Impact of Social Capital on Enterprise Technological Innovation and Entrepreneurial Performance ---- Research Based on Nano-technology Companies in China

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Abstract

Chinese nanotechnology enterprises have been confronted with various challenges. There have also been great opportunities, including government support, economic transformation, global market demand, new enterprises and management modes. Therefore, it is now the right time to investigate an important question: how nanotechnology enterprises in China overcome challenges and seize opportunities?

In this thesis, the impact of social capital on R&D investment and technological innovation has been explored. The impact of both the “scale” and “intensity” of social networks on a firm’s performance have been compared. A case analysis was carried out to verify the conclusions drawn from the theoretical analysis on the current situation of nano-calcium carbonate enterprises in China.

The following key issues have been examined:

1. The impact of senior managers’ political influence on R&D investment in nanotechnology enterprises.
2. The impact of human capital and R&D investment on the technological innovation of nanotechnology enterprises in China.
3. The quality of the social network to the firm’s performance.

This thesis further confirmed the above conclusions derived from chapters 3-5 through a case study of six nano-calcium carbonate enterprises presented in chapter 6. This research has found that if an enterprise in China wants to develop well, corporate social capital and entrepreneurial social capital are indispensable resources. At the same time, the application of any established theories relating to Chinese enterprises must consider conditions specific to China.

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I also appreciate very much all the kind effort from the doctors and hospitals when I was seriously ill over the period of my PhD study.

Finally, though no less importantly, a word for my parents, without whom it would have been extremely difficult for me to reach this stage.

Declaration

I declare that this thesis titled, "Impacts of Social Capital on Enterprise Technological Innovation and Entrepreneurial Performance--Research Based on Nanotechnology Companies in China," and the work presented in it are my own.

I confirm that this work was done wholly or mainly while in candidature for a research degree at this university and has not been submitted previously for a degree at this, or any other, university.

Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work. I have acknowledged all main sources of help. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Chapter I

Introduction

1.1 Research Background

1.1.1 Competition-cooperation as a strategic choice

Since the 1990s, the information technology revolution, with new network and communication technologies, has facilitated the world economy to step into the new economic era with information, networks and knowledge as main aspects, while the social economic environment has also had great changes. Confronted with rapidly changing and unpredictable consumer demands, the enterprises must achieve competitive advantages through persistent learning, knowledge creation and the improvement of capabilities for technological innovation. This is particularly critical for nanotechnology related companies. However, the technological innovation activity of an enterprise is the process of applying knowledge to change the world. It will certainly generate various complex relationships with many levels of society, to increase uncertainty and complexity. With such a background, there are few enterprises that can understand technological innovation based only on their own limited internal resources. Therefore, for the purpose of effective utilization of internal and external resources of an enterprise, both Research and Development investment (R & D) and technological innovation may have fundamental changes, pushing the enterprise toward openness, cooperation and network and dynamic integration.

There are two dominant theoretical views or models in enterprise development strategy. The industrial structure theory, led by Porter [1], focuses on enterprise industry, or the external environment of the enterprise, and highlights the significance of an enterprise's external environment in achieving a competitive advantage. Porter [1] proposes that the competitive advantage of an enterprise derives from the external environment, namely, the industry where the enterprise is located. The other model is the resource-based view (RBV) developed by Penrose, Barney, Peteraf, et al. [2]. RBV emphasizes an enterprise's internal environment, highlighting the resources and capabilities possessed and controlled by a single enterprise and that can generate a competitive advantage. They suggested that enterprise growth derives from the heterogeneous, inimitable, irreplaceable and high-efficiency special resources internally owned by the enterprise. Though the two theories have been widely accepted, they neglected the important fact that competitive advantage of an enterprise is closely related to its relationship network generally [3]. Therefore, the knowledge-based view [4] holds that all important resources that can bring innovation abilities to the enterprise, whether in an internal enterprise or an external enterprise, shall be incorporated into the enterprise's capacity system for utilization. The core competitiveness of an enterprise will depend on searching for knowledge, the creation of knowledge and continuous technological innovation [5]. Different from the above theories, the knowledge-based view not only highlights special resources possessed by the enterprise itself, but also emphasizes the significance of achieving and accumulating resources from external environment and pays attention to the research of enterprises. In this way, people's analytical perspective of the source of enterprise competitiveness turns to the coordination and unity of internal and external environments from single-dimensional internal or external environments.

As a matter of fact, the competitive advantage of an enterprise relies not only on the resources owned by the enterprise internally, but also the resources and capacities which are imitated by competitors in various social networks [6]. Therefore, other than internal resources possessed by the enterprise itself, the critical resources of an enterprise can be achieved through ties with enterprise external subjects through various means. Varied types of ties among enterprises can actually bring considerable relational rent and competitive advantage to the enterprise [6]. From the perspective of another resources allocation means—network, enterprises not only carry out activities in completely free and competitive market in an "atomic pattern," but also have interactions and interplays between one another. In very early time organizational theory scholars [7] and structural sociologists [8], holding the view of an open system, insist that the most important part of the organizational environment is the social network comprised by its external relations. Such a view highlights the fact that the economic behaviours, the same as any other social behaviour, were not carried out in a closed system, but embedded deeply into various social networks [3]. Of course, we can comprehend such a social network as the assembly comprised of a series of associated social relationship nodes. It can be a friendly relationship, leader-member relationship and pure economic relationship such as cooperative relationship, trading relationship, etc. In sum, such a view can be concluded as the social embeddedness of economic behaviour. The enterprise can obtain the required information, knowledge, funds and other resources through various relationship networks established in the past, and further improve operating efficiency, innovation abilities and competitive capacity on this basis.

Along with the technological improvements, it is becoming more difficult for individual enterprises to survive and develop by only their own virtue. Correlative dependence and mutual cooperation among enterprises are more indispensable. Just as pointed out by American economist Quine, outsourcing was considered to be a disadvantage of an enterprise in the past. However, along with the changes of the competitive environment, outsourcing has become a critical factor for the successful operation of intelligent enterprises. Despite this, various types of cooperation and learning among enterprises do not mean that they do not compete with each other. On the contrary, the cooperation and competition of enterprises are generally interwoven. Similar to enterprises in Silicon Valley, one of the cradles of high and new technology, during the development process of global new technology, these enterprises carry out continuous cooperation and competition, and thus keep their positions as the leaders of world technology. In fact, enterprises in Silicon Valley, while carrying out fierce competition, also carry out communication and cooperation with various official or unofficial organizational forms. They learn and use new knowledge and skills jointly [9]. The cooperation and competition among enterprises is a dynamic balancing process, which enables the enterprises in Silicon Valley to realize the diffusion process of information, knowledge, experience and innovation, and thus increases the returns of cooperation to the largest extent.

Many enterprises know that they cannot carry out production, operation and innovation activities separately in a network competitive environment for an extended period of time. To maintain sustained competitive advantages, the enterprise shall cooperate with different organizations, achieve development opportunities and exchange various types of information, knowledge and other resources. The enterprise established various social relationships to realize the complementation of each other's advantages, shared information and knowledge, risk and benefit. So they can obtain sustainable development. Lin Nan's research has proven that dynamic and complicated co-opetition relationship network, comprised by the enterprise and other enterprises or organizations (colleges and universities, scientific research institutions, suppliers, customers, government, etc.), has become critical for the growth and development of modern enterprises [10]. In addition, to research and see through the enterprise's competitive behaviours more thoroughly, we must put the enterprise into its socio-economic network for exploration and research [11].

In sum, along with the rapid development of economic globalization and science and technology, market competition has become increasingly fierce and it is difficult for an enterprise to achieve a competitive advantage in the international market with fierce competition, only by virtue of its own limited resources and R&D strengths. How to integrate internal and external resources of the enterprise to the greatest extent, strive for competition by cooperation and seek for development by cooperation is one of the main aspects of an enterprise's strategic choice in the 21st century. Since the 1980s, western enterprises, especially transnational corporations under powerful market competitive pressure, have begun to carry out strategic adjustments for competitive relationships among enterprises and have marched toward large-scale co-opetition from single competition in the past [12], namely, adopting co-opetition as a new strategy. It is foreseeable that the new development strategy will impose significant and profound influences on the enterprise's technological innovation activities.

1.1.2 Technological innovation, the impetus for the enterprise's sustainable development

Innovation is the engine for economic development and inexhaustible impetus for prosperity of a country. As the world economy develops in the direction of globalization, in terms of an enterprise or a region and even a country, improving technological innovation abilities has become the only way to cultivate the core competitiveness of an enterprise and improve international competitiveness. However, the constantly changing economic environment has resulted in higher requirements and challenges for the flexibility, adaptability, reactive capacity and innovation speed of an enterprise. In the face of the international market with fierce competition, technological innovation has become the uppermost tool for economic growth, industrial development and improvement of enterprise competitiveness [13]. An enterprise will “either make innovations or die” [14]. It confronts a keen market competition; innovation is becoming the inexhaustible fountain and impetus for the survival and development of an enterprise, increasingly [15]. In terms of nanotechnology companies in China, they shall have an even larger impetus and demand on technological innovation.

Above all, “economic transformation” as advocated by the Chinese government, has provided more preferential measures to encourage Chinese enterprises to increase investment in technological innovation. For example, compared to other enterprises, the income tax of new high-tech enterprises in China is decreased to 15% from 25%. Secondly, for an ordinary enterprise to achieve competitive advantage, it shall adapt to the changing market demands and satisfy diversified individual demands of customers by virtue of rapid technological innovation. Through persistent technological innovation, the enterprise can see through and obtain those resources of potential value and enterprise characteristics more profoundly, to form heterogeneous capacities in the internal enterprise, which cannot be imitated by competitors [16]. Otherwise, the enterprise cannot achieve competitive advantages in market competition.

Thirdly, as an emerging field, nanotechnology is recognized to have extremely large application potential and related enterprises are expected to have less concern about the technological innovation investment risk. In addition, the market potential of nanotechnology products can also facilitate the enterprise to carry out technological innovation. Technological gaps with international competitors are also smaller, compared to that in other industries, for nanotechnology based enterprises in China. Based on the above reasons, we would expect that Chinese companies in the nanotechnology field may be more willing to make resource investment supporting technological innovation.

1.2 The challenges faced by the Chinese nanotechnology enterprises and their responses

Why China as the research context?

Compared to Europe, various economic systems, corresponding legal systems, enterprise systems and operating habits of China have developed differently[17]. The effects of social capital as “the third type of resources allocation means” [18] produced in Europe may be weakened. China’s economy is in the rapid growth stage and it is able to unscramble the relationship of “reciprocal causation” in the analytical method through tracking and observation.

Besides, according to the latest data of the Organization for Economic Cooperation and Development, China has more investment in the scientific research field than Europe, and nanotechnology is one of the significant fields of such scientific research [19].

Many top managers of nanotechnology enterprises in China have technical backgrounds. They usually begin these businesses with funding from the government and have extensive networks with other nanotech firms, meaning social capital is particularly important to the nanotechnology enterprises in China. However, little research has been conducted about the importance of social capital to these enterprises and on which parts of social capital are most helpful to their development. This thesis might represent the very first systematic study of the impact of social capital on nanotechnology related enterprises in China. The results of this thesis are expected to provide some guidance to the operating activities of these enterprises.

1.2.1. Challenges and dilemmas faced by Chinese enterprises

The value and competitive advantage of nanotechnology enterprises derive from continuous knowledge creation, utilization and diffusion within the enterprises. They are organizations with the capacity of learning, creating, transferring, utilizing and managing knowledge, and their tasks are not only to use internal or external existing knowledge to solve the problems encountered in the product development and production process, but also to create fresh knowledge to meet the demands of new products and market more quickly than competitors when facing new problems, which cannot be solved by existing knowledge. Compared to traditional enterprises, nanotechnology companies show characteristics in the following aspects:

I. Continuous knowledge creation and technological innovation are the most critical elements for an enterprise to achieve competitive advantages. Knowledge has taken the place of traditional production factors (such as capital, land, labour force, etc.) to become the uppermost capital and fortune of nanotechnology enterprises. Contrary to the rule of "diminishing marginal returns" of traditional production factors, knowledge has the effect of "increasing marginal returns." Therefore, the enterprises pay significant attention to investment in knowledge development and production, and consider technological innovation as one of the most important means for an enterprise to achieve competitive advantages [20].

II. R&D investment accounts for a relatively large proportion of sales volume. By only focusing on R&D activities an enterprise should have continuous knowledge creation and technological innovation. People generally measure the enterprise's R&D by virtue of the proportion of R&D investment in sales volume. For example, the evaluation of high-tech enterprises in China explicitly stipulates that R&D investment of an enterprise with an annual sales volume of less than RMB 50 million shall account for more than 6% of the enterprise's sales volume. The proportion is even higher for nanotechnology companies [21].

III. As highly-educated employees within an enterprise occupy a considerable proportion of the whole, intellectual capital has become the uppermost economic resource. Intellectual capital includes not only human capital in ordinary meaning, but also resources such as value, knowledge, etc. possessed by the enterprise organization. High-quality talents with innovation consciousness and innovation ability are the subjects for technological innovation of the enterprise. Therefore, to improve the technological innovation ability of an enterprise, the nanotechnology enterprise shall pay significant attention to the selection and cultivation of innovative talents, and highly-educated employees shall also occupy a relatively high proportion of all enterprise employees. Similarly, the evaluation of high-tech enterprises in China also explicitly stipulates that R&D personnel shall account for over 10% of total employees of the enterprise and personnel with a college degree or above shall account for over 30% [21]. Such proportions are often doubled for nanotechnology companies that have made investigations, and personnel with a bachelor's degree or above who often account for over 40% of total staff, generally.

IV. High-tech products occupy a relatively large proportion of the total income of an enterprise. In the fierce competition of the modern market, "mass customisation" has replaced the traditional "Fordism" of mass production [22], and the enterprise's profits do not rely on low-cost advantages brought by scale economy any longer, but lie on high profits obtained through persistent technological innovation and product innovation. Therefore, a high-tech product is critical for nanotechnology enterprises to achieve excess profit and a competitive advantage. The evaluation of hi-tech enterprises in China also explicitly stipulates that the income of hi-tech products shall account for over 60% of the total income of an enterprise [21].

V. The enterprise organizational structure is inclined toward flexibility, networking [23]. To adapt to the changing market and diversified and individualized customer demands, to obtain information about market demands timely and to overcome shortcomings, such as information distortion caused by traditional bureaucratic organization, nanotechnology enterprises attach great importance to establishing good cooperative relationship networks with users, suppliers, the government, universities, competitors and other external organizations [24]. Therefore, the organizational structure of nanotechnology enterprises adopt “mass customisation” and are more and more inclined toward flexibility and networking.

VI. Dynamic learning organization. Along with knowledge globalization and the continuous shortening of the product life cycle, enterprises shall update their proprietary knowledge and create new knowledge persistently. The establishment of a learning organization aims to break through the upper limit of personal ability, create new knowledge, cultivate brand-new, foresighted and wide thinking modes, and strive to realize the organization’s knowledge vision within the enterprise through persistent co-learning. Thus, learning is considered a kind of purposeful pursuance of an enterprise to ceaselessly break through development extremity and retain and improve production capacity, innovation ability and competitive capacity in the sharply changing market environment. Of course, the learning referred to here not only includes learning by doing and learning by using, but also contains learning by searching, learning by R&D, learning by interacting, learning by technology spill over and scientific and

> technological progress among industries, etc. Employees can create more knowledge by learning from and exchanging with each other through various forms of organization. Therefore, nanotechnology enterprises must improve their technological innovation ability by virtue of persistent and continuous knowledge creation, to achieve competitive advantages in the market competition. "When [the] original market begins to decline, new technologies advance rapidly, competitors increase several times over and product life cycle is shortened increasingly, only those enterprises which ceaselessly create new knowledge, spread the new knowledge all over the whole organization and develop new technologies and new products rapidly can succeed" [4] [25].

In China, middle and small-sized enterprises make up the majority. Due to the limitation of scale and strength, there are relatively few resources that can be utilized and developed within the enterprises. The key for an enterprise to reduce the uncertainty of growth and possibility of failure and to achieve sustainable development on this basis is to obtain the various resources urgently needed for the rapid development of the enterprise from an external environment, which is one of the significant factors for evaluating the survival and development capacity of an enterprise in an environment with increasingly fierce competition. Therefore, the analysis and research [26] on the successful technological innovation of domestic and international enterprises discovers that those enterprises with great success in technological innovation always pay significant attention to the effective integration of internal and external resources. In terms of nanotechnology enterprises, they are more willing to integrate internal and external resources by means of improving social capital, so as to improve the enterprise's core competitiveness persistently on such a basis.

A study in China demonstrated that a lack of timely and accurate market information, shortage of R&D investment and increase of the difficulty of obtaining new knowledge have become the principal barriers to the technological innovation of hi-tech enterprises in China [27]. Besides, our case study also shows that enterprises are suffering from the severe challenge of limited resources during the process of improving technological innovation ability. Though opportunities and potential markets are more abundant than ever, the acquisition of information is one of the largest dilemmas [28]. The formation and perfection of a national innovation system and regional innovation system have created a good external environment for the formation of technological innovation systems and an innovation network of the enterprises. It has become a critical path for enterprises to obtain external resources by integrating internal and external environments organically through the improvement of social capital. With ceaseless promotion of corporate social capital, the subject of enterprise technological innovation has evolved into multiple subjects from a unitary subject. Therefore, it is the development need of technological innovation theory to combine social capital theory into the development of technological innovation theory and to research the technological innovation theory from a wider perspective.

1.2.2 . Approach for nanotechnology enterprises to improve technological innovation

Along with the continuous development of economic and knowledge globalization, the limited resources possessed by a single enterprise or company cannot meet the requirement of technological innovation at this point, and the interdisciplinary characteristics of innovation, such as technological cooperation, technological alliance, innovation network, virtual enterprise, etc. appear in succession [29]. Therefore, to improve innovation ability, domestic and international enterprises highlight technological cooperation and exchanges with universities, scientific research institutions, the government, competitors, suppliers, dealers, technological intermediary organizations, financial institutions, customers, etc. [30]. As a matter of fact, the contact between enterprises and external organizations has become an activity of constructive significance. Through wide cooperation and contact with external behavioural agents, an enterprise can not only obtain the funds, technology, talents and information necessary for technological innovation, but also acquire new knowledge (including explicit knowledge and tacit knowledge), since knowledge creation and acquisition and the integration of internal and external resources have become critical factors for an enterprise to improve their technological innovation ability [31]. The relationship between innovation and resources is shown as the following:

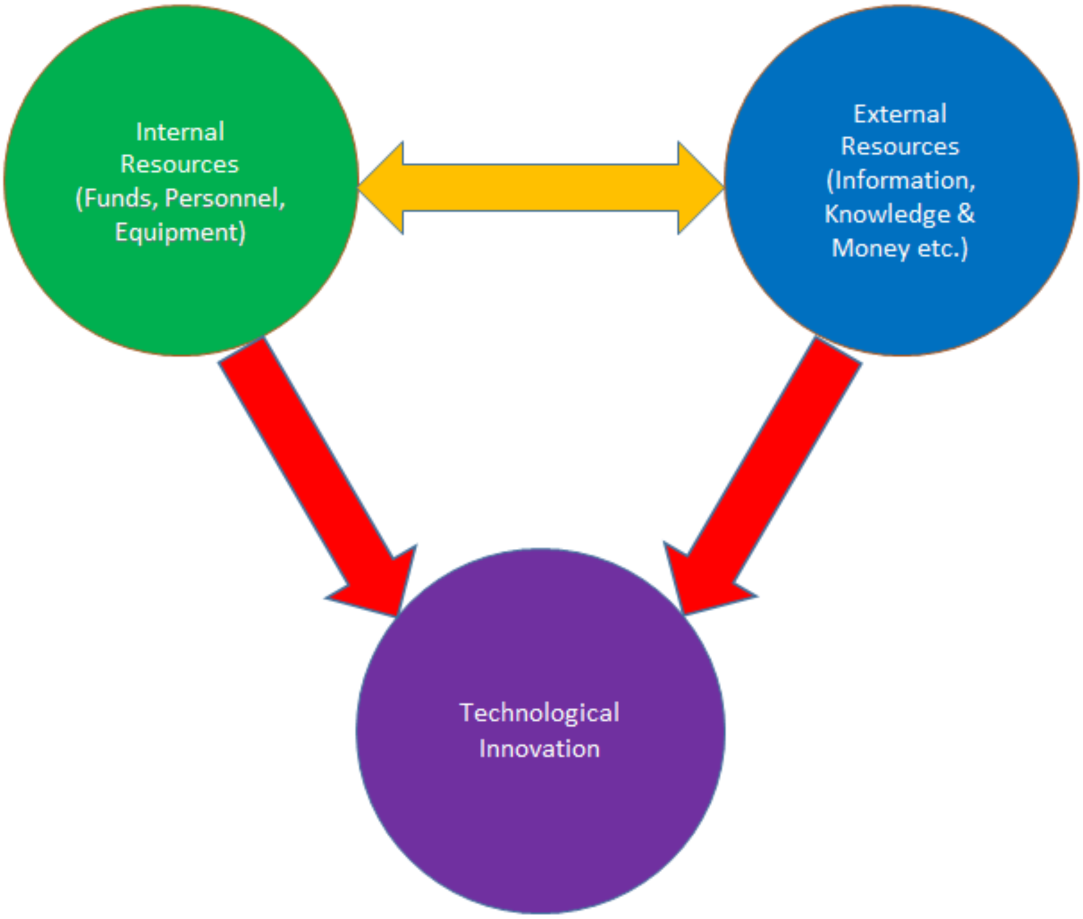

FIGURE 1 THE RELATIONSHIP BETWEEN INNOVATION AND RESOURCES

For nanotechnology enterprises, knowledge is clearly very important. Nanotechnology enterprises must create and develop new knowledge continuously. Since knowledge acquisition and development are a social process [32], enterprises based on technologies should strengthen cooperation and exchange with external organizations to maintain long-term success.

Technological innovation is a continuous evolutionary process, which will not only suffer from the constraints of institutional norms and social conventions, but also be influenced by the intensity and range of interaction between organizations or individuals [33]. This is while the degree for an enterprise to obtain resources such as information and knowledge by establishing external relationship is constrained by social capital embedded in the relationships. Social capital in the relationship can facilitate the enterprise to make full use of various resources of exchange objects. Through close social interaction, enterprises can increase the depth, width and effect of resource exchange [34].

Therefore, any enterprise cannot carry out long-term production, operation and technological innovation activities separately in a network competition environment. To keep the sustained competitive advantages, an enterprise must cooperate with different external organizations and obtain various types of information, knowledge and other resources necessary for the sustainable development of the enterprise. This is done by establishing various social relationships, to realize the strategic relationship of information and knowledge sharing, risk sharing and benefit sharing. Practice has proven that a dynamic and complicated co-opetition relationship network comprised by enterprises and organizations (colleges and universities, scientific research institutions, the government, technological intermediary organizations, financial institutions, etc.) has become critical for the growth and development of modern enterprises [10].

1.3 The purposes and objectives of this research

China has one of the largest number of nanotechnology enterprises. A lot of nanotechnology enterprises, in the process of start up and development, have benefited from Chinese government funding and policy support. At the same time, the top managers or entrepreneurs of these nanotechnology companies, often the owner of the core technology, are closely related to the universities or research institutes in China. This means that social capital plays a particularly important role in the development of nanotechnology enterprises in China. On the other hand, research on social capital in China has been mainly concentrated on the study of traditional manufacturing industries [35][36], because the manufacturing industry is comparatively mature. Therefore, it has more historical performance and data to support related research. However, the nanotechnology industry is a new and emerging industry in China, which makes the related research more difficult and challenging. This research attempts to combine the study of social capital and the nanotechnology industry for the first time at the backdrop of China.

This PhD aims to study the relationship between the various parts of corporate social capital and technological innovation and the corporate performance from the perspective of social capital theory. Since the emphasis of each chapter is different, the data sampling will also be different and can be divided as follows:

1. Analyse the impact of an entrepreneur's political influence on technological innovation performance with the data from part of the listed companies;
2. Analyse the degree of impact of corporate social capital and R&D investment in technological innovation of nanotechnology enterprises in China with the data from a questionnaire survey;

3. Analyse the impact of entrepreneurial social capital on the performance by approach thought with the data from some nanotechnology companies in China.

4. Through interview with six nano-calcium carbonate enterprises, the researcher has further promoted and verified part of the conclusions reached in previous three chapters, and analysed the reasons for deviation simultaneously.

1.4 Structure of the Thesis

The analytical thoughts and part of the conclusions can be summarized in the following schematic diagram as shown in Figure 2.

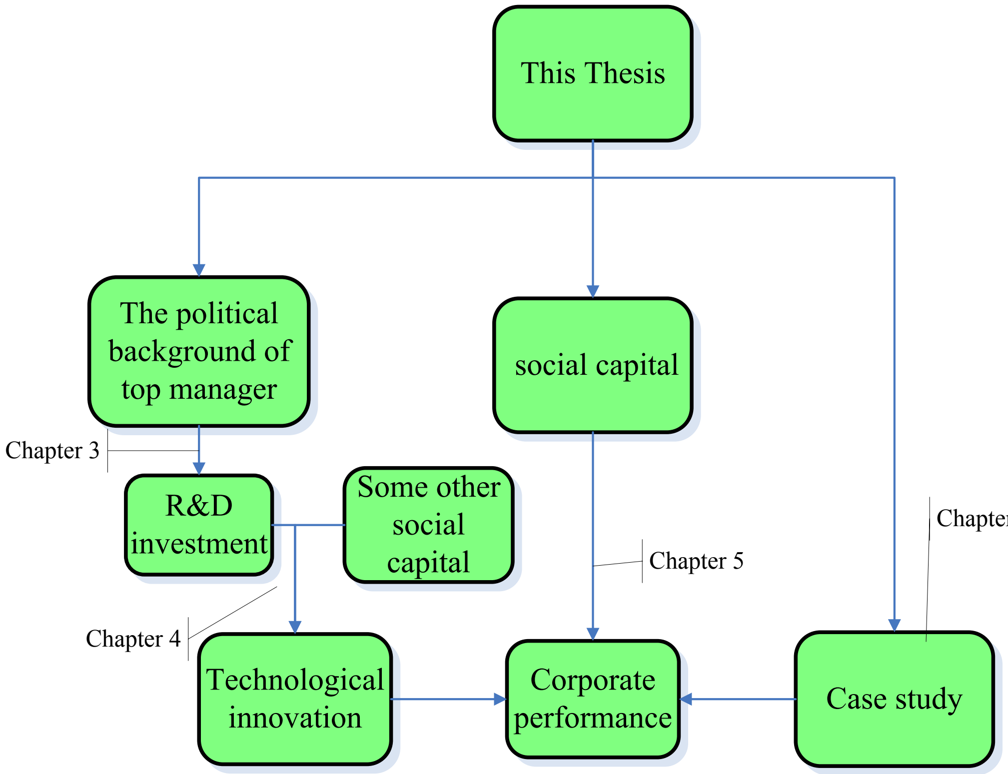

FIGURE 2 THE SCHEMATIC DIAGRAMS OF ANALYTICAL THOUGHTS AND PART OF THE CONCLUSIONS

Chapter II

Capital, Innovation, Performance and the Current Situation of Nanotechnology Enterprises in China

2.1 Social Capital Theory

2.1.1 Social Capital

The concept of social capital was put forward by Bourdieu [37] at the earliest, who stated that social capital refers to the sum of social ties possessed by an individual or group and derives from the establishment, maintenance and resource exchange of social ties. In the subsequent 20 years, the concept of social capital has been generalized continuously. There are different definitions in through different pieces of research, which can be summarized into four categories, namely, I. Network theory, which indicates that social capital is exactly social network from the perspective of form and it is the relationship structure embedded in two or more participants [38][39]; II. Integrity and criterion theory, which believes that social capital refers to the integrity, criterion and values embedded in a social network [40]; III. Resource theory, which considers that social capital refers to various resources that can be obtained or mobilized in and through interpersonal and inter-enterprise relationship networks [41]; IV. Ability theory, which shows that social capital refers to the connection between action subject and the society and the ability of taking in scarce resources through such connection [42]. Adler and Kwon [43] have summarized the most representative definitions of the concept of social capital made by international scholars.

We know from various viewpoints on social capital theory that the ultimate purpose of social capital or relationship operation is to obtain various actual or potential resources. The various definitions for different scholars are listed in Table 1. For example, the network theory of social capital [38] highlights the structural features comprising social capital or social networks, while these structural features are favourable for some actions of the individuals in the structure, such as obtaining resources or support, etc. However, ability theory of social capital pays attention to the ability of related subjects to obtain resources or benefits through a social network. Criterion theory of social capital, generally with an eye on macroscopic social capital (such as a residential community), attaches great importance to how the trust and values within the group influence internal cooperation and mutual support. The above theories are identical with resource theory of social capital, in essence, and the only difference is that the latter focus on the result of the relationship operation—obtaining resources. The relevant scholars and their works and views are shown in the follow following table:

External Versus Internal	Authors	Definitions of Social Capital
External	Baker Belliveau, O'Reilly and Wade Bourdieu and Wacquant	"A resource that actors derive from specific social structures and then use to pursue their interests; it is created by changes in the relationship among actors" (1990: 619). "An individual's personal network and elite institutional affiliations" (1996: 1572). "the sum of the resources, actual or virtual, that

	Boxman, De Graaf, and Flap	accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition" (1992: 119).
	Burt	"The numbers of people who can be expected to provide support and the resources those people have at their disposal" (1991: 52).
	Knok	"Friends, colleagues, and more general contacts through whom you receive opportunities to use your financial and human capital" (1992: 9). "The brokerage opportunities in a network" (1997b: 355).
	Portes	"The process by which social actors create and mobilize their network connections within and between organizations to gain access to other social actors' resources" (1999: 18).
		"The ability of actors to secure benefits by virtue of membership in social networks or other social structures" (1998: 6).
Internal	Brehm and Rahn Coleman	"The web of cooperative relationships between citizens that facilitate resolution of collective action problems" (1997: 999).

	Fukuyama	"Social capital is defined by its function. It is not a single entity, but a variety of different entities having two characteristics in common: They all consist of some aspect of social structure, and they facilitate certain actions of individuals who are within the structure" (1990: 302)
	Inglehart	"The ability of people to work together for common purposes in groups and organizations" (1995: 10). "Social capital can be defined simply as the existence of a certain set of informal values or norms shared among members of a group that permit cooperation among them" (1997).
	Portes and Sensenbrenner	"a culture of trust and tolerance, in which extensive networks of voluntary associations emerge" (1997: 188)
	Putnam	"those expectations for action within a collectivity that affect the economic goals and goal- seeking behaviour of its members, even if these expectations are not oriented toward the economic sphere" (1993: 1323).
	Thomas	"Features of social organization such as networks, norms, and social trust that facilitate coordination

		and cooperation for mutual benefit" (1995: 67). "Those voluntary means and processes developed within civil society which promote development for the collective whole" (1996: 11).
Both	Loury Nahapiet and Ghoshal Pennar Schiff Woolcock	"naturally occurring social relationships among persons which promote or assist the acquisition of skills and traits valued in the marketplace... an asset which may be as significant as financial bequests in accounting for the maintenance of inequality in our society" (1992: 100). "The sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network" (1998: 243). "The web of social relationships that influences individual behaviour and thereby affects economic growth" (1997: 154). "The set of elements of the social structure that

		affects relations among people and are inputs or arguments of the production and/or utility function" (1992: 160). "The information, trust, and norms of reciprocity inhering in one's social networks" (1998: 153).

TABLE 1 DEFINITIONS OF SOCIAL CAPITAL [43]

Lin Nan [41], one of the representatives of resource theory of social capital, has put forward the theory of social resources first on the basis of developing and amending Granovetter's "weak tie strength hypothesis." In his opinion [41], the so-called resources are things which are considered to be valuable by the group through certain procedures in a society or group and the occupation of these things will increase the occupant's survival opportunity. He divides the resources into personal resources and social resources according to their attributes. Personal resources refer to resources such as wealth, appliances, gift, physique, knowledge, status, etc. which are possessed by an individual and can be allocated by the individual, while social resources refer to those which are embedded in an individual's social network, are not occupied by individuals directly, but are obtained through direct or indirect social relationships between individuals. Possession of such resources enables the individuals to meet personal survival and development demands in a better way. Lin Nan [41] has proposed social capital theory on the basis of the theory of social resources. In 2005, Lin Nan provided a definition of social capital in the book of *Social Capital—Theory of Social Structure and Action*, namely, that social capital is "(a kind of resources) invested in social relationships and expected to obtain returns," "a kind of resources inlaid in social structure and to be obtained or allocated through purposeful actions."

Therefore, one can summarize that the social capital operation aims at mobilizing or obtaining the resources or abilities embedded in social network structure, and actors can achieve social capital or make it flow towards the direction favourable for themselves through purposeful actions.

However, resources mobilized by instrumental action depend on the action capability of action subjects and characteristics of resources embedded in the network structure. Lin Nan [41] proposed three hypotheses of social resources, namely, (1) status strength hypothesis—the higher an individual's social status is, the more opportunities he/she will have to take in social resources; (2) weak tie strength hypothesis—the more heterogeneous an individual's social network is, the higher probability he/she will have to take in social resources through weak ties; (3) social resources effect hypothesis—the more abundant an individual's social resources are, the more ideal the result of instrumental action is.

2.1.2 Corporate Social Capital

It's well known that the first person who went beyond the individual level to research social capital was Coleman [38]. He felt that social capital is comprised of certain aspects of social structure, which are favourable for actors to realize specific targets—no matter whether the actor is an individual or a legal person. Organizational social capital is a certain peculiarity of the structure possessed by the organization, which can bring specific actions or resources and, finally, overall benefits to the organization as a group. Burt [44] believes that social capital is the opportunity and structural whole of utilized financial capital and human capital obtained through friends, colleagues and a kind of more generalized contract. In his opinion, the logic of social capital will be inevitably expanded to the enterprise level, "relationships within the enterprise and between enterprises are social capital." Further, Burt [45] has put forward the contingency values of social capital and considers that the social capital value of managers has a negative correlation with the number of peers. Those who propose the concept of corporate social capital truly, and carry out systematic analysis on it, are Leenders and Gabbay [46]. They define corporate social capital as the "tangible or intangible resources which are obtained by enterprises through social relationships and can facilitate the realization of its targets." Since this, many scholars in management have defined corporate social capital and organizational social capital by reference to the concept of social capital. They believe that an enterprise is not an isolated action individual, but a node on an enterprise network with various ties with each aspect of the economic field. The economic activity of an enterprise is carried out by being embedded in various social relationships, since it plays an important role in obtaining structural information and control advantages [44] [45], creating intellectual capital and organizational competitive advantage [47], improving corporate performance [48], etc. Such a category of social capital, emphasizing organizational level and the level between organizations and mutual trust and cooperation, has drawn the attention of more and more economists and management scholars. Among these persons, Nahapiet & Ghoshal [47] and Tsai and Ghoshal [49] are convinced that social capital is the sum of actual and potential resources, which can be obtained by people from relationships with other persons; they divide corporate social capital into three dimensions, namely, structural embedded social capital, relational embedded social capital and cognitive embedded social capital.

2.1.3 Entrepreneurial Social Capital

Most of the research related to corporate social capital involve entrepreneurial social capital or social networks [50], but only a few have mentioned the concept of entrepreneurial social capital and carried out profound research. Westlund and Bolton [51] believe that entrepreneurial social capital is associated with exploring a new path, establishing a new enterprise and solving social problems. Most of the literature does not refer to the concept of entrepreneurial social capital directly, but uses entrepreneurial social networks. In their opinion, entrepreneurial social networks are the relationship networks formed by a series of nodes connected together by some special types of social relationships, and different aspects of the networks lie in that the are comprised of different types of social relationships. Entrepreneurial social capital, embedded in local cultural and tradition [50], is the product of the cooperation of various institutions, networks and business partners [52], and also the support network of entrepreneurs with an eye on obtaining resources and benefits fundamentally.

Scholars in China have carried out exploratory research on the concept of entrepreneurial social capital. Li [53] believes that entrepreneurial social capital refers to the social relationships owned by the entrepreneur. Chen and Zhou [54] consider that the so-called entrepreneurial social capital is the entrepreneur’s social relationships established on enterprise group paradigms under the guidance of reputation and specification, and is the entrepreneur’s capacity to mobilize internal and external resources. Hui [55] proposes that entrepreneurial social capital is a kind of social capital owned by an individual, and mainly means the sum of the network system, social prestige and trust with entrepreneur individual dependence as the main feature and entrepreneur individual as the central node. Yang, et al. [56] are convinced that entrepreneurial social capital refers to the entrepreneur’s ability to obtain required resources by utilizing their social network. Yu [57] thinks that the so-called entrepreneurial social capital is the assembly of actual or potential resources established on the basis of trust, specification and network and embedded in existing stable social networks and the structure of the entrepreneur. He, et al. [58] put forward that entrepreneurial social capital is a kind of intangible resource of the entrepreneur and such resources are favourable for an enterprise to obtain material, information and emotional assistance, so as to achieve the enterprise's objectives.

In related empirical research, scholars have divided entrepreneurial social capital into different types according to their own definitions. For example, Batjargal and Liu [50] and Li and Zhang [59] have carried out research on the impact of entrepreneurs' friendship and political relationship networks on corporate performance respectively, while Park and Luo [60] have divided the relational ties of enterprise managers into the relationship with other enterprise managers and the relationship with governmental officials. In addition, Collins and Clark [61] divide the social capital of top corporate managers into strong ties and weak ties. Contact objects of strong ties mainly include the personnel in sales departments, R&D departments, production departments and other internal departments of the enterprise, while contact objects of weak ties contain independent directors, suppliers, customer groups, financial institutions, competitors, cooperation alliances, governmental organizations, trade associations and others.

Chinese scholars such as Li [62] think that there are 3 types of social networks that are helpful for the success of entrepreneurs, namely, social network pointing to a cadre group in a planned economy department, the internal network of an enterprise and social relationships of the entrepreneur. Bian and Qiu [48] divide corporate social capital into vertical ties, horizontal ties and social ties of an enterprise. Since they take legal representative as the research object in the final measurement, their research object is also entrepreneurial social capital. Zhou [54] believes that entrepreneurial social networks can be divided into the market network comprised by the entrepreneur and customers, suppliers, retailers, etc.; inner organizational network comprised by entrepreneurs and shareholders, employees, partners, etc.; environmental network comprised by entrepreneurs and the government, banks and other organizations; as well as the entrepreneur's blood resource network, land resource network, learning resource network, etc. However, He, et al. [58] divide the social network of corporate top managers into the social network between enterprise leaders and customers, dealers, suppliers, middle-level managers and employees, and the social network between corporate top managers and the government and industrial associations.

2.2 Social Capital and Technological Innovation

2.2.1 Impact of Social Capital on Technological Innovation

The effects of social capital are varied, and include solidarity, information, and social influence benefits [63][64]:

Solidarity benefit: In Bourdieu's [65][37] view, social capital functions to maintain inequality through a network of mutual acquaintances and recognition. Network members enjoy benefits that non-members do not. Thus, social capital is like a "club good," serving to maintain the privileges and status of the club members. Benefits are given by one member to another to increase cohesion. This kind of benefit, known as solidarity benefit [66][67], confers exclusive opportunities, such as convenient access to resources and business contracts [68][47], regardless of the virtues or capabilities of the recipient.

Information benefit for organizational innovativeness: Unlike Bourdieu [65][37], Coleman [38] focuses on the benefit of social capital for the development of intellectual capital. At the organizational level, social capital enhances organizational innovativeness by facilitating the flow of information [38][47][67]. Thus organizational innovativeness mediates the link between social capital and business performance. Compared with solidarity benefit, the information benefit of social capital creates less social inequality and produces fewer negative effects on the wider society. Social influence brings benefits to organizational innovativeness.

Finally, effective implementation of innovations may need critical productive resources or cooperation from business partners**.** Social capital provides a firm with critical productive resources or cooperation so that it can transform its innovative ideas into profit [42][47][69][67].

2.2.2 Impact of Individual or Entrepreneurial Social Capital on Innovation

Impact of Individual Social Capital on Innovation

The research of Pirola-Merlo and Mann [70] shows that individuals independently working on the project can produce innovation behaviours and the interaction of members of a project team can also trigger innovation behaviours. For example, sharing, expanding and criticizing/filtering various ideas among members. Such interaction of members can encourage individuals to produce innovative ideas. Shalley [71] applies laboratory research methods to compare the difference between individuals in independently working states and in cooperative states in the aspect of individual innovation. It was found that exchanges and interactions of team members can improve the innovation level of individuals. In certain working fields, social interaction with others can improve an individual's understanding of such a field and facilitate the production of feasible and unique methods [72]. Communicating and interacting with several different persons can promote the innovation ability of individuals [73].

The increase of interaction with others can enhance mutual understanding, trust and self-identity; but on the other hand, continuously strong self-identity and trust will restrict the absorption of new information and different ideas [47]. Expansion of the number of persons in interaction is favourable for individuals to receive more information and knowledge, and can facilitate the exchange and production of new ideas. However, the development and maintenance of the interaction with others needs great investment in time and energy. Ann and Cannella [74] used 173 scientists in the biomedical field as research samples, and analysed the relationship between the individual's relationship quantity and density, as well as knowledge creation, and verified that they have an inverted U shape relationship.

Impact of Entrepreneurial Social Capital on Innovation

Johannisson [75] investigated different regions in the same period in Sweden and discovered that active social behaviours of the entrepreneur are helpful for business investment. Lipparini [76] has put forward a report that shows entrepreneurs play an important role in the integration and management of external resources and innovative contacts. The research of Mosakowski [77] indicates that an entrepreneur's network resources and corporate competitiveness have a positive correlation. Thompson [78], by virtue of research, demonstrates that an entrepreneur's success relies on his occupation of a valuable strategic position in the market. With the resources, information and priority obtained due to power relationships and stakeholder transactions, an enterprise has realized the differentiation of products and services, so as to possess a competitive advantage. Offstein [79], through research, believes that a company's social capital, especially the social capital of top managers, improves the competitive consciousness, motive and capacity of the company, which is favourable for taking plenty of vigorous competitive behaviours. Jenssen and Koenig [80] have carried out investigations on 100 entrepreneurs in Norway and discovered that strong ties in the entrepreneur's personal network are an important channel for information acquisition, while weak ties are a significant financing source. Julien and Andriambeloson [81] reached the conclusion that the relationship network has important influences on an enterprise's innovation performance through the enterprise's absorbing capacity by virtue of investigations on 147 middle and small-sized enterprises. Jack by virtue of profound investigation of 14 entrepreneurs in Scotland, discovered that entrepreneurs with strong ties can not only obtain plenty of information and knowledge, but also maintain, expand and improve the reputation of the enterprises and entrepreneurs. Watson studied the positive impact of an entrepreneur's formal and informal networks on the enterprise's survival, development and expansion by use of a vertical database.

In China, Zhang [82] discussed the relationship between the embeddedness of social networks and innovation of entrepreneurs from the perspective of entrepreneur's coordination of function realization during the innovation process. She pointed out that the embeddedness of the social network is an important condition for entrepreneurs to engage in innovation activities. Bian [83], through research on entrepreneurs in Pearl River Delta, shows that the three resources are necessary for establishing an enterprise, namely, commercial information, venture capital and the first order, deriving from social network of the entrepreneur. Wei [84] is convinced that in different development stages of an enterprise, the types of entrepreneur networks are also different, and the middle and small-sized enterprises shall actively complete the evolution of the entrepreneur's network from the personal network to the social network during the transition from the initial stage to growth stage. Liu [85] has researched and summarized the relationship between the social network of the entrepreneur and venture success. Zeng [35] believes that entrepreneurs with stronger social enthusiasm have stronger innovation abilities than introverted-type entrepreneurs. Zhou [86] considers that the entrepreneur's network is formed during the process of the entrepreneur's utilization of innovation ability of other enterprises for cooperative innovation, overcoming various problems such as insufficient voluntary supply of the enterprise's innovation activities caused by the imperfect intellectual property market, overuse of innovation activity achievements, etc. to a certain extent. Guo [87] has studied the impact of the entrepreneur's trust level on the growth of high-tech enterprises. He [88] divides the entrepreneur's social relationships into 3 aspects, namely, government relationship, corporate relationship and employee relationship, and has studied the relation between entrepreneur's social relationships and the growth of high-tech enterprises.

2.2.3 Impact of Corporate Social Capital on Innovation

From the perspective of the relationship between social capital within the enterprise and the innovation, Tsai and Ghoshal [49], by virtue of the data from large-scale transnational electronics enterprises, have proposed the manifestation pattern of structural dimension—manifestation pattern of social interaction and relational dimension—namely, the trust has a significant influence on departmental resource exchange, which finally influences the product innovation.

Some scholars think that social capital will influence the knowledge and resources obtained by the enterprise, which will facilitate technological innovation. Among these scholars, Yli-Renko [89] through empirical research on 80 high-tech enterprises in England, verified that the quantity of external knowledge obtained by a new enterprise from key customers depends on the 3 aspects in social capital relation, namely, social communication level among enterprises, relational quality and the level of creating network contacts through the relationship. Knowledge acquisition can facilitate the enterprise to achieve a competitive advantage through the development of new products, technological uniqueness and sales cost efficiency. Greve and Salaff [90] by analysing the action mechanism of corporate social capital in the complicated innovation process, have proposed that corporate social capital plays an extremely important role in the production of new thoughts and the integration of existing knowledge, especially effective integration of the internal and external resources of the enterprise. It is significant to obtain resources necessary for the complicated innovation through the various social networks of the enterprise as social capital is favourable for the enterprise to carry out technological innovation in a better way. In addition, Chaminade and Roberts have analysed the 6^{th} generation of innovation model, and connected the stimulus in the model with corporate social capital. They have demonstrated that social capital can promote innovation by the case of an enterprise in Norway transforming from a traditional enterprise to a knowledge-based enterprise.

As to the impacts of the increase of social capital on innovation, Landry, et al. [91], by virtue of investigation on 440 manufacturing enterprises in different industries in the southwest region of Montreal, Canada, have reached the following conclusions: marginal increases of social capital, especially participating assets and relational assets, have improved the possibility of enterprise innovation to a large extent; social capital has also influenced the breakthrough degree of enterprise innovation obviously, and network assets have the most remarkable function.

Some scholars in China have divided social capital into horizontal, vertical and social relationship capital, and studied the relationship between the 3 types of social capital and technological innovation performance. Chen and Li [92] have handled the questionnaire investigation of over 50 enterprises and carried out regression analysis on the data collected. Their studies have reached the following conclusions: horizontal social capital of an enterprise has a relatively strong correlation with technological innovation; vertical social capital has a positive correlation with the enterprise's technological innovation performance; perfecting the relationship with external entities can improve corporate social capital and enhance the enterprise's technological innovation strength and performance. Zhang [93], by virtue of empirical research, is convinced that corporate social capital can influence the acquisition of information, knowledge and funds of the enterprise, so as to influence the technological innovation performance of the enterprise.

In addition, some other scholars have carried out research on the conceptual model of social capital influencing technological innovation performance. Wei [94], from the perspective of the characteristic dimension of social capital, has put forward the conceptual model of corporate social capital based on absorbing capacity and technological innovation performance. He believed that corporate social capital realizes positive influences on absorbing capacity and technological innovation performance, through the functions of structural dimension and relational dimension on cognitive dimension. Dai and Xie [95] have proposed the conceptual model of social capital influencing technological innovation mechanisms. They reached the following conclusion through the data of 110 questionnaires and the research of the structural equation model. In terms of knowledge stock, product innovation, process innovation and corporate performance, overall effects of various exogenous variables in the order from the highest to the lowest shall be social capital within the enterprise, horizontal social capital of the enterprise, research and development, social capital on supply chain, and social capital between the enterprise and the government and universities.

Kuang and Peng [96] comprehend social capital as various ties between the enterprise and external environment and have reached the following conclusions by analysing their investigation data of 125 middle and small-sized enterprises in Jiangxi Province. Social capital, such as internal ties, vertical ties and social ties of the enterprise, has a significant positive influence on the enterprise's technological innovation performance. In addition, the perfection degree and profitability of the enterprise's incentive system also have a remarkably positive influence on the enterprise's technological innovation performance.

2.2.4 Various Types of Social Capital

Effects of strong and weak ties

There has been an on-going debate on strong and weak ties. Granovetter [97] identified the strength of ties as "the combination of mutual obligations, intimacy, emotional intensity and the amount of time." The weak ties among interpersonal relationships facilitate the reaching of particular aims by accessing more social capital. Strong ties are those involving frequent interaction and intense emotional relationships; whereas weak ties are conceptualized as the ties involving less interaction and fewer emotional relationships. The basic argument by Granovetter suggests that a weaker tie is more likely to allow you to access more relevant and current information than a stronger tie, because a weak tie is more likely to form a bridge between different social circles [97]. This bridge functions as a unique direct tie between two networks, which do not already possess a tie [44]. According to weak-tie theory, strong ties are less likely to act as a bridge, because strong ties make the actors familiar with particular qualifications, especially with the knowledge being transferred [97].

The benefits of each tie depend on the type of knowledge, process of knowledge creation and the strategy of knowledge creation [99]. Knowledge can be considered as two different types. Explicit knowledge refers to the type of knowledge that is codified in formal and systemic language. Explicit knowledge can be stored, retrieved and transmitted relatively easier through various mechanisms [98]. On the other hand, tacit knowledge refers to the type of knowledge that cannot be codified in formal or systemic language. Tacit knowledge is of paramount importance for individuals to understand the world and accomplish their duties [99]. Unlike explicit knowledge, tacit knowledge is embedded and processed within the minds of the individuals, and it can be acquired through practical and relevant experiences. These qualities of tacit knowledge hinder the communication of tacit knowledge to other relevant parties, slow down the knowledge sharing process and increase the communication costs [101].

On the other hand, it is more convenient to acquire and share explicit knowledge. Formally coded knowledge can be acquired and then protected by patents and other intellectual property rights [101].

Weak ties are not proper for transferring tacit knowledge, since interaction is infrequent and therefore not allowing the interpretation and modification of knowledge; moreover tacitness and complexity create ambiguity, which has a negative effect on knowledge transfer [102]. Transfer of tacit knowledge may require the development of a shared code in a long-term, strong relationship and working closely [103]. According to March, strategies linked to knowledge creation aim to explore new opportunities or exploit existing capacities. Complex search, innovation, variation, risk-taking, relaxed control and loose discipline are the concepts that characterize exploration. In exploratory strategy, the focus is gathering new information on many different alternatives. The emphasis is on identifying viable alternatives, rather than fully understanding how to develop any one innovation. In the process of searching for knowledge, weak ties are more appropriate for the acquisition of new knowledge [104]. The creation and transfer of knowledge require stronger ties. Discussing, sharing, brainstorming and engaging in joint discovery and experiences require strong ties [105]. Strong ties are needed for the reformulation and validation of new knowledge that requires trust and willingness [106].

Impact of different dimensions of social capital

According to Nahapiet and Ghoshal [47], there are three different (organizational) dimensions of social capital, known as structural, relational and cognitive dimensions, to explain social capital. They also analysed how each of these dimensions contributes to the sharing of knowledge and the creation of intellectual capital.

Structural dimension of social capital refers to social interaction. Tsai and Ghoshal [49] suggest that the position of an actor's contacts in a social setting of interactions may provide advantages for the actor. Actors can access valuable resources through the positions they possess in a social structure.

Relational dimension of social capital refers to the nature of the personal relationship between the people as manifested in terms of the strength of the ties. Trust, norms, emotional intensity and intimacy are among the major factors that reflect the strength of the tie [107].

Cognitive dimension of social capital refers to shared codes, narratives and language [47]. Also, Mairand Marti [108] suggests that the cognitive dimension refers to how normative and mimetic forces shape behaviours, and their implications.

Structural social capital, as one of the three dimensions of social capital, considers the social interactions between individuals and groups. Networks themselves are the basis of this dimension [47]. Networks allow organizations to know who possesses what sort of knowledge that, in return, makes that knowledge more visible for the members of the organization [109]. Qualities of the networks (network centrality, strength of the ties, structural holes and etc.), specifically implied by the social network theories have various effects on accessing and sharing knowledge. For example, the individuals and groups who are positioned at the centre of the network receive knowledge in a faster and more intensive way [49], and their strong ties allow individuals to share tacit knowledge.

Another dimension of social capital is referred to as relational social capital. Relational social capital reflects the trust between the individuals and groups. This type of trust is based on benevolence and competence that, in return, allows the members of the organization to access clear and reliable knowledge in a less costly way [110]. Competence-based trust has a major impact on knowledge transfers involving highly tacit knowledge. When the knowledge required is more experiential, difficult to verify or tacit in nature, the knowledge seeker requires a relatively larger amount of competence-based trust in the provider of that knowledge [110].

The third dimension of the social capital is called cognitive social capital. This type of social capital consists of several aspects including common language, common codes and vision. Cognitive social capital aims to transfer knowledge from the individual level to group level within the organization [111]. The relationship between social capital and innovation becomes crystal clear when we consider that the innovation performance of an organization heavily depends on some conditions, such as the interaction between the members of the organization, norms that facilitate the commitment to organizational vision and mission, and mutual trust within the organization.

Impact of social networks with different types of actors

Social networks with suppliers and customer: The enterprises of good customer and supplier relationships can obtain the required information from customers in a timely manner, learn about the problems to be solved and discover the possibility of innovation. For example, an enterprise can learn about the use of products from consumers, consumer's evaluations and suggestions for the products, and obtain certain product development information; can learn about the product's sales and demand information from distributors and their views on the enterprise's R&D and design. These are all favourable for the enterprise, allowing them to be aware of the technological innovation direction in the future. In addition, the enterprise can also learn about the supply, price and other information of raw materials as such information is the precondition for the enterprise to carry out technological innovation. Von Hippel [112], after plenty of investigation and research on technological innovation of American enterprises, has revealed the important role of leading users as the information source of innovation thinking. Particularly, product innovation carried out by users independently has provided a great amount of valuable innovation information for the manufacturers. For example, they can provide the enterprise with concept, design and other information on new products that may be extremely important for innovation. Therefore, through communication and cooperation with leading users, an enterprise can seize the information resources in the aspects such as changes in customer demand in a timely manner in the environment of dynamic change, adjust its R&D strategy, and exploit various products or services meeting customer demand, so as to achieve competitive advantage in increasingly fierce market competition. Yli-Renk, et al. [113] through empirical research in 180 high-tech enterprises in England, has verified that the quantity of external knowledge obtained by a new enterprise from key customers depends on corporate social capital. The research shows that social capital between a technology-based enterprise and its major customers can facilitate the knowledge acquisition of the enterprise and enhance its innovation ability, so that the enterprise can achieve a competitive advantage. What's more, an enterprise can also obtain certain funds through financing from customers and suppliers.

Network relationships with competitors and other enterprises can also enable the enterprise to obtain information about market demand and technological development from competitors [114], and to seize the R&D trend of competitors simultaneously, such as technological development trends, technological R&D knowledge, market development knowledge, innovation management knowledge, etc. Horizontal relationship capital is favourable for the acquisition of these innovation resources and can promote enterprise innovation. Therefore, enterprises shall carry out the cultivation of the horizontal relationship capital of corporate social capital positively.

Relationships with universities, scientific research institutions, the government, financial institutions and other external organizations can help the enterprise achieve innovation resources such as information, knowledge, funds, etc. For example, the enterprise can obtain funds through good relationships with governmental departments, financial institutions and venture capital institutions. For instance, Uzzi [115] has carried out a research on the relationship between enterprises and banks. He concluded that social capital existing in an enterprise-bank relationship can reduce the financing cost of the enterprise, which can obtain low-cost innovation funds; enterprises can obtain government policy information such as technological policy information, industrial policy information, regional development policy information, ecological environment policy information, financing policy information, etc. from governmental departments; enterprises can achieve such information as market development knowledge, technological R&D knowledge and technological development trends from scientific research institutions; enterprises can obtain innovation management knowledge from venture institutions. Thus, enterprises with social relationship capital can achieve innovation resources such as information, knowledge, funds, etc.

2.3 Social Capital and Entrepreneurial Performance

2.3.1 Social Capital and Performance

In the last 30 years scholars have achieved plenty of research results in terms of the functions of social capital or social networks in enterprise operations. Most of the research has affirmed the positive effect of social capital, and some of these scholars have discovered that interpersonal relationship ties, relationship networks and strategic alliances can provide the enterprise with better opportunities for resource configuration, increase an enterprise's survival probability, and improve the corporate performance [115]. Besides, other research shows that enterprises or businesses occupying a favourable position in a relationship network can obtain new knowledge about the development of other enterprises, so as to improve the knowledge innovation and competitiveness of such enterprises [47][49]. In addition, some of these studies have indicated the negative effect of social capital. Uzzi [115] considers that the positive effect will be transformed after network embeddedness exceeds the limit point. Other scholars discover that the exchange of repeated relationships with relational partners will decrease corporate performance. On average, enterprises of high diversity in network relationships will have lower corporate performance [116].

The function of "relationship" in the transition economy of China has drawn the attention of numerous scholars. Some scholars believe that relationship is one of the most important influence factors for transnational corporations to succeed in China, and is also the direction for business practices of Western countries in the new century. Related empirical research shows that enterprises good at utilizing relationships can obtain more sales revenue and better development and business performance [60]. However, private enterprises utilize the relationships more. Some scholars also think that a relationship cannot be regarded as competitive advantage. It is difficult to keep and share the relationships, and the status of relationships in the transition economy of China is declining.

In the research related to the relationship between corporate social capital and corporate performance, quite a few have involved entrepreneurial social capital or social networks. For example, Burt, et al. [45] discovered that successful top managers in France and the United States are all inclined to occupy a favourable position in abundant social networks in the position of the structural hole. Batjargal and Liu [50], on the basis of empirical analysis on 158 venture investment decision-making projects in China, discovered that entrepreneurial social capital (such as friend relationships) can play the role of information connection and reduction of social risk and uncertainty, and play an important role in the process of obtaining venture investment of an enterprise. Park and Luo [60], based on the data from a questionnaire survey of Chinese enterprises, studied the relation between relationships or interpersonal ties and corporate performance, and finally discovered that interpersonal relationship ties between enterprise managers and top managers of other enterprises and governmental departments is favourable for improving corporate performance. However, it is limited to sales growth and has a limited influence on corporate profit growth. In addition, the correlation between them will be regulated by several variables, such as corporate ownership, business department, enterprise scale, growth rate of the industry, etc. Li and Zhang discovered that in terms of high-tech enterprises newly established in China, a manager’s political network and human capital have a significant positive correlation with corporate performance, and such a correlation will be regulated by corporate ownership and the market competition degree of the industry. Acquaah [117], through repeating the research of Peng and Luo by the sampling enterprises in Ghana, discovered that relationship networks or social relationships between enterprise managers and top managers of other enterprises, governmental departments and association leaders have a significant positive correlation with corporate performance, while enterprise competition strategy (low-cost leader or differentiation strategy) will regulate such correlation between social relationship networks and corporate performance.

2.3.2 Social Capital and Venture Success

Whether entrepreneurial social capital can facilitate the venture success

As to whether the entrepreneurial network can promote the development and success of a new cause, researchers have proposed the "network success hypothesis," which says they consider the entrepreneurial network to have a positive relationship with venture success. Such a hypothesis has attracted numerous scholars to carry out verification from an empirical perspective, but the verification result is still in dispute.

Aldrich, et al. [118] carried out first-hand research observing the impact of the entrepreneur's network on venture success. Explanatory variables employed in their studies include the scale, density and ease of approaching the network resources of entrepreneur's personal network. The conclusion has been reached as follows: close-degree of network resources is important and has a positive correlation with the decision of starting a new business. For the enterprises that have been established for less than 3 years, the network density has a negative correlation with the profits of a new enterprise, while the approaching degree of network resources has a positive correlation with the profits. Hansen [119] measured the entrepreneur's netting activities from 3 aspects, namely, how many members in the entrepreneurial team come from the entrepreneur's personal network, the scale of entrepreneurial network, and the frequency of network communication. He discovers that entrepreneurial team members from the entrepreneur's personal network have a significant positional relationship with venture success. However, different from previous research, in his opinion, the density of entrepreneurial network has a positive correlation with venture success. Though there is a dispute, Aldrich, et al. and Hansen actually take the same position that an entrepreneurial network can support venture success, and they only have different views on what networks are more favourable for promoting the venture success. Ostgaard and Birley [120] employ 4 variables to describe the characteristics of entrepreneurial network in their research, namely, network scale, the time for maintaining and expanding the network, network density and the intensity of network utilization, using the growth rate of sales, employees and profits in 3 years as the indexes to measure the venture success. They concluded both the scale of entrepreneurial network and the time for maintaining and expanding the network have significant positive correlation with the growth rate of employees (but it is irrelevant to the other two variables).

Liao and Harold [121], through contrast a experiment and research, have reached the conclusion that the total social capital amount between entrepreneurs and non-entrepreneurs does not have a significant difference, but the tie pattern of different dimensions of social capital is different. They also discover that relational dimension degree of science and technology type entrepreneurs is higher than that of non-SandT type entrepreneurs. The research of Offstein [79] shows that corporate social capital, especially the social capital of top managers, has improved the company's competitive consciousness, motive and ability, and it is favourable for taking plenty of complicated and vigorous competitive behaviours. Lin [41] is convinced that entrepreneurship is a complex social phenomenon. He divides the factors influencing the success of entrepreneurs into 3 categories, namely, entrepreneur's ability, entrepreneurial social capital and entrepreneur's strategic behaviour. The research result indicates that successful entrepreneurs are those persons who can adjust their strategies according to their social capital and ability.

While empirical test results support the "network success hypothesis," some other researchers have obtained frustrating results. Cooper, et al. carried out a tracking study to grasp entrepreneur's netting activities and information sources, and investigate if these activities have any relationship with the survival of enterprises 3 years later. They did not discover any significant correlation between the two variables. Aldrich and Reese [122] have investigated the characteristics of the entrepreneurial network by virtue of network scale and the time used for developing and maintaining commercial contacts by analysing entrepreneurs from North Carolina, in the United States. Their research shows that enterprises that had survived 2 years (the maintenance of the same enterprise with the same proprietor) and income increases do not have any correlation with the variable of netting.

How can entrepreneurial social capital promote venture success?

Though there are still many disputes on the issue of whether entrepreneurial networks can promote venture success, some researchers believe that the "network success hypothesis" is well-grounded and will try to find explanations for such a phenomenon. Entrepreneurs can only extract value from their perception, resources and skill range. To research a successful entrepreneurial process, it is required to inspect how opportunities are perceived and evaluated, how execution strategies are put forward and implemented, and how resources are integrated. Generally speaking, social capital has provided the networks favourable for the discovery of opportunities and identification, collection and configuration of scarce resources [115]. An entrepreneurial network is helpful for the exploitation entrepreneurial process, and is also associated with providing and spreading key information and other necessary resources.

At first, an entrepreneurial network is favourable for the discovery of opportunities. The first step of venture success is the perception and judgment of market opportunity. In the viewpoint of management scholars, accumulation of knowledge, information and other resources carried out through social relationships have produced a new "productive opportunity" and constituted the driving force for the development and growth of a new cause. During the process of discovering opportunities, Aldrich and Reese [122] are convinced that an entrepreneurial network enables new entrepreneurs to contact new and different thoughts and universal views, so as to provide reference for their selection of potential ideas or causes. Uzzi [115] believes that personal network's support for discovering opportunities by entrepreneurs derives from the transfer and spread of information directly. Entrepreneurs are always in the position of "structural hole" described by Burt [45] and possess at least 2 non-overlapping networks. The information from a single network cannot provide complete business value, which can be manifested only by the integration of such information. The structural hole is always the channel of market characteristics and product and resource information flow. Low and Abrahamson [123] have provided a vivid example related to the discovery of opportunities by an entrepreneur through personal networks: a successful Swedish entrepreneur has maintained a network of management consulting experts and the information provided by these experts enables him to know that CAD/CAM technology can solve customer problems, namely, providing the information required by him. In addition, experts in another network maintained by him can provide information to help him judge if the technology required by the market is feasible. Through careful development and management of the two networks, he has established over 30 leading companies successfully within 15 years.

Secondly, entrepreneurial network is favourable for resource integration. The development prospects of an entrepreneurial enterprise may depend on the entrepreneur's ability to seize external resources (including physical capital such as capital, suppliers, etc. and intangible capital such as information, knowledge, etc.). Johannisson [75] points out that an entrepreneur is a person of networks and his personal network is the means for existing entrepreneurs to obtain resources from the environment for information exchange. Many studies have discovered the phenomenon that enterprise founders rely on personal networks to employ financing and other commercial resources. Enterprise founders make use of their own personal networks with individual and commercial contacts to obtain resources and information that cannot be achieved (or achieved at a low price) in the market. Due to friends or relative relationships in network partners, the opportunity of obtaining the resources at a favourable price through personal networks can be produced. By providing special resources for entrepreneurs for free or at a price lower than market price, these network partners do a favour for entrepreneurs, or return a favour for the benefits obtained from entrepreneurs previously. A real example is as follows: a spouse may not earn a salary, due to working in the entrepreneurial company, and a friend in the business provides new or second-hand production equipment for free. An enterprise can obtain resources from the network which cannot be achieved in the market, and relevant cases include the reputation. For example, orders from a large enterprise that do not order goods from an entrepreneurial company generally, or new technical information obtained from friends, which is hardly purchased, etc. Obviously, once an entrepreneur can obtain cheaper resources more frequently from his/her own personal network, he/she will have a better opportunity to realize a cost advantage, surpassing the competition.

Situational factors influencing the relationship between entrepreneurial social capital and entrepreneurship

Structural characteristics of the network are focuses concerned by social network theorists. The analysis of the structure of entrepreneurial networks can be carried out from the following 4 perspectives: scale, the strength of ties, density and range [43]. The scale can be measured by the quantity of ties. The larger the quantity of ties, the larger the network scale. Generally speaking, people of relatively more ties can obtain higher revenues. The strength of ties refers to the frequency and intensity of contact relying on such ties. Besides, density, as a relative concept, means the percentage of the quantity of ties among nodes relative to all possible ties. The size of this proportion indicates the denseness of the network. In addition, the range refers to the diversity of theses network ties and diversity mentioned here has double meanings, namely, function and spatial position. On the one hand, functional diversity may be realized due to spanning the networks of different functions. For example, entrepreneurs possess both talent networks and investor networks. On the other hand, network diversity may also be achieved by permeating into different spatial positions.

Through profound investigations on 14 entrepreneurs in Scotland, Jack discovered that the strong ties of entrepreneurs have a significant influence on commercial activities. Entrepreneurs of strong ties can not only obtain plenty of information and knowledge, but also maintain, expand and improve the reputation of the enterprises and entrepreneurs by virtue of strong ties. The strong tie always lurks in the entrepreneur's personal network even though it is not used, and has provided a favourable mechanism and effective node for deploying and using weak ties in a wider social network simultaneously. John Watson studied the positive impact of an entrepreneur's formal network and informal network on the enterprise's survival, development and expansion by use of a vertical database. Network intensity has a positive correlation with the survival of an enterprise, and the network's range also has a positive correlation with the development of an enterprise.

Low and Abrahamson [123] discovered that network characteristics of successful entrepreneurs vary with the environment. A key link for venture success is organizational design and implementation, while the nature of such an implementation process varies from an environment to another environment, namely, an effective process in an environment may fail in another environment. In a new industry, successful entrepreneurs have strong ties between two non-overlapping networks. In the development stage, successful entrepreneurs have a weak tie network, while in the mature stage, they have a strong tie network. When explaining network characteristics of successful entrepreneurs in a new industry, in their opinions, the founder of a new organization has strong ties in two or more non-overlapping networks. Due to profound knowledge and understanding of these strong ties and the fact that these networks are non-overlapping, the entrepreneur can establish a new organizational form by connecting the two or more networks. Though the entrepreneurial network is associated with the entrepreneur's benefits, experiences and even personality, the entrepreneur can improve the probability of venture success by effective management and integration of the network.

Researchers discover that the promoting function of an entrepreneurial network on venture success is influenced by external environment. Just as Timmons emphasized, a dynamic entrepreneurial process depends on the overall integration of factors. The nature and mixing of factors always vary with different social-economic environments, and will become different due to different industries. Liao and Welsch [124] have researched the difference of the structures of entrepreneurial networks in different industries. In their opinion, the establishment and development of a technology-based enterprise especially relies on the combination of the enterprise's unique knowledge and the knowledge possessed by external partners. Therefore, technology-based entrepreneurs can obtain more benefits from tie embeddedness, and carry out more and freer exchange of non-redundant information. Thus technology-based entrepreneurs shall establish a network full of weak ties to obtain the knowledge efficiently.

2.4 The History and Current Situation of the Nanotechnology Industry in China

2.4.1 The introductions for the nanotechnology industry

The Nano-technology company, with the basis of new material technology and integrated with other applications, consists of microelectronics and computer technology, environment and energy, medicine and health, biotechnology, aerospace and aviation, national security and so on.

The Nano-technology company is characterized by the following three aspects: firstly, the Nano-technology industry is established based on the nano-materials technology, which plays a decisive role in the formation of the industry; secondly, the nano-materials technology has been applied to new product development and production processes, forming high-tech products of the market; thirdly, enterprises using the Nano-technology or similar technology constitute a group, which is sufficient to constitute a new industry due to its certain scale of market. Therefore, the Nano-technology industry has the common characteristics of high-tech industries, but also displays its own traits different from the general high-tech industry as below:

High Input:

The research and development of nano-materials requires a large amount of capital investment, decided by the characteristics of the Nano-technology, such as the knowledge-intensive and personnel-intensive, as well as the industry risks of the nano-materials technology. Since the technology of the nano-materials industry application appears much more complex than that of the traditional industries, and usually indicates multiple disciplines involved, the research on nano-materials requires much sophisticated equipment and talent investment, accounting for a huge amount of capital. Furthermore, in order to seize the market, the replacement rate of the nano-material products shows rather fast, often requiring disposable and large investments. In particular, once the products form the market scale production, it is essential to invest more capital. Additionally, the nano-materials Industry, starting from the initial technical research to the middle pilot test and the final industrial production, displays an increasing trend of the investment required in the three stages, i.e. the subsequent funding requires greater than the former.

High Risk:

High risk is one of the most important features of the Nano-technology industry. Since the technology involved in the industry mostly lies at the forefront of modern science and technology with a significant advancement, it belongs to the venture industry, with significantly higher risks than the general industry. Its high risks indicate the following areas:

(1) The technical risks.

Due to the complexity of the research and development of the Nano-technology, the technology development faces various uncertainties, such as technical difficulties, the results maturity, the commercialization gap, the development life cycle, and the technical lifetime. In particular, Nano-technology mostly lies at the forefront of contemporary science and technology with obvious advance features, hence, it is rather difficult to determine the probability of success of the research results transformed into the industrial production and new products.

(2) The market risks.

In the process of the Nano-technology products from the research and development to trial production, mass production, and the benefits produced, it will take one to two years for the short cases, but 6-8 years, or longer, for the long cases. During the process, it may appear there are unpredictable changes. If the products cannot meet the requirements of the market, or are replaced by some newer and more advanced product, the pre-investment in the research and development will become unproductive investments, resulting in losses to the investors.

(3) The financial risks.

With the in-depth development of the Nano-technology companies, the demand for capital will rapidly increase. For another, the financing for the research and development of Nano-technology is very low, thus, it is very likely to face the capital chain rupture in a certain stage of the nano-materials development. Nano-materials enterprises tend to encounter a deficiency of funds, leading to the difficult turnover of cash flow and the lack of ability to pay. For the objective existence of these risks, accordingly numerous financing activities of Nano-technology end in failure.

(4) The management risks.

If the managers of nano-materials enterprises are more adept at technology than management, the possibility of failure tends to increase due to mismanagement.

High-yield:

The risks and benefits of the investment are two sides of a problem. The high-risk and high-yield of the investment tend to be complementary. As Nano-technology is an innovative activity, the products with the design, technology, and means of production based on Nano-technology demonstrate greatly enhanced performance and even special properties that the traditional materials have not shown. Besides, it can also significantly improve labour productivity, the resource utilization rate and efficiency of work. In other words, nano-materials products appear with high added values. Once industrialization is successful, it can bring tremendous social and economic benefits for enterprises. After Nano-technology companies overcome the effects of the above uncertainties, the accompanied advantages will be immediately shown, such as the advanced performance, production technology and means, and the relatively few competitors in the market. Its return rate of investment appears much higher than traditional industries, reflecting the law of high-risk and high-yield.

The highly concentrated knowledge and technology:

Since the multiple disciplines involved in the field of Nano-technology, the complicated knowledge cross and wide penetration, and increasing efficiencies of the technologies and products transformed from the knowledge, Nano-technology has been widely applied in various fields of modern industry and becomes the common key technologies.

The obvious Industrial Innovation cluster effects:

The development of nano-materials is no longer simply the development of the materials itself, but new products or overall development. Nano-materials development is involved with a variety of knowledge, disciplines and numerous talents. When it merges into other areas and traditional industrial sectors, it will form a new high-tech group, which cannot only assist the upgrading of traditional industries, but can also penetrate various aspects of business, transportation and defence, medicine and health, culture and education, organization and management, social services, and family life beyond the scope of pure technology and pure production, eventually having far-reaching effects of radiation on the industrial structure, employment structure, social structure, lifestyle, ways of thinking or even their philosophy.

2.4.2 The History of Chinese Nano-technology Industry

The Nano-technology industry in China started from the overall transfer of a private enterprise in Zhejiang from the Institute of Solid State Physics in Hefei in 1996. Through years of development, these Nano-technology enterprises are developing well comprehensively and have made great contributions to the development of the hi-tech industry in China. Though a large number of these Nano-technology enterprises are small, they're vibrant and are representatives of new Chinese industries. [125]

The Nano-technology industry, in the early stage, was dominated by powder materials. After rapid development, China has several nano-powder production lines which can produce oxide, nitride, metal and alloy, carbide, carbon nano-tube and other compound powder materials. These enterprises mainly depended on single nano-powder manufacturing technology at the beginning of the 1990s. The powder products produced by these factories are extremely simple. Due to lack of effective dispersion technology and surface modification technology, the aggregation problem of nano-particles cannot be solved well by virtue of both gas phase method and liquid phase method, which has brought certain difficulties in the application of nano-particle materials [127].

Since 2000, China's Nano-technology has developed rapidly, which is evident from the perspective of the number of patents. In the Derwent Innovations Index, China's number of patents related to nanotechnology ranks third. The proportion of patents related to material applications is increasing gradually, which has changed the situation dominated by patents of nano-metre material preparation. These patents have promoted the development of the nano-metre materials application industry in China [126]. However, these patents still have certain limitations, which will be mentioned in the next chapter.

In 2000, there were more than 100 nano-metre material technology companies registered with private capital investment of about RMB 700 million or RMB 800 million. By the end of 2004, there were over 300 companies registered and most of them belonged to application-type nano industries, which almost accounts for 85% of the whole nano industry. After 2004, the unhealthy situation by speculation with the concept of nano-metre in the society have taken a turn for the better, and some entrepreneurs dedicated to Nano-technology do not name their companies with the word of nano-metre. They concentrate on the development of nano-metre applications of technology seriously and most make use of nano-metre material technology to realize upgrading and modification of the products of these enterprises. According to incomplete statistics, in case such enterprises are included in the nano industry, there are now more than 1,000 Nano-technology enterprises in China [127]. The 1,000 Nano-technology enterprises involved in nano-metre material technology, environment and water treatment industries, nano-drug, nano-energy industry, nano-electronics industry, traffic and agriculture, high-tech manufacturing industries and some others. In the aspect of applying nano-metre material technology to transform traditional industries, the following industries develop well: fine chemicals, textile, building, light industry, electric power and material industry.

Though China's nano industry has completed the transformation from pure manufacturing to applications, the application of technology still belongs to low-tech, and the innovation strength of Nano-technology and nano-metre application technology in combining national strategic demands is not enough. Although China's patent number related to nanometre has increased rapidly in recent years, patents, which could actually be used, are few and the patents combining IT, IC and nano-biotechnology account for only a relatively small proportion [128]. In the long term, there is still a gap between China's nano industry and that of internationally advanced countries in the aspect of international competitiveness, and the gap is inclined to be widened continuously in recent years. Since the problem of the detachment of fundamental research, usually carried out at universities, and application development and research, carried out mainly by the industries, has not been solved well, nano industry lacks the support of sustainable technological innovation. Especially for the nano-powder industry, there are troubles for such an industry to enter into the market only by the support of single manufacturing technology. To enable the enterprise's products to enter into the market, entrepreneurs have to carry out fundamental research that the enterprises are not good at due to a lack of technical support of scientific research institutions, which has not only influenced innovation ability, but also prolonged the technological updating cycle. In this way, the enterprises even lose the great opportunity of entering the market [125].

In sum, China's nano-material industry still faces various challenges, as follow:

1. It is in small scale and enterprises with less than 100 employees account for about 80% of the total;
2. There are not many products dominated by Nano-technology and most of the Nano-technology enterprises are dedicated to developing nano-metre applied technology;
3. There is not close cooperation between Nano-technology enterprises, between nano industry and scientific research institutions. The industry chain and product chain haven't been formed;
4. Most of the industries lay particular emphasis on the application of nanotechnology in traditional industries, and enterprises applying nanotechnology in high-tech field and international strategic demand field account for a small proportion [129].

In case these problems can not be solved, they will influence the healthy development of nano industry in China. There are also challenges confronted by nanotechnology enterprises in the "transition." The transition confronted by nano industry in China mainly refers to the transition of technological innovation. It is a vital problem during transitional period of Nano-technology in China to accept new nano-metre manufacturing and application technologies and facilitate the technological upgrade of enterprises [125].

2.4.3 Current Situation, Compared to Developed Countries

From the perspective of general industry growth law, there are five types of impetus to promote industrial development, namely, technology, demand, resource, enterprise and government, during which, technology, demand and resource are 3 object factors, while the other two are subject factors. They play different roles in industry growth and jointly constitute the main impetus for industry growth.

In terms of the five types of driving force, several key problems related to the nano industry in China have not been solved, or there are several problems related to the nano industry in China compared to more developed countries:

A. Technology is the engine for industry growth, but most of the nano-technologies and patents in China are still laboratory technologies rather than technologies for market-oriented and industrialized production. At present, national nanotechnology research mainly depends on scientific research institutions, which rely on the national financial support and does not have sustained and tenacious vitality itself. There is still a long distance between research achievements obtained in the laboratory and the market. Besides, the research objective of scientific research institutions does not lie in actual products, but in paper and more scientific research funds [128]. According to the statistics, the proportion of nano-metre scientific research achievements transformed into actual products is less than 5% in China, and Nano-technology enterprises must face weak R&D ability and R&D risks at the same time [130]. China's Nano-technology enterprises are congenitally deficient from the perspective of initial development stage. Quite a few enterprises involved in the nanometre field at the earliest are non-state-owned and private enterprises, while state-owned and collective enterprises making an investment in the nano industry are mainly for the purpose of transforming their traditional industries. Nano-technology enterprises in China with registered capital at initial stage of less than RMB 50 million account for about 80%, while those with registered capital of more than RMB 100 million are enterprises aiming to apply nanotechnology to transform their traditional industries. It is too grave to let these enterprises undertake the task of nanotechnology R&D of China. The awkward R&D situation shall be changed by the reform of government policies [128]. Only the government can lead the research and development of such difficult but promising scientific research tasks, since the government's anti-risk capability is incomparable to any enterprises. However, before the reform, the current situation in China forces entrepreneurs to seek information exchange and cooperation with scientific research institutions and even the government. The enterprises and scientific research institutions can jointly research and develop specific technologies required by enterprises to help their project R&D, or enterprises can participate in national large-scale technology R&D by taking charge of certain specific small-scale technology R&D to promote their own technological level by virtue of national funds and technical guidance [125].

B. Demand is the traction for industry growth; however, national demand for nanometre products mainly refers to intermediate demands rather than end demand. Similar to electroplating industry, nano industry is a process industry and horizontal industry. Since nano-material is not an end product, it can not exist independently. Nano-materials can survive only by being applied to downstream consumer goods and can be developed and expanded only by relying on some other industries. Though there are many varieties of

Nano-technology enterprises in China, only a few varieties can focus on large industries. In this way, Nano-technology enterprises, as an industry in the development stage, lack anti-risk capability. After the financial crisis in 2008, since the overall economy became depressed, downstream enterprises of Chinese Nano-technology enterprises had difficulty in their operation and reduced their demands on Nano-technology products. When the situation became worse, the survival environment of Chinese Nano-technology enterprises became extremely tough, let alone development. Relevant data show that after 2008, the proportion of R&D investment of Chinese Nano-technology enterprises was decreased by about 50% compared to that in 2000 [131]. Thus, a vicious circle was formed: to maintain daily operations, enterprises must cut down various expenses--financial pressure forced the enterprises to cut down R&D expenditure--the reduction of R&D investment resulted in slow R&D progress and it became more difficult to promote new competitive products--enterprise competitiveness was decreased further. To get rid of such a vicious circle, enterprises urgently needed entrepreneurs to raise funds and discover commercial opportunities; or to maintain the enterprises until the financial crisis passed; or to seek development of new products and enter the industry chain with small influences of financial crisis, and it would be best to manufacture end products; or to seek transformation overall and give up the nano industry. These are various methods for enterprises to overcome difficulties, but the information about market demands is the direction for enterprise development.

C. Resource is the foundation for industry growth. Resources for industry growth shall include natural resources, human resources and capital resources. The nano industry in China lacks capital resources and human resources now, and the scale of the nano industry can not be separated with intellectual capital and funds capital. In terms of intellectual capital, the nano industry lacks market-oriented entrepreneurs and management talents [132]. How to choose the products with a large market in the future? How to carry out product development? How to carry out product packaging and publicity? These matters can be completed only by senior talents, especially technical management talents who can carry out technology R&D and management, and connect R&D work with enterprise management, simultaneously. In terms of funds capital, the development bottleneck of nano-materials enterprises lies in how to raise funds and carry out financing [133]. Any industry requires the investment of a large amount of funds at the development stage. For example, when e-commerce and internet enterprises arise, they benefit from the investment of a batch of venture capitalists. Whether nanotechnology enterprises can find an attractive business model to raise funds in a capital market is a problem which has not been solved by such enterprises as yet.

D. Enterprise is the subject of industrial activities. However, at present, Chinese Nano-technology enterprises are still relatively independent in space and in market, and have not entered into global industrial division links, nor found their own positions in the industrial division. Once an industry wants to realize great development, in the condition of globalization and new economy, there must be a batch of enterprises entering global production systems, even though they start from the low end of the production system. In this way, the industry will have great development prospects and catch up with the steps of world industrial progress quickly with a participating plan [134]. In addition, regional agglomeration of Nano-technology enterprises has not been formed, the domestic industry chain system is incomplete, and market functions supporting the nano industry, such as instrument and equipment, process design, product design, etc., have not yet been established.

E. Government is the policy maker. However, the macroscopic development policy of the nano industry has not formed, truly. We know that such countries as the United States, Japan, etc. are positive in the development of the nano industry. Taiwan has promoted a series of measures for the vigorous development of Nano-technology, and formed 3 principal high new industries including the high-tech industry, high-tech traditional industry and emerging nano-biotechnology and nano-electronics industries [135]. The Nano-technology plan of Taiwan has realized the transformation of Taiwan's nano industry from the OEM stage to the self-dependent innovation stage. By contrast, China has not set up an overall plan for the development of the nano industry.

2.4.4 Problems Confronted and One of the Solutions: Social Capital

In the future, the nano industry in China shall find its own development pattern. As for how to seek for the industrial development pattern, the core is to find its own development position in the global industrial value chain through industrial development law. The nano industry must form regional industry agglomeration and see a position by itself in certain subdivided industry fields and the link of the value chain, through profound research to achieve enterprise competitive advantage and industry aggregation effect [136]. Aggregation may refer to undertaking the transfer of the global value chain to carry out outsourcing production for international enterprises, or may refer to forming a nano-material supply base with complete national associated industries, according to existing technologies and resources. The application of Nano-technology and nano-materials are involved in extremely wide fields and it is required to choose several fields of competitive advantage for concentrated development. The internal labour division system of the nano industry shall be decomposed continuously. Such links as R&D, design, material manufacturing and trade shall be implemented by specialized enterprises step by step, so as to improve the overall labour division efficiency of the industry.

Part of this research is to find whether the corporate or entrepreneurial social capital can help to solve these problems. The hypothesis is that social capital might be one of the best methods to solve problems confronted by Chinese nanotechnology enterprises. Social capital has good functions to influence the above aspects [137]. If entrepreneurs can make use of social capital properly, the social capital might bring more abundant information about scientific research and markets, more financing channels and more excellent management talents and methods.

Meanwhile, China has had rapid economic growth in recent years and past research theories related to the effect of social capital on the enterprises have not been tested in the Chinese high-technology enterprises, especially Chinese Nano-technology enterprises. Secondly, China is unique and social capital may contain different factors in China. The confirmatory study and finding these new factors are both necessary by focusing on the Chinese Nano-technology enterprises.

Chapter III

The Relationship between Political Influence and Innovation Investment

3.1 Theoretical Analysis and Research Hypothesis

Political relationships are one type of entrepreneurial social capital and an enterprise can achieve more scarce resources by virtue of it. These resources include more convenient financing [140][167], more fiscal subsidies [168], more preferential tax [169] and more governmental orders [170]. Under the background of China, the lack of formal institution and high risk of innovation itself have brought extremely great instability and uncertainty for the technological innovation activities of middle and small-sized high-tech enterprises. Enterprises can obtain investment guarantees for innovation activities from the government to reduce the innovation risk. Wang, et al. [171], through research on listed middle and small-sized companies, discovered that enterprises with social capital have significantly more innovation investment since they can obtain more external financing. Such an effect can be called a “support effect” of social capital. However, there are also costs for enterprises to seek and obtain social capital, and numerous enterprises consume plenty of enterprise resources to fight for social capital. What is more serious is that an enterprise’s technological innovation activity has an obvious hysteresis effect, will not bring considerable short-term profits for the enterprise generally, and has risk factors simultaneously. And the short-term effect of social capital is more obvious. Once the entrepreneurs seek such short-term profits, they will certainly apply limited resources and energy to obtain social capital, and will certainly cut down the investment in technological innovation [172]. Such an effect can be called the “crowding out effect” of social capital.

We believe that both of the effects, reflecting the diminishing marginal effects, were likely to exist in the history. Initially, almost no companies invested resources in this area. However, once the first enterprise invests resources in this field, it will get a large return of profits; hence the "supporting effect" has manifested. With the increase of various companies investing resources in this area and the investment in the development and maintenance of this relationship, the output ratio (i.e. the corresponding earnings divided by the investment) will gradually reduce. When the output ratio becomes less than the critical point, "the effect of crowding out" starts to show. One of the goals of this chapter is to explore whether the investments of the Nano-technology industry of China in this area have been at a critical point in the overall environment of China.

The following two alternative hypotheses are hereby proposed on the basis of the above analysis.

Hypothesis 3-1A: enterprises with political influence will make more investment in technological innovation (support hypothesis).

Hypothesis 3-1B: enterprises with political influence will make less investment in technological innovation (crowding out hypothesis).

3.2 Sample and Research Method

3.2.1 Sample and Data Source

In this chapter, all listed companies involved in nanotechnology in 2013 were selected as the sample. In the filtering process, we have used data from various resources to make sure whether the listed companies meet our requirement. These resources include news reports, annual financial reports and special announcements.

After choosing our final sample, we have collected the data and coded certain variables based on following data resources:

(1) Annual financial report,

(2) Database of listed companies, and

(3) Public reports.

From the annual financial report and listed company database, we mainly collect firm level variables and the coding text of the chairman and CEO on top of the manager's social capital and demographic characteristic variables. This study has also tried to collect additional second-hand data on the background of the chairman and CEO from public resources, such as news reports online or on industrial magazines. Removing companies with incomplete data on R&D expenditure, this study has finally obtained 180 effective sample observation values.

3.2.2 Variable Declaration

Dependent Variables

Rdratio is a dependent variable for measuring the enterprise's investment in R&D expenditure, namely, the proportion of R&D expenditure in annual operating income. Indexes of enterprise technological innovation are generally divided into innovation investment and innovation output indexes. Most of the literature uses enterprise's investment in R&D expenditure to measure the enterprise's innovation investment. The data derived from the annual reports of the listed companies.

Techratio is another dependent variable that signifies the enterprise's investment in technological manpower, namely, the proportion of the number of technical staff in the current year in the total number of enterprise employees. The more the technical staff indicates that the enterprise is more willing to invest resources to carry out technological innovation. The data derived from annual reports of the listed companies.

Explanatory Variables

A) Lnasset represents the enterprise scale, which shall be expressed by the natural logarithm of the year-end total assets of the enterprise. Once the enterprise scale is larger, it will be more competent to carry out innovation investment.
B) Lnprofit represents the enterprise's profitability, which shall be expressed by the natural logarithm of annual net profits of the enterprise. Once the enterprise has stronger profitability, it will be more competent to carry out innovation.
C) Type represents the type of controlling shareholder of the enterprise, namely, property ownership of the enterprise. In case the controlling shareholder of the enterprise is non-state-owned nature, the Type is defined as 1. Otherwise it will be defined as 0.
D) Hitech represents the industry nature of the enterprise. According to the classification of industries carried out by the China Securities Regulatory Commission, sample enterprises are distributed into more than a dozen industries in total. For the convenience of research, this chapter will divide all

enterprises into two industry categories, namely, high-tech industry and non-high-tech industry. In case the enterprise is in the IT industry, the electronics industry, the pharmaceutical industry and the modern service industry, it will be in high-tech industry and the Hitech is defined as 1. Otherwise, it will be defined as 0. Generally speaking, the nature of high-tech industry has decided that the enterprise's innovation investment will be relatively high.

E) Social is an explanatory variable, which signifies whether the enterprise has political influence. In case any member of the board of directors of the enterprise took or takes office in central or local party and governmental department, or serves as an NPC member or CPPCC member in the past or at present, the Social is defined as 1. Otherwise, it will be defined as 0. This information is derived from the background materials of the information about the board of directors and the management disclosed in annual reports of the listed companies. To research the impact of political influence on enterprise innovation, the explanatory variable will be divided into 2 categories. I. Any member of the board of directors of the enterprise once taken office in party and governmental department, which will be expressed by Social 1. II. Any member of the board of directors of the enterprise serves as NPC member or CPPCC member, which will be expressed by Social 2. Since national laws stipulate that any person undertaking party and government work now can not hold a post in any enterprise, Social 1 represents that the entrepreneur worked in party and governmental department in early years and went into business later, which is a type of congenitally inherited and passive social capital. However, NPC member or CPPCC member is just a political identity, which is generally obtained by the entrepreneur after achieving success and winning recognition. Therefore Social 2 embodies a type of acquired and positive social capital and can represent an enterprise's enthusiasm for social capital.

This chapter will verify the impact of the two different forms of political influence on enterprise innovation, respectively.

3.2.3 Model Specification

To verify the hypotheses proposed, the following basic models are hereby constituted.

$$Rdratio=\alpha+\beta_1 Social+\beta_2 Lnasset+\beta_3 Lnprofit+\beta_4 Type+\beta_5 Hitech+\varepsilon \quad (3\text{-}1)$$

$$Techratio=\alpha+\beta_1 Social+\beta_2 Lnasset+\beta_3 Lnprofit+\beta_4 Type+\beta_5 Hitech+\varepsilon \quad (3\text{-}2)$$

Model (3-1) is for verifying the relationship between an enterprise's investment in R&D expenditure and social capital, while model (3-2) is for verifying the relationship between an enterprise's investment in technological manpower and social capital.

3.3 Result Verification and Analysis

3.3.1 Descriptive Statistical Analysis

Table 2 shows the statistical condition of the enterprise's political influence. Among the 180 enterprise samples, 59 have political influence, accounting for 32.78% of all samples, in which, there are 12 enterprise samples with a member of the board of directors who worked in party and governmental departments in the past, accounting for 6.67% of the total sample. There are 47 enterprise samples with a member serving as NPC member or CPPCC member, accounting for 26.11% of the total sample. These data show that it is a universal phenomenon to possess political influence in the investigated enterprises. Particularly, many entrepreneurs seek political identity, such as being an NPC member or CPPCC member after running an enterprise successfully.

Type of political influence	Party, Government	NPC, CPPCC	Total
Total sample number	180	180	180
Number of samples with political influence	12	47	59
Proportion	6.67%	26.11%	32.78%

TABLE 2 THE STATISTICAL CONDITION OF ENTERPRISE'S POLITICAL INFLUENCE

Table 3 indicates the descriptive statistical characteristics of dependent variables and control variables. Mean value of Rdratio is 0.06213, the minimum value is 0.02577, and the maximum value is 0.1347. We can see that sample enterprises' investment in R&D expenditure has significant difference. The mean value of Techratio is 0.2760, minimum value is 0.07618, and the maximum value is 0.7446. These data demonstrate that enterprise investment in technological manpower also has great difference.

	Rdratio	Techratio	Lnasset	Lnprofit	Type	Hitech
Mean	0.06212	0.2760	11.43	8.657	0.9333	0.4999
Std.Dev	0.02578	0.07618	0.6017	0.6220	0.2501	0.5389
Min	0.006853	0.09745	9.9840	7.437	0	0
Max	0.1347	0.7446	12.72	10.36	1	1

TABLE 3 STATISTICS OF DEPENDENT VARIABLES AND CONTROL VARIABLES

Variables		1	2	3	4	5	6	7
1	Lnprofit	1						
2	Lnasset	0.043	1					
3	Hitech	0.086	0.040	1				
4	Type	0.103	0.059	-0.158*	1			
5	Social1	0.026	-0.044	0.069	0.071	1		
6	Social2	0.050	0.006	0.245**	-0.095	-0.159	1	
7	Social	0.061	-0.018	0.266**	-0.051	0.383**	0.851**	1

TABLE 4 PEARSON CORRELATION COEFFICIENT OF ENTERPRISE'S POLITICAL INFLUENCE

3.3.2 Regression Analysis

	Rdratio			
Social	-0.010** (0.017)			
Social 1		-0.008 (0.275)		-0.011 (0.143)
Social 2			-0.008* (0.058)	-0.010** (0.033)
Type	-0.006 (0.416)	-0.005 (0.497)	-0.007 (0.370)	-0.006 (0.431)
Hitech	0.014*** (0.001)	0.011*** (0.004)	0.013*** (0.001)	0.013*** (0.001)
Lnasset	0.000 (0.938)	0.000 (0.951)	-2.081E-5 (0.995)	0.000 (0.931)
Lnprofit	-0.001 (0.628)	-0.002 (0.573)	-0.002 (0.610)	-0.001 (0.629)
F-Value	3.219**	2.244	2.758**	2.675**
R-Square	0.085	0.061	0.073	0.085
Adjusted R-Square	0.058	0.034	0.047	0.053

(* means p<0.1,** means p<0.05,*** means p<0.01)

TABLE 5 IMPACTS OF POLITICAL INFLUENCE ON INVESTMENT IN R&D EXPENDITURE

Table 5 shows the regression result of model (3-1). The coefficient of Social is -0.01, which is significant in the level of 1.7%. It indicates that the proportion of R&D expenditure of enterprises with political influence in prime operating revenue is 1.0% lower than that of enterprises without political influence. Such a result demonstrates that hypothesis 1B is well-grounded; once an enterprise is keen on seeking political influence it will cut down its investment in technological innovation. To investigate the action mechanism of political influence further, we divide the political influence into two categories again, namely, any member who had previously worked in party and governmental department, and any member serving as an NPC member or CPPCC member now, for regression analysis respectively. The second column shows the investment in R&D expenditure of enterprises with any member of the board of directors previously working in party and governmental department, and the result shows that the coefficient of Social 1 is -0.008 with non-significant statistics, which indicates that such political influence has no impact on innovation investment. The third column shows the investment in R&D expenditure of enterprises with any member of the board of directors serving as NPC member or CPPCC member now and the result shows that the coefficient of Social 2 is -0.008, significant in the level of 10%, which indicates that the proportion of R&D expenditure of enterprises with such political influence in prime operating revenue is 0.8% lower than that of other enterprises. One can see from above results that the reason for enterprises making small innovation investment is that entrepreneurs invest their limited resources in fighting for political influence after they obtain certain success and neglect the construction of their innovation ability. After putting Social 1 and Social 2 into the equation for regression in the fourth column, we can obtain the same results, namely, Social 2 has significant adverse impact on innovation investments.

Results from the first four columns show that, except for industry attributes of the enterprise, enterprise scale, profitability, property ownership, region and other variables have no significant impact on the enterprise’s investment in R&D expenditure. However, whether the enterprise is in high-tech industry it has a positive impact on an enterprise’s innovation investment, which is significant in the level of 1%. The result indicates that innovation is critical for the survival and development of an enterprise in the high-tech industry.

Table 6 shows the regression result of model (3-2), and the conclusion is similar to the above results. As a whole, the proportion of technical staff of enterprises with political of the in total employees is 3.2% lower than that of enterprises without political influence, which is significant in the level of 1%. After careful analysis, we discover that Social 1 has no significant impact on investment in technological manpower, while Social 2 has significant adverse impact. The conclusion demonstrates again that entrepreneurs pay less attention to innovation investment due to seeking for political influence.

The condition of control variables is analysed next. Hitech is still significant in the level of 1%, which shows that one of the characteristics of high-tech enterprises is that the proportion of technical staff is larger than that of other enterprises. However, Lnaseet has no adverse impact on an enterprise's investment in technological manpower, which is significant in the level of 1%. It shows that the enterprise does not invest corresponding technological manpower capital for innovation with the expansion of the enterprise scale.

	techratio			
Social	-0.032*** (0.009)			
Social 1		-0.002 (0.925)		-0.013 (0.51)
Social 2			-0.036*** (0.006)	-0.037*** (0.005)
Type	-0.02 (0.379)	-0.019 (0.412)	-0.023 (0.308)	-0.022 (0.332)
Hitech	0.031*** (0.008)	0.023** (0.045)	0.030*** (0.009)	0.031*** (0.008)
Lnasset	-0.02** (0.033)	-0.019** (0.044)	-0.019** (0.040)	-0.019** (0.037)
Lnprofit	0.010 (0.258)	0.009 (0.315)	0.010 (0.260)	0.010 (0.257)
F-Value	3.595**	2.117**	3.729**	3.156**
R-Square	0.094	0.057	0.097	0.099
Adjusted R-Square	0.068	0.03	0.071	0.067

Note: intercept term is omitted; bracket of the coefficient value shall be P value; *, ** and *** show significant levels of 10%, 5% and 1% respectively.

TABLE 6 IMPACTS OF SOCIAL CAPITAL ON INVESTMENT IN TECHNOLOGICAL MANPOWER

3.4 Conclusion

This chapter has studied the impact of political influence on technological innovation investment. Research results show that investment in both R&D expenditure and technological manpower of enterprises with political influence is much smaller than that of enterprises without political influence. Through further research, we also discover that such an impact mainly derives from the acquired political influence such as NPC member or CPPCC member. This research demonstrates that when entrepreneurs are keen on seeking for political influence, they will reduce investment in technological innovation, so that social capital has a “crowding out effect” on technological innovation. The Nano-technology industry of China has passed the critical point.

Chapter IV

Impact of Human Capital of Top Manager and R&D Investment

As we described in the previous section, the Nano-technology companies require greater investment and face greater risks, but can also bring greater benefits, compared to other high-tech enterprises. How to improve the utilization efficiency of limited funds while reducing the risks of innovation is the most urgent issue of the Nano-technology companies. This chapter focuses on the impact of the present human capital and capital investment on the output efficiency of the Nano-technology, trying to discover the factors of improving innovation efficiency, partially answering the questions of the Nano-technology companies, and how to allocate the limited resources into the more efficient output section.

4.1 Research Hypothesis

In nanotechnology enterprises with high density of technologies and knowledge, how much can human capital and R&D investment do for independent innovation? Since the overall educational level of an enterprise's human capital can fully reflect the overall quality of the enterprise's human capital, the following hypotheses are hereby proposed:

Management talents with a technical background play a critical role in the decision-making of technical resources allocation and innovation project, and hypotheses are put forward on this basis:

H4-1: the educational level of enterprise employees has positive correlation with independent innovation.

H4-2: the proportion of technical staff has a positive correlation with independent innovation.

H4-3: the proportion of top managers with professional technical backgrounds has a positive correlation with independent innovation.

From the perspective of human capital, salary is the earnings of human capital investment and the value embodiment of human capital. As to technology-intensive enterprises, the proprietary management ability of a top management team is also a key investment factor. Since technological innovation has great complexity, risks and uncertainty, in case the remuneration obtained by the management of the enterprise is lower than the risk level undertaken by them or lower than their own human capital value, top managers will not act to their own real level truly and will only pay attention to short-term performance. In case the return rate obtained by them is no less than that of corresponding managers in other enterprises, they will pay attention to their own innovation ability of human capital and facilitate the enterprise's technological innovation. Therefore, the following hypothesis is hereby put forward:

H4-4: the salary of top managers has a positive correlation with independent innovation.

To manage the uncertainty caused by R&D investment, the development of new products and new technologies requires new management technologies and new abilities. To adapt to these new uncertainties, top managers must carry out relearning persistently and the original human capital value will be derogated, so as to increase the cost of the manager himself and weaken his pursuance of innovation. The age characteristic of top managers even intensifies such an inclination. Since the age of a top manager represents his work experience and risk propensity, this characteristic will influence his strategic idea and strategic choice. According to relevant empirical research conducted in foreign countries [173], young top managers are more inclined to try bold and unprecedented innovation risk behaviours, while once the top managers are older they will be more inclined to avoid risks and lack long-term strategic objectives. Once entrepreneurs or top managers are older, their strategic decision-making behaviours are more conservative [174][175]. Therefore, the following hypothesis is hereby proposed:

H4-5: the average age of top managers has a negative correlation with independent innovation.

According to human capital theory, characteristics of top managers such as work experience will influence the strategic choice and corporate performance of technology-based enterprises. Human capital theory shows that an experienced enterprise team will be more efficient, will improve the human capital of a person and reduce the uncertainty of opportunity selection, and will bring more valuable returns

[176]. Relevant literature often uses the “number of years from the employment of the enterprise to the current year” as the variable of the tenure of top managers of human capital. Therefore, the following hypothesis is hereby proposed:

H4-6: the tenure of top managers has a positive correlation with independent innovation.

The investment of R&D funds is the indispensable key resource for an enterprise to develop new products and new technologies. Quite a few scholars have carried out research on the relationship between R&D investment and technological innovation and corporate performance, and reached a unanimous conclusion that R&D expenditure has a positive correlation with technological innovation and corporate performance. Therefore, we make the following hypothesis:

H4-7: R&D investment has a positive correlation with independent innovation.

4.2 Research Design

4.2.1. Dependent variables

Since patent refers to the patent application index, this chapter adopts the average number of "patents for invention" applied for by the enterprise in one year for measurement.

4.2.2. Explanatory variables:

It is generally accepted that the sales revenue of new products and an enterprise's patent index are two variables for measuring an enterprise's innovation performance. The sales revenue of new products embodies the ultimate value brought by technological innovation products, and the patent index is the direct index to measure the enterprise's technological innovation. However, according to the disclosed conditions at present and with the limitation of data acquisition approaches, it's difficult to acquire the data related to sales revenue of new products. Thus, this study selects the number of patents applied for by the enterprise as the explained variable, and measures the patent index by virtue of patent number/industry mean value by reference to the practice of China.

As to explanatory variables, it is required to consider the selection of human capital index. There are many measurements for human capital, including cost measurement, value measurement, education stock method and others. At present, there is not uniform conclusion for the measurement of human capital. Each measurement method has its own advantages and disadvantages and pertinence. In addition, considering the availability and measurability of data, this chapter has adopted two quantifiable characteristic indexes—employees and top managers for exploration and research by reference to the research in previous literature and according to the demand of the research purposes.

(1) Proportion of technical staff. In Nano-technology enterprises, technical staff are the key capital of an enterprise and indispensable human investment for an enterprise to carry out technological innovation. This chapter adopts the proportion of technical staff of total employees to measure the stock of technological human capital of the enterprise.
(2) Proportion of highly-educated employees. According to human capital theory, receiving formal education is the core for the development of human capital. In compliance with the current situation of human capital in China, this study employs the educational level of employees as the substitute variable of human capital, and measures the educational level of enterprise employees by the proportion of employees with a bachelor's degree or above of total employees disclosed by the enterprise [177][178][179].
(3) Salary of top managers. According to above analysis, the measurement methods of human capital value include historical cost method, human resource discounted future wage method, discounted future income method, etc. However, due to the limitation of the availability of data, existing literature can only select the measurable substitute variable to measure the human capital [180]. As to the human capital evaluation indexes, the average salary of top managers is adopted as the index to reflect the human capital [181]. In our opinion, the salary of top managers can reflect the human capital value of these top managers and, therefore, the average salary of top managers can serve as the substitute variable.
(4) Technical background of top managers. It is widely believed that professional background is also one aspect of human capital [182]. We confirm the top managers with work experience related to R&D or obtaining the professional titles such as engineer as the top managers with technical background, and

consider the proportion of top managers with technical background in total top managers as the measurement index.

(5) Tenure of top managers. According to the literature [138], work experience in an enterprise or industry is a significant aspect of human capital. This study considers the number of years from the earliest time when a single top manager entered into the top management team of the enterprise to the year when the research is carried out as the tenure of the top manager, and the following formula has been used for the calculations: $Tenure = \Sigma tenure_i / n$, in which, n refers to the number of top managers.

(6) Average age of top managers. Compared to older top managers, young top managers are more willing to take risks and are more inclined to undertake innovation projects of risk. Therefore, this study selects the average age of top management team as the substitute variable of the age of top managers [183].

(7) R&D index. There is no lack of research on the relationship between R&D investment and technological innovation with numerous domestic and international studies, and most of them show that the investment of R&D funds has significant influence on the output of technological innovation [184][185]. Therefore, this study, according to the handling method of existing literature, adopts R&D intensity as the relative index of R&D expenditure, and the natural logarithm of R&D expenditure shall be the absolute index.

	Variable symbol	Variable name	Variable definition
Human capital	Tech	The proportion of technical staffs	Ratio of technical staffs in total enterprise employees
	Edu	Proportion of highly-educated employees	Ratio of employees of bachelor degree or above in total employees
	Salary	Average salary of top managers	Total remuneration of top managers/ number of top managers
	Back	Professional technical background of top managers	Number of top managers with professional technical background/ total number of top managers
	Tenure	Tenure of top managers	Time of top managers from entering into the top management team to t year/ number of top managers
	Age	Average age of top managers	Total ages of top managers/ number of top managers
R&D investment	RND	R&D intensity	R&D expenditure/ operation income
	LnR&D	LogarithmeticsR&D investment	Natural logarithm of R&D expenditure

TABLE 7 THE LIST OF VARIABLES

4.2.3. Control variables

The control variables include enterprise scale and age of foundation (AF).

(1) Enterprise scale. As to the enterprises of different scales, their innovation ability is different. Child [186] has carried out analysis on the correlation of any two indexes of the five commonly-used scale indexes, namely, number of enterprise customers, number of enterprise employees, enterprise capacity, net assets of the enterprise and sales revenue of the enterprise, and discovers that the correlation coefficient varies from 0.31 to 0.88 and the correlation coefficient between the number of employees and net assets is the highest. Child [186] believes that the number of employees is the most representative index of the scale of organization. Kimberly [187] has summarized 80 studies and discovered that 80% of the literature uses the number of employees to measure the enterprise scale. In above relevant literature review, Hall [185], Chin [188], Francis and Smith [189] consider the number of enterprise employees as a control variable of the scale, and think that the larger the enterprise scale is, the stronger innovation ability it has. Fixed costs of the HR department maintained by the enterprise will generate scale economies effect caused by patent along with the change of person number. Enterprise scale represents the quantity of available resources of the enterprise. Therefore, this study adopts the natural logarithm of the number of enterprise employees as control variable of the scale: Scale=ln (total number of employees).

(2) Age of foundation (AF). Hall [185], Chin [188], Francis and Smith [189] all consider the enterprise age as control variable of the innovation output. According to this chapter, enterprises having been established for a longer time are more experienced in the patent application process, and will be more effective in the aspect of patent output. However, some people also think that the decision-making process of an enterprise will become programmed as time

goes by and younger enterprises will be advantageous in technological progress. Therefore, this study adopts the age of foundation as the control variable.

On the basis of the above arrangement, this study has established the following multivariable linear regression models to study the impact of human capital and R&D investment on independent innovation output, respectively.

$Patent = \beta_0 + \beta_1 Tech + \beta_2 Edu + \beta_3 Salary + \beta_4 Age + \beta_5 Back + \beta_6 Tenure + \beta_7 AF + \beta_8 Scale + \varepsilon$
Model 4-1

$Patent = \beta_0 + \beta_1 RND + \beta_2 AF + \beta_3 Scale + \varepsilon$ Model 4-2-1

$Patent = \beta_0 + \beta_1 lnR\&D + \beta_2 AF + \beta_3 Scale + \varepsilon$ Model 4-2-2

$Patent = \beta_0 + \beta_1 Tech + \beta_2 Edu + \beta_3 Salary + \beta_4 Age + \beta_5 Back + \beta_6 Tenure + \beta_7 RND + \beta_8 AF + \beta_9 Scale + \varepsilon$ Model 4-3-1

$Patent = \beta_0 + \beta_1 Tech + \beta_2 Edu + \beta_3 Salary + \beta_4 Age + \beta_5 Back + \beta_6 Tenure + \beta_7 lnR\&D + \beta_8 AF + \beta_9 Scale + \varepsilon$
Model 4-3-2

β_0 refers to the intercept term of the model and β_i represents the corresponding impact factor of independent variable or control variable for dependent variable. Model 3 adopts the proportion of technical staff of the enterprise, proportion of employees with a bachelor’s degree or above, the salary of top managers, the average age of top managers, the technical background of top managers, the working years of top managers and R&D intensity as independent variables. This study has carried out linear regression analysis for complete samples at first, and expects that β_1, β_2, β_3, β_5, β_6 and β_7 are positive numbers, while β_4 is a negative number.

4.3 Sample Selection

This chapter aims at the research on the Nano-technology industry in China. Nano-technology has been applied to many fields successfully, including medicine, pharmacy, chemistry, bioinstrumentation, manufacturing, optics, national defence, etc., as we have discussed in previous chapters. This chapter adopts the form of a questionnaire survey and targets companies with products including the word “nano” in their names. The questionnaires were carried out with the help of a government contact person.

In total, 589 questionnaires were sent out. There were 172 questionnaires received, a recovery rate of 29.2%. SPSS, Eviews and excel are adopted as the statistical analytical tools.

4.3.1 Descriptive Statistics and Preliminary Analysis

Data in Table 8 show that mean value of total patents applied for by sample enterprises was 5.6034 and the standard deviation was about 1.3972. The average R&D intensity of sample enterprises was 3.77%. According to related data, R&D expenses of the world top 500 enterprises account for over 65% of global R&D expenses. Technological development expenses of each enterprise account for 10%-20% of the sales volume on average and the proportion is rising ceaselessly [190]. In addition, it is generally acknowledged internationally that an enterprise can survive only when its R&D expenses take up 2% of the company’s sales revenue and can have competitiveness only when its R&D expenses take up 5% of the sales income. These data show that the R&D investment of Chinese Nano-technology enterprises is still far lower than the international competitive standard. The mean values of the proportion of technical staff and the proportion of highly-educated employees of the sample enterprises are 25.07% and 27.23% respectively, which shows that there are about 25 technical staff and 27 employees with bachelor's degrees or above out of 100 employees. The average age of top managers is 43-55 with a mean value of 50, which shows that top managers are inclined to be younger and most of them are 40-50 years old. The mean value of the technical background of top managers is 28.18%, there are about 2-3 employees with professional technical backgrounds in the 10 top managers. The average tenure of top managers is 4.54 years, which is lower than some research results such as Wiersema's [175] result of 9.25 years and Bantel's [174] result of 14.79 years. It can be explained by connection with the enterprise's age of foundation: the nano industry is an emerging industry and some of the enterprises have been transformed from traditional industry. In this way, the maximum sample enterprise age is 30 years. Besides, to cooperate with the enterprise transformation, new top managers of technical background are also needed.

	Min	Max	AVG	S.D
Patent	0.8566	9.7761	5.6034	1.3972
Tech	0.0067	0.9788	0.2507	0.2031
Edu	0.0052	0.8016	0.2722	0.1807
Salary	3.1749	155.002	38.7486	32.4315
Age	50.02	55.099	43.83	2.086
Back	0.0000	0.6679	0.281814	0.1453
Tenu	1.00	8.5945	4.5435	1.5751
RND	0.0018	0.2611	0.03769	0.04199
Ln R&D	9.6499	16.3300	13.5953	1.3545
AF	3	26	13.91	5.688
Scale	4.9403	11.2797	7.8602	0.7932

TABLE 8 DESCRIPTIVE STATISTICS AND PRELIMINARY ANALYSIS

Due to the special institutional background of China, enterprises of different nature will influence the constitution of top managers through an engagement mechanism, so as to influence the human capital of enterprise's top managers. This chapter has divided the samples into state-owned enterprises and non-state-owned enterprises according to the different nature of the share held by actual controllers of the samples selected. An enterprises will be state-owned enterprises, if the nature of shares held by actual controllers is state-owned share, state share or state-owned legal person share. Others will be non-state-owned enterprises in addition to above share nature. In the effective questionnaires, state-owned enterprises occupy 45.3%, but they do not account for such a high proportion in the actual Nano-technology industry in China. During the process of questionnaires, some of them have adopted the form of a government contact person, while state-owned enterprises are more willing to give answers. According to the contrast of mean values of various variables of state-owned enterprises and non-state-owned enterprises in Table 9, both the proportion of technical staff and the proportion of highly-educated employees of non-state-owned enterprises are higher than those of state-owned enterprises, while the mean values of the salary, average age, technical background and tenure of top managers of state-owned enterprises are higher than corresponding mean values of those of non-state-owned enterprises, which has reflected the special incentive and employment background of the management of state-owned enterprises in China. Top managers of state-owned enterprises are generally appointed by the relevant state units, and such managers generally come from SASAC, a state organization or other state-owned enterprises. However, most of the top managers of non-state-owned enterprises are from the professional manager market. According to the R&D investment index, R&D intensity of non-state-owned enterprises is higher than that of state-owned enterprises, which indicates that non-state-owned enterprises are more motivated to carry out R&D than state-owned enterprises.

	State-owned enterprises (N=78)	Non-state-owned enterprises (N=94)
Patent	5.6954	5.5249
Tech	0..2275	0.2701
Edu	0.2505	0.2904
Salary	40.5115	37.2810
Age	51.2371	48.9716
Back	0.2819	0.2651
Tenu	5.2396	3.9640
RND	0.02434	0.04869
lnR&D	18.2250	18.3534
AF	14.8600	12.564
Scale	8.2852	7.5063

TABLE 9 VARIABLES UNDER DIFFERENT CONDITION

Variables		1	2	3	4	5	6	7	8	9	10	11
1	Patent	1										
2	Tech	-0.21**	1									
3	Edu	0.248**	0.034	1								
4	Ln salary	-0.231**	0.128	0.099	1							
5	Back	0.198**	0.063	0.074	0.054	1						
6	Tm	0.176*	0.064	0.003	-0.022	0.098	1					
7	Age	-0.234**	0.016	-0.100	-0.058	0.069	0.064	1				
8	rnd	-0.184*	-0.096	-0.017	-0.052	-0.019	0.040	-0.055	1			
9	Ln r&d	0.155*	-0.080	0.061	0.018	-0.077	-0.087	0.023	-0.138	1		
10	Scale	0.244**	-0.115	-0.094	0.087	0.004	0.060	-0.003	0.019	0.130	1	
11	AF	0.094	0.007	-0.042	0.097	0.013	0.101	-0.001	0.122	-0.047	0.082	1

Note: N = 172; * represents that it is significant in the level of 0.1 (two-tailed test); ** represents that it is significant in the level of 0.05; *** represents that it is significant in the level of 0.01 (two-tailed test).

TABLE 10 PEARSON CORRELATION COEFFICIENT OF MAJOR VARIABLES

4.3.2 Regression Analysis

The Pearson Correlation Coefficient of Major Variables were shown in Table 10

(1) Complete sample regression test

Above all, this study has separately tested the impact of human capital index and R&D investment on patent output respectively (model 4-1, model 4-2-1 and model 4-2-2), as shown in Table 11 and Table 12. When the model removes the variable of R&D investment (namely, model 4-1) and only considers the effect of the variable of human capital on patent output, we discover that all human capital indexes have passed the significance test. Similarly, relative value and absolute value indexes of R&D investment in model 4-2 have also passed the significance test respectively at the level of 5% and 10%. In this way, hypothesis H4-7 is supported. However, the proportion index of technical staff is opposite to the expected result. The regression coefficient is a negative number and hypothesis H4-2 does not get support. All other human capital indexes such as education level of employees and salary, average age, technical background and tenure of top managers have passed the hypothesis test, thus, hypotheses H4-1, H4-3, H4-4, H4-5 and H4-6 are supported. The control variable of the enterprise scale is significant in the level of 1%, which shows that the enterprise scale is a significant influencing factor affecting the independent innovation output. The enterprise's age of foundation does not pass the significance test, which indicates that the age of foundation of high-tech enterprises is not a significant influence factor affecting the innovation output. Adj-R^2 values of model 4-1 are larger than 20%, which demonstrates that the goodness-of-fit of the models is good. And Adj-R^2 values of model 4-2 are less than 0.1, which demonstrates that the model needs to be further improved and to introduce more variables.

Variable	Model 1
Tech	-1.568***(-0.228)
Edu	1.773***(0.229)
Salary	0.008***(0.190)
Age	-0.148***(-0.221)
Back	1.636*(0.170)
Tenure	0.146**(0.164)
AF	0.013(0.053)
Scale	0.384***(0.218)
Adj-R^2	0.286
F	9.438

TABLE 11 REGRESSION RESULT OF MODEL 4-1

Variable	Model 4-2-1	Model 4-2-2
RND	5.755**(0.173)	
LnR&D		0.134*(0.131)
AF	0.013(0.053)(p=0.486)	0.020(0.082)(p=0.275)
Scale	0.416***(0.236)	0.388***(0.220)
Adj-R^2	0.078	0.065
F	5.761	4.907

TABLE 12 REGRESSION RESULT OF MODEL 4-2

Table 13 is the regression result of model 3. According to the regression result, we can see that overall significance F value of the model is larger than 22 and is significant in the level of 1%, which indicates that the goodness-of-fit of the model is good. In addition, the Adj-R^2 value is larger than 27%. Since all variance inflation factors of independent variables are less than 10, there is not a serious collinearity problem. The proportion of technical staff has a significant negative correlation with patent output, which is opposite to the expected result of hypothesis H4-2 and may be caused by an inconsistent statistical calibre of technical staff, relatively wide range and non-core R&D personnel disclosed in the annual report. The overall quality of technical staff cannot reflect the core R&D talents required for innovation, which results in a negative correlation between the disclosed proportion of technical staff and patent output.

Variable	Model 4-3-1	Model 4-3-2
Tech	-1.398***(-0.203)	-1.445***(-0.210)
Edu	1.801***(0.233)	1.718***(0.222)
Salary	0.009***(0.203)	0.008*** (0.183)
Age	-0.135***(-0.202)	-0.145*(-0.216)
Back	1.715***(0.178)	1.869***(0.194)
RND	5.280**(0.159)	
LnR&D		0.116*(0.112)
AF	0.012(0.048)(p=0.464)	0.018(0.075)(p=0.258)
Scale	0.402***(0.228)	0.375***(0.213)
Adj-R^2	0.284	0.272
F	9.399	8.877
D.W	1.883	1.894

TABLE 13 REGRESSION RESULT OF MODEL 4-3

The proportion of highly-educated employees has a significant positive correlation with independent innovation output in the level of 1% in both model 4-3-1 and model 4-3-2, which indicates that enterprise employees of higher educational levels are more favourable for the independent innovation of the enterprise, since technological innovation is a type of investment of high knowledge and high technology and requires the participation of the talents with active thinking and high sensitiveness. Education will increase the information and technology stock of a person, including the cognition and pursuance of opportunities. The higher the educational level of overall human capital, the higher the overall quality of an enterprise's human capital, and the larger the effects on enterprise technological innovation. The result has verified hypothesis H4-1. In regression result of model 4-3-1, the salary of top managers has a significant positive correlation with patent application index in the level of 1%, which shows that the salary of top managers has positive effects on technological innovation. Salary can reflect the human capital value directly. When top managers think that their human capital value gets due returns, they will give full play to their human capital capacity and consider long-term benefits for the enterprise, so as to facilitate the enterprise technological innovation. The result has verified hypothesis H4-4.

The average age of top managers has a negative correlation with the patent application index and is significant in the level of 1%, which indicates that younger top managers or entrepreneurs are favourable for enterprise technological innovation. Once top managers are older, they are more inclined to avoid the projects with risks and to make strategic decisions conservatively, which is unfavourable for the enterprise's long-term development. However, young top managers are willing to try innovative risk-taking behaviours, which is identical with the research conclusions found in other countries (Child [173], Bantel and Jackson [174]), and has also verified the hypothesis H4-5 in this study.

The technical background of top managers has passed the significance test in the level of 1%. Top managers of professional technical background have a technological cognitive basis and are more familiar with the possibility, required technical conditions and environment and the significance of technological innovation than those of other professional backgrounds. They are more inclined to highlight the investment favourable for technological innovation when making decisions, so as to improve the efficiency of patent output. In this way, hypothesis H4-3 has been verified.

The tenure index of top managers has a significant positive correlation with patent output, which shows that the work experience of top managers in the enterprise has a positive function for improving enterprise technological innovation. The tenure of top managers represents a kind of resource that is helpful for the accumulation of enterprise ability and implementation of differentiation strategies. In high-tech enterprises, the accumulation of work experience of top management teams in each field (such as technology, market, etc.) will improve the enterprise's insight into technological progress and understanding on the market, which is favourable for the production of new products. In this way, hypothesis H4-6 in this study has been verified.

R&D expenditure refers to funds investment for technological innovation, which is an indispensable condition for an enterprise to carry out innovation. The regression result shows that absolute indexes of R&D intensity and R&D expenditure have a positive correlation with technological innovation, which is significant in the level of 5% and 10%. We can see that R&D expenditure can facilitate the technological innovation and that hypothesis H4-7 in this study has been verified.

According to the comparison between Table 11, Table 12 and Table 13, the significance of model 1, model 2 and model 3 does not have any obvious change, which indicates that the variables of both human capital and R&D investment have a significant influence on patent output index, but the goodness-of-fit of each model has changed, to a certain extent. When model 4-3 removes the variable of human capital (namely, model 4-2), from the perspective of both R&D relative index and R&D absolute index, the goodness-of-fit of model 4-2 is less than that of model 4-3 which adds the variable of human capital. It can be seen that the variable of human capital has influenced the output effect of R&D investment to some extent. However, from the perspective of the goodness-of-fit of model 4-1 and model 4-3, after the variable of R&D investment is added, the change of the goodness-of-fit is not obvious. In addition, according to regression coefficient, after the variable of human capital is added into model 4-2, the coefficient of R&D investment index of model 4-3 is decreased, which also shows that the human capital index has a larger effect on patent output than R&D investment. Therefore, the conclusion is reached through comprehensive comparison that human capital investment is more favourable for independent innovation output than R&D investment.

4.4 Conclusions and Policy Suggestions

4.4.1 Conclusions

This chapter has verified the impact of an enterprise's human capital and R&D expenditure on the enterprise's independent innovation, and the specific results are as follows:

(1) Above all, the study has carried out descriptive statistical analysis and Person correlation coefficient analysis on each variable. We discover that the educational level of employees and the salary, technical background and tenure of top managers have a significant positive correlation with the independent innovation of the enterprise. Thus hypotheses H4-1, H4-3, H4-4 and H4-6 are verified preliminary.

(2) This study also considers the regression tests of human capital and R&D funds for independent innovation respectively, and human capital and R&D funds for independent innovation jointly. We discover that test result of hypothesis H4-2 is opposite to the expected result, namely, the proportion of technical staff has a negative correlation with independent innovation output. However, the proportion of highly-educated employees and the technical background, salary, age and tenure of top managers have passed the significance test, thus all other hypotheses have been verified. In addition, from the perspective of the goodness-of-fit of the models, the effect of human capital investment on independent innovation output of high-tech enterprises is slightly larger than that of R&D investment.

This study shows that the human capital of the employees and top managers and R&D expenditure of high-tech enterprises can drive the independent innovation output of the enterprise effectively. Qualitative analysis on empirical results shall be as follows: I. The human capital level of employees includes the overall educational level of enterprise employees and the proportion of technical staff. But all regression results show that the proportion of technical staff has a negative correlation with independent innovation output, which is opposite to the expected result. A possible reason could be as follows: technical staff contained a wide range, which can not really reflect the core R&D talents required by the enterprise to carry out technological innovation, finally resulting in the decrease of overall R&D level of technical staff.

The educational level of employees has a significant positive correlation with the enterprise's independent innovation, which shows that a higher overall educational level of employees is more favourable for facilitating the independent innovation output of the enterprise. The core of human capital theory is the education and learning of a person and the knowledge and skills possessed by him, especially the education. According to human capital theory, formal education is an important aspect of human capital. People can increase their knowledge and improve their skills during the educational process. The higher the educational level, the stronger the ability in accepting, digesting and absorbing new information, new methods and new ideas. Technological innovation needs employees with creativity and high knowledge levels to solve the problems encountered by the enterprise in the market of strong competitiveness. Since the educational level of employees can reflect their overall quality and knowledge level, this study uses the proportion of employees with a bachelor's degree or above as the substitute variable of educational level of employees, and the empirical test result has also verified that the educational level of employees has a positive correlation with an enterprise's independent innovation.

II. Human capital stock of top managers will improve the investment decision-making ability and creativeness of top managers. The human capital of top managers mentioned in this study includes their technical background, salary level, tenure and average age of top managers. The technical background of top managers has a significant positive correlation with an enterprise's independent innovation, which indicates that the more top managers of technical background there are, the more helpful it is for technological innovation output. The top managers of professional technical background have a technological cognitive basis and are more familiar with the possibility, the required technical conditions and environment, and the significance of technological innovation than those of other professional backgrounds. They are more inclined to highlight the investment favourable for technological innovation when making decisions, so as to improve the efficiency of patent output.

From the perspective of human capital theory, the salary level of top managers can reflect the human capital value of top managers. According to a survey of top managers in different industries in China carried out by a national consulting company, top managers still pay significant attention to the salary. Providing the salary of market competitiveness for top managers by an enterprise can not only meet the material needs of top managers themselves and their families, but also embody the recognition of their talent value at the material level, and can enhance the sense of belonging of top managers [191].

The proprietary ability of top managers is an important investment for an enterprise to carry out technological innovation. When the human capital value of top managers is recognized by the enterprise, they will give full play to their abilities, consider long-term benefits of the enterprise, improve enterprise competitiveness positively and facilitate the independent innovation output.

The average age of top managers has a significant negative correlation with the enterprise's independent innovation. The age of a top manager can reflect his adaptability and creative spirit. Older managers are more inclined toward economic benefits and occupational stability, more inclined to make decisions with small risk and avoid risks, and unconfident about their own decisions generally to form negative viewpoints step by step. In comparison, young managers have a stronger adaptability and creative spirit, and are more inclined to undertake risks for the enterprise's long-term development, so as to facilitate the enterprise's innovation output.

The tenure of top managers will influence the strategic choice of an enterprise. Top managers of longer tenure in an enterprise can improve the mutual cooperative level and are favourable for strategic accumulation and resource acquisition of the enterprise, since they have mastered internal operations, information and technologies of the enterprise and maintained good interpersonal relationships. This allows them to reduce internal conflicts, intensify the communications and understanding of internal members, and improve the work efficiency of an enterprise team, which is favourable for the enterprise to be able to carry out innovation.

4.4.2 Policy Suggestions

According to this study, the enterprise's human capital and R&D funds can drive the effectiveness of the independent innovation of high-tech enterprises, and quantifiable human capital indexes can be adopted in the two aspects of employees and top managers. This study applies the natural logarithm of R&D intensity and R&D expenditure as the substitute variable of R&D expenditure respectively and proposes the following suggestions through research results:

I. Improve overall employee quality, highlight internal cultivation of professional personnel and cultivate core talents related to technological innovation. Since skills and knowledge possessed by human capital carriers cannot always adapt to or meet the demands of knowledge creation of an enterprise completely, nor adapt to the changes of the external environment, it is required to enlarge the enterprise's investment in on-the-job training for employees, especially for technical staff, so as to improve the quality of human capital by in-service education. Technology and knowledge-intensive high-tech enterprises shall, combining their own characteristics, establish relatively perfect employee training plans, carry out in-service education and training for employees, and increase the investment in human capital, so that employees can obtain high-tech knowledge through learning, learn about the technical conditions of the enterprises through production process and engineering design, and understand user's feedback information and market demands by learning about technology and acquaintance with production process. It is required to combine employee cultivation and scientific research closely to improve the human quality of core technical staff of the enterprises. Besides, enterprises shall attract and retain strategic talents and core talents who have received higher education and have creative spirits, through establishing a perfect internal training mechanism.

II. Improve the quality of the management decision-making level of an enterprise. Technological innovation achievements can bring excess profits for an enterprise, improve the enterprise competiveness, and generate huge market competitive pressure, which requires decision makers of high-level leadership to have innovative ideas and strategic insight. However, innovation itself has certain uncertainty, and there will be market risks along with the application of innovative technologies. Therefore, enterprise innovation decision-making will be influenced by the risk tolerance of management decision-makers. To improve the quality of the top management decision-making level, enterprises can take measures from the following several perspectives:

(1) Improve the proportion of technical managers in all managerial roles. As to high and new technology, top managers of a technical background can learn about the required conditions and environment for and the possibility of technological innovation, will pay more attention to an enterprise's investment in product and technological innovation, and will also improve the requirement on the ability of technical staff of the enterprise, so as to improve the enterprise's overall technical level.

(2) Keep reasonable and high-efficiency age structure of top managers. Young people have the psychological quality of undertaking risks courageously and a relatively strong innovative impetus. In addition, the young management layer has a relatively good energy and learning ability, and can drive the innovation output of high-tech enterprises effectively. Enterprises shall be bold in promoting and using young managers. However, young managers will also suffer from the limitation of

inadequate experience. Compared to the young, middle-aged and elder managers have rich basic knowledge and practical experience and can think about problems carefully with high sharpness in considering problems. Therefore, it is required to keep the top management team younger and consider internal reasonable age structure simultaneously.

(3) Reduce the intervention of governmental departments in the tenure of top managers to provide a longer tenure for top managers. Once a top manager works in an enterprise for a longer time, it is more favourable for him to learn about the internal conditions of the enterprise, and he can form long-term stable expectations, reduce short-term behaviours and enhance the enterprise's initiative and enthusiasm about independent innovation.

(4) Enlarge the salary incentive for top managers. According to this study, the salary of top managers is the embodiment of human capital value. Once the salary of top managers is higher, it goes that top managers have larger human capital value in the enterprise, especially in non-state-owned enterprises, which can be verified by virtue of the test result of grouped samples in this chapter.

III. From the perspective of descriptive statistical analysis, R&D funds investment intensity in Nano-technology enterprises is inadequate, and must increase investment of R&D funds continuously to guarantee the quantity and quality of R&D activities. Since R&D activities have high risk, fund shortage is one of the key factors restricting the technological innovation of high-tech enterprises. The government shall make joint efforts with enterprises and research institutions to improve the scientific research and development capacity of high-tech enterprises, encourage the R&D and technological innovation of high-tech enterprises by virtue of financial allocations for technologies and fiscal taxation policies to enlarge the source of funds for technological innovation simultaneously.

IV. In the aspect of R&D output, enterprises shall strive to improve the efficiency of patent output, enhance the number of patents and quality, and spare no effort to realize rapid increases in patent applications. On the other hand, enterprises shall also enhance the patent management, highlight the management of intellectual property, apply for patent licensing in a timely manner, and protect their own research achievements by legal means. In addition, the government shall strengthen the guidance for enterprises, perfect the system construction to provide a good institutional environment and policy environment for technological innovation for enterprises. The government shall also support enterprises to intensify various communications at home and abroad. So the enterprises can learn lessons from foreign countries in an open environment, and stimulate an enterprise's potential in technological innovation to improve the overall independent innovation level of China.

Chapter V

Research in the Impact of Social Capital on the Corporate Performance of Nano-technology Enterprises

Along with the continuous progress of the integration of the world economy, economic globalization has been expanded ceaselessly, which makes the economic environment more complicated with each passing day and the competition of enterprises extremely fierce. Therefore, enterprises must get hold of information quickly and accurately, and learn about various types of new knowledge and new technologies to expand their own innovation abilities and promote technological innovation performance, so as to maintain the competitive advantage and cope with complicated and changing economic situations.

Therefore, innovation becomes a core factor for an enterprise's survival and development. The key of enterprise innovation is for the entrepreneur to become a vital resource for the survival and development of an enterprise. Entrepreneurs can provide the enterprise with vigorous support in the aspect of information, funds, etc. through their contact with suppliers, the government, scientific research institutions, financial institutions and other external organizations and individuals, so that the enterprise can integrate internal and external resources fully to realize great-leap-forward development of innovation. Besides, Nano-technology enterprise is an important part of high-tech enterprises in China, which plays a great role in the process of promoting scientific and technological progress and facilitating economic transformation and upgrading. However, Nano-technology enterprises suffer from dual influences of R&D risk and market risk deeply and are weak compared to other industries. The inherent fragility of Nano-technology enterprises makes them depend on their external environment and world economic organization more during their operation and development process than general enterprises. Obtaining necessary resources from external organizations has become one of the available strategies for Nano-technology enterprises to realize rapid development and improve corporate performance. This highlights the importance of corporate social capital to the corporate performance. Corporate social capital mainly refers to actual and potential resources available in the social network structure, which equals the product of resources of the owner in his social network structure and his obtaining ability [192]. Now China is still in the late transitional period, moving from a planned economy to a market economy, formal systems such as laws, regulations, etc. are to be perfected, and most of the economic behaviours have been embedded into interpersonal social networks. In the relationship-based society, enterprises always need to obtain resources by virtue of the relationships in their social network, so as to support the future development of enterprises. Many Nano-technology enterprises in China are in the initial or growth stages. It has been pointed out that different types of social capital will play different roles in different development stages of enterprises [193]. With Nano-technology enterprises as the research object, this chapter will study the impact of corporate social capital on corporate performance, and the influence mechanism of entrepreneurial social capital promoting technological innovation performance.

5.1 Definition of the connotations of corporate social capital and corporate performance

With reference to the measurement method of Geng, et al. [36] and other related literature, and in combination with industry characteristics of Nano-technology enterprises, this chapter has measured the corporate social capital of Nano-technology enterprises from the perspective of 3 structural characteristics of social network, namely, heterogeneity, strength and position. Corporate social capital of Nano-technology enterprises can be divided into 6 measurement dimensions, namely, commercial social network scale, commercial social network intensity, political social network scale, political social network intensity, technological social network scale and technological social network intensity.

In addition, the measurement of corporate performance can be carried out in 2 aspects, namely, the economic index and the social index. Economic performance can be measured by virtue of the financial performance index, while social performance shall be measured by the index of prime operating revenue.

5.2 Research hypothesis

5.2.1 Commercial social capital and corporate performance

Entrepreneurial commercial social capital is the ability of entrepreneurs to fully learn about market trends and meet enterprise demands through establishing good relationship networks with external markets, which mainly exist in relationship networks between enterprises. Enterprises can obtain resources, information and knowledge from the external environment by virtue of commercial social capital, which is favourable for coping with environmental uncertainty to improve corporate performance. In addition, enterprises can also obtain the source of new ideas through exchange and communication with customers, so that innovation power can be provided for enterprises continuously. What is more, the exchange and contact between entrepreneurs and competitors and other enterprise managers are favourable for realizing resource sharing and complementation of technologies, information and knowledge of enterprises, and accelerating the production, application and development of new technologies.

On the other hand, the establishment of long-term and effective contact between entrepreneurs and suppliers can shorten the development time of new technologies greatly and establish a more reasonable product development process. Besides, establishing a good relationship between entrepreneurs and employees is favourable for sharing internal knowledge and information, promoting internal learning, creating a good innovation atmosphere and improving technological innovation performance. Through investigations and interviews, we also confirmed that most of the operators generally obtain market information, such as price, by virtue of informal contact channel with commercial partners. Mesquita, et al. [195], through empirical research on enterprises in the furniture industry in Argentina, discovered that commercial social capital of the peer is extremely important for guaranteeing the supply of cooperation resources, because when enterprises are in the same industry or market segment, they are confronted with similar challenges, are more likely to reach uniform strategic cooperation, and find it easier to obtain benefits from industrial standards. Therefore, once the commercial social network scale of Nano-technology enterprises is wider, more market information can be obtained and corporate performance may be better. In addition, once the commercial social network intensity is stronger, it can reduce the transaction cost and prevent opportunistic behaviours. Thus, commercial social capital of Nano-technology enterprises may improve the economic performance and social performance of an enterprise.

Thus, the following hypotheses are proposed:

Hypothesis 5-1a: the commercial social network scale of Nano-technology enterprises has a positive correlation with corporate performance, namely, the commercial social network scale has a positive correlation with the economic performance and social performance of an enterprise.

Hypothesis 5-1b: the commercial social network intensity of Nano-technology enterprises has a positive correlation with corporate performance, namely, commercial social network intensity has a positive correlation with the economic performance and social performance of an enterprise.

5.2.2 Political social capital and corporate performance

Political social capital is mainly embodied in good interaction between enterprises and the government through entrepreneurs, and the relationship network established between enterprises and governmental departments. It is favourable for the enterprises to:

1. Obtain financial support from the government, including financing party,

governmental subsidies and tax preferences, so as to improve the corporate performance;

2. To learn about various policy suggestions and information in a timely manner;

3. To influence government decisions by feeding back enterprise information effectively, so as to improve the predictability of technological innovation.

Luo, et al. [196] proposed that enterprises of a political identity can deliver a good reputation and enable banks to know the relatively small loan risks, which is convenient for such enterprises to carry out financing. When studying the relationship between local government and subsidy income, Chen [197] discovered that once the local government has larger influence, the companies with local government backgrounds can obtain more subsidy income and this can reflect the competitive advantage of such enterprises more. Especially when confronted with financial distress, enterprises of political resources are more able to tide over difficulties with the assistance of government.

Thus, the following hypotheses are proposed:

Hypothesis 5-2a: political social network scale has a positive impact on corporate performance, namely, the political social network scale has a positive impact on the economic performance and social performance of an enterprise.

Hypothesis 5-2b: political social network intensity has a positive impact on corporate performance, namely, the political social network intensity has a positive impact on the economic performance and social performance of an enterprise.

5.2.3 Technological social capital and corporate performance

Technological social capital mainly exists in the social networks established between enterprises and other colleges and universities, scientific research institutions, etc. Entrepreneurs can learn about cutting-edge technologies and avoid repeated innovation of the enterprise. Entrepreneurial technological social capital is favourable for enterprises to obtain new technologies, new knowledge and new information rapidly and quickly, to combine them with the enterprise's current production situation, to improve internal technological innovation, to prevent and resist natural risks effectively, to guarantee product quality safety, and to promote stable development. Larsson et al. [198] discovered that a lack of contact with external experts is one of the barriers for small enterprises to realize expansion. Successful enterprises are more inclined to adopt professional suggestions. A social relationship between entrepreneurs and technical resource owners can facilitate knowledge learning and transfer of enterprises and the effective integration of the internal and external technical resources of enterprises. Therefore, technological social capital can not only relieve the constraint of the limitation of internal resources of enterprises, but also reduce R&D cost and improve the innovation speed of enterprises [194], so as to improve the corporate performance.

Thus the following hypotheses are proposed:

Hypothesis 5-3a: technological social network scale has positive impact on corporate performance, namely, the technological social network scale has positive impact on the economic performance and social performance of an enterprise.

Hypothesis5-3b: technological social network intensity has positive impact on corporate performance, namely, the technological social network intensity has positive impact on the economic performance and social performance of an enterprise.

5.3 Research design

5.3.1 Research sample and data source

This study selected 178 nanotechnology companies registered in China as the sample all passed the “high-tech enterprises review,” and adopts the data acquisition mode of combining a telephone and network survey because of time pressures. The data obtained from such survey modes can be retained only through mutual verification. Effective samples obtained were 87 Nano-technology enterprises, including those in information, energy, environmental protection, biomedical, manufacturing, national defense and other fields. SPSS and Excel are used as the statistical analysis tools. The reason for adopting the different data acquisition modes from those in previous chapters is to prevent possible system deviation. Of those collected, 32 sample enterprises are from relatively developed regions such as Shanghai, Zhejiang, Guangdong, Jiangsu, Tianjin, Beijing, Fujian, Shandong, etc., accounting for 36.8%, while the other 57 enterprises are distributed in other regions, accounting for 63.2%. In the aspect of ownership pattern, there are 35 state-owned enterprises, accounting for 40.2% of the total samples, and 52 private enterprises, accounting for 59.8%. Private enterprises are more than state-owned enterprises in all Nano-technology companies, which indicates that along with the development of China's economy and progress of social reform, the quality of private enterprises has been improved fundamentally and they have become the indispensable main force for economic development.

5.3.2 Variable design

Dependent variables

This study adopts net profit to reflect the enterprise's profitability and uses the natural logarithm of net profit in data analysis. When measuring the social performance of nanotechnology enterprises, we employ the prime operating revenue to measure the enterprise's social performance approximately. Considering the hysteresis effect of the impact of social capital, we adopt the data of prime operating revenue in 2013 and use the natural logarithmic form in data analysis.

Independent variables

Corporate social capital depends on social network, while social network can be woven by the contact and cooperation between top manager groups in enterprises and external subjects, or be constructed by the interaction between enterprises and other economic organizations. Therefore, corporate social capital can be measured not only by the replacement of social capital of corporate top managers, but also as corporate social capital of economic organizations (refer to Table 14).

Social capital type	Network scale	Network intensity
Commercial social capital	Number of top managers with work experience in other enterprises	As to any top manager takes office in international or national industry association, or serves as the president of provincial-level industry association, the assignment shall be 1, and other assignments shall be 0.
Political social capital	Number of top managers with work experience in the government and relevant government departments or with military service experience	Political identity such as NPC member or CPPCC member shall be national-level assignment which is 1, and other assignments shall be 0
Technological social capital	Number of colleges, universities and scientific research institutions which the enterprise once cooperated with	Subsidy amount for technological innovation projects

Table 14 Measurement Indexes of the Social Capital of Nanotechnology Enterprises

(1) Corporate commercial social capital

The measurement of corporate commercial social capital shall be carried out in 2 aspects, namely, commercial network scale, which represents the universality of commercial social capital, and commercial network intensity, which represents the strength of the relation between enterprises and commercial partners. As to the former, this study has referred to the measurement of the horizontal relationship network carried out by Sun, et al., [36] and can be measured by the number of top managers with work experience in other enterprises. As to the latter, with reference to the measurement of social capital by virtue of the relationship with industry association carried out by Chen, et al. [199], the network intensity of an enterprise can be reflected by whether any top manager of an enterprise once served as or now serves as the leader of an international-level or national-level industry association through variable assignment, since the leader of industry associations can deliver various types of information to the peer, including excellent operating performance, good social reputation and wide popularity of the enterprise. The maximum value of the index in corporate top managers is used to represent the enterprise's network intensity. The assignment for taking office in an international-level or national-level industry association in the past or at present and serving as the president of provincial-level industry association shall be 1, and other assignments shall be 0.

(2) Corporate political social capital

Corporate political social capital can be measured from the perspective of the political network scale and political network intensity. Work experience in governmental departments enables the top managers to have certain political resources. As to the measurement of the political network scale, this study adopts the total number of top managers taking office in governmental departments and governmental relevant departments in the past or at present, or with military service experience disclosed to reflect the political network scale. As to the measurement of political network intensity, this study adopts the top manager's highest political identity as an NPC member or CPPCC member to reflect the strength of political connection possessed by the enterprise. Political identities as an NPC member or CPPCC member in sample enterprises are generally divided into the national level, provincial level, municipal level, etc. By reference to the assignment by virtue of "whether having political identity" carried out by Niessen, et al., this study carries out assignment by virtue of whether having the political identity as an NPC member or CPPCC member. In case of any political identity, the assignment shall be 1. Otherwise the assignment shall be 0 [200].

(3) Corporate technological social capital

When measuring the network scale of technological social capital, technological cooperation between enterprises will not be considered to avoid confusion with commercial social capital. The cooperation degree between enterprises and scientific research institutions can reflect the technological network scale of technological social capital, while cooperation degree shall be embodied by the quantity of cooperation projects and the cooperation amount.

Technological network scale of an enterprise can be measured by the quantity of colleges, universities and scientific research institutions that the enterprise has cooperated with. The natural logarithm of the amount of governmental subsidies for technological innovation projects of primary businesses can serve as an indirect standard to measure the technological network intensity indirectly.

Control variables

This chapter has carried out control on relevant variables, which may influence corporate performance as follows:

Region: according to the overall order of all provinces and regions in China in 2007 for the process of marketization carried out by Fan, Wang and Zhu, Shanghai, Zhejiang, Guangdong, Jiangsu, Tianjin, Beijing, Fujian and Shandong ranking in the top eight are developed regions and in late transitional period with the code of 1, while other provinces and regions are underdeveloped areas and in the middle transitional period with the code of 0;

Ownership pattern: the code of state-owned enterprises and private enterprises shall be 1 and 0 respectively; (contrary to the previous statement)

Type of leading Nano-technology enterprises: in case they are national level, the code shall be 1, otherwise the code is 0;

Industry: assignment for farming, forestry, animal husbandry and fishery shall be 1, and assignment for processing and manufacturing industry shall be 0;

Age of foundation: surviving years from the foundation date of the enterprise or official renaming date to 2014.

5.4 Data analysis and results

5.4.1 Correlation analysis

According to the Pearson correlation coefficient of each dimension of corporate social capital (please refer to Table 15), social capital has a positive correlation with overall corporate performance. The profit and prime operating revenue have a relatively strong positive correlation with political network intensity and the technological network scale. In addition, technological network intensity has significant positive effects on prime operating revenue only, while commercial social capital has a relatively weak correlation with corporate performance and does not pass the significance test.

	Variables	1	2	3	4	5	6	7	8
1	Political network scale	1							
2	Political network intensity	0.005	1						
3	Technological network scale	0.042	0.018	1					
4	Technological network intensity	-0.143	0.024	-0.051	1				
5	Commercial network scale	0.065	-0.028	0.000	-0.110	1			
6	Commercial network intensity	-0.128	0.004	-0.092	-0.101	-0.059	1		
7	Profit NP	-0.035	0.298**	-0.48	-0.008	0.094	-0.041	1	
8	Prime operating revenue	-0.091	0.297**	-0.055	0.361**	-0.105	0.068	0.182	1

Note: N = 87; * represents that it is significant in the level of 0.1 (two-tailed test); ** represents that it is significant in the level of 0.05; *** represents that it is significant in the level of 0.01 (two-tailed test).

TABLE 15 PEARSON CORRELATION COEFFICIENT OF MAJOR VARIABLES

5.4.2 Multivariable linear regression analysis

To analyse the relationship between social capital and corporate performance further, this study has adopted the multivariable linear regression method and established two groups of regression models—social capital and net profit and social capital and prime operating revenue for analysis. DW test values of both regression models approach 2, which indicates that regression models do not have an obvious autocorrelation. Variance inflation factors (VIF) of both models are 1-1.5, which shows that the models do not have the multi-collinearity problem. Therefore, the results of the regression model are reliable. F values of Model 1 and Model 2 are 1.102 and 2.994 respectively, and have passed the significance test, which indicates that social capital can explain both economic performance and social performance of the enterprise. The industry of model 2 in control variables has a significant negative correlation with prime operating revenue, and other control variables do not have a significant correlation with the corporate performance.

	Model 1 (net profit)		Model 2 (prime operating revenue)	
	β	t	β	t
Enterprise nature	-0.095	-0.317	0.286	1.193
Region	0.144	0.515	0.069	0.307
le-type				
Type of leading enterprises (le-type)	0.063	0.082	0.964	1.577
AF Age of foundation	-0.025	-1.248	0.016	1.012
Political network scale	-0.108	-0.470	-0.158	-0.859
Political network intensity	1.248**	2.587	1.017**	2.632
Technological network scale	-0.012	-0.483	-0.016	-0.831
Technological network intensity	-0.013	-0.214	0.151***	3.010
Commercial network scale	0.066	0.946	-0.023	-0.405
Commercial network intensity	-0.139	-0.370	0.225	0.749
F value	1.102		2.994	
Adjusted R^2	0.012		0.188	

Note: N = 87; + represents P<0.1; * represents P<0.05; ** represents P<0.01; *** represents P<0.001.

TABLE 16 REGRESSION RESULT OF CORPORATE SOCIAL CAPITAL OF NANOTECHNOLOGY ENTERPRISES AND CORPORATE PERFORMANCE

(1) Commercial social capital and corporate performance

The regression coefficient of commercial social capital in the model shows that commercial network scale does not have significant effects on net profit and prime operating revenue, which indicates that commercial network scale does not have a significant correlation with the economic or social performance of an enterprise. Thus, hypothesis 5-1a is wrong.

Commercial network intensity has an insignificant positive correlation with net profit and prime operating revenue, and hypothesis 5-1b is wrong. Such a result is the same with that of Sun, et al. [36] in essence. It is because most Nano-technology enterprises either have been established for a long time or have been transformed from relevant industries through upgrading, the market share or market sales territory of their commodity is relatively stable, commercial partners such as suppliers, retailers, etc. are also stable, commercial network differentiation of enterprises is limited, and commercial social capital does not have significant effects on the performance differentiation of such enterprise group. In other words, the R&D of an enterprise shall be based on market demand. Once the principle is violated, the R&D risk will be increased greatly.

(2) Political social capital and corporate performance

We can see from the model that the political social network scale has an insignificant correlation with both the economic and social performance of an enterprise, and hypothesis 5-2a is invalid. The political network intensity has a significant positive correlation with the profit (β=1.248, $P<0.05$) and social performance (β =1.017, $P<0.1$). Thus, hypothesis 5-2b has been verified.

Political network scale does not have significant effects on corporate performance, while political network intensity has significant effects on corporate performance, which indicates that a “deep relationship” or “deep background” is more favourable for an enterprise to gain assistance from governmental departments than a “shallow relationship.”

In the relationship-oriented social environment of China, if any Nano-technology enterprises want to obtain resources from the government, they must establish a good relationship with them. Once the relationship is stronger, they can obtain more supporting resources from the government.

(3) Technological social capital and corporate performance

The regression coefficient shows that the technological network scale has a positive correlation with both net profit and prime operating revenue, but the significance test is not passed. Such a result indicates that the technological network scale has insignificant effects on both the economic and social performance of an enterprise, and hypothesis 5-3a is not verified. However, though technological network intensity does not have significant influences on the net profit, it has significant positive effects on prime operating revenue ($\beta = 0.151$, $P<0.01$). This demonstrates that technological network intensity has limited influences on economic performance, but significant impacts on social performance of an enterprise, and hypothesis 5-3b is supported partially. This may indicate that Nano-technology has relatively strong dependence on the technology, and the promotion of technological network intensity is favourable for Nano-technology enterprises to improve the R&D success rate and reduce the risks. It also shows that the technological cooperation depth of Nano-technology enterprises and scientific research institutions is more important than cooperation width. In reality, some enterprises may declare that they are cooperating with certain colleges and universities or scientific research institutions for the purpose of certain benefits. Such "modifying cooperation" cannot promote the corporate performance truly and what makes true contribution to the performance is long-term deep technological cooperation with colleges and universities or scientific research institutions.

5.5 Conclusion

Empirical research shows that commercial social capital does not have significant effects on the correlation coefficient of corporate performance; political network intensity in political social capital has positive effects on corporate performance; technological social capital has a positive correlation with corporate performance, but technological network scale does not have significant influences on corporate performance, and technological network intensity has significant positive effects on the social performance of an enterprise.

In terms of the operators of Nano-technology enterprises, on the one hand, Nano-technology enterprises shall cultivate and develop corporate social capital positively and utilize social capital to obtain resources required for enterprise development to resist unpredictable risks, so as to improve the corporate performance. Political social capital and technological social capital must be highlighted and maintained by Nano-technology enterprises at the present stage, but the cultivation and development of commercial social capital shall be paid particular emphasis according to the development stages of the enterprises. On the other hand, it is required to strengthen the cultivation of "strong tie" and "deep background." Some literature emphasized that corporate performance can be promoted as long as "there is any tie." But according to this study, what works truly on corporate performance is the quality of the tie, namely, "strong tie" or "deep background." Operators of Nano-technology enterprises shall pay more attention to cultivating the intensity of the social network relationship rather than only building a "superficial" social relationship.

Chapter VI

The Case study of Social Capital, R&D and Firm Performance

According to the ideas of case research experts Eisenhardt and Graebner [139], case research is an extremely objective method, which is closer to and more compliable with reality, and also a rigorous empirical approach. They have introduced two different case analysis approaches in detail, namely, phenomenon-driven research and theory-driven research. Phenomenon-driven research refers to trying to establish a theory from the phenomenon in the condition of lacking a feasible theory, while theory-driven research requires the author to establish a frame by gripping existing theories closely and then exploring vigorous qualitative data to verify and develop the theory. It is favourable for carrying out complicated theoretical research which quantitative analysis cannot be used for. This chapter adopts theory-driven research.

After the research and discussions of the previous three chapters, this chapter seeks for appropriate case research object. Eisenhardt and Graebner [139] point out that the object of a single case study shall be an unordinary and extreme case, which is more favourable for deep theoretical exploration. To improve the quality and reliability of the argument of case research, the research has made reasonable and comprehensive use of the materials of various sources and carried out repeated checks for the data acquired to decrease research error. This chapter has adopted some of the enterprises in the nano-calcium carbonate industry in China as the research subjects. The nano-calcium carbonate industry has developed very rapidly in the past decade in China. By virtue of this case, this chapter has analysed the compliance of the conclusions of the previous three chapters in the industry. We discover that the conclusion is not completely identical with the conclusions reached previously and there are some abnormal phenomena. In addition, we have also analysed the deep-level reasons for this.

6.1 Case Analysis

Introduction of industry background:

Calcium carbonate is one kind of inorganic chemical material and the main component of shells of marine organisms, snails, pearls, eggshells [141] and limestone. There are three kinds of crystal forms of calcium carbonate: calcite, aragonite and vaterite. The calcite belongs to the trigonal system of which the morphology is rhomb. The calcite has the most thermodynamic stability. The vaterite belongs to the hexagonal system of which the morphology is spherical. The vaterite is a thermodynamic instability system. The aragonite belongs to orthorhombic system of which the morphology is needle. The thermodynamic stability of aragonite is between that of the calcite and vaterite.[142][143][144]. The atomic crystal structure of calcite calcium carbonate is shown in Figure 3. The red ball is the oxygen atom, the blue ball is the calcium atom and the white one is the carbon atom.

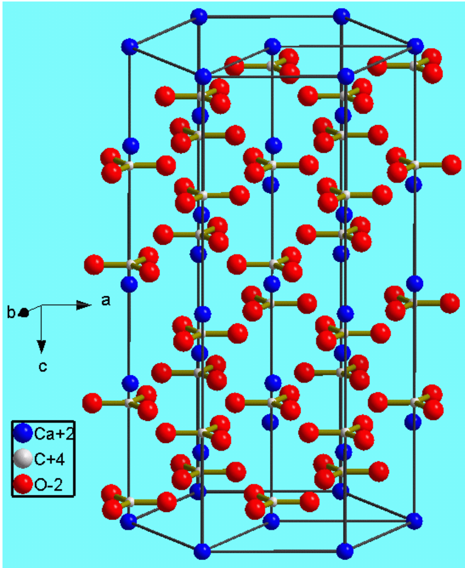

Figure 3 The crystal structure of calcite calcium carbonate [141]

Nano-calcium carbonate is also called super fine calcium carbonate with a standard name of calcium carbonate superfine powder. The typical sizes of the calcium carbonate particles vary from around 10nm to 50nm, as shown in Figure 4 of the Electron Micrograph of nano-calcium carbonate reported by Yu et al [145]. The main manufacturing processes of the calcium carbonate are shown in Figure 5. The quality of the products is generally determined by the reaction temperatures, gas flow and the stirring speed. In China, most nano-calcium carbonates are produced by using high-gravity carbonization technology, as will be discussed in the following sections.

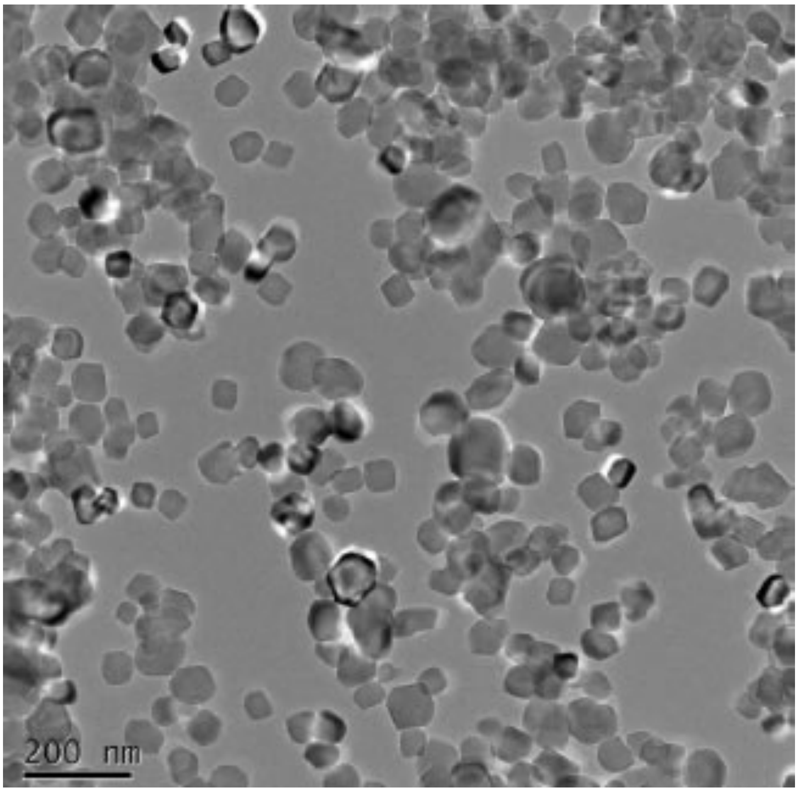

FIGURE 4 ELECTRON MICROGRAPH OF NANO-CALCIUM CARBONATE[146]

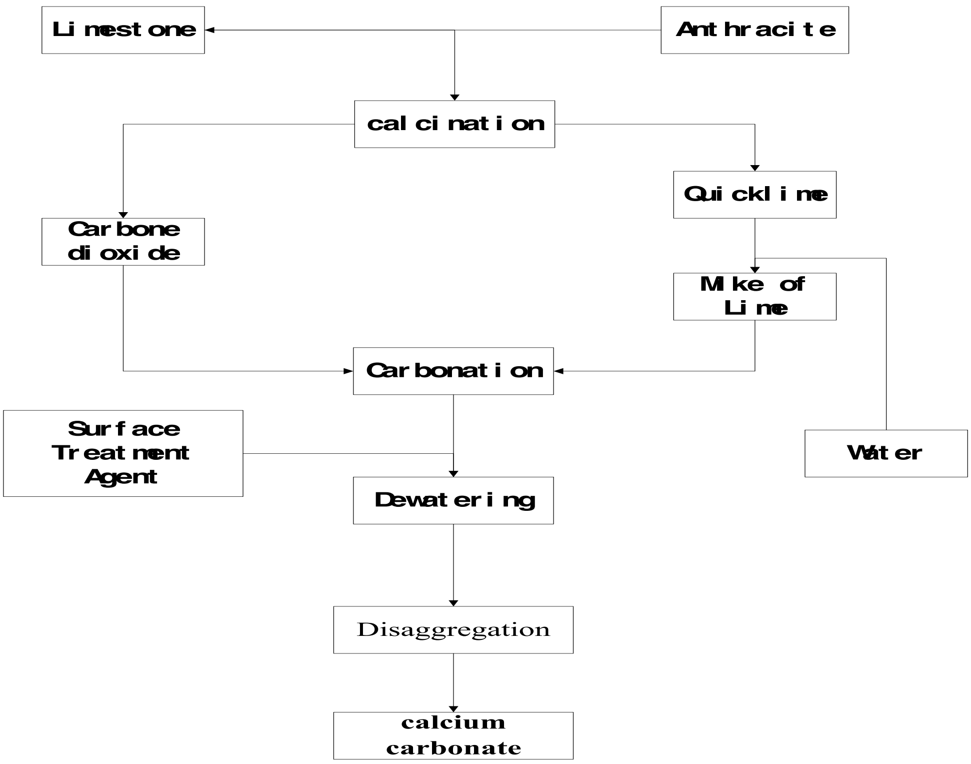

FIGURE 5 MANUFACTURING PROCESS OF THE CALCIUM CARBONATE [147]

As important inorganic industrial chemicals, calcium carbonates have a wide range of applications. Because of the size effects, the nano-calcium carbonates could have superior properties compared with that of normal calcium carbonate. One of the main applications of calcium carbonates is in the construction industry, either as a building material or limestone aggregate for road building or as an ingredient of cement or as the starting material for the preparation of a builder's lime by burning in a kiln. In ancient times, people used limestone to build walls and houses. Calcium carbonate is also used in the purification of iron from iron ore in a blast furnace. The carbonate is calcined *in situ* to give calcium oxide, which forms a slag with various impurities and separates from the purified iron [141]. Calcium carbonate is widely used as an extender in paints, sealants, and decorating fillers [141].

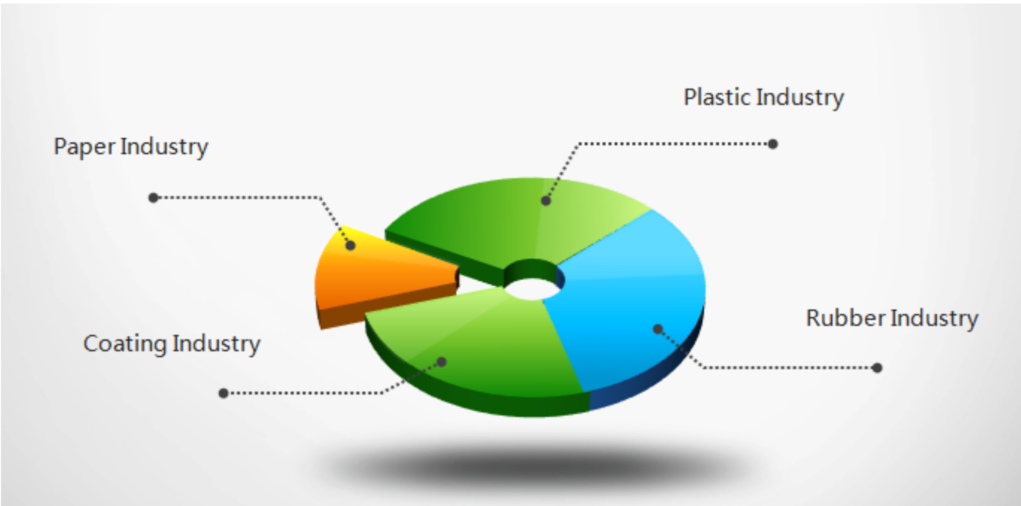

FIGURE 6 THE APPLICATION DOMAIN OF THE NANO-CALCIUM CARBONATES

The nano-calcium carbonates have also been widely used in paper, plastic, coating, rubber and other industries [145][146][148][149][150] as shown in Figure 6. Among these, the most mature industry for the application of nano-calcium carbonate is the plastics industry. The nano-calcium carbonate is mainly applied to top-grade plastic products, since it can improve the rheological property of parent plastics and enhance the moldability. When used as a plastic filler, it can toughen and reinforce the plastics, improve the bending strength and flexural modulus, heat deflection temperature and dimensional stability of the plastics, and provide the thermal hysteresis property of the plastics [151][152][153]. The notch impact strength of HDPE resin was increased up to about seven times when doped with 20% calcium carbonate, as shown in Figure 7 [151]. When nano-calcium carbonate is used in ink products, it can show excellent dispersity and transparency, good gloss, remarkable ink absorption and high aridity. When the nano-calcium carbonate is used as ink filler in resin-type ink, the product will have various advantages such as good stability, high glossiness, strong adaptability, etc. without any influence on the drying property of printing ink [147].

Figure 8 shows the effect of nano-$CaCO_3$ particles on the mechanical properties of nano-CaCO3/epoxy/carbon fibres composites. The performance indicators have been increased by about 20% when the appropriate quantity of nano-$CaCO_3$ was doped [153]. Figure 9 shows the typical compressive force–displacement curves of the pure epoxy cast and nano-$CaCO_3$/epoxy cast. The figure suggests that the specimens, with the content of nano-CaCO3 particles increasing from 4 wt.% to 8 wt.%, have an obvious yielding behaviour and vibration [153].

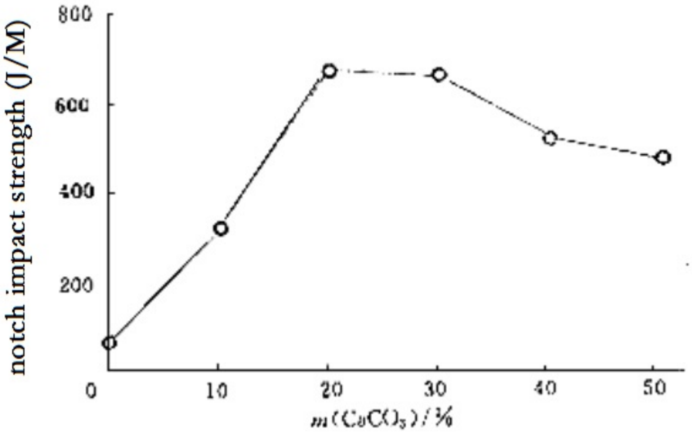

FIGURE 7 THE RELATIONSHIP BETWEEN THE NOTCH IMPACT STRENGTH OF HDPE RESIN AND THE ADDITIVE AMOUNT OF CALCIUM CARBONATE [151]

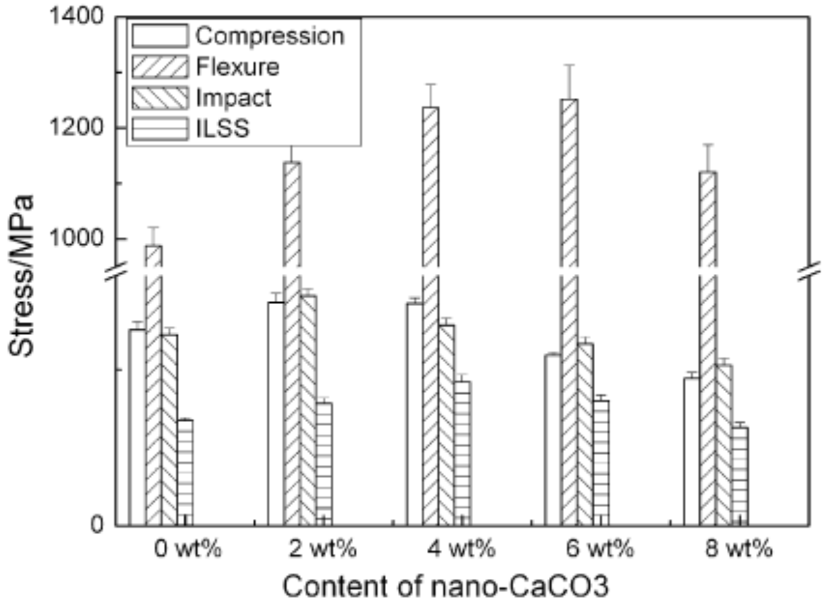

Figure 8 Mechanical properties of nano-CaCO3/epoxy/carbon fibres composites[153]

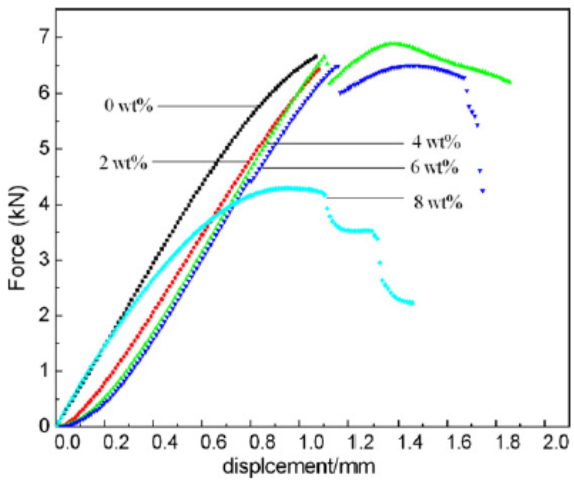

Figure 9 Typical force–displacement curve of pure and nano-CaCO3/epoxy cast.[153]

At present, there are over 40 nano-calcium carbonate enterprises in China, which are mainly distributed in Guangdong, Guangxi, Jiangsu, Anhui, Zhejiang, Jiangxi, etc. Enterprises in Guangdong Province account for about 70% of the total enterprises in China. Among the enterprises of relatively large scale, only Jiawei Chemical Group Co., Ltd. can realize an annual output of about 100,000t. As to other enterprises, annual output is generally about 10,000-30,000t. Total output of nano-calcium carbonate in China is about 800,000t/year [154]. There are different grades in nano-calcium carbonate products which are generally classified according to the application industry and particle size. Now, some top-grade nano-calcium carbonate enterprises in China still need to import products from Japan, the United States and Europe [155]. The price of imported products is about 2-3 times of that of domestic products. The products of the highest price are from the Oriental Shiraishi Corporation, established at the beginning of last century with the price of RMB 11000/t, and are mainly used as filler for top-grade offset ink. However, the highest price of domestic nano-calcium carbonate exclusively used for the ink is RMB 4000/t. The next is the product produced by America Solvay with the price of RMB 6000/t and this product is mainly applied to fill in silicone sealant used in architecture. Nevertheless, the corresponding domestic product can be only a middle-grade product with the price of RMB 1600-3000/t and the highest price of RMB 3500/t [155]. Thus we can see that there is a large gap between domestic products and foreign products in the aspect of quality and price. The nano-calcium carbonate industry was started late in China and ordinary light calcium carbonate was developed from the 1970s or 1980s, while nano-calcium carbonate was developed at the beginning of the 1990s and developed rapidly after 2000 [156]. The amount of imported nano-calcium carbonate products has been reduced step by step since 2003 and is decreased progressively by about 30% annually. At present, the imported nano-calcium carbonate products in the domestic market mainly centre on high-end products, and the market share of the imported products is less than 5% by measurement in the aspect of quantity. By 2005, there were about a dozen nano-calcium carbonate enterprises in China, rising from 1 or 2 such enterprises at the beginning, increasing by 20%-30% on average in recent years [156]. The nano-calcium carbonate industry is one of the representative industries in the Nano-technology industry in China. We have investigated 6 enterprises in the industry to analyse in comparison the compliance degree of some conclusions in the previous three chapters with the actual conditions of such enterprises through combining the current situation of the nano-calcium carbonate industry. In this way, we can learn about the current development situation, problems and prospects of the Nano-technology industry in China better. In this process, we discover some unrevealed and significant factors influencing industrial development and the deviation of the theory from the reality.

6.2 Analysis Results of the Previous Several Chapters and Current Development Situation of the Industry:

In Chapter III, we have proposed the hypothesis that political influence has adverse effects on technological innovation investment. In the past decade, the nano-calcium carbonate industry in China has developed rapidly. In the 6 enterprises we have carried out investigations on, top managers of 4 of the enterprises have the political influence defined in Chapter III. Besides, we also discover that the 4 enterprises are also those with relatively high annual output among the investigated enterprises. After deep investigation on the possible relationship between the two, we discover some factors at a deeper level, which may influence the development of the nano-calcium carbonate industry. These factors may widely exist in other nanotechnology industries in China.

A. Near-sightedness of China's capital. Overall, the Chinese manufacturing industry was undoubtedly in a rapid development period in the past decade, and the return on capital is far higher than possible risks with the effects of various favourable factors [157]. In such a condition, entrepreneurs are not willing to invest a large amount of funds in technological innovation that has high risks, as it is focused on the future. They were more likely to expand the scale of production [158].

B. Influence of the local government. Local government guided the investment promotion work with the thinking of GDP in the past decade [159]. Local government is more willing to expand enterprise productivity, improve regional GDP and absorb more employees. The entrepreneurs also generally want to make the enterprise larger and stronger as quickly as possible. They are willing to rely on governmental power to make an investment to expand the reproduction scale through bank loans and with the profits earned previously [160].

C. With common impacts of the above two factors, except if there is any low-risk, predictable, low-investment and high-return technological breakthrough, enterprises will develop along the way of rapid expansion of low-level product production line. However, along with the relatively often repeated construction of the low-technology-level process and equipment in China recently, the productivity of nano-calcium carbonate is excessive. The designed productivity of some companies has exceeded 200,000t, but the operating rate is less than 50% and they still carry out low-level expansion [161]. Besides, they do not carry out factory planning with an eye on the whole country and planning is only dominated by the local government of Guangdong and Guangxi. This has facilitated the further deterioration of the market competition environment. Since the nano-calcium carbonate industry did not develop properly, the technology and equipment used are at different levels. The good and poor products are mixed up in the market. Some nano-calcium carbonate enterprises mix superfine heavy calcium carbonate in the product and sell the product in the name of nano-calcium carbonate in the market, and the factory entry price of some products is less than RMB 1200/t. In this case the overall quality level of the nano-calcium carbonate market is decreased. In addition, due to governmental support, the out-dated production capacity cannot be eliminated by the market rapidly, but is supported with great effort through dependence on external funds and such an enterprise becomes a zombie company. It will bring a relatively large risk to these external funds again.

With the impact of these factors, the hypothesis that political influence has adverse effects on technological innovation investment from Chapter III has been verified. Besides, the “crowding out effect” described in Chapter III and the above factors are interwoven together with the phenomenon of mutual enhancement. Logically, an entrepreneur’s expectations for technological investment shall be low risk, low investment and high return. In the case of no forerunners to refer to, the R&D personnel of an enterprise cannot have any guarantee to meet the expectations of the boss and generally adopt two means to cope with such challenges: 1. Cooperate with scientific research institutions to carry out original research because researchers in scientific research institutions have the expertise, while the enterprise attaches great importance to technologies that can be put into practical use. Though their targets are not identical completely, they can take what they need to realize the win-win situation; 2. Continue in the direction that has been approved to be feasible. In this way, the expectations of low risk and high return can be satisfied partly, but the existing risk lies in that R&D cannot be always successful due to technical difficulty. The investment needed could be very high as well. However, it might be the optimal solution that can be found. With their great efforts, the nano-calcium carbonate enterprises have obtained some achievements in terms of technological promotion, but all these achievements are technological breakthroughs obtained by virtue of the two approaches, without exception.

A. The grinding equipment. Due to a lack of good depolymerizing equipment, the processing performance of nano-calcium carbonate products was poor before 1995. Some application enterprises are even more like to use ordinary light calcium carbonate. Some grinding equipment has been imported into China from Japan and Germany. This grinding equipment has been improved and developed greatly in China, with intellectual property developed. Compared to original imported equipment, the productivity is higher, while the costs are lower [162].

B. Synthesis control technology. The key for the production of nano-calcium carbonate products is carbonization and crystallization control and dispersion technologies [163]. The quality of crystallization control technology can decide the particle size, uniformity, etc. of products, and the dispersion technology is used to disperse nano-particles sufficiently in a microcosmic condition, reduce the specific surface energy of crystal particles, and mitigate the agglomeration and coagulation of crystal particles, so as to give rise to the characteristics of nano-particles to the largest extent. Crystallization control technology has experienced considerable development in China in recent years. For example, technologies such as high-speed shearing emulsification carbonization, high-gravity carbonization, ultrasonic cavitation, etc. have reached a relatively high level. One of the leaders in China in this area is Professor Chen Jianfeng of Beijing University of Chemical Technology. However, the carbonization process in China is batch-type carbonization. The smaller the batch processing amount of carbonization is, the more uniform are the particle sizes of the product distributed. In addition, there must be certain differences between two batches of carbonized slurries, and the storage tank of a relatively large volume is generally adopted for homogenizing treatment. However, internationally advanced carbonization technology adopts the continuous highly shearing emulsification carbonization process and has realized industrialization. Supported by automatic control technology, the quality control stability of products is obviously higher than domestic technology. For carbonization control technology, the key process during carbonization reaction is gas-liquid mixing. One of the key tasks is to control the particle size and the size distribution of crystal particles by the control of the reaction temperatures. The temperature is controlled in a relatively low level, generally lower than 28℃, so that the energy consumption for controlling carbonization process can be increased. Such technologies as stirring carbonization, atomizing carbonization, high-gravity carbonization, highly shearing emulsification carbonization, membrane separation carbonization (developed by cooperation between an enterprise and Tsinghua University in 2006), etc. appear in the late period [166]. All these technologies have an improved gas-liquid mixing effect and promoted contact surface area and the homogenizing degree of gas-liquid reaction system greatly. It is unnecessary to control the temperature of the reaction process in this condition in a relatively low range. At present, by taking some substances, such as organic dispersing agent, inorganic high-valence electrolyte, etc. as a crystal form control agent, 60-80nm crystal particles can be prepared with the carbonization temperature of 25-35℃. Thus the control cost is reduced [165].

C. Surface treatment technology：There is still a certain gap between domestic enterprises and foreign enterprises in the aspect of surface treatment process and equipment [164]. Domestic enterprises fall behind mainly in the aspect of application technologies and equipment manufacturing technologies. Wet activated surface treatment agent mainly adopts stearic acid, coconut oil, etc. for surface treatment. Dry coating generally employs a titanate coupling agent as the activating agent with the treatment process dominated by normal temperature or warming batch-type coating treatment. Activating equipment is mainly dominated by conventional stirring and mixing equipment. A few enterprises have adopted relatively high rotating speeds—over 1400RPM, or use an emulsifying machine to carry out activation. Activating technology cannot achieve breakthroughs because China does not pay much attention to

R&D and application technologies. In-situ synthesis technology has not realized industrialization yet, but foreign enterprises have adopted the continuous carbonization and activation integrated equipment and realized in-situ synthesis truly. During the reaction process, the dispersing agent shall be injected quantitatively and stably, which can also serve as an activating agent for surface treatment. In-situ synthesized activated calcium carbonate particles can form more chemical bonds with the active agent and the combination will be more secure, so that calcium carbonate particles can show good hydrophobic property and lower surface energy.

In the interviews participants[202] also reflected that since the products have become more and more high-end, the past approaches also need to reform step by step to cope with higher and higher R&D difficulty [161]. Besides, larger funds investment is also needed. Large-scale enterprises will have relatively great advantages undoubtedly. For example, the most critical for product analysis and test is particle size and morphology. However, very few domestic enterprises have electron microscopic detection ability, and only a few have the ability of particle size analysis and specific surface area BET measurement. Some enterprises can only represent the change of particle size of products by specific surface area tested through the penetrant method and it is extremely rough and easy to cause confusion. When the test value is larger than $7m^2/g$, the data fluctuates extremely unstably and this is mainly because the agglomeration is enhanced along with the reduction of the primary particle size of products, especially when the average particle size is less than 60nm. In the same production condition, secondary particle size will be increased and the impact of breaking plant and classifying equipment on the change of particle size of products increases, thus salutatory changes of the data in the test results occur and the data loses significance. During the investigation process, we discover that there are great differences among all enterprises in terms of the testing instrument. There are small enterprises which do not possess any middle-end or high-end testing instruments and carry out production only by virtue of experience in most conditions. In addition, there are also enterprises which possess transmission electron microscopes, BET specific surface area analyser, Haake rheometer, laser particle detector, moisture automatic tester, etc. and can carry out tests for products at any time during the production process.

In Chapter IV, the most doubtful problem was that the proportion of technical staff has negative correlation with the patents has also been answered by front-line technical staff in these six enterprises [203]. Though the annual output value of the 6 interviewed enterprises has a relatively large difference, the proportion of technical staff does not have such a wide gap. At first, technical staff can be divided into R&D personnel who shall be responsible for the R&D of new technologies and technical support personnel who shall guarantee the successful production. Though they are not distinguished clearly in some conditions, technical staff may shoulder both posts. However, in statistical analysis, it is not good to confuse them and such conditions shall be improved. Besides, the government encourages enterprises to apply for patents by means of direct and indirect financial support, and therefore enterprises will apply for some patents every year for external publicity. However, whether the patent is feasible technically or is favourable for product upgrading of enterprises is not the emphasis. On this occasion, in case the number of patents applied for by an enterprise every year is relatively small (less than 10-15 patents/year), it may not always reflect the R&D achievements.

Other conclusions from Chapter IV and Chapter V have been verified in the interview process. Particularly, the impact of “strong ties” on corporate performance in Chapter V have been verified by the living example. During the development process of the nano-calcium carbonate industry in China, there were three major technological breakthroughs due to cooperation between enterprises and scientific research institutions: 1) The high-gravity nano-calcium carbonate production technology researched under the leadership of Professor Chen Jianfeng of Beijing University of Technology in 2000; 2) The kettle-type stirring crystal form control agent injection carbonization technology of East China University of Science and Technology; and 3) The technology of producing nano-calcium carbonate by membrane dispersion micro-structural reactor developed by virtue of cooperation between Shandong Shengda Technological Development Co., Ltd. and Tsinghua University in 2006. All these technological breakthroughs are the results of “strong cooperation” between enterprises and scientific research institutions.

Evaluation and summary:

Through interview with the 6 nano-calcium carbonate enterprises, we have further promoted and verified some of the conclusions reached in previous chapters, and analysed the reasons for deviation simultaneously. My research found that for Nano-technology enterprises in China, the corporate social capital and entrepreneurial social capital are indispensable resources for their development, playing a far more important role than that in any other industries.

Chapter VII

Summary & Future Work

This study has carried out comprehensive and systematic analysis and quantitative research on the mechanism of corporate social capital influencing the technological innovation performance of Chinese Nano-technology and related enterprises. In this chapter, the research work presented in the above chapters is summarized, main conclusions, theoretical and practical significances, and innovative points of the research are elaborated upon, the shortages of the research on this basis are explained, and directions for the future research are provided.

7.1 Main Research Conclusions

The acceleration of the integration of the global economy has put forward new challenges for enterprise technological innovation, and knowledge acquisition and utilization have become the most important source of technological innovation. The acquisition of new knowledge cannot be separated from contact with the external environment, while the digestion and utilization of knowledge are inseparable from the contact among relevant functional departments inside the enterprise. According to the practice of enterprise technological innovation and existing theoretical research, the key for an enterprise to improve its technological innovation level is to obtain and utilize knowledge effectively through internal and external social capital. With Chinese enterprises as the research subject, this work has studied in detail the relationships between corporate social capital and technological innovation performance comprehensively and systematically on the basis of proposing and verifying the measurement dimensions of corporate social capital, and also analysed different impacts of the social capital of top managers and core R&D members on enterprise technological innovation and entrepreneurial performance. The main research conclusions have been summarized in Table 17 as follows:

	Chapter III	Chapter IV	Chapter V
Dependent variables (result)	R&D investment Proportion of technical staffs	Number of patents applied by enterprises	Profit before taxation (NP) (Logarithm) Operating income
Explanatory variables (reason)	Political influence	Proportion of technical staffs (negative correlation) Proportion of highly-education employees (positive correlation) Salary of top managers (positive correlation) Technical background of top managers (positive correlation) Tenure of top managers (positive correlation) Age of top managers (negative correlation) R&D expenditure (positive correlation)	Political network scale Political network intensity Technological network scale Technological network intensity Commercial network scale Commercial network intensity
Control variables	Enterprise scale Profitability	Scale Age of foundation	Region State-owned or

	State-owned or non-state-owned High-tech and non-high-tech Region		non-state-owned Age of foundation Whether it's national-level leading enterprise

TABLE 17 MAIN CONCLUSIONS

This work has found that the political influence of the top managers has a negative correlation with technological innovation and investment. Since the enterprise's resources are limited, when entrepreneurs are keen to seek political influence, they will reduce investment in technological innovation, so that the social capital has a "crowding out effect" on technological innovation. The conclusion that enterprises seeking social capital will reduce investment in technological innovation tells us that an enterprise will choose technological innovation only when the earnings of technological innovation are higher than those of social capital. According to endogenous growth theory, the long-term increase of an enterprise and even a country is inseparable from technological innovation. However, according to rent-seeking theory, fighting for political influence—the "rent" will distort the resources allocation and cause rent loss, so as to bring loss for the whole social welfare. To make enterprises dedicated to technological innovation, the government shall strengthen the system construction and reduce the "rent" available for enterprises by virtue of social capital to the greatest extent, so as to limit the crowding out effect of political influence on technological innovation. It also shows that there is a still long way to go for Chinese enterprises.

As to the impact of R&D investment and part of the corporate social capital on technological innovation, the educational level of employees and salary, technical background and tenure of top managers have significant positive correlations with enterprise's independent innovation. We have discovered that the test result of hypothesis H4-2 is opposite to what was expected, namely, that the proportion of technical staff has a negative correlation with independent innovation outputs. However, the proportion of highly-educated employees, and the technical background, salary, age and tenure of top managers have passed the significance test, thus all other hypotheses have been verified. In addition, from the perspective of the goodness-of-fit of the models, the effect of human capital investment on the independent innovation output of high-tech enterprises is slightly larger than that of R&D investment. In chapter 6, we have also analysed the deep-level reasons.

Our empirical research shows that commercial social capital does not have significant effects on the correlation coefficient of corporate performance; political network intensity in political social capital has positive effects on corporate performance; technological social capital has a positive correlation with corporate performance, but technological network scale does not have significant influence on corporate performance, and technological network intensity has significant positive effects on the social performance of an enterprise. The key quality of any relationships is a "strong tie" or "deep background." The proprietors of Nano-technology companies should pay more attention to cultivating the intensity of social network relationships.

7.2 Future Research

It is a new attempt to place Nano-technology enterprises as the research subject for discussing the relationship between corporate social capital and technological innovation performance. However, people have not reached a consensus in the definition of social capital so far, and therefore there is not uniform understanding on the definition of corporate social capital. This research only starts from the "structural dimension" and "relational dimension" of the social capital research. In this study, we define the connotation of corporate social capital as the range and quality of various social relationships established by the enterprise on the basis of trust and standard and the ability of obtaining external resources on this basis after combining the definitions of corporate social capital made by domestic and international related scholars. And we also divide corporate social capital into vertical relationship capital, horizontal relationship capital and social relationship capital.

From Chapters III to V, the factors of social capital have been quantified. However, social capital is a concept containing wide contents, and most can hardly be quantized digitally (such as trust), which is also the difficulty for subsequent research. They are, however, important to the enterprises and corporate performances. Social capital refers to the resources that are possessed by individuals or organizations in a social structure and can bring benefits for them. The carrier of social capital is the social network, which can be manifested in diverse patterns such as trust, standard, educational background, etc. One essence of social capital is that it is a kind of resource and the user, namely, the owner of social capital, can obtain benefit by utilizing such a resource. From the perspective of economics, such benefit can be direct profit, or indirect profit brought by reducing certain costs. For example, members in a specific relationship network have a relatively high trust degree. There must be a certain standard to maintain the network, and when internal transactions of this relationship network are carried out, an excessively high transaction cost to be paid during the market exchange process can be reduced. For the convenience of analysis, we divide corporate social capital into two parts, namely, internal corporate social capital and external corporate social capital. The former refers to an interpersonal relationship network established inside the enterprise on the basis of trust of enterprise members, which can facilitate the communication and coordination of all departments of the enterprise, so as to enhance the working efficiency and cohesion within the enterprise. The latter refers to the social network that exists outside the enterprise and is favourable for the enterprise to take in various scarce resources. Internal corporate social capital includes the social capital between ordinary employees, between ordinary employees and managers, and between managers. External corporate social capital includes the vertical tie of the enterprise, namely, the tie between enterprise and local governmental departments and subordinate enterprises or departments; and horizontal tie of the enterprise, namely, the tie between enterprise and other enterprises, scientific research institutions, colleges, universities, financial institutions, intermediary organizations and customers.

This research, on the basis of domestic and international related research and in combination with the definition of corporate social capital, has constructed the conceptual model and theoretical hypothesis of how an entrepreneur’s political influence affects the technological investment and how the technological innovation and part of the corporate social capital influence technological innovation performance from the perspective of resources necessary for enterprise technological innovation. Besides, it has also carried out profound analysis and study on the relations of explanatory variables and how enterprises can obtain external resources by improving the social capital. Though the whole model is not “black box,” relations between any two variables are still extremely vague and the research is also relatively rough. I would hope that it is understandable since the social capital theory has not appeared for a long time and also there are various special “relationship” factors in China.

It is a new attempt of the author to study enterprise technological innovation by use of social capital theory. After the empirical analysis on the part of Chinese enterprises, most of the conceptions have been verified. However, this research has not carried out profound analysis on the relations of explanatory variables and how the enterprises can obtain external resources by improving social capital. In my view, further research may include two methods: 1) Trying to quantify the factors that have not yet been quantified and then using linear regressions to find the correlation of factors; and 2) Using a new method like fuzzy theory to deal with difficult factors, which might bring new results. All these, however, are subjects for research in the future.

List of abbreviations

AF	Age of Foundation
BET	Brunauer, Emmett and Teller
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CEO	Chief Executive Officer
CPPCC	Chinese People's political Consultative Conference
D.W	Durbin Watson
GDP	Gross Domestic Product
HDPE	High Density Polyethylene
HR	Human Resource
IT	Information Technology
IC	Integrated Circuit
KBV	Knowledge-based View
NP	Net Profit
NPC	National People's Congress
OECD	Organization for Economic Co-operation and Development
R&D	Research and Development
RBV	Resource-based View
RMB	Chinese Currency
RPM	Revolutions per Minute
SASAC	State-owned Assets Supervision and Administration Commission of the State Council
SPSS	Statistical Package for Social Science
STD.DEV	Standard Deviation
VIF	Variance Inflation Factor

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