
market value	3.75	2019	2021
corporate performance	3.75	2019	2021
firms market value	3.46	2019	2021

The clustering analysis of the keywords reveals the hot issues in this research area. As shown in Figure 2-9, CiteSpace automatically generated 9 clusters with modularity Q = 0.7581 (> 0.5) and weighted mean silhouette S = 0.9351 (> 0.7), indicating that the clusters are very significant and reasonable. According to their size, in order, they are #0 knowledge sharing; #1 entrepreneurship; #2 intellectual property rights; #3 human capital; #4 firm performance; #5 technology; #6 intellectual capital; #7 social capital; #8 competitiveness; and #9 intellectual property. Further integrating these keyword clusters, we can find that the main research hotspots in this area include knowledge sharing, entrepreneurship, intellectual property and technology, firm performance, and competitive advantage.

<Figure 2-9> Keyword Clustering



III. Intellectual Capital, Corporate Social Responsibility, and Technological Innovation

3.1 Research Background and Framework

In the era of the knowledge-based economy, intellectual capital based on knowledge has gradually become a vital strategic resource for enterprises to gain competitive advantages and realize value appreciation (Bayraktaroglu et al., 2019), which has a profound impact on their financial performance and technological innovation. Technological innovation is the core element for the long-term development of enterprises. In order to survive and progress in the highly competitive and unpredictable market environment, enterprises must obtain sustainable competitive advantages through technological innovation (Hormiga & García-Almeida, 2016). Promoting technological innovation has become the key for enterprises to achieve the goal of increasing their size and strength. However, for most enterprises, technological innovation based on R&D activities means facing the uncertainty of results and the instability of cycles in the innovation process. They need to invest many R&D resources and manage the high intensity of innovation risks (Zhang et al., 2016).

Therefore, if enterprises want to improve their innovation performance, it is particularly necessary to carry out technological innovation activities by strengthening their talent pool and building innovative organizations. Intellectual capital is an important strategic resource for enterprises, which helps alleviate the insufficient investment in R&D resources and enhances the motivation of technological innovation (Subramaniam & Youndt, 2005). Based on the division of intellectual capital structure by Pulic (2000), there are differences in the degree of influence of different types of intellectual capital on technological innovation. Among them, human capital could promote technological innovation by providing core resources such as employees' knowledge and skills (Fait et al., 2021), while structural capital could promote technological innovation by building an organizational structure that drives innovation, developing a standardized innovation system, and creating a positive innovation culture (AlQershi et al., 2021). Therefore, it is essential to explore the impact of intellectual capital and its components on technological innovation.

The mechanism of the effect of intellectual capital on technological innovation has increasingly become a hot topic of academic research. While scholars have contributed many research results, they have also had many debates. Some scholars argued that intellectual capital and its elements could motivate enterprises to carry out technological innovation and positively affect technological innovation. For example, Harrison and Sullivan (2000) highlight that intellectual capital could enhance the returns of strategically important businesses across the board while enhancing enterprises' innovation capabilities. Furthermore, Hayton's (2005) empirical study of 237 high-tech enterprises in the United States showed that intellectual capital is a source of technological development that could significantly increase enterprise innovation performance by reducing risk. Meanwhile, Chahal and Bakshi (2015), through an empirical study of the banking industry, confirmed that intellectual capital could positively affect technological innovation and improve the competitive advantage of enterprises.

Of course, other scholars argue that intellectual capital and its elements could negatively affect technological innovation. For example, Subramaniam and Youndt (2005) studied the impact of intellectual capital and its elements on enterprises' innovation capability within 93 organizations. They found a significant negative relationship between human capital and innovation capability. Cao et al. (2016) explored the differences in the effects of intellectual capital and its elements on innovation performance in different life cycles. They found that enterprises' human capital in the growth stage showed a significant negative effect on innovation performance. Zha et al. (2015) analyzed if organizational capital would negatively affect low-cost innovation based on structural equation modeling.

Some scholars' studies found that the impact of intellectual capital on technological innovation is not a simple linear relationship. For example, Bejinaru (2017) and Bratianu (2017) criticized the linearization of the study of intellectual capital in academia. They pointed out that the assumption of a direct and linear causal relationship between intellectual capital and firm performance is false. Many researchers ignore the intangible nature of intellectual capital and even make it tangible, while all intangible resources are non-linear in nature. Using the usual linear logic not only fails to reflect the value of intellectual capital but may also lead to misinterpretation of the results. Zhan and Li (2018) examined empirical data from 39 developing countries using a threshold test model. They found that the effect of intellectual capital on technological innovation showed a significant U-shaped relationship after controlling for variables such as economic level and R&D investment.

With the increasingly significant effect of stakeholders on business conditions, firms increasingly need to consider their responsibilities to customers, employees, investors, and even society when making technological innovation decisions. In the current political and economic environment, it is important and urgent for enterprises to actively fulfill their social responsibility, helping them maintain long-term sustainable development and increase their business performance (Li et al., 2020). For example, Luo and Du (2015) confirmed the positive relationship between CSR and technological innovation through an empirical study, i.e., the more CSR activities a firm performs, the more innovative the firm is.

Intellectual capital is the sum of the knowledge and experience of the employees embedded in the enterprise and the enterprise's relationships with external stakeholders (Cabello & Kekäle, 2008). One of the ways a firm fulfills its social responsibility is by using its employees' internal knowledge and experience to create multilevel value for external stakeholders (McWilliams & Siegel, 2001). It could be seen that the connotation of intellectual capital and the goal of CSR coincide in some respects and have a high degree of intrinsic relevance. The two have a certain synergistic effect on technological innovation. However, scholars currently ignore the role of CSR when studying the impact of intellectual capital on technological innovation. We argue that it is necessary to explore the role CSR plays in the relationship between the effect of intellectual capital on technological innovation.

Although existing studies have explored the relationship between intellectual capital and technological innovation, there is still a lack of in-depth research on the specific mechanisms of intellectual capital and its elements on technological innovation, mainly in the following aspects.

First, as the status of intellectual capital as a strategic resource is increasingly consolidated, scholars have paid sufficient attention to the effect of intellectual capital on technological innovation. However, most previous studies have defaulted to a linear relationship between the two, ignoring the possibility that intellectual capital as a whole and its constituents have a non-linear impact on technological innovation. Second, as firms pay an increasing amount of attention to considering stakeholders when making decisions, it is more important for firms to consider the fulfillment of social responsibility when making technological innovation decisions through intellectual capital. This helps reduce inefficient R&D investments and reasonably protect the interests of all parties. However, few scholars have studied and answered the practical question of “how CSR affects intellectual capital and technological innovation.” Third, in China’s market environment, state-owned and private enterprises face very different constraints in technological innovation. The existing literature has not sufficiently compared how enterprises with different ownership characteristics use intellectual capital to influence technological innovation. Therefore, we argue that there is a need to further explore the mechanisms of the role of intellectual capital on technological innovation in detail.

Based on the preceding analysis, this study analyzes the impact of intellectual capital on technological innovation from the standpoint of factor endowment theory, using data from Chinese A-share listed firms between 2014 and 2019. The study introduces CSR as a moderating variable to investigate the moderating effect of CSR on the relationship between intellectual capital and technological innovation. The differences in the effects of intellectual capital on technological innovation under various ownership properties are then investigated further. It is hoped that this will provide empirical references for enterprises to pay attention to the accumulation of intellectual capital and technological innovation practices.

The rest of the chapter is organized as follows: Section 2 reviews the previous literature on intellectual capital, corporate social responsibility and technological innovation and presents the research hypotheses. Section 3 describes the sample data and research design. Section 4 discusses the empirical results and analysis. Section 5 concludes this chapter and provides recommendations.

3.2 Theoretical Basis and Research Hypothesis

3.2.1 The Effect of Intellectual Capital on Technological Innovation

Regarding the connotation of intellectual capital, Stewart (1994) believed it is distinguished from physical capital and is the sum of a set of intangible knowledge, skills, and experience in an organization. Intellectual capital is closely related to value creation and is a strategic resource that accelerates value creation and increases competitive advantage (Riahi-Belkaoui, 2003; Ujwary-Gil, 2017). This view, based on a resource-based theory, is usually less associated with specific products and services and more with a firm's resources and capabilities, such as how to develop and deploy intangible assets that could lead to competitive advantages (Gallego et al., 2020).

Gallego et al. (2020) stated that intellectual capital should include strategic design capability, which could influence process and innovation management. The application of strategic design increases the value of intangible assets, promotes enterprise innovation, generates systems that integrate tangible products and intangible services, and triggers changes in organizational structures. AlQershi et al. (2021) argued that by improving structural capital, firms could develop new structures that will contribute to value creation and sustain superior performance. These inferences were supported in the study by Ali and Anwar (2021), who found a significant positive correlation between the elements of intellectual capital and value creation.

Regarding the components of intellectual capital, academics have formed dualistic, triadic, and pluralistic theories. Among them, the dualism proposed by Pulic (2000) is widely used by academics. He believes that intellectual capital could be divided into human and structural capital. Human capital refers to the individual employee's knowledge reserve, innovation ability, cognitive judgment, experience skills, and work attitude, while structural capital refers to the knowledge management, organizational culture, information system, and institutional norms embedded within the organization. The later emerged triadic and pluralistic viewpoints are not essentially different from the above dualism. They are basically obtained by expanding and extending the concept of structural capital on the basis of dualism. However, the subdivision of the concept does not affect the correctness of various theories of intellectual capital structure classification. Therefore, this study draws on Pulic's (2000) dualistic framework, which states that intellectual capital consists of human and structural capital, to investigate the impact of intellectual capital and its elements on technological innovation.

Factor endowment theory suggests that the abundance of production factors could increase enterprises' incentives to produce. Provided the advantages of factor endowment are greater than the corresponding production costs and high returns could be obtained from the factor input, enterprises will accept the corresponding production decisions (Leiter et al., 2011). Similarly, enterprise technological innovation cannot be achieved without the support of intellectual capital and its constituents. Enterprises' motivation to make technological innovation decisions will vary according to the size of the intellectual capital; that is, the intellectual capital of different sizes will exert different effects on technological innovation. When the increased cost of enhancing intellectual capital is lower than the endowment benefit generated by enhancing intellectual capital, enhancing intellectual capital could stimulate enterprises' enthusiasm for technological innovation, generating a positive impact. On the contrary, if the increased cost of enhancing intellectual capital is higher, and even its endowment benefit cannot compensate for the increased cost, the enterprise will lose the incentive of technological innovation. Then, intellectual capital will have a negative impact on enterprise technological innovation.

As a special kind of decision, an enterprise's technological innovation decision is characterized by high technical requirements, a long duration and instability, and the long-term benefits it produces are often greater than the short-term benefits (Wang & Wang, 2012). Technological innovation is not only difficult to bring direct economic inflow to enterprises in the short term but also requires enterprises to invest a large amount of intellectual capital in carrying out technology research, which, to a certain extent, crowds out or constrains enterprises' investment in other operational projects (Chen et al., 2014). Due to the high opportunity cost of technological innovation, many entrepreneurs and executives do not have the subjective willingness to implement technological innovation.

A study by Niu et al. (2019) found that under a supervisory corporate governance mechanism, executives are likely to undermine an enterprise's motivation to engage in technological innovation in order to achieve their short-term performance and compensation contracts. Cao et al. (2016) explored the differences in the impact of intellectual capital on innovation performance under different enterprises' life cycles. They found that the positive effect of intellectual capital on innovation performance is higher in the maturity period than in the growth period. Apparently, firms usually do not initiate technological innovation without sufficient intellectual capital and incentives for innovation effectiveness.

Combining the factor endowment theory and the essential characteristics of technological innovation, we believe that the relationship between intellectual capital and technological innovation is not a simple linear relationship but a U-shaped relationship. Intellectual capital has a "double impact" on technological innovation. When intellectual capital is at a low level, weak intellectual capital is usually accompanied by a low willingness and investment in technological innovation. This is due to the fact that technological innovation involves R&D expenditures, technological upgrading, product renewal, and organizational management. In terms of human capital, firms do not only need to increase the number of R&D personnel, and salary expenditures, and increase training; in terms of structural capital, they need to establish information management systems, improve process norms, and create an innovation culture. Increased investment in intellectual capital often leads to higher operating costs for firms (Grajkowska, 2011).

Moreover, a lower level of intellectual capital usually indicates a weaker physical base when the enterprise is mostly in the start-up or growth stage. The risks associated with implementing technological innovation are often higher than those associated with investing in other operational projects (Wu & Zhang, 2021). Thus, even if intellectual capital grows within a certain range, enterprises are still not very motivated to carry out technological innovation in order to control costs and risks. It could be seen that there is a "regressive" effect of a low level of intellectual capital on technological innovation. However, when the intellectual capital continues to grow beyond a certain threshold, the human capital (e.g., the number of R&D personnel and training) reaches a high level, and employees expect that they could obtain higher benefits by exchanging their knowledge, experience, and expertise. As a result, the willingness and quality of knowledge-sharing becomes higher, and the flow and updating of knowledge within the enterprise are improved (Fait et al., 2021).

In terms of structural capital, enterprises also have richer information management systems, complete process specifications, and sufficient intellectual capital to support technological innovation. Moreover, at this time, the increased cost of implementing technological innovation may be much lower than the comprehensive benefits of technological innovation, and the firm has sufficient capital accumulation and the ability to cope with the risks that may be caused by technological innovation. The firm should actively pursue technological innovation at this time (Hervas-Oliver et al., 2015). Thus, it could be seen that there is an "incremental" effect of the high level of intellectual capital on technological innovation. In summary, we propose the following research hypotheses.

H1. *Intellectual capital has a U-shaped effect on technological innovation.*

H2. *Human capital has a U-shaped effect on technological innovation.*

H3. *Structural capital has a U-shaped effect on technological innovation.*

3.2.2 Intellectual Capital, CSR, and Technological Innovation

According to the stakeholder theory, firms need to consider stakeholders' expectations and support when making technological innovation decisions. As a typical stakeholder-driven behavior, fulfilling CSR could deepen the intimate relationship between a firm and its stakeholders, thus helping the firm to obtain valuable stakeholder support for technological innovation (Kang et al., 2010). This may complement the internal resources that intellectual capital provides for technological innovation, which in turn affects the effectiveness of firms' use of intellectual capital for technological innovation (Xin, 2014). For example, Gangi et al. (2019) showed that CSR engagement positively affects intellectual capital. CSR could create trusting relationships, stimulate tacit knowledge sharing, and make it explicit, thus benefiting the entire firm.

They also argued that firms actively fulfilling their social responsibility help improve managers' reputations and recruit more talented employees. A similar opinion appears in the study of Cegarra-Navarro et al. (2021). They argued that fulfilling the responsibility for the ecological environment contributes to corporate reputation. It also promotes the understanding and sharing of environmental information, which drives firms to improve their technology to meet or improve environmental standards continuously. However, at the stage where an enterprise's intellectual capital accumulation is relatively weak, the excessive fulfillment of CSR could consume the available resources of firms, seriously distract them from technological innovation, and ultimately reduce the efficiency of technological innovation (Yuan et al., 2015). Therefore, the impact of CSR on technological innovation could be summarized as an incentive effect and crowding-out effect.

The incentive effect of CSR could help alleviate the knowledge dilemma of technological innovation, improve the cooperative relationship between firms and stakeholders, acquire external knowledge and skills to carry out innovation, and improve the efficiency of an enterprise's technological innovation (Bellamy et at., 2017). The crowding-out effect of CSR could make enterprises bias their resource focus toward stakeholders and seriously crowd out the resource input for technological innovation activities, thus weakening their incentive for technological innovation (Li et al., 2018). As a result, while CSR plays an important role in promoting technological innovation, an impractical CSR performance may have a negative impact on technological innovation by crowding out resources.

When intellectual capital is at a low level, the crowding-out effect of CSR is stronger than the incentive effect, which will enhance the negative influence of intellectual capital on technological innovation. Enterprises with a low level of intellectual capital usually have weak profitability and innovation levels. Most of them are in the start-up or growth stage, facing serious resource scarcity and business risks, with limited human capital to invest in technological innovation. Structural capital such as the organizational processes, knowledge management systems, and innovation culture are not yet sound, so improving CSR is more likely to crowd out enterprises' originally insufficient technological innovation resources.

Although the incentive effect of CSR is conducive to the acquisition of external knowledge and skills from stakeholders, the fulfillment of social responsibility in the start-up or growth stage of such enterprises requires the entrepreneurs to invest many resources to maintain the relationship with stakeholders. The investment of these resources will easily make the enterprise sink into existing customer relationships and divert the enterprises' focus on technological innovation, thus crowding out the enterprises' technological innovation resources. This will have a negative impact on the use of intellectual capital for technological innovation. It follows that CSR enhances the negative effect of intellectual capital on technological innovation when enterprise's intellectual capital is at a low level.

When intellectual capital exceeds a certain threshold, the incentive effect of social responsibility is stronger than the crowding-out effect, which could enhance the positive effect of intellectual capital on enterprise technological innovation. Enterprises with a high level of intellectual capital have strong human capital, and their structural capital has been improved to a certain extent. The comprehensive benefits of using intellectual capital to carry out enterprise technological innovation are greater than the costs, and enterprises are more eager to carry out relevant technological innovation activities in order to enhance their competitive advantages and sustainable development capabilities. CSR as an external mechanism could quickly help enterprises obtain knowledge, skills, and relationships from stakeholders that are beneficial to technological innovation, and improving CSR will have a strong incentive effect on enterprise technological innovation.

At the same time, the higher intellectual capital means that the internal resources of firms are sufficient, and firms are no longer limited to the contradiction of resource allocation between fulfilling CSR and carrying out technological innovation. Thus, they are less likely to be constrained by the problem of resource scarcity when the crowding-out effect of CSR is greatly reduced. In other words, CSR will enhance the positive effect of intellectual capital on technological innovation after a certain threshold is exceeded. Based on the above analysis, the following hypotheses are proposed:

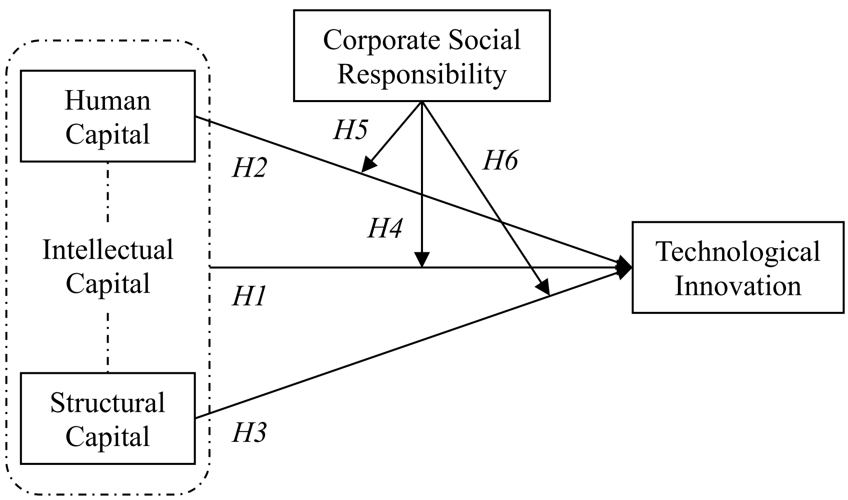
H4. *CSR could positively moderate the relationship between intellectual capital and technological innovation.*

H5. *CSR could positively moderate the relationship between human capital and technological innovation.*

H6. *CSR could positively moderate the relationship between structural capital and technological innovation.*

The analysis framework of the research is shown in Figure 3-1 below.

<Figure 3-1> Analysis Framework



3.3 Research Design

3.3.1 Selection of Samples and Acquisition of Data

This study used Chinese A-share listed firms from 2014 to 2019 as the research sample. To ensure the reliability of the research results, we continued the practice of previous studies and adhered to the following principles in processing the sample:

(1) The samples of listed firms whose stock abbreviations are preceded by the prefixes ST and *ST[1] were excluded, mainly because the operating conditions of such firms are poor. Their financial data may seriously deviate from the data when operating normally, thus affecting the objectivity of the results.

(2) The samples of listed firms in the financial industry were excluded, mainly because the business nature and financial indicators of such firms are significantly different from those of firms in other industries, and their analysis may be biased when combined. This is one of the more common ways of handling data.

(3) Since the sample size was already large enough, the sample of listed firms with abnormal data and missing data were directly excluded to avoid errors.

Finally, we obtained a total of 15,757 valid observation samples. The technological innovation data were derived from Chinese Research Data Services Platform (CNRDS), the data of CSR were derived from Hexun's CSR report, and other financial data were derived from China Stock Market & Accounting Research Database (CSMAR).

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[1] **ST** refers to Special Treatment. According to the rule of China's stock exchange, stocks of listed firms with unusual financial or other conditions (e.g., negative net profit for two consecutive years) are subject to special treatment, and the prefix ST is added to their abbreviations, hence the name ST stocks. The primary purpose of this rule is to warn investors that the stock is a risky investment. If the condition of an ST stock deteriorates further, it may be given the prefix ***ST**, indicating that this stock is at significant risk of delisting and must be taken very seriously.

3.3.2 Variable Definitions

(1) Dependent Variable

Previous scholars have two main approaches to measure technological innovation (INO): one is from the perspective of technological innovation output, measured by indicators such as the number of patent applications, the number of patents granted, and the percentage of new product sales, and the other is from the perspective of technological innovation input, measured by indicators such as R&D expenses and the number of R&D personnel. Unlike the indicators focusing on measuring technological innovation inputs, output indicators emphasize the need for firms to achieve substantial results in technological innovation, thus having better screening effects. Since patent applications involve product upgrades, technology, or method improvements that require a certain degree of technicality and innovation to pass, enterprises' efforts regarding patent applications reflect the degree of their efforts for technological innovation. To measure technological innovation, we selected the number of patent applications and then added 1 to the value to produce the logarithm.

(2) Independent Variables

In this study, we used intellectual capital efficiency (ICE), human capital efficiency (HCE), and structural capital efficiency (SCE) to measure intellectual capital, human capital, and structural capital, respectively, with definitions derived from the value-added intellectual coefficient (VAIC) method. VAIC was developed by Pulic (2000). This method does not directly calculate the intellectual capital. It considers that the types of resources in the development process of a firm can be divided into physical and intellectual capital, both of which jointly contribute to the performance of a firm through value appreciation.

The core concept of VAIC is first to calculate the value-added component of the firm and then divide the value-added component of the firm by physical capital and intellectual capital, respectively, to obtain the degree of contribution of physical capital and intellectual capital to the value-added component of the firm. The VAIC consists of three components: capital employed efficiency (CEE), human capital efficiency (HCE), and structural capital efficiency (SCE), where the sum of HCE and SCE is called intellectual capital efficiency (ICE), i.e., ICE = HCE + SCE. Since ICE could be used to measure intellectual capital, it could be calculated by the VAIC method to indirectly measure intellectual capital. The specific relationship and calculation concepts are as follows:

a. ICE = HCE + SCE.

b. HCE = VA / HC = Value-Added / Human Capital, where VA = Wage Costs + Interest Costs + Profit Before Taxes, and human capital is measured using wage costs, which are measured using cash paid to and for employees in the cash flow statement.

c. SCE = SC / VA = Structural Capital / Value-Added, where SC = VA − HC.

It should be noted that there is no consensus or mainstream opinion among academics on the measurement model of VAIC. Scholars disagree widely on how Value-Added should be calculated. To resolve some of the controversies, scholars have modified their calculations of Value-Added from time to time (Marzo, 2021). According to Singla (2020) alone, there are currently four main ways of calculating VA. What these formulas have in common is that all of them include profit after tax, and wage costs, and most of them include taxes, interest, and depreciation, and sometimes amortization (Pulic, 2000; Riahi-Belkaoui, 2003; Chen et al., 2005; Ghosh & Maji, 2015; Nazari & Herremans, 2007).

In addition, some scholars believe that Value-Added should be calculated directly using Sales minus Costs in financial statements (Iazzolino & Laise, 2013). In this study, we adopted a common method used by academics in recent years when studying Chinese samples, which is very similar to the calculation method of Riahi-Belkaoui (2003) and Chen et al. (2005). Considering the actual situation of the information disclosure of listed firms in China, this formula directly uses the concept of profit before tax and does not include depreciation or amortization (Li & Zhang., 2017).

(3) Moderating Variable

Rankins (RKS) and Hexun are the two more authoritative CSR rating agencies in China, and their CSR scores are often used by scholars who use Chinese listed firms as samples for their research. Listed firms that do not publish CSR reports are excluded from the RKS's CSR scores, making the sample size much smaller when using data from the RKS Ratings than those from the Hexun Ratings. Both Hexun's and RKS's CSR scores contain three-level dimensions. Among them, Hexun's CSR scores is divided into five first-level dimensions, including shareholders (30%), employees (10% or 15%), customers & suppliers (10% or 15%), environment (10%, 20%, or 30%), and society (10%, 20%, or 30%). The proportion of index scores in each part varies according to the specific industry to which the firm belongs (Zhong et al., 2019). Each dimension not only examines the numerical indicators of social responsibility but also considers logical indicators to ensure the professionalism, rigor, and reliability of the evaluation results (Xiong et al., 2016).

In contrast, RKS's CSR scores do not follow stakeholder theory but are divided into four first-level dimensions unrelated to the type of CSR: macrocosm, content, technical, and industry. Each RKS's CSR indicator is scored manually. According to the level of detail of the content corresponding to this indicator disclosed by the firm in the CSR report, the evaluator gives a score of 0 to 4. However, the RKS only discloses scores for first-level indicators, not specific scores for second-level and third-level indicators. The main advantage of RKS's CSR scores is that the weights of its indicators always maintain high stability, while Hexun's CSR scores have seen some degree of fluctuation in the weights in recent years. Zhong et al. (2019) showed that RKS's and Hexun's CSR scores differed significantly in rating results. RKS's CSR scores are more suitable for evaluating the CSR disclosure quality, and Hexun's CSR scores are more suitable for evaluating the CSR performance. Considering that this study follows stakeholder theory and focuses on CSR performance, this study chose data from Hexun to measure CSR.

(4) Control Variables

This study controlled for year and industry and selected some other control variables, mainly referred to Li and Zhang (2017) and Yuan et al. (2015). For example, firm size (Size) and firm age (Age) may be related to scale economies effects and affect firm performance. Financial leverage (Lev) reflects the non-systematic risk. Growth capacity (Growth) influences the choice of innovative investment projects. Profitability (Roa) reflects how much support could be given to innovation. The nature of ownership (State) may be related to who ultimately makes innovation decisions. The percentage of independent directors (Indir) reflects the firm's governance structure. Cash flow sufficiency (Cfo) affects technological innovation investment. Top 10 shareholders' shareholding (Top10) also reflects the governance structure, and its relationship with technological innovation has been widely noticed. The proportion of fixed assets (Ppe) reflects the investment and operation of the firm's assets (Wang et al., 2021) The definition and metrics of the relevant variables are shown in Table 3-1.

<Table 3-1> **Definition of Variables**

Types	Names	Symbols	Definition
Dependent Variable	Technological Innovation	INO	The number of patent applications for listed firms is added by 1 and taken as a logarithm.
Independent Variables	Intellectual Capital	ICE	ICE = HCE + SCE
	Human Capital	HCE	HCE = VA / HC; VA= Salary Expense + Interest Expense + Pre-Tax Profit; HC = Salary Expense
	Structural Capital	SCE	SCE = SC / VA; SC = VA − HC
Moderator	Corporate Social Responsibility	CSR	Hexun's CSR scores
Control Variables	Firm Size	Size	Take the total assets of the listed firm to the logarithm.
	Financial Leverage	Lev	Total liabilities / Total Assets
	Growth Capacity	Growth	Changes in operating income for the period / Operating income in the previous period
	Profitability	Roa	Net profit / Total assets
	Nature of Ownership	State	State = 0 or 1; private take 0; state-owned take 1
	Percentage of Independent Directors	Indir	Number of independent directors / Total number of directors
	Cash Flow Sufficiency	Cfo	Net operating cash flow / Total assets
	Top 10 Shareholders' Shareholding	Top10	The sum of the shareholding ratio of the top 10 shareholders
	Proportion of Fixed Assets	Ppe	Fixed assets / Total assets
	Firm Age	Age	Year of observation minus year of firm establishment

3.3.3 Model Construction

To test the impact of intellectual capital and its elements (human capital and structural capital) on technological innovation, the following four research model was developed in this study, combined with the research hypotheses.

$$\begin{aligned} INO_{i,t} &= \alpha_0 + \alpha_1 ICE_{i,t} + \alpha_2 ICE_{i,t}^2 \\ &+ \sum\nolimits_k \alpha_k Controls_{i,t,k} + Year_{i,t} + Ind_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3.1}$$

$$\begin{aligned} INO_{i,t} &= \alpha_0 + \alpha_1 HCE_{i,t} + \alpha_2 HCE_{i,t}^2 + \alpha_3 SCE_{i,t} + \alpha_4 SCE_{i,t}^2 \\ &+ \sum\nolimits_k \alpha_k Controls_{i,t,k} + Year_{i,t} + Ind_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3.2}$$

$$\begin{aligned} INO_{i,t} &= \alpha_0 + \alpha_1 ICE_{i,t} + \alpha_2 ICE_{i,t}^2 + \alpha_3 CSR_{i,t} \\ &+\alpha_4 ICE_{i,t} \times CSR_{i,t} + \alpha_5 ICE_{i,t}^2 \times CSR_{i,t} \\ &+ \sum\nolimits_k \alpha_k Controls_{i,t,k} + Year_{i,t} + Ind_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3.3}$$

$$\begin{aligned} INO_{i,t} &= \alpha_0 + \alpha_1 HCE_{i,t} + \alpha_2 HCE_{i,t}^2 + \alpha_3 SCE_{i,t} + \alpha_4 SCE_{i,t}^2 \\ &+\alpha_5 CSR_{i,t} + \alpha_6 HCE_{i,t} \times CSR_{i,t} + \alpha_7 HCE_{i,t}^2 \times CSR_{i,t} \\ &+\alpha_8 SCE_{i,t} \times CSR_{i,t} + \alpha_9 SCE_{i,t}^2 \times CSR_{i,t} \\ &+ \sum\nolimits_k \alpha_k Controls_{i,t,k} + Year_{i,t} + Ind_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3.4}$$

Model 1 (formula 3.1) tests the relationship between intellectual capital and technological innovation. Model 2 (formula 3.2) further tests the relationship among human capital, structural capital, and technological innovation. Model 3 (formula 3.3) is based on Model 1 (formula 3.1) with the cross-product term of intellectual capital and CSR, to test the moderating effect of CSR on the influence of intellectual capital on technological innovation. Model 4 (formula 3.4) is based on Model 2 (formula 3.2) with the cross-product terms of human capital, structural capital, and CSR, respectively, to further test the moderating effect of CSR on the influence of the elements of intellectual capital on technological innovation.

3.4 Data Analysis

3.4.1 Descriptive Statistics

The results of the descriptive statistics are presented in Table 3-2.

The mean value of technological innovation (INO) is 2.639, and the standard deviation is 1.811, indicating that Chinese listed firms' overall level of technological innovation is still low. There are some differences in the level of technological innovation among different listed firms. The mean value of intellectual capital efficiency (ICE) is 3.124, and the median value is 2.457, which indicate that the intellectual capital of most firms is far below the average level, reflecting the phenomenon of the insufficient accumulation of intellectual capital value among Chinese listed firms in general.

The mean values of human capital efficiency (HCE) and structural capital efficiency (SCE) are 2.472 and 0.652. The median values are 1.947 and 0.509, indicating that most listed firms' human capital and structural capital are below average. The contribution of human capital to the value-added of intellectual capital is higher than that of structural capital. However, it can be seen from the standard deviation of the two that the degree of variation of the structural capital of listed firms is smaller than that of the human capital.

The mean value of CSR is 22.693, the median value is 21.740, and the standard deviation is 12.566, which indicate that the level of corporate social responsibility performance of listed firms in China is normally distributed. The difference in corporate social responsibility performance among different firms is obvious. In addition, the mean value of the nature of ownership (State) is 0.315, indicating that 31.5% of the sample firms are state-owned enterprises.

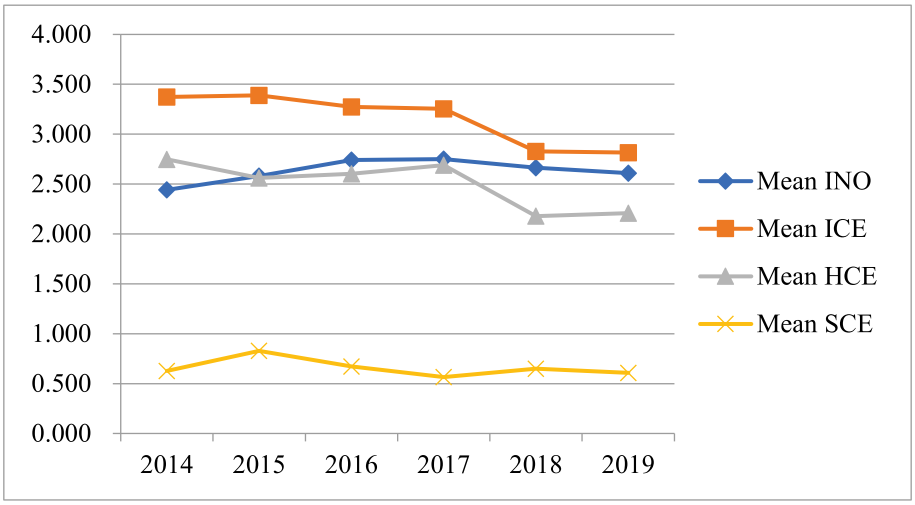
<Table 3-2> **Descriptive Statistics (n = 15757)**

Variables	Max	Min	Mean	Median	SD
INO	9.909	0.000	2.639	2.773	1.811
ICE	279.535	− 62.712	3.124	2.457	5.531
HCE	278.538	− 63.727	2.472	1.947	4.428
SCE	277.612	− 0.100	0.652	0.509	3.356
CSR	90.010	− 9.990	22.693	21.740	12.566
Size	28.636	17.813	22.298	22.124	1.324
Lev	0.987	0.008	0.421	0.410	0.227
Growth	429.036	− 0.982	0.344	0.111	4.234
Roa	0.964	− 1.859	0.044	0.040	0.074
State	1.000	0.000	0.315	0.000	0.464
Indir	0.800	0.200	0.377	0.364	0.056
Cfo	0.876	− 0.742	0.049	0.048	0.073
Top10	98.588	1.310	58.804	59.741	14.816
Ppe	0.954	0.000	0.210	0.174	0.163
Age	61.000	4.000	18.161	18.000	5.510

Prior research concluded that a firm's resources are dynamically evolving and flowing. A firm's resource stock must reach a specific size to affect its effectiveness. The flow of resources means that a firm's resource stock may be different at any point in time, which also means that there is an impact on firm effectiveness (Ployhart et al., 2009). Moreover, changes in human capital, especially the loss of key talent, could affect organizational operations and damage structural capital, which could negatively impact firm performance (Madsen et al., 2002; Hatch & Dyer, 2004). For this reason, we explore the impact of year-to-year changes in intellectual capital and its elements on technological innovation.

A set of descriptive statistics is given in Table 3-3. It can be seen that the mean values of ICE and HCE for each year are greater than the mean values of SCE, which implies that the human capital of the sample as a whole is at a higher level of development compared to the structural capital. Combining the trends presented in Figure 3-2, we can see that the year-to-year trends of intellectual capital and its elements remained consistent with the trends of technological innovation in some years, while showing inconsistencies in other years. As an example, the year-to-year trends of the mean values of ICE and INO were inconsistent from 2015 to 2017, while from 2017 to 2019, the trends of the mean values of ICE and INO reached a clear consistency. This indicates that the flow of intellectual capital could make a difference in the impact of intellectual capital on technological innovation, and this difference in impact may also be related to the size of the stock of the intellectual capital.

<Figure 3-2> Trends in the Mean Value of Intellectual Capital and Enterprise Technological Innovation by Year



<Table 3-3> The Average Value of Intellectual Capital and Enterprise Technological Innovation for Each Year

	2014	2015	2016	2017	2018	2019
INO	2.442	2.581	2.743	2.75	2.663	2.611
ICE	3.374	3.39	3.275	3.256	2.829	2.816
HCE	2.748	2.562	2.604	2.691	2.178	2.208
SCE	0.626	0.828	0.671	0.565	0.65	0.608

3.4.2 Regression Analysis

Table 3-4 reports the regression results of the models. The regression coefficient of ICE2 in Model 1 was significantly positive (β = 0.110, $p < 0.01$), indicating a U-shaped relationship between intellectual capital and technological innovation. To verify this U-shaped effect more precisely, we used the utest command to test it. The results showed that the slope of the relationship between intellectual capital efficiency and technological innovation was characterized by a negative change (β = − 0.0842, $p < 0.01$) and then a positive change (β = 0.0579, $p < 0.01$). The Fieller interval of intellectual capital efficiency at a 95% confidence level was [118.3167, 147.6273], and the extreme point was 131.1483, which is right within the Fieller interval. This indicates a threshold effect on the influence of intellectual capital on technological innovation, and the threshold point was at the value of 131.1483 of intellectual capital efficiency. When the value-added rate of intellectual capital was less than 131.1483, intellectual capital had a negative effect on technological innovation. The lower the value-added rate of intellectual capital, the higher the level of technological innovation. When the value-added rate of intellectual capital was greater than 131.1483, intellectual capital positively affected technological innovation. The higher the value-added rate of intellectual capital, the higher the level of technological innovation.

The above results support the U-shaped relationship between intellectual capital and technological innovation, and H1 is verified. Model 2 further verified the relationship among the elements of intellectual capital (human capital and structural capital) and enterprise technological innovation. The regression coefficients of HCE2 and SCE2 were 0.081 ($p < 0.01$) and 0.039 ($p < 0.01$), respectively, indicating that both human capital and structural capital have a U-shaped effect on enterprise technological innovation, and H2 and H3 are supported.

<Table 3-4> Regression Analysis Results

Variables	(1)	(2)	(3)	(4)
	INO	INO	INO	INO
ICE	− 0.156*** (− 14.14)		− 0.044*** (− 3.13)	
ICE2	0.110*** (10.60)		0.024* (1.81)	
HCE		− 0.152*** (− 14.88)		− 0.060*** (− 4.43)
HCE2		0.081*** (9.04)		− 0.039 (− 1.59)
SCE		− 0.035** (− 2.44)		− 0.002 (− 0.14)
SCE2		0.039*** (2.70)		0.008 (0.51)
CSR			0.073*** (8.36)	0.076*** (8.41)
ICE×CSR			− 0.187*** (− 13.16)	
ICE2×CSR			0.124*** (9.64)	
HCE×CSR				− 0.152*** (− 11.16)

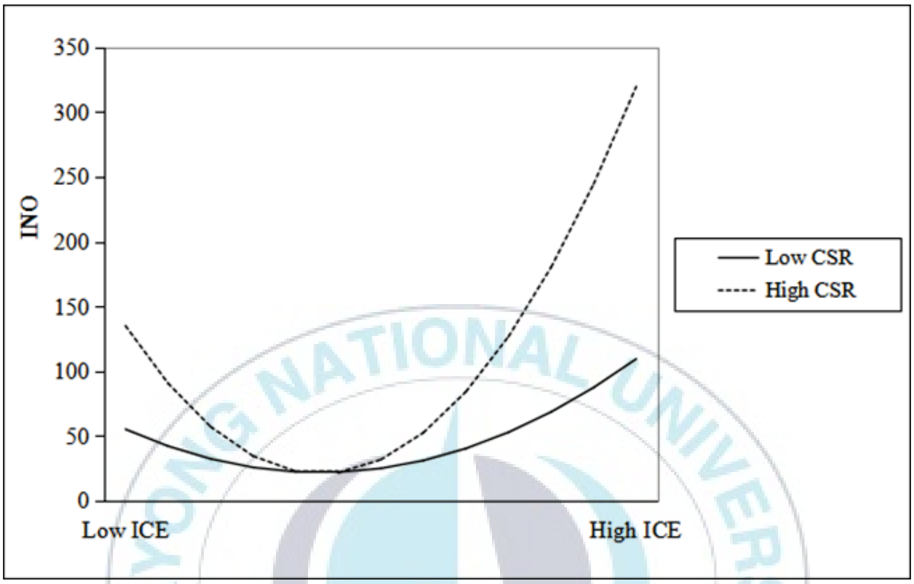
<Table 3-4> *Cont.*

Variables	(1)	(2)	(3)	(4)
	INO	INO	INO	INO
HCE2×CSR				0.159***
				(6.22)
SCE×CSR				− 0.128***
				(− 4.46)
SCE2×CSR				0.125***
				(4.55)
Size	0.496***	0.498***	0.500***	0.501***
	(64.37)	(64.61)	(63.97)	(64.21)
Lev	0.021***	0.023***	0.018**	0.019**
	(2.68)	(2.94)	(2.30)	(2.50)
Growth	− 0.028***	− 0.028***	− 0.028***	− 0.028***
	(− 4.55)	(− 4.54)	(− 4.58)	(− 4.57)
Roa	0.049***	0.066***	0.022**	0.033***
	(6.17)	(7.69)	(2.56)	(3.53)
State	− 0.012*	− 0.012*	− 0.018**	− 0.019***
	(− 1.71)	(− 1.75)	(− 2.57)	(− 2.75)
Indir	− 0.003	− 0.003	− 0.001	− 0.002
	(− 0.50)	(− 0.55)	(− 0.21)	(− 0.26)
Cfo	0.018***	0.015**	0.026***	0.024***
	(2.71)	(2.23)	(3.77)	(3.52)
Top10	− 0.039***	− 0.040***	− 0.037***	− 0.038***
	(− 5.96)	(− 6.16)	(− 5.73)	(− 5.86)
Ppe	− 0.137***	− 0.137***	− 0.143***	− 0.144***
	(− 18.20)	(− 18.26)	(− 18.98)	(− 19.17)
Age	− 0.069***	− 0.068***	− 0.067***	− 0.066***
	(− 10.21)	(− 10.11)	(− 9.98)	(− 9.87)
Year	YES	YES	YES	YES
Ind	YES	YES	YES	YES
N	15757	15757	15757	15757
R^2	0.4191	0.4205	0.4255	0.4275
F	333.66	316.91	314.67	286.18

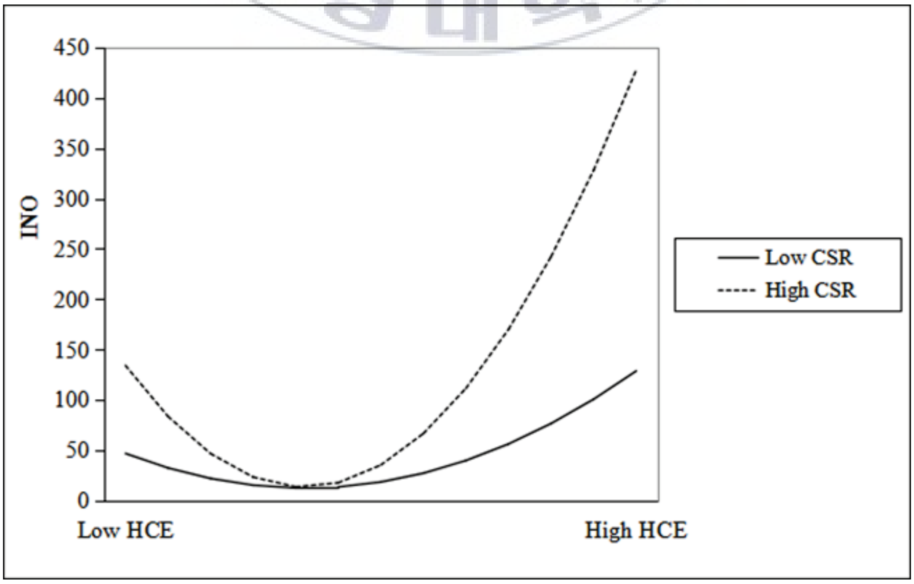
Note: Values in parentheses are *t*-values; *, **, and *** indicate significant at the 10%, 5%, and 1% levels, respectively.

In order to test the moderating effect of CSR on the relationship between intellectual capital and technological innovation, the interaction term of intellectual capital and CSR was added to Model 3. The results showed that the regression coefficient of ICE2 × CSR was significantly positive ($\beta = 0.124$, $p < 0.01$), indicating that CSR can positively regulate the U-shaped relationship between intellectual capital and technological innovation. The enhancement of CSR could make the U-shaped relationship between intellectual capital and technological innovation more concave. Before the extreme value point, the slope between intellectual capital and technological innovation is negative, and the moderating effect of CSR makes their negative effect more obvious. After the extreme value point, the slope is positive and the moderating effect makes their positive effect more obvious, so H4 is supported. To visualize the moderating effect of CSR, we plot the moderating effect of CSR on the relationship between intellectual capital and technological innovation. As shown in Figure 3-3, the enhancement of CSR strengthened the negative effect of intellectual capital on technological innovation at lower levels, but when intellectual capital exceeded a certain threshold, the enhancement of CSR strengthened the promotion of intellectual capital on technological innovation. Model 4 further tests the moderating effect of CSR on human capital–technological innovation and structural capital–technological innovation. The regression coefficients of HCE2 × CSR and SCE2 × CSR are 0.159 ($p < 0.01$) and 0.125 ($p < 0.01$), respectively, implying that CSR positively moderates the relationship between human capital–technological innovation and structural capital–technological innovation, creating a U-shaped relationship. H5 and H6 are verified. Accordingly, Figure 3-4 and Figure 3-5 demonstrate the moderating effects of CSR on the relationship between human capital and technological innovation, and CSR on the relationship between structural capital and technological innovation, respectively.

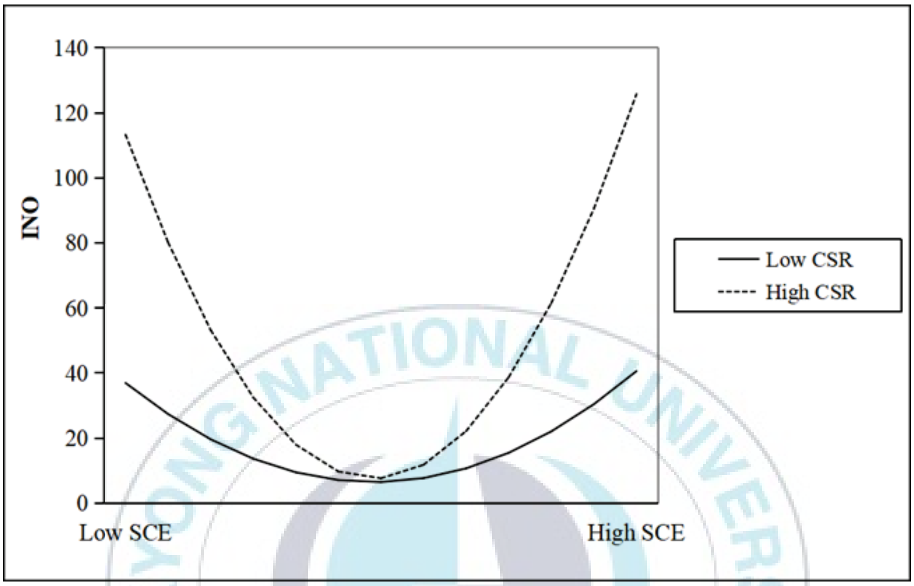
<Figure 3-3> The Moderating Effect of CSR on the Relationship between Intellectual Capital and Technological Innovation



<Figure 3-4> The Moderating Effect of CSR on the Relationship between Human Capital and Technological Innovation



<Figure 3-5> The Moderating Effect of CSR on the Relationship between Structural Capital and Technological Innovation



3.4.3 Further Analysis

The previous regression results show that intellectual capital and its elements (human capital and structural capital) have a significant U-shaped relationship with enterprise technological innovation. Moreover, CSR could positively moderate the above U-shaped relationship. Since the different ownership nature of the listed firms in China may also affect the implementation of enterprise technological innovation, we further explored whether and how the constraint of ownership nature impacts the above U-shaped relationship.

Table 3-5 presents further regression results for enterprises with different ownership properties. The results in columns 1 and 5 show that intellectual capital had a significant U-shaped effect on technological innovation for both state-owned and private enterprises. The regression coefficient of state-owned enterprises was higher than that of private enterprises, indicating that state-owned enterprises are more susceptible to the effect of intellectual capital and focus more on the value creation of intellectual capital. The results in columns 2 and 6 show that human capital had a significant U-shaped relationship with technological innovation in both state-owned and private enterprises, and structural capital had a significant U-shaped relationship with technological innovation in private enterprises.

In contrast, this relationship was not significant in state-owned enterprises. Some possible reasons are as follows:

(1) The sample size of this study is limited, so the results of data analysis cannot fully reflect the U-shaped relationship between structural capital and technological innovation in state-owned enterprises.

(2) Compared with private enterprises, state-owned enterprises are more likely to be subject to government control and intervention. Both the approval of innovation projects and R&D funds are often influenced by government decisions, reducing the role of structural capital in technological innovation.

The results in columns 3 and 7 show that the positive moderating effect of CSR on the U-shaped relationship between intellectual capital and enterprise technological innovation held in both state-owned enterprises and private enterprises. The positive moderating effect was higher in private enterprises than in state-owned enterprises, indicating that private enterprises could better play the U-shaped role of intellectual capital in enterprise technological innovation by actively fulfilling their social responsibility. The results in columns 4 and 8 indicate that CSR positively moderates the U-shaped effects of human capital and structural capital on enterprise technological innovation in state-owned and private enterprises.

<Table 3-5> Further Regression Analysis Results

Variables	State-owned Enterprises				Private Enterprises			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ICE	− 0.175***		− 0.136***		− 0.144***		− 0.02	
	(− 7.59)		(− 3.51)		(− 11.49)		(− 1.33)	
ICE2	0.150***		0.101***		0.085***		0.051**	
	(6.66)		(3.08)		(7.39)		(2.00)	
HCE		− 0.148***		− 0.062*		− 0.153***		− 0.094***
		(− 7.76)		(− 1.87)		(− 12.03)		(− 3.91)
HCE2		0.092***		− 0.636***		0.079***		− 0.195***
		(5.26)		(− 5.14)		(7.18)		(− 2.92)
SCE		− 0.038		− 0.022		− 0.075***		− 0.022
		(− 1.16)		(− 0.45)		(− 3.75)		(− 1.00)
SCE2		0.045		0.024		0.076***		− 0.044
		(1.35)		(0.53)		(3.81)		(− 1.56)
CSR			0.034**	0.082***			0.098***	0.096***
			(2.36)	(4.74)			(8.78)	(7.74)
ICE×CSR			− 0.081***				− 0.246***	
			(− 2.67)				(− 14.50)	

<Table 3-5> *Cont.*

Variables	State-owned Enterprises				Private Enterprises			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
ICE2×CSR			0.082***				0.117***	
			(4.06)				(4.61)	
HCE×CSR				− 0.193***				− 0.170***
				(− 5.13)				(− 7.69)
HCE2×CSR				0.749***				0.362***
				(5.76)				(5.19)
SCE×CSR				− 0.242*				− 0.111***
				(− 1.83)				(− 5.34)
SCE2×CSR				0.248*				0.142***
				(1.93)				(4.83)
Size	0.560***	0.561***	0.560***	0.566***	0.407***	0.409***	0.414***	0.417***
	(44.48)	(44.56)	(43.46)	(43.92)	(43.96)	(44.20)	(44.33)	(44.66)
Lev	− 0.029**	− 0.027**	− 0.029**	− 0.025**	0.040***	0.042**	0.037***	0.038**
	(− 2.30)	(− 2.13)	(− 2.31)	(− 1.98)	(4.14)	(4.30)	(3.80)	(3.96)
Growth	− 0.035***	− 0.034***	− 0.035***	− 0.034***	− 0.024***	− 0.024***	− 0.024***	− 0.023***
	(− 3.71)	(− 3.68)	(− 3.71)	(− 3.70)	(− 3.04)	(− 3.05)	(− 3.00)	(− 3.00)

<Table 3-5> *Cont.*

Variables	State-owned Enterprises				Private Enterprises			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Roa	0.020*	0.034***	0.021*	0.031**	0.062***	0.077***	0.025**	0.044***
	(1.73)	(2.72)	(1.68)	(2.33)	(5.83)	(6.73)	(2.17)	(3.42)
Indir	0.003	0.003	0.005	0.003	− 0.014*	− 0.015*	− 0.013*	− 0.013*
	(0.29)	(0.30)	(0.47)	(0.33)	(− 1.82)	(− 1.84)	(− 1.69)	(− 1.71)
Cfo	− 0.008	− 0.01	− 0.009	− 0.007	0.032***	0.029***	0.044***	0.040***
	(− 0.77)	(− 0.97)	(− 0.83)	(− 0.66)	(3.70)	(3.25)	(5.02)	(4.48)
Top10	− 0.**041*****	− 0.042***	− 0.043***	− 0.044***	− 0.056***	− 0.057***	− 0.053***	− 0.053***
	(− 3.78)	(− 3.87)	(− 3.88)	(− 4.04)	(− 6.84)	(− 6.94)	(− 6.52)	(− 6.53)
Ppe	− 0.202***	− 0.203***	− 0.203***	− 0.204***	− 0.088***	− 0.089***	− 0.099***	− 0.099***
	(− 16.36)	(− 16.42)	(− 16.36)	(− 16.50)	(− 9.71)	(− 9.80)	(− 10.92)	(− 10.97)
Age	− 0.037***	− 0.036***	− 0.036***	− 0.036***	− 0.079***	− 0.079***	− 0.077***	− 0.076***
	(− 3.55)	(− 3.49)	(− 3.48)	(− 3.46)	(− 9.32)	(− 9.26)	(− 9.14)	(− 9.07)
Year	YES	YES	YES	YES	YES	YES	YES	YES
Ind	YES	YES	YES	YES	YES	YES	YES	YES
N	4959	4959	4959	4959	10798	10798	10798	10798
R^2	0.574	0.575	0.5756	0.5792	0.3372	0.3393	0.3501	0.3525
F	207.46	195.95	190.79	173.63	165.93	157.91	161.04	146.39

Note: Values in parentheses are *t*-values; *, **, and *** indicate significant at the 10%, 5%, and 1% levels, respectively.

3.4.4 Robustness Tests

In the robustness test, we used the number of invention patent applications (INO’) instead of the number of patent applications (INO) to measure enterprise technological innovation. Using the number of invention patent applications as a proxy variable for technological innovation is necessary because invention patent is the most creative and novel category of all patent classes (Wang et al., 2021). It usually contains disruptive or breakthrough results and reflects the high-end achievements of firms in technological innovation. The robustness test results are shown in Table 3-6.

The regression coefficient of ICE2 in Model 1 was 0.099 ($p < 0.01$), indicating a U-shaped relationship between intellectual capital and enterprise technological innovation. H1 is still supported.

The regression coefficients of HCE2 and SCE2 in Model 2 were 0.075 ($p < 0.01$) and 0.029 ($p < 0.10$), respectively, indicating a U-shaped relationship among the elements of intellectual capita (human capital and structural capital) and enterprise technological innovation. H2 and H3 are still supported.

The regression coefficient of ICE2 × CSR in Model 3 was 0.111 ($p < 0.01$), indicating that CSR positively moderates the U-shaped relationship between intellectual capital and technological innovation. H4 is still supported.

The regression coefficients of HCE2 × CSR and SCE2 × CSR in Model 4 were 0.137 ($p < 0.01$) and 0.115 ($p < 0.01$), respectively, indicating that CSR has a positive moderating effect in the U-shaped relationship among the elements of intellectual capita (human capital and structural capital) and enterprise technological innovation. H5 and H6 are still supported.

<Table 3-6> Robustness Tests

Variables	(1)	(2)	(3)	(4)
	INO’	INO’	INO’	INO’
ICE	− 0.137***		− 0.037***	
	(− 12.00)		(− 2.60)	
ICE2	0.099***		0.022	
	(9.22)		(1.59)	
HCE		− 0.136***		− 0.056***
		(− 12.95)		(− 4.00)
HCE2		0.075***		− 0.029
		(8.07)		(− 1.15)
SCE		− 0.023		0.007
		(− 1.50)		(0.45)
SCE2		0.029*		− 0.001
		(1.90)		(− 0.02)
CSR			0.077***	0.080***
			(8.56)	(8.57)
ICE×CSR			− 0.164***	
			(− 11.21)	
ICE2×CSR			0.111***	
			(8.32)	
HCE×CSR				− 0.132***
				(− 9.40)
HCE2×CSR				0.137***
				(5.20)
SCE×CSR				− 0.117***
				(− 3.96)
SCE2×CSR				0.115***
				(4.06)

<Table 3-6> ***Cont.***

Variables	(1)	(2)	(3)	(4)
	INO’	INO’	INO’	INO’
Size	0.514***	0.516***	0.515***	0.516***
	(64.72)	(64.94)	(63.83)	(64.04)
Lev	0.003	0.005	0.001	0.002
	(0.34)	(0.60)	(0.06)	(0.27)
Growth	− 0.027***	− 0.027***	− 0.027***	− 0.027***
	(− 4.36)	(− 4.35)	(− 4.34)	(− 4.34)
Roa	0.041***	0.058***	0.012	0.024**
	(4.97)	(6.51)	(1.37)	(2.52)
State	0.007	0.006	0.001	− 0.001
	(0.92)	(0.89)	(0.13)	(− 0.02)
Indir	0.002	0.002	0.004	0.003
	(0.33)	(0.29)	(0.60)	(0.56)
Cfo	0.015**	0.011	0.020***	0.018**
	(2.09)	(1.63)	(2.83)	(2.55)
Top10	− 0.062***	− 0.063***	− 0.061***	− 0.062***
	(− 9.28)	(− 9.47)	(− 9.20)	(− 9.34)
Ppe	− 0.142***	− 0.142***	− 0.146***	− 0.147***
	(− 18.27)	(− 18.32)	(− 18.77)	(− 18.92)
Age	− 0.063***	− 0.062***	− 0.061***	− 0.061***
	(− 9.02)	(− 8.92)	(− 8.83)	(− 8.73)
Year	YES	YES	YES	YES
Ind	YES	YES	YES	YES
N	15757	15757	15757	15757
R^2	0.3829	0.3842	0.3881	0.3898
F	286.94	272.48	269.47	244.88

Note: Values in parentheses are *t*-values; *, **, and *** indicate significant at the 10%, 5%, and 1% levels, respectively.

3.5 Chapter Summary

3.5.1 Conclusions

This study empirically investigated the relationship between intellectual capital and technological innovation based on 15,757 sample data of Chinese A-share listed firms from 2014 to 2019 and then examined the moderating effect of CSR on the above-mentioned relationship. The study results are as follows.

(1) There is a significant U-shaped relationship between intellectual capital and its elements and technological innovation, indicating that the effect of intellectual capital and its elements on technological innovation has a threshold effect. The findings break through the previous linear research framework of 'the higher the intellectual capital, the stronger the technological innovation' and explore the specificity of intellectual capital's impact on technological innovation in more depth. When the level of intellectual capital is low, innovation costs and risks coexist. The lack of advantage of intellectual capital endowment makes enterprises less motivated to innovate. When intellectual capital exceeds a certain threshold, the comprehensive benefits obtained from technological innovation driven by high intellectual capital far outweigh the costs, and enterprises' motivation for technological innovation increases.

(2) CSR positively moderates the U-shaped relationship among intellectual capital, its elements, and technological innovation. CSR can make the U-shaped effect of intellectual capital and its elements on technological innovation more concave. When intellectual capital is at a low level, the crowding-out effect of CSR is stronger than the incentive effect, and increasing CSR is more likely to crowd out the technological innovation resources of enterprises, thus enhancing the negative effect of intellectual capital on technological innovation. When intellectual capital exceeds a certain

threshold, the incentive effect of CSR is stronger than the crowding-out effect. To enhance the competitive advantage, enterprises urgently need to carry out technological innovation activities. Actively fulfilling social responsibility can help enterprises obtain the knowledge, skills, and relationships needed for technological innovation from external stakeholders, thus enhancing the positive effect of intellectual capital on enterprise technological innovation.

(3) The U-shaped relationship between intellectual capital and technological innovation still holds for both state-owned and private enterprises. The U-shaped relationship between structural capital and technological innovation exists only in private enterprises and not in state-owned enterprises, indicating that the effect of structural capital on technological innovation in state-owned enterprises is not significant. CSR plays a positive moderating role in the U-shaped effect of intellectual capital and its elements on technological innovation. This finding is verified in both state-owned and private enterprises.

3.5.2 Implications

Some implications can be drawn from the findings of this study. On the one hand, there is a threshold effect on the positive effect of intellectual capital on technological innovation. Enterprises should strive to complete the accumulation of intellectual capital, pay attention to the introduction of talents, increase technical training, establish a sound knowledge management system, improve organizational processes, and create an innovation culture according to their own resources and technological innovation needs, so as to provide strong intellectual capital to promote technological innovation. On the other hand, as CSR could strengthen the effect of intellectual capital on enterprise technological innovation, managers of enterprises with low intellectual capital should maintain CSR fulfillment within a reasonable range to avoid the negative impact of excessive CSR fulfillment on technological innovation. For enterprises with larger intellectual capital, they should actively undertake social responsibility and enhance good relationships with stakeholders to improve the efficiency and output of enterprise technological innovation.

3.5.3 Discussion

There are still some limitations in this study, which could be further explored in the future. First, the data used in this study are all from China's A-share listed firms, so the research results may not, to some extent, have international universality. Moreover, this study tests the differences between state-owned and private enterprises. China's unique enterprise ownership system also makes it difficult to find similar research samples in other countries. As the implementation of CSR and the decision-making of technological innovation strategies may be affected by the institutional and economic environment, we could try to distinguish between developed and developing countries in the future to test whether the above conclusions are still supported. Second, in this study, we did not distinguish between industries. We may not draw the same conclusion by using data from some industries alone, so further investigation is still necessary. Finally, there are disputes about the definition of intellectual capital and VAIC in academia. In particular, some scholars have identified significant differences in calculation methods of VA. We suggest conducting a comparative study between countries in the future to explore which VAIC measurement model is better for a particular country. As the mainstream of academia holds a triadic view of intellectual capital, it is also necessary to integrate relational capital when the data conditions permit in the future.

IV. Knowledge Sharing, Intellectual Capital, and Ambidextrous Innovation

4.1 Research Background

For many high-tech enterprises, knowledge-based technical resources are the core competitive advantage on which they rely for survival. Whether to adapt to an increasingly complex market environment or become bigger and stronger based on an existing market position, enterprises are inseparable from the absorption, transformation, and application of knowledge (Martín-de Castro, 2015). Making full use of knowledge reserves and technical resources and insisting on innovation-driven high-quality development has become the key to success for such enterprises (Yu & Yan, 2021). Among these, knowledge sharing is one means by which individuals can apply their knowledge to innovation to enhance their status within the organization. Likewise, it is an important way for enterprises to acquire creative capabilities, reduce production costs, promote a broader open innovation strategy, and achieve revenue growth (Wang & Noe, 2010; Bogers, 2011). Knowledge sharing can help enterprises become learning organizations with an efficient resource flow, promote diffusion of knowledge throughout the enterprise, and generate intellectual capital through the integrated operation of business and value processes (Jo & Joo, 2011), thereby providing the impetus for enterprises to innovate at different levels.

The ambidexterity characteristics of innovation have been widely discussed. Depending on the source of novelty, enterprise innovation can be subdivided into exploratory innovation (applying new knowledge, skills, and resources to produce breakthrough results) and exploitative innovation (using existing knowledge, skills, and resources to improve the status quo) (Zhang et al., 2016). Different types of innovation have different effects on the development of the firm. Overdoing exploratory innovation may put firms in a resource dilemma, while totally exploitative innovation may lead to rapid obsolescence in the face of frequent technological changes (Mihalache et al., 2014). Therefore, to reconcile the conflict between limited enterprise resources and unlimited market ambition, decision-makers need to strike a balance between exploratory and exploitative innovation (Li et al., 2010). Again, since the required knowledge, skills, and resources for exploratory and exploitative innovation may differ significantly, it is necessary to explore the specific mechanisms that drive ambidextrous innovation.

Studies on the antecedent influences of enterprise innovation in the literature have mainly focused on the knowledge or resource level. Most of the literature suggests that knowledge sharing helps to promote enterprise innovation (Chiang & Hung, 2010; Yeşil et al., 2013), but there are many possibilities for further research on this relationship. On the one hand, most scholars have studied the impact of knowledge sharing on innovative performance and capability while ignoring its impact on different types of innovation. Due to the ambidexterity characteristics of innovation, different types of activities may have different requirements for knowledge sharing, and these deserve further discussion. On the other hand, existing studies consider the direct impact of knowledge sharing on enterprise innovation, but do not explore the specific mechanism through which knowledge sharing affects ambidextrous innovation, thereby failing to open the black box of the sharing mechanism.

At the same time, intellectual capital is the product of the integration of various resources after knowledge sharing and should be regarded as a critical motivation for ambidextrous innovation (Jo & Joo, 2011). Although there have been some studies on the relationship between knowledge sharing and intellectual capital, and the relationship between intellectual capital and enterprise innovation, few scholars have integrated them to study the relationship among all three simultaneously. In addition, few scholars have studied which of the three elements of intellectual capital is a better match for the two types of ambidextrous innovation. As Bogers (2011) argued, in the age of open innovation it is important for both academics and managers to better understand the relationship between knowledge sharing and other relevant factors. For these reasons, we developed a conceptual framework of "knowledge sharing – triadic intellectual capital – ambidextrous innovation". We attempt to clarify the mechanism of action between knowledge sharing and ambidextrous innovation to provide effective management strategies for entrepreneurs to try out different types of innovation.

The rest of this chapter is organized as follows: Section 2 reviews and discusses the relevant literature and theoretical foundations. Section 3 states the relationships among variables and research hypotheses. Section 4 describes the sample data and research design. Section 5 presents the empirical results of the data analysis. Section 6 concludes this chapter and provides some recommendations.

4.2 Theoretical Basis

4.2.1 Knowledge Sharing

A power-based view of knowledge holds that the heterogeneity of knowledge gives its possessor the power to dominate it. The knowledge owner has the power to decide whether to monopolize the knowledge within certain limits or to transfer it to others. For the long-term development of firms, especially in open innovation projects, managers need to break individual control over knowledge to promote knowledge sharing so that more employees have access to this knowledge (Terhorst, 2018). To date, there are various definitions of knowledge sharing among scholars. For example, some have taken an outcome-based view: one party provides specific knowledge or skills to another to help solve a practical problem at work or in another setting (Wang & Noe, 2010; Nonaka et al., 2000). Other scholars consider a process-based perspective and point out that knowledge sharing is the transfer of knowledge to others through communication and connection, which is usually accompanied by contribution, acceptance, learning, and transformation of knowledge (Yang, 2007; van den Hooff & de Leeuw van Weenen, 2004). Therefore, drawing on both outcome-based and process-based perspectives, this study understands knowledge sharing as a series of behaviors centered on knowledge transfer and absorption generated through interactive exchanges among different subjects within a firm to solve problems and facilitate effective work (Wang & Wang, 2012).

Usually, scholars divide knowledge sharing into tacit and explicit knowledge sharing (Hau et al., 2013; Nonaka, 1994). Tacit knowledge refers to professional knowledge and skills that are difficult to express, not easily manifested and usually owned by individuals. It is usually applied only in specific contexts and requires close interaction among subjects for successful sharing. Explicit knowledge can be encoded as text or pictures and can be shared in electronic or paper form (Orlikowski, 2002). According to Haas and Hansen (2007), different types of knowledge have different benefits when shared. For example, tacit knowledge sharing improves the quality of work and demonstrates one's ability to do the job but does not save time; explicit knowledge sharing saves time but does not increase the quality of work or make one's strengths perceived by others. Knowledge sharing is a two-way interaction in that the act of assisting others to solve problems also allows the knowledge sharer to acquire new knowledge or skills from feedback and interactive discussions (Liu & Liu, 2008;

Darroch & McNaughton, 2002). According to one view, knowledge sharing, especially when colleagues help each other, is a form of open innovation that can create value for an enterprise while reducing the uncertainty and complexity caused by the use of external resources (Yun et al., 2017). Thus, encouraging knowledge sharing is an important way to maintain an organization's creativity and competitiveness (Hau et al., 2013; Hung et al., 2011).

4.2.2 Intellectual Capital

It is generally believed that John Kenneth Galbraith introduced the concept of intellectual capital, which he considered to be the sum of a firm's stock of intellectual assets and the motivation for value creation (Grajkowska, 2011; Bontis, 2001). He also tried to use it to explain the difference between a firm's market value and the book value (Hsu & Fang, 2009). Later, Stewart (1994) refined the definition of intellectual capital to include any knowledge or capability that could give a firm a competitive advantage or make a firm's actual value exceed its book value. Therefore, in this study, intellectual capital refers to the sum of intellectual resources such as experience, skills, talents, relationships, and institutions that can give a competitive advantage or create market value for a firm.

In academic circles, there are different views on the structure of intellectual capital: dualism, triadism, or pluralism. Among these, the mainstream view is that intellectual capital comprises human, structural, and relational capital (Longo & Mura, 2011; Turner et al., 2013; Wang et al., 2014), which is also adopted in this study. Human capital refers to all knowledge and skills possessed by employees, such as their innovative capabilities, knowledge reserves, and know-how. Structural capital refers to all kinds of knowledge and capabilities within the firm, such as management capabilities, operational processes, business norms, and even infrastructure. Relational capital reflects the resources that could be obtained through internal or external relationships. For example, the firm's employee relations, customer relations, government interaction (Xu & Wang, 2019). The intellectual resources in these three dimensions intermingle within the firm to realize the continuous growth of intellectual capital thereby promoting innovation (Turner et al., 2013). Some scholars do not mince words when they claim that the foundation of the popular open innovation paradigm lies in traditional intellectual capital theory. They view human and structural capital as the source of a firm's absorptive capacity and repeatedly emphasize the importance of relational capital (Barrena-Martínez et al., 2020).

Much of the early literature thought more about customer relationships and referred to relational capital as customer capital, but this is increasingly less used (Macchi et al., 2014). Other scholars have used the expression "social capital". For example, Ali et al. (2021) adopt a multidimensional perspective, dividing intellectual capital into four dimensions and juxtaposing social capital with relational capital. The concept of social capital they use focuses on the relationship among employees or between a firm and its employees and could be referred to as "internal relational capital". This division makes sense, but considering that the theory of social capital, promoted by prominent sociologists such as Pierre Bourdieu, has connotations no less important than intellectual capital (Setini et al., 2020), we try to avoid using the term "social capital" as a subset of intellectual capital.

4.2.3 Ambidextrous Innovation

The concept of ambidextrous innovation derives from ambidextrous learning. Levinthal (1993) and March (1991) introduced the terms "exploratory learning" and “exploitative learning” in their study of organizational learning. Whereas exploratory learning focuses on finding new knowledge and perspectives, exploitative learning focuses on refining and consolidating existing knowledge. Regardless of the firm’s size or stage of development, each learning strategy is essential for gaining a competitive advantage (Macchi et al., 2014). However, studies also show that the ambidexterity characteristics of organizational learning have a more significant impact on innovation (Tian et al., 2021). Following the classification of ambidextrous learning, scholars in the field of innovation management have started to classify innovation by borrowing the exploratory/exploitative dichotomy, and the concept of ambidextrous innovation emerged (He & Wong, 2004; Güttel et al., 2015). Ambidextrous innovation refers to a firm’s simultaneous realization of both exploratory and exploitative innovation (Lin & Chang, 2015). The former refers to disrupting existing knowledge and technology; discovering new designs, methods and processes; creating new products or services; or developing new markets. The latter improves and upgrades designs, methods, and processes based on existing knowledge and technologies to further reduce costs and improve product or service quality (Lin & Chen, 2015).

Many scholars consider exploratory and exploitative innovations to be in competition, and a balance should be found between them (Mihalache et al., 2014; Li et al., 2010). Others suggest that the two may be complementary (Blindenbach-Driessen & van den Ende, 2014). This difference has led to disagreement about how to measure ambidextrous innovation. Scholars who adopt the complementary view tend to add or multiply the scores of the two types of innovations (Jansen et al., 2016; Li et al., 2016), while those who adopt the balanced view often subtract the two scores and then take the absolute value (Cao et al., 2009). Interestingly, many scholars use both the product and the absolute value after subtraction to support the complementary view

(Xie & Gao, 2018). Of course, many studies treat exploratory and exploitative innovation directly as separate dimensions (He & Wong, 2004; 48).

Ambidextrous innovation may not be a static concept. Some scholars argue that ambidexterity should be studied from an incremental and radical perspective (Kang & Hwang, 2019), while others look at the openness of innovation, in which exploration is inbound open innovation and exploitation as outbound (Yun et al., 2021b). There is also a view that ambidexterity may no longer be able to explain new business practices fully under the open innovation paradigm and that there is a need to move to the concept of multidexterity (Robbins et al., 2021). Given these divergences, as well as our greater focus on the finiteness and scarcity of firm resources, we remain conservative in using the traditional ambidexterity concept of exploratory and exploitative innovation as the object of study, and prefer to measure them separately as distinct dimensions. This also helps us clarify which form of innovation is best suited to which intellectual capital element to promote innovation.

4.3 Hypotheses

4.3.1 Knowledge Sharing and Intellectual Capital

The knowledge base theory argues that the main reason for the existence of the firm as an organizational form is that it is more effective than a market for sharing and transferring knowledge. To enhance its overall strength and competitiveness, a firm must focus on integrating knowledge resources and applying them to the production and development of products or services (Grant, 1996). The source of a firm's competitive advantage is the integrated knowledge, not the knowledge itself. The way to solve the problem of knowledge heterogeneity within the firm is to transform individual knowledge into collective knowledge, which emphasizes the importance of knowledge integration (Spender, 1996). In other words, unintegrated knowledge can hardly form intellectual capital in the true sense. Moreover, the efficiency of knowledge integration would be affected by the degree of knowledge sharing (Grant, 1996). The results of existing empirical studies show that knowledge sharing significantly and positively affects human, structural, and relational capital. The flow and exchange of knowledge within a firm not only increases the depth of intellectual capital, but active knowledge sharing among individuals deepens an understanding of their own knowledge and skills and enhances the application ability of others. Through repeated sharing and practice, the optimized knowledge is rooted in the organization and the trust among different people will be strengthened (Wang et al., 2014; Akhavan & Khosravian, 2016).

In addition, Oliveira et al. (2020) argued that knowledge sharing not only improves all elements of intellectual capital and facilitates the formation of human capital, but it also reduces the loss of knowledge associated with changes in human resources (Hsu, 2008). By exporting their experiences and skills, knowledge sharers can deepen their re-understanding of acquired knowledge, while knowledge receivers use this new knowledge to improve their own work methods. It greatly facilitates collaboration and complementarity among employees, improves the firm's overall capabilities, and accelerates the accumulation of human capital. Knowledge sharing also provides the ground for the growth of structural capital (Wang et al., 2014). Firms can compile high-quality individual knowledge in the form of workbooks and repositories that are shared throughout the firm to increase the spread of knowledge. Firms can also ensure the growth of structural capital by improving policies, systems, and processes to strengthen its infrastructure. Meanwhile, knowledge sharing likewise leads to an increase in relational capital (Shih et al., 2010). With frequent communication and interaction, mutual trust and appreciation will grow significantly because of knowledge sharing and exchanges to assist each other in overcoming key problems, which helps build relational capital. Accordingly, we propose the following research hypothesis:

H1a. *Knowledge sharing has a significantly positive effect on human capital.*

H1b. *Knowledge sharing has a significantly positive effect on structural capital.*

H1c. *Knowledge sharing has a significantly positive effect on relational capital.*

4.3.2 Intellectual Capital and Ambidextrous Innovation

The relationship between intellectual capital and innovation has been extensively studied, but the complexity of intellectual capital and enterprise innovation leaves ample research space for other scholars. In particular, a common line of research is to subdivide these concepts to investigate the relationship among the subdivisions. For example, Chen et al. (2014) argued that closed innovation strategies have been replaced by open innovation strategies. Previous theories of intellectual capital focused on the firm's internal aspects and were not suitable for open innovation. Thus, they reconstructed the traditional model of intellectual capital, distinguished between external and internal intellectual capital, and researched their relationship to innovation. Similarly, Zhou et al. (2019) classified open innovation as inbound- and outbound-oriented and investigated the mediating role of intellectual capital in the strategic flexibility of two-way open innovation. They argued that both inbound and outbound open innovation require human, structural, and relational capital to provide the underlying resources for the integration of innovative ideas and the commercialization of technology. It follows that while there seems to be a consensus that intellectual capital could influence innovation, many details still need to be examined.

(1) Human Capital and Ambidextrous Innovation

Human capital is so crucial for explaining organizational and innovation theories that it often transcends intellectual capital to combine with concepts from other domains to form new frameworks. Abouzeedan and Hedner (2012) incorporate human capital with open, financial, and systems capital to construct a new innovation capital model to explain the open innovation paradigm. Most existing studies focus on how firm executives influence enterprise innovation, but often ignore the role of employees. For example, Liu et al. (2019) found that human capital on the board of directors of high-tech firms has a significant impact on ambidextrous innovation and concluded that directors with higher levels of education and overseas study help firms to grow. However, the success of a firm’s innovation strategy is also highly dependent on intelligent employees, who are not only the providers of innovative ideas, but also concrete executors and implementers of them (Meng et al., 2019). For example, Zhang et al. (2018) examined the inverted U-shaped relationship between open innovation and profitability and the moderating role of human capital, which positively moderates the inverted U-shaped relationship in technology-oriented firms but has a negative effect in production-oriented firms.

In some earlier studies, Hayton (2005) showed that human capital diversity contributed to the innovation of high-tech new ventures in the United States, and the study by Bogers et al. (2018) further found that employee diversity contributed to a firm’s open innovation strategy. In particular, employee diversity in knowledge and educational background was positively associated with openness at the firm level, and work experience diversity was not directly related to it. Kang and Snell (2009) argued that different types of employees promote different forms of enterprise innovation. Specialist employees usually have more in-depth knowledge in a particular field and are less willing and capable of exploring knowledge outside their field. Thus, they are more likely to focus on exploitative innovation. Although generalist employees are hardly an authority in a particular field, they master more knowledge in different fields and have an unusual perspective. They are good at generating new ideas and solutions through ambidextrous learning and are more inclined to promote exploratory innovation within the firm. Based on the above reasons, we propose the following research hypothesis:

H2a. *Human capital has a significantly positive effect on exploratory innovation.*

H2b. *Human capital has a significantly positive effect on exploitative innovation.*

(2) Structural Capital and Ambidextrous Innovation

The development of a firm is a process of constant adaptation to changes in the environment and adjustments to its organizational structure, strategy and behavior, and structural capital plays a vital role (Becheikh et al., 2006). For example, Jayabalan et al. (2021) showed that intellectual capital, including structural capital, contributes to frugal open innovation to help organizations with low profitability, such as private colleges and universities, out of financial distress. As stated by Wu et al. (2008), the structural capital of a firm contains all encoded knowledge that is not related to human resources and anything that has a higher actual use value than material value for the firm. At the same time, their findings suggest that structural capital can significantly and positively affect the firm’s innovation capability. Both for large and small firms, structural capital largely explains the effectiveness of new idea generation (Aramburu & Sáenz, 2011). The reuse of encoded knowledge helps strengthen the firm’s existing knowledge base. A dexterous organizational structure, standardized business processes, a rich knowledge base, and an excellent corporate culture also provide strong support for the firm's innovation strategy (Subramaniam & Youndt, 2005). Firms that implement open innovation strategy, to consolidate structural capital, need to use more effective ways to manage knowledge and pay particular attention to the inflow and outflow and whether the knowledge is easy to decode (Matricano et al., 2020).

The empirical study by Barrena-Martínez et al. (2020) showed that structural capital has a significantly positive linear effect on a firm's collaboration with external subjects to develop product innovations. They describe it as successful open innovation and suggest that this may be because structural capital components such as organizational processes and intellectual property rights help develop the firm's ability to absorb and exploit external knowledge. Thus, stronger structural capital is conducive to exploitative innovation based on the existing knowledge base. Meanwhile, although exploratory innovation is riskier and more uncertain than exploitative innovation, robust structural capital not only provides a supply of knowledge, but also provides institutional protection and cultural incentives. As a prerequisite for innovative performance, firms engage in exploratory learning intending to explore new advanced technologies or opportunities and stimulate the creativity of their employees. Faced with the trend toward openness to innovation and the resulting differences in mental and coding schemes, firms have elevated their willingness to undertake exploratory learning to understand new external knowledge accurately (Lazzarotti et al., 2015). It could motivate employees to break through path dependence and use more cutting-edge knowledge to obtain breakthrough results, ultimately promoting exploratory innovation. Based on this, the following research hypothesis is proposed.

H2c. *Structural capital has a significantly positive effect on exploratory innovation.*

H2d. *Structural capital has a significantly positive effect on exploitative innovation.*

(3) Relational Capital and Ambidextrous Innovation

As mentioned earlier, relational capital refers to the knowledge and capabilities embedded in a firm's internal and external social relationships. As a core component of relational capital, trust and commitment directly influence the ability to collaborate among partners, and this ability significantly affects innovation (Cullen et al., 2000). Internally, relational capital enhances cooperation and interaction among employees, the exchange of ideas about each other's work, and opportunities for new ideas to be generated and implemented. Externally, relational capital emphasizes the importance of working closely with upstream and downstream partners to establish common goals. This provides an opportunity for firms to integrate the knowledge accumulated internally with the knowledge held by external participants to improve their innovation capabilities (Ryu et al., 2021). Especially in the context of open innovation, good external relational capital plays a key role in the success of start-ups or early stages of the product life cycle (Macchi et al., 2014). For example, Bharati and Chaudhury (2019) showed that the more relational capital an organization has, the more big-data innovation it has. They argued that many work tasks would be simplified if relationships with business partners were well used to gather technical information.

Relational capital not only helps firms absorb useful knowledge from outside, but it also facilitates the transformation of internal knowledge into product and process innovation and accelerates the speed of innovation (Onofrei et al., 2020). Meanwhile, the role of relational capital and innovation may not be unidirectional but rather reciprocal. Lenart-Gansiniec (2016) believes relational capital and innovation are interdependent because an increasingly open innovation environment widens mutual communication channels and builds exchange platforms for previously unfamiliar innovation subjects, making it possible for organizations to harvest new ones external relationships in their innovation activities. The results of the empirical study by Michelino et al. (2014) also indicates that collaborative development with other firms might increase all elements of intellectual capital. For this study, we specifically argue that, on the one hand, the knowledge bases firms are usually heterogeneous internally and externally, and reliable relationships will influence technical assimilation and help firms acquire new knowledge and ideas (Bharati & Chaudhury, 2019), which is conducive to exploratory innovation. On the other hand, trust-based communication may deepen the understanding of existing knowledge, which in turn improves the practical methods and processes and promotes exploitative innovation. Based on this, we propose the following research hypothesis.

H2e. *Relational capital has a significantly positive effect on exploratory innovation.*

H2f. *Relational capital has a significantly positive effect on exploitative innovation.*

4.3.3 Knowledge Sharing and Ambidextrous Innovation

Knowledge sharing and knowledge creation are inextricably linked from the perspective of knowledge management. Knowledge sharing creates chances for organizations and individuals to incorporate different perspectives. Singh et al. (2021) emphasize the critical role of top management in focusing on internal knowledge sharing to support open innovation. They argue that firms could effectively manage knowledge only when employees are willing to share what they know, thereby sustaining innovation at the individual, team, and firm levels; seizing changing and fleeting market opportunities; and meeting customer needs quickly and with minimal cost. Knowledge sharing is important not only among employees, but also among entrepreneurs and managers. For example, Setini et al. (2020) examined open innovation communities consisting of women entrepreneurs in Bali. They concluded that the knowledge sharing brought about by such communities is a self-improvement process. The information exchange motivates the women and the resulting information is ultimately used to create various innovations to meet market needs, thereby positively influencing performance.

Wang and Wang (2012) showed empirically that knowledge sharing has a significantly positive effect on innovation performance and can lead to better knowledge management. Yeşil et al. (2013) pointed out that the process of driving innovation in firms is highly dependent on the knowledge and experience of individuals, and that knowledge sharing can precisely integrate fragmented knowledge to form a strong innovation capability, which translates into innovation performance. Chiang and Hung (2010) also pointed out that knowledge sharing is a valuable input for innovation because knowledge flow within an organization can facilitate performance. Both exploratory and exploitative innovations are unlikely to leave the core resources, which are based on tacit and explicit knowledge. Scuotto et al. (2020) argued that innovation evokes an open process that combines these two forms of knowledge, forming a virtuous circle that establishes a link between the exploitation and exploration of knowledge and the exploitation and exploration of technology. The mutual exchange, learning, and understanding generated by this form of knowledge sharing accelerate the diffusion and application of new knowledge within the firm, as well as the development and commercialization of new products, and knowledge sharing is bound to become a proper part of ambidextrous innovation. Based on this, we propose the following research hypothesis:

H3a. *Knowledge sharing has a significantly positive effect on exploratory innovation.*

H3b. *Knowledge sharing has a significantly positive effect on exploitative innovation.*

4.3.4 Triadic Intellectual Capital as a Mediator

Management scholars have widely recognized the positive effect of knowledge sharing on intellectual capital (Oliveira et al., 2020). Many studies have also shown that different elements of intellectual capital bring different effects to enterprise innovation or performance, and such effects are sometimes even negative (Xu & Wang, 2019; Chahal & Bakshi, 2015). Other studies have argued that intellectual capital could mediate the positive impact of knowledge sharing on performance. Firms should not only pay attention to the guidance of knowledge sharing, but also understand how it affects the firm through different elements of intellectual capital. Some scholars have advocated that decision-makers should establish appropriate mechanisms to ensure that intellectual capital can be properly planned to achieve the desired effects of decisions (Wang et al., 2014). Scholars have done many studies on proximate topics. For example. Lo et al. (2020) verified the mediating role of triadic intellectual capital in open strategies on innovation performance by using a sample of listed service firms. However, the literature still lacks a discussion of how knowledge sharing affects firm innovation through different elements of intellectual capital. This is especially true for ambidextrous innovation, an outcome variable that is controversial for seeking either balance or complementarity.

We argue that there is a mediating role for intellectual capital between knowledge sharing and ambidextrous innovation. At the human level, whether for exploratory or exploitative innovation, knowledge sharing provides employees with an original knowledge base that can effectively enhance their innovative skills and thinking and drive the formation of innovative activities at all levels. At the organizational structure level, knowledge sharing not only helps firms acquire new knowledge and ideas, but also promotes improved organizational structure, shapes the atmosphere of innovation for everyone, and drives the progress of the knowledge management system. At the internal or external relationship level, knowledge sharing deepens the intimate relationship between employees and cooperative enterprises through frequent interaction and communication. Moreover, the collision of knowledge in multiple fields triggers new thinking and increases the probability of sparking innovation from both sides, ultimately promoting ambidextrous innovation generation. Based on the above reasons, we propose the following research hypothesis:

H4a. *Human capital mediates the effect of knowledge sharing on exploratory innovation.*

H4b. *Human capital mediates the effect of knowledge sharing on exploitative innovation.*

H4c. *Structural capital mediates the effect of knowledge sharing on exploratory innovation.*

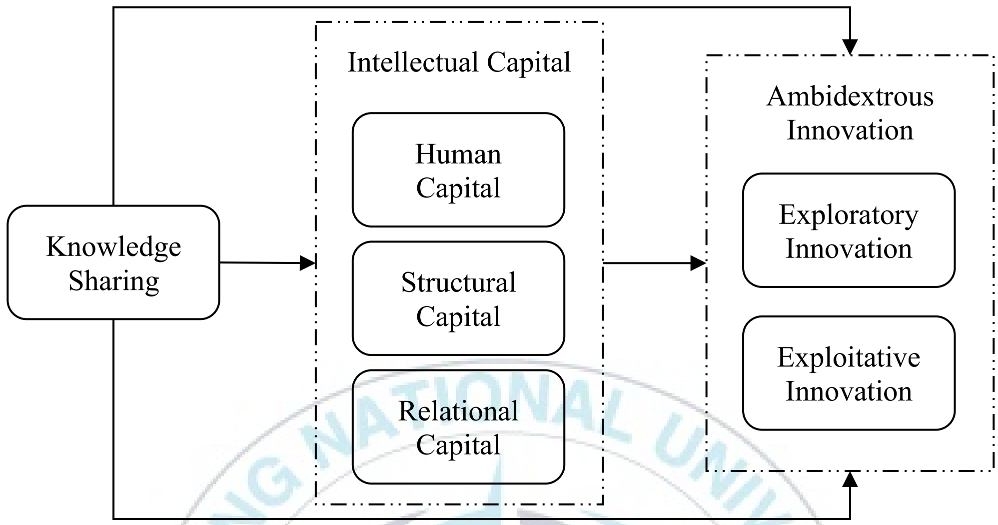
H4d. *Structural capital mediates the effect of knowledge sharing on exploitative innovation.*

H4e. *Relational capital mediates the effect of knowledge sharing on exploratory innovation.*

H4f. *Relational capital mediates the effect of knowledge sharing on exploitative innovation.*

In Figure 4-1 we constructed a conceptual framework of knowledge sharing, triadic intellectual capital, and ambidextrous innovation.

<Figure 4-1> Conceptual Framework



4.4 Methods

4.4.1 Participants and Procedure

In this study, high-tech industries (e.g., computer, communication, and biomedical), which are more knowledge-intensive, were taken as samples. There were two major reasons. First, compared with other industries, high-tech industries have a greater demand for knowledge, and it is very common to share knowledge through various forms within enterprises. Second, high-tech industries are undergoing rapid change, so they must rely on innovation to continuously develop or upgrade their technology to survive and grow. We used a questionnaire, which is more commonly used in the study of intellectual capital, to conduct a survey of high-tech enterprises in Jiangsu Province, which has one of the more developed economies in China. The respondents comprised senior managers, middle managers, and general technical staff. Considering the practical difficulties of collecting the questionnaire face-to-face under the current social and public health conditions, the survey was distributed mainly through the researchers' social network, and respondents were invited through online channels such as e-mail and SNS apps. The statistical software we used was SPSS and AMOS 28.0. The survey lasted from 15 March to 15 May 2021; 600 questionnaires were distributed, and 459 responses were received. After eliminating obviously invalid responses, a total of 349 valid samples passed screening for a valid response rate of 58.17%. Among these, the sample distribution characteristics are shown in Table 4-1.

<Table 4-1> The Distribution Characteristics of the Sample

Characteristics	Type	Frequency	Percentage (%)
Gender	Male	230	65.90
	Female	119	34.10
Position	Senior Management	17	4.87
	Middle Managers	75	21.49
	General technical staff	257	73.64
Industry	High-tech Manufacturing	169	48.42
	High-tech Services	153	43.84
	Others	27	7.74
Number of employees	1-50	46	13.18
	51-200	46	13.18
	201-500	72	20.63
	501-1000	74	21.20
	＞1000	111	31.81
Work experience (year)	＜1	48	13.75
	1-5	122	34.96
	5-10	103	29.51
	＞10	76	21.78
Registered capital (CNY)	＜10 Million	39	11.17
	10-50 Million	58	16.62
	50-100 Million	90	25.79
	＞100 Million	162	46.42
Firm age (year)	＜3	15	4.30
	3-5	29	8.31
	5-10	74	21.20
	10-15	79	22.64
	＞15	152	43.55

4.4.2 Measures

To ensure the reliability and validity of each construct, all items of the questionnaire were selected from existing established scales. At the same time, some items were appropriately modified according to the characteristics of the sample and purpose of the study. The whole questionnaire was measured using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The complete survey questionnaire translated from Chinese is shown in Appendix.

(1) Knowledge Sharing

We adopted a seven-point scale to measure knowledge sharing, such as “employees frequently communicate with each other about their work” and “employees regularly participate in job-related training”, which mainly refers to the studies of Zhang et al. (2016) and Wang and Wang (2012).

(2) Intellectual Capital

Although existing studies disagree about dualism, triadism and pluralism, most studies using the questionnaire method tend to divide intellectual capital into human, structural, and relational capital according to triadism. This study also adopted this classification, and the practical scale used refers to the studies of Bontis (1998), Hsu and Fang (2009), and Wang et al. (2014). Human capital consisted of 5 items, such as “Employees generally have good professional knowledge” and “Employees generally have a strong sense of innovation”; structural capital consisted of 5 items, such as “Our company has efficient decision-making mechanisms” and “Our company has an effective information management system”; and relational capital consisted of 4 items, such as “Our company maintains good relationships with suppliers” and “Our company maintains good relationships with our partners”.

(3) Ambidextrous Innovation

For ambidextrous innovation, according to previous studies, we divided it into two dimensions: exploratory innovation and exploitative innovation, which were measured separately. The practical scale refers to the research of Cao et al. (2009) and Ma et al. (2017). Exploratory innovation consisted of 4 items, such as “Our company is introducing a new generation of products or services” and “Our company is introducing industry-leading technology”, and exploitative innovation also consisted of 4 items, such as “Our company is improving the quality of existing products or services” and “Our company is trying to reduce the cost of an existing product or service”.

4.4.3 Common Method Bias

Since all items in each questionnaire were filled out by a single respondent, a spurious common variance may result from the homogeneity of the data and the use of the same measurement tool, thus requiring a test for common method bias (CMB). To this end, this study used Harman’s single factor test to conduct an unrotated exploratory factor analysis (EFA) of all question items to determine whether a single factor explained more than 40% of the variance in a reasonable way (Podsakoff et al., 2003; Kock et al., 2021). During the test, six factors with characteristic roots greater than 1 were extracted, and the total explanation of variance was 70.80%. Among these, the first factor explained 35.74% of the variance, which met the empirical criteria and indicated that the study had no serious CMB problem.

4.5 Results

4.5.1 Measurement Model

(1) Reliability

<Table 4-2> Reliability and Validity Test Results

Constructs	Items	Loadings	CR	Cronbach's α	AVE
Knowledge Sharing (KS)	KS1	0.693	0.877	0.866	0.556
	KS2	0.711			
	KS3	0.721			
	KS4	0.796			
	KS5	0.794			
	KS6	0.786			
	KS7	0.712			
Human Capital (HC)	HC1	0.811	0.890	0.837	0.671
	HC2	0.791			
	HC3	0.814			
	HC4	0.838			
	HC5	0.843			
Structural Capital (SC)	SC1	0.877	0.923	0.902	0.769
	SC2	0.881			
	SC3	0.860			
	SC4	0.899			
	SC5	0.868			
Relational Capital (RC)	RC1	0.741	0.892	0.872	0.724
	RC2	0.869			
	RC3	0.881			
	RC4	0.905			
Exploratory Innovation (EY)	EY1	0.834	0.890	0.869	0.718
	EY2	0.842			
	EY3	0.854			
	EY4	0.859			
Exploitative Innovation (EE)	EE1	0.848	0.916	0.868	0.785
	EE2	0.883			
	EE3	0.883			
	EE4	0.890			

Before evaluating the structural model, the reliability of the questionnaire was tested. We use the more commonly used Cronbach's alpha for the test: knowledge sharing, 0.866; human, structural, and relational capital, 0.837, 0.902, and 0.872, respectively; and exploratory and exploitative innovation, 0.869 and 0.868, respectively. All of these values are greater than the critical value of 0.700, indicating that the internal consistency of the latent variables was satisfactory, and the questionnaire had good reliability. The specific data are shown in Table 4-2.

(2) Validity

We used two indicators, convergent and discriminant validity, to assess the validity of the measurement model. As can be seen from Table 2, all factor loadings in this study ranged from 0.693 to 0.905, which was greater than 0.55; the composite reliabilities (CR) of each latent variable ranged from 0.877 to 0.923, which was greater than 0.70; and the average variance extracted (AVE) ranged from 0.556 to 0.785, which was greater than 0.50. All these values were within a reasonable range, indicating that each construct has good convergent validity. As shown in Table 4-3, the square root of AVE for each latent variable on the diagonal was higher than the correlation coefficient between this and other latent variables, indicating that the model had good discriminant validity (Fornell & Larcker, 1981).

<Table 4-3> Square Roots of AVE and Correlation Coefficients

Constructs	1	2	3	4	5	6
1. KS	**0.745**					
2. HC	0.456**	**0.819**				
3. SC	0.427**	0.450**	**0.877**			
4. RC	0.314**	0.476**	0.398*	**0.851**		
5. EY	0.197	0.374**	0.390**	0.268	**0.847**	
6. EE	0.393	0.470**	0.460*	0.309**	0.244**	**0.886**

Note: The bold diagonal elements are the square roots of each AVE.
* $p < 0.05$; ** $p < 0.01$

4.5.2 Structural Model

(1) Model Fitness

Before testing the research hypotheses, we constructed the structural model in Amos 28.0 and tested the fit of the model. Some of the important fit indices are shown in Table 4-4. As can be seen, these show that the measurement model exhibited an adequate fit to the data and could proceed to hypothesis testing.

<Table 4-4> Overall Fit Indices of the Measurement Model

	χ^2/df	CFI	TLI	NFI	RFI	GFI	RMSEA
Scores	1.539	0.97	0.966	0.92	0.912	0.902	0.038
Criteria	< 3	> 0.9	> 0.9	> 0.9	> 0.9	> 0.9	< 0.05

(2) Path Coefficient

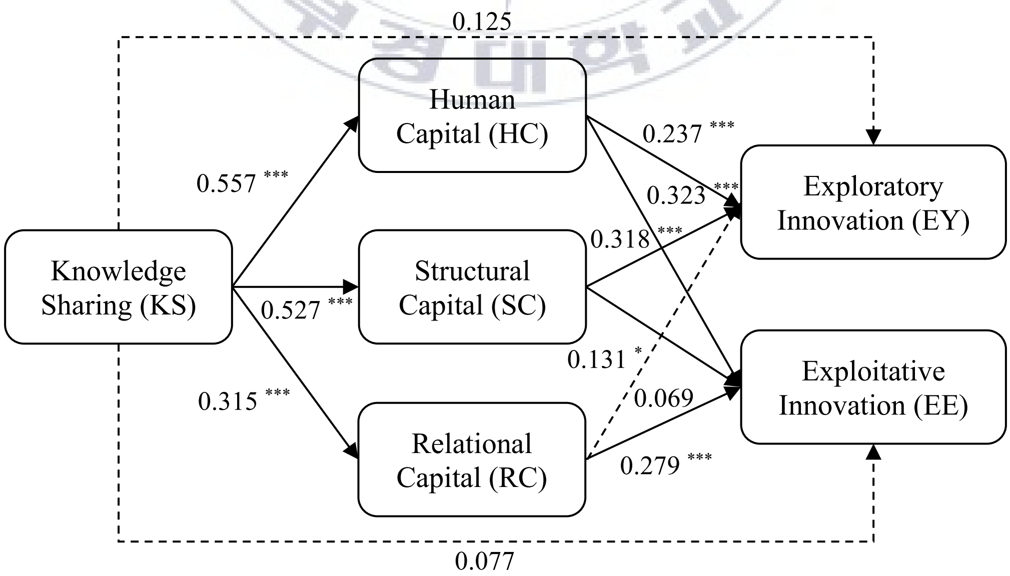
The results of the hypothesis tests are shown in Table 4-5, and the path coefficients of the structural model are shown in Figure 4-2. In the test of the relationship between knowledge sharing and intellectual capital, there was a significant positive effect on human capital ($\beta = 0.557$, $p < 0.001$), structural capital ($\beta = 0.527$, $p < 0.001$), and relational capital ($\beta = 0.315$, $p < 0.001$). H1a, H1b, and H1c were supported. In the test of the relationship between intellectual capital and ambidextrous innovation, there was a significant positive effect of human capital on exploratory innovation ($\beta = 0.237$, $p < 0.001$) and on exploitative innovation ($\beta = 0.323$, $p < 0.001$). H2a and H2b were supported. Structural capital on exploratory innovation ($\beta = 0.318$, $p < 0.001$) and exploitative innovation ($\beta = 0.131$, $p = 0.044$) also showed a significantly positive effect, H2c and H2d were supported. No significant effect of relational capital on exploratory innovation was detected, while there was a significant positive effect on exploitative innovation ($\beta = 0.279$, $p < 0.001$). H2e was not supported but H2f was. No significant effect of knowledge sharing on either exploratory or exploitative innovation was detected, so H3a and H3b were not supported.

<Table 4-5> Standardized Path Coefficients

	Paths			Coefficients	*t*	*p*	Remarks
H1a	KS	→	HC	0.557	11.879	***	Accept
H1b	KS	→	SC	0.527	11.388	***	Accept
H1c	KS	→	RC	0.315	5.706	***	Accept
H2a	HC	→	EY	0.237	3.406	***	Accept
H2b	HC	→	EE	0.323	4.823	***	Accept
H2c	SC	→	EY	0.318	4.040	***	Accept
H2d	SC	→	EE	0.131	2.019	0.044	Accept
H2e	RC	→	EY	0.069	1.109	0.268	Reject
H2f	RC	→	EE	0.279	4.535	***	Accept
H3a	KS	→	EY	0.125	1.706	0.089	Reject
H3b	KS	→	EE	0.077	1.452	0.147	Reject

Note: *** $p < 0.001$

<Figure 4-2> Research Model and Testing Results



Note: * $p < 0.05$; *** $p < 0.001$

(3) Mediating Effects

After testing the main research hypothesis, we further used bootstrapping analysis to detect the mediating effect of intellectual capital between knowledge sharing and ambidextrous innovation. The number of samples with replacement was 5000, and the confidence interval was 95%. The test results are shown in Table 4-6. Among the mediating effects detected in this study, all paths except the path "knowledge sharing → relational capital → exploratory innovation" did not contain 0 at the 95% confidence interval ($p < 0.05$). It showed that both human capital and structural capital play a mediating role in the effect of knowledge sharing on exploratory and exploitative innovation. In contrast, relational capital plays a mediating role in the effect of knowledge sharing on exploitative innovation but does not play a mediating role in the effect of knowledge sharing on exploratory innovation. H4a, H4b, H4c, H4d, and H4f were supported, but H4e was not. Based on the results of the test of mediating effects, it can be further concluded that the total effect of knowledge sharing on exploratory innovation through two mediators (human capital and structural capital) was 0.5194. The total effect of knowledge sharing on exploitative innovation through three mediators (human capital, structural capital, and relational capital) was 0.6123.

<Table 4-6> Results of the Test for Mediating Effects

	Paths	Effect	SE	LLCI	ULCI
H4a	KS→HC→EY	0.2511	0.043	0.1714	0.3394
H4b	KS→HC→EE	0.2747	0.054	0.1750	0.3837
H4c	KS→SC→EY	0.2683	0.042	0.1875	0.3535
H4d	KS→SC→EE	0.1612	0.034	0.0946	0.2278
H4e	KS→RC→EY	0.0517	0.033	-0.0130	0.1164
H4f	KS→RC→EE	0.1764	0.031	0.1156	0.2372

4.6 Chapter Summary

4.6.1 Conclusions

Based on the 349 survey samples, we examined the impact of knowledge sharing on ambidextrous innovation (exploratory and exploitative innovation) through different elements of intellectual capital (human, structural, and relational) using structural equation modeling, and we obtained the following conclusions.

(1) Knowledge sharing has a significantly positive effect on different elements of intellectual capital, indicating that the greater the active knowledge sharing in an enterprise, the more likely it is to promote the accumulation of intellectual capital. This was consistent with the findings of some previous studies. Human capital and structural capital both showed significantly positive effects on exploratory innovation and exploitative innovation, which may indicate that as employees' personal knowledge grew and skills improved, and the organization's knowledge continued to be deposited, the processes continued to be optimized, and structures continued to improve. However, it is important to note that relational capital significantly affected exploitative, not exploratory, innovation. It may have indicated that many high-tech enterprises realized that good internal and external relationships help to redevelop and reuse existing knowledge. Thus, relational capital plays a positive role in developing exploitative innovation. However, exploratory innovation places more emphasis on disrupting existing knowledge, sometimes even trying to replace the dominant paradigm in the current market. It requires a high degree of expertise and originality, and the help that could be obtained from relational networks is more limited. Managers should be aware of the risks of over-reliance on relational capital and avoid over-searching and over-collaborating (Barrena-Martínez et al., 2020).

(2) Unexpectedly, there was no significantly direct effect between knowledge sharing and ambidextrous innovation. While we realized that this might be an isolated phenomenon limited by the research instrument, we still speculated that the process of encouraging knowledge sharing as a means of strengthening internal management did not in itself significantly stimulate innovation. Only intellectual capital increased through effective knowledge sharing could truly promote innovation. It is a reminder to decision-makers that a focus on strengthening internal management without paying attention to enhancing the hard and soft power of the firm through the introduction of new talent and technology may make promoting enterprise innovation tantamount to trying to get blood from a stone. In a situation where a firm seriously lacks knowledge reserves and the employees' personal skills are seriously inadequate, no matter how much knowledge sharing is encouraged, it cannot effectively improve the firm' overall capability. At this time, it not only does not contribute to the accumulation of intellectual capital, but also may become a burden to innovation because of the excessive time spent on management activities.

(3) The three elements of intellectual capital (human capital, structural capital, and relational capital) mediate to a certain degree the effect of knowledge sharing on ambidextrous innovation (exploratory and exploitative). Among them, knowledge sharing will have a significantly positive impact on exploratory innovation through the mediation of human and structural capital, respectively, and a significantly positive impact on exploitative innovation through the mediation of human, structural, and relational capital. Since the effect of knowledge sharing on ambidextrous innovation is not significant, all of these mediating effects are full mediations. In addition, the mediating effect of human capital between knowledge sharing and exploratory innovation was not detected because of its non-significant effect on exploratory

innovation. This again suggests that decision-makers should pay attention to the pivotal role of intellectual capital and its elements in the positive effect of knowledge sharing on other outcome variables.

4.6.2 Implications

The possible theoretical contributions of this study include the following. First, the driving mechanism of ambidextrous innovation is further clarified. Based on previous studies, we investigated how knowledge sharing affects ambidextrous innovation through intellectual capital, thereby enriching the research perspective of knowledge management behavior. Second, most existing studies discuss the effects of knowledge sharing on overall enterprise innovation. Knowledge sharing will produce different effects for different types of innovation activities, which may not be controversial. So, we explored the differences in the effects of knowledge sharing on exploratory and exploitative innovation in more depth. It is a supplement to the field of knowledge management behavior. Finally, regarding the three different elements of intellectual capital as mediating variables, we analyzed the differences in the indirect effects of knowledge sharing on exploratory and exploitative innovation through these different elements. This reveals which element of intellectual capital was the most prioritized and important to accumulate for these two modes of innovation.

This study may also provide some implications for specific business practices. First, the importance of intellectual capital for innovation is mentioned once again. From the human level, it is necessary to improve employee knowledge and skills, but also to recruit new talent. From the organizational level, a complete knowledge base, a flexible organizational structure, and a tolerant corporate culture may help stimulate employees' innovative energy. From the relationship level, building good internal /

external relationships and upstream / downstream relationships, and strengthening interaction with stakeholders, may contribute to the long-term and stable development of firms, and is conducive to exploitative innovation. Second, the benefits of encouraging knowledge sharing are obvious. It gives employees the opportunity to interact and learn from each other, which strengthens human capital by increasing the average level of employees' knowledge and skills. New ideas generated during the interaction may help improve the organizational structure and business processes to increase structural capital. Moreover, the trust and reciprocity built by employees during the sharing and interaction process may also strengthen the relational capital. Finally, under the condition of limited resources, firms should match the differentiated intellectual capital according to the type of innovation they focus on. For exploratory innovation, firms should focus on improving their knowledge base, decision-making mechanisms, operational processes, and business structures to consolidate human and structural capital. For exploitative innovation, firms could appropriately strengthen their investment in building internal–external relationships, and improve the quality of their products or services by learning from the experience of other entities.

4.6.3 Discussion

For a long time, academia has tended to focus on how the management activities of a firm could drive innovation while ignoring the question of whether inappropriate management behavior could be detrimental to innovation. It seems to have become such a mindset that it has sometimes led management to turn a blind eye to employee complaints about the misuse of management tools. For this study, it seemed that it was difficult to apply knowledge sharing directly to innovation. Does this suggest that at some point, the tools used by decision-makers to strengthen internal controls (including strengthening internal knowledge management) may not be conducive to innovation?

For example, in recent years, some Chinese firms have forced their employees to install mobile workplace apps to clock in and out of work, in an attempt to prompt knowledge sharing through these apps while strengthening internal controls even during non-working hours. However, it is doubtful how much energy employees have left for meaningful knowledge sharing and innovation after being overwhelmed with these management activities (Wang et al., 2022). In the study by Hau et al. (2013), organizational rewards reduced employees' knowledge sharing intentions. In the study by Hsu and Fang (2009), structural capital showed a mildly negative correlation with new product development performance. All these seem to imply that we cannot ignore the negative impact on enterprise innovation from ineffective managerial behavior that deprives employees of their individual will and do not consider the state of the firm. Few studies address how a specific management tool designed to facilitate knowledge sharing would affect intellectual capital and enterprise innovation, and this study has been no exception.

It is time to shift the focus to the well-being of the individual employee. Existing research has focused too much on the organization, often ignoring individuals. Even when individuals are the subject of study, scholars prefer to examine how some attributes of top management affect performance or strategic choices. However, labor relations under the neo-liberal ideology are pure and utilitarian (Ettlinger, 2017). What determines the way employees behave is, first of all, their individual interests, and only secondly might it be collective interest combined with individual interests. After the continuation of COVID-19 restrictions and the normalization of remote work, individualism in the workplace is rapidly increasing, and the Great Resignation and severe labor shortages that have occurred in many developed countries speak volumes about this trend. Specifically with respect to the concepts relevant to this study, knowledge sharing on the surface may appear to be a behavior that tends toward collectivism, which presupposes in-group identification and cooperation (Bao et al., 2015). However, the empirical results of many studies showed that both individual and collective orientations positively affect knowledge sharing intention (Yu, 2014; Kim, 2020). This seems to indicate that individualism and collectivism are not entirely opposite; they could coexist under certain conditions. For example, Yun et al. (2017) argued that open innovation is one such field that allows them to merge. Successful open innovation is determined by individuals, but in the process, they may develop cohesion among themselves and, as a result, their collectivism could contribute their mastery of knowledge and reduce the complexity of open innovation. This model of transforming from individual intelligence to collective intelligence is essentially a process of knowledge sharing. It integrates a large group of people with specialized skills to do something collectively to achieve synergy (Yun et al., 2021a).

A strong link between knowledge sharing intention and open innovation seems to have emerged. However, as mentioned earlier, not all management behavior is effective, and not all initiatives aimed at promoting knowledge sharing are consistent with an open innovation culture. A prerequisite is a culture of altruism within the group, which refers to the lowering of one's own comfort level to enhance the comfort level of others for the sake of the group's growth prospects, with tolerance at its core (Yun et al., 2020). This encompasses both the tolerance of ordinary employees toward each other and entrepreneurs or managers toward their subordinates. Many firms claim to be implementing an open innovation strategy while at the same time trying to eliminate an individualist orientation through various means, which often puts a great deal of psychological stress on employees (Wang et al., 2022). Employees who could share knowledge have usually invested considerable time or money in their abilities, and they expect to receive their due rewards, including psychological ones. This makes many people prefer to accept a sub-standard salary as long as they gain sufficient status and respect (Ettlinger, 2017). In other words, firms' attempts to eliminate individualism and enhance collectivism, while making employees psychologically more anxious, have instead strengthened their sense of self. This also explains one possible reason for the Great Resignation.

Thus, as scholars in this research area know, studying the relationship between knowledge sharing and open innovation from the perspective of individualism and collectivism is not new. Meanwhile, the psychological factors contained herein that may lead employees to change their jobs may greatly affect intellectual capital elements such as human capital. Existing studies have invariably ignored the well-being of individual employees when discussing individualism and have paid little attention to whether those lauded management tools actually contribute to innovation. We suggest that future studies categorize management tools designed to encourage knowledge sharing from a behavioral perspective, rather than limiting the categorization to using the attributes of knowledge (i.e., explicit & tacit). At the same time, more consideration should be given to the value and feelings of employees as independent individuals. Qualitative or quantitative research could both be used to explore which types of management tools are genuinely effective and which ones may be ineffective or even burdensome to employees and the business. In addition, the antecedent variables of ambidextrous open innovation (Yun et al., 2021b) or "multidexterous" innovation (Robbins et al., 2021) could also be discussed more.

V. Conclusions

5.1 Summary of Main Findings

This thesis focuses on the core proposition of "how intellectual capital affects innovation," and aims to explore how modern firms rely on intellectual capital to enhance their innovation capabilities in the context of knowledge economy, which increasingly emphasizes CSR. With the help of scientific software such as CiteSpace, Stata, SPSS, and Amos, we apply a combination method of literature and theoretical research, bibliometric and mapping knowledge domains, multiple regression model based on secondary data, and structural equation model based on survey questionnaire. Through two sub-research, we answered four sub-questions layer by layer: How do intellectual capital and its different elements affect technological innovation? What role does the fulfillment of CSR play in the relationship between intellectual capital and technological innovation? How does knowledge sharing for the purpose of promoting enterprise innovation affect different elements of intellectual capital? What are the differential effects of intellectual capital and its different elements on the ambidexterity characteristics (exploratory and exploitative) of innovation? After a more in-depth theoretical derivation, the thesis mainly draws the following findings.

(1) Intellectual capital and its elements (human capital and structural capital) show U-shaped effects on technological innovation.

Previous research on knowledge management and intellectual capital field has typically used questionnaire surveys and SEM as a research method. Scholars have often found that survey data collected in some cases show that an element of intellectual capital positively affect innovation. However, when data are re-collected in other cases, this effect becomes negative. Even so, probably because the commonly used SEM analysis software defaults to a linear relationship between variables, few scholars are aware that intellectual capital and innovation may be nonlinear (U-shaped or inverted U-shaped). Although a few scholars have attempted to measure intellectual capital by redefining the VAIC formula using secondary data, they have also not attempted to include a quadratic term in the regression equation for testing.

This thesis breaks through this mindset and chooses a more commonly used VAIC formula in China to measure intellectual capital, confirming the U-shaped relationship between intellectual capital and technological innovation, i.e., the existence of a threshold effect between them. Technological innovation shows a strange “decreasing trend” in the early stage of accumulating intellectual capital. It may be because early investment in intellectual capital requires much higher funding than middle and later stages, crowding out the resources for innovation. As the saying goes, it takes a good blacksmith to make steel. Firms must first accumulate a certain level of intellectual capital before making substantial innovations. If a firm does not have enough intellectual capital but tries to challenge complex innovation, it will likely harm its long-term development. Moreover, when we distinguish the nature of firm ownership, technological innovation in state-owned firms is more susceptible to intellectual capital than private firms. But the relationship between structural capital and technological innovation is significant for private firms but not for state-owned firms.

(2) The fulfillment of corporate social responsibility positively moderates the effect of intellectual capital on technological innovation.

Although fulfilling CSR inevitably takes up some of the firm’s resources, our findings are consistent with most other studies that have examined the economic consequences of fulfilling CSR, suggesting that fulfilling CSR can enhance the firm's reputation and thus its performance and value. In particular, for the sample of "listed firms" in this thesis, CSR disclosure could help firms gain recognition in the capital market, reduce financing costs, and broaden access to financing. In this thesis, CSR positively moderates the U-shaped effect of intellectual capital and its elements (human capital and structural capital) on technological innovation, i.e., it makes the slope of the regression curve steeper. Even in the early growth stage of firms, when the output of technological innovation decreases with the growth of intellectual capital, firms with higher levels of CSR usually have higher levels of technological innovation.

Our group regression results also indicated that CSR has a higher positive moderating effect on private firms than state-owned firms, suggesting that private firms can reap higher returns from actively fulfilling CSR. From the stakeholder theory perspective, this may be because community stakeholders defined by Charkham (1992), such as the government and its controlled regulators, medias, and local communities, have greater influence in China. Private firms' fulfillment of CSR is often aimed at satisfying the demands of these types of stakeholders. In contrast, state-owned firms, which the government also controls, are subject to much less pressure from community stakeholders and therefore can benefit less from actively fulfilling CSR. Therefore, to reduce external obstacles in the development process, private firms should pay more attention to timely CSR fulfillment and disclosure.

(3) Knowledge sharing has a significant positive effect on intellectual capital and its elements, but no direct effect on exploratory and exploitative innovation.

Knowledge management aims to enhance competitiveness, and we demonstrate again that knowledge sharing has a significant positive effect on all dimensions of intellectual capital. In terms of the hierarchical nature of knowledge, it can be divided into individual, team, and corporate knowledge. For the firm, the knowledge known by a single employee is not too helpful. Only the knowledge mastered by more people within a specific scope may constitute a competitive advantage. Corporate knowledge is also not a simple sum of individual knowledge. Before it is transformed into corporate knowledge, individual knowledge must be fully shared. Moreover, corporate knowledge is not limited to the technical knowledge related to production but also includes the institutional knowledge of coordinating production personnel (Qin & Ding, 2007). This explains, to some extent, why structural capital and relational capital are also classified as knowledge-based assets.

However, inconsistent with the research results of many scholars, our study shows no significant relationship between knowledge sharing and ambidextrous innovation. This may indicate that knowledge sharing does not directly promote innovation. The value of knowledge sharing can only be realized after the knowledge shared by others is internalized into its knowledge reserve. From knowledge sharing to innovation, firms first need to go through accumulating intellectual capital. Therefore, what is equally essential as encouraging knowledge sharing is to ensure that this process can solidify the firm's knowledge base and increase intellectual capital reserves. If a firm's behavior of encouraging knowledge sharing cannot effectively improve the conversion rate of individual knowledge owned by employees into the intellectual capital owned by the firm, then such knowledge sharing is ineffective and may even bring adverse effects to the firm because it consumes employees' energy.

(4) By and large, intellectual capital and its elements have significant positive effects on exploratory and exploitative innovation, acting as complete mediators between knowledge sharing and ambidextrous innovation.

We found significant positive effects of all three elements of intellectual capital on exploratory and exploitative innovation, except for no significant relationship between relational capital and exploratory innovation. Since knowledge sharing also has no significant effect on ambidextrous innovation, human and structural capital play a fully mediating role between knowledge sharing and exploratory innovation, while all three elements of intellectual capital play a fully mediating role between knowledge sharing and exploitative innovation. This again suggests that knowledge sharing is the critical antecedent of knowledge management, and that intellectual capital is central to core competitiveness. For these reasons, although many studies adopt the opposite causality to this thesis, arguing that intellectual capital can positively influence knowledge sharing and further drive innovation, we are skeptical of this view, even though these influence relationships appear to be significant.

We believe that the competitive advantage from knowledge management is ultimately expressed in various forms of performance, such as financial and innovation performance and that intellectual capital is the direct source of this set of performance or competitive advantage. Knowledge sharing should serve intellectual capital rather than intellectual capital serving knowledge sharing. Although many existing studies treat intellectual capital and its elements as an antecedent variable of knowledge sharing, the conceptually reversed causality inevitably leads to a misallocation of resources. If knowledge sharing rather than intellectual capital is regarded as the outcome variable, it is easy for firms to set the amount of knowledge sharing behavior as the assessment target and ignore the original purpose of knowledge sharing, which is to accumulate intellectual capital. As Mumford (2000) says, it's doubtful that some practices that seem to be taken for granted really work, and they may actually inhibit creativity. Like some mobile workplace apps designed to facilitate knowledge sharing within the firm that have been widely criticized in recent years, another of our studies suggests that some firms have promoted them heavily but may instead be undermining the employees' innovative capacity (Wang et al., 2022).

5.2 Limitations and Future Research

Although this thesis has chosen some newer perspectives to investigate the mechanism of the role of intellectual capital on enterprise innovation through empirical studies, completing the proposed theoretical conception, and forming some meaningful research conclusions. However, due to the limited research capacity and data that can be obtained, this thesis still has some shortcomings.

First, we do not go beyond the traditional dualistic and triadic views to further subdivide the dimensions of intellectual capital. Nor do we go beyond the traditional way of classifying innovation but choose the more common exploratory, exploitative, and technological innovation as outcome variables. In recent years, many scholars in the field of intellectual capital have tried to explore new dimensions to explain new phenomena based on the existing dimensions, while scholars in the field of innovation have gradually shifted their research focus to more specific types of innovation, such as business model and open innovation, in response to the development of the market situation. Therefore, the following research should focus on new intellectual capital dimensions and innovation types to study new management practices. In addition, we also do not consider whether the dimensions of intellectual capital affect each other, for example, whether structural capital becomes a mediating variable for human capital to influence enterprise innovation, which is also a shortcoming of this thesis.

Second, measuring intellectual capital more accurately is a complex issue. The first sub-study uses financial data to measure intellectual capital through the VAIC method. However, in previous studies, there are many different ways of calculating VAIC. Although this thesis uses a formula for calculating VAIC that is more commonly used in China and was eventually approved by reviewers, during the review process, a reviewer also presented his understanding. He argued that, referring to Iazzolino and Laise (2013), Value-Added (VA) should be calculated as the difference between sales and costs. To answer this controversy, we searched a large number of papers. As Singla (2020) states, the core of VAIC is how VA is defined, and scholars frequently modify the VAIC model to change the definition of VA. Scholars mainly disagree on whether depreciation and amortization should be calculated. However, this is related to each country's tax laws and accounting standards. Therefore, in the future, more attention should be paid to assessing whether the used VAIC calculation formula is suitable for the actual situation in the location of the study subject.

Finally, given the ease of data availability, the first sub-study tests only China's listed firms. However, most firms are not listed and face more severe capital problems. It is more relevant to research how to effectively develop, utilize, and manage non-listed firms' intellectual capital. Although we also used a questionnaire survey method in the second sub-study to fill this gap, there is still the problem of under-representation and the limitation of the survey sample to high-tech firms in Jiangsu, failing to cover other provinces and other types of firms. Moreover, affected by the epidemic, it was difficult for us to have the opportunity to conduct face-to-face interviews with firms' executives to obtain more accurate and reliable primary information further. This makes it possible to under-consider the potential factors affecting intellectual capital and firm innovation. In the future, we can try to record more primary data through field visits and use other methods such as qualitative research to identify more representative factors influencing intellectual capital and enterprise innovation.

Innovation is essentially a "human process" and is always human-centered. While intellectual capital, premised on the human capital theory, is undoubtedly an essential factor influencing enterprise innovation. However, this thesis's research findings show that not all dimensions of intellectual capital and various knowledge management tools can promote enterprise innovation in all cases. Especially when ESG is increasingly promoted, knowledge management and innovation strategies are facing many new and unprecedented demands. Since ESG theories involves more aspects and theoretical research combined with knowledge management is not mature enough to effectively guide management practices, this article only discusses the earlier developed CSR theories for the time being, which makes this study may have some flaws in novelty. From CSR theories to ESG theories, stakeholders are no longer only concerned with the social impacts of business operations and have expanded their focus to include how firms ensure the implementation of actions from their governance structures. Specific to this article, intellectual capital has both internal and external attributes, and ESG also emphasizes external responsibility and internal governance, which coincide with each other. As ESG disclosure gradually becomes an institutional requirement for listed firms, intellectual capital disclosure will become a hot topic for research. Therefore, we could try further to combine intellectual capital and ESG theories in the future.

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APPENDIX

Questionnaire Survey on Knowledge Sharing and Innovation in High-tech Enterprises.

Dear friends,

Hello! We are conducting a questionnaire survey on knowledge sharing and innovation in high-tech enterprises. The target group of this survey is the middle or senior management and technical employees of high-tech enterprises in Jiangsu Province. We hope you will take time out of your busy schedule to fill out this questionnaire and answer the following questions with your current work status and true feelings. The questionnaire is collected anonymously, and there is no right or wrong answer. We are very honored to hear your opinion. Thank you for your support and participation, and we wish you good luck in your work!

First, we need to know a small amount of information related to you and your company. This information is for statistical purposes only. No one can know your specific identity through this information. Please feel free to fill in.

01. What is your gender?	◎ Male ◎ Female
02. What industry does your company belong to?	◎ High-Tech Manufacturing ◎ High-Tech Services ◎ Others
03. How many employees does your company have?	◎ 1-50 ◎ 51-200 ◎ 201-500 ◎ 501-1000 ◎ >1000

04. How many years has your company been in business?	◎ <3 ◎ 3-5 ◎ 5-10 ◎ 10-15 ◎ >15
05. What is the registered capital of your company?	◎ <10 Million ◎ 10–50 Million ◎ 50–100 Million ◎ >100 Million
06. What is your position in your company?	◎ Senior Management ◎ Middle Managers ◎ General Technical Staff
07. How many years have you been working?	◎ <1 ◎ 1-5 ◎ 5-10 ◎ >10

Next, we need to know how much you agree with the following items. Where 1 means strongly disagree, 2 means disagree, 3 means somewhat disagree, 4 means no opinion, 5 means somewhat agree, 6 means agree, and 7 means strongly agree.

Part 1. Knowledge Sharing								
KS1	Employees frequently communicate with each other about their work.	1	2	3	4	5	6	7
KS2	Employees regularly participate in job-related training.	1	2	3	4	5	6	7
KS3	Employees are constantly learning new job-related knowledge from each other.	1	2	3	4	5	6	7
KS4	Employees regularly express their opinions in meetings.	1	2	3	4	5	6	7
KS5	Employees frequently share their work experience and skills with each other.	1	2	3	4	5	6	7
KS6	Employees frequently discuss key problem-solving issues together.	1	2	3	4	5	6	7
KS7	Employees often present their unique ideas and perspectives.	1	2	3	4	5	6	7

Part 2. Human Capital								
HC1	Employees generally have good professional knowledge.	1	2	3	4	5	6	7
HC2	Employees generally have solid work experience and skills.	1	2	3	4	5	6	7
HC3	Employees generally have a strong sense of innovation.	1	2	3	4	5	6	7
HC4	Employees generally have strong problem-solving skills.	1	2	3	4	5	6	7
HC5	Employees generally have independent research skills.	1	2	3	4	5	6	7

Part 3. Structural Capital								
SC1	Our company has an efficient decision-making mechanism.	1	2	3	4	5	6	7
SC2	Our company has an effective information management system.	1	2	3	4	5	6	7
SC3	Our company has a good innovation atmosphere and culture.	1	2	3	4	5	6	7
SC4	Our company has a flexible organizational structure.	1	2	3	4	5	6	7
SC5	Our company has a standardized internal system and norm.	1	2	3	4	5	6	7

Part 4. Relational Capital								
RC1	Our company maintains good relationships with our employees.	1	2	3	4	5	6	7
RC2	Our company maintains good relationships with our suppliers.	1	2	3	4	5	6	7
RC3	Our company maintains good relationships with our customers.	1	2	3	4	5	6	7
RC4	Our company maintains good relationships with our partners.	1	2	3	4	5	6	7

Part 5. Exploratory Innovation								
EY1	Our company is introducing a new generation of products or services.	1	2	3	4	5	6	7
EY2	Our company is expanding into new product ranges.	1	2	3	4	5	6	7
EY3	Our company is working to open new markets and channels.	1	2	3	4	5	6	7
EY4	Our company is introducing industry-leading technology.	1	2	3	4	5	6	7

Part 6. Exploitative Innovation								
EE1	Our company is improving the quality of existing products or services.	1	2	3	4	5	6	7
EE2	Our company is increasing production or reducing material losses.	1	2	3	4	5	6	7
EE3	Our company is trying to reduce the cost of an existing product or service.	1	2	3	4	5	6	7
EE4	Our company is improving the production equipment or process.	1	2	3	4	5	6	7

Your answer is very helpful for our research, thank you again for your cooperation and participation, and have a nice day.

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