



Article Research on Collaborative Innovation Mode of Enterprise Group from the Perspective of Comprehensive Innovation Management

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Abstract: At present, collaborative innovation has become an integral part of corporate group strategy. However, there are few collaborative innovation research pieces focusing on corporate groups. This article takes Tus-Holdings, a model enterprise in the field of science and technology services, as the research object, uses case study methods, and systematically analyzes the corporate group's strategy, customers, R&D, management, finance, talent, and other factors from the strategic, business, and support levels under the framework of total innovation management research on the collaborative innovation model of management and the form of cooperative surplus. The research found that the collaborative innovation model is an important support for enterprise groups to build a comprehensive, collaborative innovation system; the internal collaborative innovation model of enterprise groups shows nonlinearity and diversity; collaborative surplus performance is closely related to the collaborative innovation mode, and different collaborative innovation modes will produce a different collaborative surplus. These research results have important theoretical value and practical significance for modern enterprise groups to correctly implement collaborative innovation strategy and improve the efficiency of collaborative innovation.

Keywords: total innovation; group enterprises; collaborative innovation model; cooperative surplus

1. Introduction

Under the background of open innovation, the complexity and integration of technological innovation have become increasingly intensified, and collaborative innovation has become an inevitable choice for the survival and development of enterprises [1,2]. Since the emergence of the enterprise organizational form represented by the Adam Smith nail factory, after more than 200 years of development, the enterprise organizational form has undergone many changes. The enterprise group formed with property rights as a link has become one of the most common and most dynamic organizational forms under the framework of the modern enterprise system and has become one of the important collaborative innovation forces. Enterprise groups can achieve performance improvement through collaborative innovation of the industry–university research model with scientific research institutions, governments, and other subjects. For example, research in the field of industry-university research has made rich achievements in the collaborative innovation mechanism, influencing factors and performance evaluation of enterprises, scientific research institutions, and governments [3–5], and can also rely on external innovation networks to obtain relevant innovation resources [6,7]. In addition to the above two ways, the enterprise group also realizes that different member enterprises within the group share specific 'resources', and can also rely on collaborative innovation to achieve the overall value greater than the sum of the value of each part, thereby enhancing the competitiveness of the enterprise group [8]. From the perspective of the network, the internal network



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Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). of an enterprise group is a strong relationship network, which can bring resource effects to member enterprises [9]. Further research finds that the internal network of enterprise groups has a significant role in promoting inward open innovation. In the practice of enterprise groups, a collaborative innovation strategy can enhance the competitiveness of the enterprise group once it has formed a consensus; thus, the internal collaborative innovation as important planning of an enterprise group's strategy is actively explored. Most of the current studies incorporate innovation synergy into the research framework of technological innovation and place technological innovation at the core of collaborative innovation relationships. However, innovation research in the non-technical field is also an important part of the innovation field [10]. Only when the two kinds of innovation cooperate with each other can the innovation performance be the best [11]. In addition, non-R&D enterprises and non-R&D-intensive enterprises also play an important role in innovation in economic and innovation strategic management [12]. Compared with other organizational structures, enterprise groups have entered a stable period of development. The importance of innovation in strategy, business, management, and other elements cannot be ignored. The collaborative innovation of enterprise groups should be balanced and comprehensive, and the research results from this perspective need to be further enriched. Collaborative innovation is conducive to the formation of 'new resources', resulting in knowledge spillover, bringing 'collaborative surplus' to enterprises, and breaking through resource constraints [13]. The cooperative innovation model is an important method for various elements of enterprise groups to obtain collaborative surplus through nonlinear organic combinations [14].

The existing research results in the field of collaborative innovation models within enterprise groups are rarely involved. Based on the existing research results, the main purpose of this paper is to answer the following questions: 'First, what types of collaborative innovation models mainly exist within enterprise groups. Second., what are the characteristics of these collaborative innovation models. Third, these collaborative innovation models will bring what kind of collaborative surplus'.

2. Theoretical Basis and Research Framework

2.1. Connotation, Motivation, and Research Level of Collaborative Innovation

The founder of Synergetics, Harken, proposed that "Synergetics is to study a complex system composed of a large number of subsystems inter acting in a complex way. Under certain conditions, the synergy phenomenon and synergy effect are produced among the subsystems through nonlinear interaction, so that the system forms a self-organizing structure of space, time or space-time with certain functions" [15]. "The value of the enterprise as a whole may be greater than the sum of the values of each part, and the effectiveness of the collaborative model partly stems from the benefits brought by economies of scale", which reflects the economic significance of Synergetics [16]. Collaborative innovation describes an organization's capability to create, integrate, and transform diverse knowledge, brainstorms, perspectives, and ideas into innovations in the context of value co-creation, which brings benefits to all participants [17–19]. The collaborative innovation mode has the advantages of risk sharing, mutual benefit, win–win and sustainable innovation, which can significantly reduce the risk and threshold [20].

2.1.1. Connotation and Motivation of Collaborative Innovation

Innovation is gradually transforming into a systematic and networked paradigm. Individual innovation activities, even small-scale and single-level cooperative innovation, are difficult to meet the needs of technological innovation. The accumulation of external knowledge requires enterprises to break through the innovation of the original single enterprise and carry out collaborative innovation [2,21]. The main driving forces for enterprises' collaborative innovation can be summarized as two aspects: breaking through resource constraints and improving enterprise performance: (1) Collaborative effect helps enterprises break through their own resource constraints and industry boundaries and bring them many benefits, such as higher innovation efficiency, lower innovation risk, highquality tacit knowledge spillovers, etc. [22,23]. The interaction between heterogeneous innovation subjects breaks the barriers in the original innovation process and forms a more open collaborative innovation network [24]. From the perspective of the resource base, enterprises carry out collaborative innovation to meet their respective strategic resource needs; that is, the complementarity of resources is the core driving force for enterprises to carry out cross-border collaborative innovation [25]. Enterprises can obtain resources such as technology, equipment, capital, business networks, and intellectual property rights by relying on the external relationships of various partners [26]. In short, collaborative innovation is conducive to the formation of "new resources", resulting in knowledge spillovers, bringing "Cooperative Surplus" to enterprises, breaking through resource constraints [13]; (2) Different from general cooperative innovation, collaborative innovation is the embodiment of win-win cooperation and overall optimization. The synergy highlights the phenomenon that heterogeneous innovation subjects use their own advantage to speed up the technological innovation process through complementary advantages and resource integration so as to achieve performance improvement in the overall network. A good collaborative innovation relationship in an open communication environment will increase the innovation performance of enterprises [27,28]. At the same time, collaborative innovation can also affect the innovation performance of innovation subjects through the knowledge integration mechanism [29]. Collaborative innovation is a complex strategy used for organizational innovation. According to "network theory", on the one hand, collaborative innovation is the organic collection of various elements, such as R&D, human resources and capital, processes, and systems [30]. On the other hand, it is the dynamic integration of complementary resources to achieve mutual complementarities between all the partners [28].

2.1.2. Research Level of Collaborative Innovation

The research level of collaborative innovation is divided into the macro level, which is the national level, the meso level, which is the industrial level, the regional level, and the micro level, which is the enterprise group level. Constrained by the difficulty of information collection, the research on the micro level is similar to a black hole; there are few research results. The current research level of collaborative innovation is mainly concentrated on the macro level and the meso level. At the macro level, national collaborative innovation research mainly focuses on the characteristics and evolution trend of national innovation networks [31]; the research on the industry–university research collaborative innovation at the national level focuses on the division of labor, positioning, cooperation mode and distribution mechanism of enterprises, scientific research institutions, and government [32,33]. At the meso level, industrial research focuses on innovation evolution, ability evaluation, risk control, enterprise competition and cooperation relationship, influencing factors, policy formulation, and so on. Regional research focuses on the evolution of industrial collaboration paths, strategy formulation, capability evaluation, operating mechanisms, and risk assessment agglomerations [34]. At the micro level, some scholars have conducted research on how to carry out collaborative innovation within enterprise groups from the aspects of corporate customers, markets, and R&D [35]. However, there are few research results at the micro level, and research needs to be strengthened.

2.2. Theoretical Paradigm and Research Progress of Comprehensive Innovation Management

Under the background of the increasingly complex and systematic trend of innovation management, in order to solve the lack of systematic and in-depth research and empirical analysis of comprehensive innovation thought, with the deepening research of multidisciplinary fields such as complexity theory, system science theory, and ecological view, in order to solve the problem of paying too much attention to technical factors in innovation, Academician Xu Qingrui systematically proposed a new paradigm of innovation management in 2006: Total Innovation Management Theory (TIM). This theory breaks the previous

pattern of management innovation theory focusing on technological innovation, establishes a new concept of ecological innovation, and expands the innovation elements and the space-time range. Comprehensive innovation management takes all-factor innovation, all-staff innovation, all-time and space innovation, and comprehensive combination as the core characteristics and takes the organic combination and collaborative innovation of various innovation factors such as technology, organization, market, strategy, management, culture, and systems as the means, and combines innovation management mechanisms, innovation management methods, and innovation management tools to achieve the state of innovation for everyone, innovation for everything, innovation at all times, and innovation everywhere, so as to achieve the improvement of competitiveness [36].

On this basis, Zheng Gang scholars put forward a five-stage comprehensive, collaborative process model ($C^{3}IS$); the model first proposed the concept of "comprehensive collaboration" between technology and non-technical elements in the innovation process. The model includes five stages: contact/communication-competition/conflict-cooperation-integration-cooperation; its meaning is that under the framework of full participation and full-time airspace, strategy, organization, culture, institution, technology, market, and other elements are coordinated and matched in an all-round way to achieve "2 + 2 > 5" through collaborative innovation, and then improve innovation performance [37]. Some scholars have studied the processing development model of the palm industry under the framework of comprehensive innovation management theory and proposed meaningful improvement measures [38].

Existing collaborative innovation generally places technological innovation at the core position. For enterprise groups, it generally enters a stable period of development. Technological innovation is important, but at the same time, the importance of strategic planning, business expansion, management improvement, and other factors also cannot be ignored. Non-technical innovation and technological innovation should be in the same important position. The collaborative innovation of enterprise groups should be balanced and comprehensive, and the research results in this field need to be further enriched.

2.3. Collaborative Innovation Mode and Collaborative Surplus

The factors of innovation resources freely flow among different subjects and dynamically select the best combination to achieve greater innovation efficiency. The difference between the total synergy effect of innovation of each innovation subject and the total effect generated by the independent innovation of each innovation subject is the collaborative surplus. Its manifestations are the invention of new products, new processes, and new equipment, the improvement of innovative human capital, the enhancement of innovation ability, the realization of economic profits, and the formation of scientific research achievements [39]. Collaborative innovation is conducive to the formation of 'new resources', generating knowledge spillover, bringing 'collaborative surplus' to enterprises, and breaking through resource constraints [14]. In addition, the collaborative innovation of enterprise groups can obtain collaborative surplus [40] so as to improve the innovation performance of enterprise groups. Therefore, obtaining collaborative surplus is the core motivation for enterprise groups to carry out collaborative innovation, and it is also the key for enterprise groups to use collaborative innovation to form competitive advantages at the group level. Chen Jin, Yao Yanhong, and other scholars have conducted in-depth research on the motivation, mechanism, and manifestation of collaborative surplus. In view of the mechanism of collaborative surplus, Chen Jin believed that enterprise groups have the effects of technical collaboration, production collaboration, and market collaboration under the influence of organizational structure, incentive mechanism, collaborative atmosphere, horizontal interaction, information bridge, and other factors. Collaborative surplus is manifested as the reduction of new product development cost and the shortening of the development cycle [35]. Although the above research has expounded and discussed the generation mechanism and measurement method of collaborative surplus, they do not elaborate in-depth on the realization path of collaborative innovation; that is, the existing

theory does not explain clearly what path enterprise groups achieve better performance than a single innovation.

The collaborative innovation model is an important method for enterprise groups to obtain collaborative surplus through a nonlinear organic combination of various factors [15]. The collaborative innovation model is closely related to enterprise innovation performance and enterprise synergy effect and has played a positive impact [41]. By mining the benefits of economies of scale, enterprise groups make nonlinear combinations of technology, strategy, organization, culture, institution, market, and other factors [37,42,43], thus forming a variety of collaborative innovation models and affecting the performance of collaborative innovation. In addition, as the command center, the enterprise group headquarters promotes internal collaborative innovation through business expansion, shared collaboration, business management, and support services [44]. It can be seen that the collaborative innovation model is the bridge of resource matching mechanism of enterprise group members, the link of various implementation mechanisms of enterprise group integration, and the key to obtaining collaborative surplus. Different collaborative innovation models will produce a different collaborative surplus so that collaborative surplus has diverse manifestations. The aggregate collection of collaborative innovation mode constitutes the formation path of collaborative surplus, so the study of collaborative innovation mode is the core link to analyzing the path of collaborative innovation.

Research on collaborative innovation of internal resources for enterprise groups has important theoretical and practical significance. Existing research fails to conduct indepth research on the main collaborative innovation modes, mode characteristics, and obtaining collaborative surplus of enterprise groups. In view of this, this paper, based on the existing research results, takes Tus-Holdings as the research object, adopts the single case study method, and systematically studies the types and characteristics of collaborative innovation modes of enterprise groups from the perspective of comprehensive innovation management, and analyzes the manifestations of the collaborative surplus of enterprise groups.

2.4. Analysis Framework

In recent years, the research results have laid a certain foundation for the study of this paper and provided new ideas. However, the existing research has not systematically expounded on the types and main characteristics of the enterprise group collaborative innovation model and the forms of collaborative surplus through the collaborative innovation model. From the perspective of comprehensive innovation management theory, based on collaborative innovation theory, this article uses case study analysis methods to construct a comprehensive, collaborative innovation model of enterprise groups with Tus-Holdings as the research object. The integrated analysis framework of this research is shown in Figure 1.



Figure 1. Integrated analysis framework.

3. Research Design

This research follows the process of case study: review theory \rightarrow design case study plan \rightarrow collect case data \rightarrow analyze case data \rightarrow research conclusion [45].

3.1. Research Methods

Case study method is one of the important methods in management research. The use of a single case or multiple cases in-depth analysis of "how" and "why" and other mechanisms to reveal the nature of the problem is of great significance in the discovery of new theories, enriching the existing theory, which is confirmed by many scholars' research [46,47]. In view of the existing theoretical gaps, this paper aims to study the main types, characteristics, and surplus of collaborative innovation model within enterprise groups. The existing literature does not have in-depth answers, nor does it involve, so an exploratory case study is needed [48,49]. Related literature also used the exploratory single-case study to study the collaborative innovation and reached some valuable conclusions [50,51]. This paper aims at the collaborative innovation model within the enterprise group and takes the ownership of the enterprise group as the link of management as the research boundary, so it is more suitable to adopt the single case study method.

3.2. Case Selection

The selection of typical cases is a common practice based on case study methodology [52]. This study believes that it is appropriate to take Tus-Holdings Co., Ltd. (Beijing, China) (hereinafter referred to as Tus-Holdings) as a case study, which is mainly based on the following considerations [53]: First, Tus-Holdings is an enterprise group that attaches great importance to innovation, and puts forward innovation theories such as "Four Gatherings", "eight major factors" and "three-dimensional triple helix". Relying on the accumulation in the field of innovation, it has become the leader of the domestic science technology service industry and is the first science and technology service enterprise group in China with assets exceeding CNY 100 billion. At present, the management assets exceed CNY 200 billion, which is representative of the industry. Second, since its establishment, Tus-Holdings has lasted for 20 years. It has developed from a single science and technology park Development and Construction Enterprise into a large enterprise group involving five strategic emerging industries such as "environmental protection, new energy, great health, digital economy, and new materials", and supporting industries such as education, culture, and style. It has gone through many different stages. The characteristics, problems, and solutions of each stage are rich and interesting, and the historical data are relatively complete. Third, Tus-Holdings develops under the guidance of the strategic policy of "pattern, strategy and synergy", which regards collaborative innovation as the core competitiveness of enterprises. At present, more than 800 enterprises have been listed and practiced in the field of collaborative innovation mode for many years, which provides a good sample for this study.

3.3. Case Enterprise Situation

Tus-Holdings Co., Ltd. (hereinafter referred to as Tus-Holdings) was established in July 2000. It is a science and technology service enterprise group focusing on management innovation and emphasizing on science and technology services field and relying on Tsinghua University. After more than 20 years of development, Tus-Holdings has built a "Science and Technology Park, Science and Technology Industry, Science and Technology Finance" trinity, collaborative cluster innovation business pattern, and more than 800 consolidated enterprises, the total assets under management exceed RMB 200 billion. Tus-Holdings has formed a complete industrial chain layout and built a complete scientific and technological innovation ecosystem in five strategic emerging industries of environmental protection, new energy, big health, digital economy, and new materials, as well as supporting industries of education, culture, and sports. Under the guidance of the strategic thinking of "pattern, strategy, and coordination", Tus-Holdings has formed some typical

collaborative innovation models according to its own business characteristics: collaborative innovation models at the strategic level, collaborative innovation models at the business level, and collaborative innovation models at the support level. These collaborative innovation models show the strong competitiveness of Tus-Holdings in the fierce market competition.

3.4. Data Collection and Analysis

This study collected various forms of data through different methods, including interviews, internal company information, and public information. (1) Public information, such as corporate public number and debt market announcement, etc.; (2) Corporate archives information, such as enterprise summary, company archives, internal meeting records, etc.; (3) In-depth interviews and semi-structured interviews; (4) Participation in Company meetings and other activities. This paper uses a multi-level, multi-data source data collection method to form a triangular verification to enhance the accuracy of the research results [52].

4. Case Analysis and Discovery

In the process of its own development, Tus-Holdings has gradually formed a relatively mature collaborative innovation model through strategic guidance. Collaborative innovation is implemented at the whole group level and involves a wide range of aspects. Member enterprises have adopted a collaborative innovation model suitable for their own development according to their own conditions. Therefore, a variety of collaborative innovation models with different characteristics have been formed within the group, showing the characteristics of all-around and all-level. The collaborative innovation model is mainly manifested in strategic collaborative innovation, strategic customer collaborative innovation, collaborative business innovation, R&D collaborative innovation, collaborative management innovation, collaborative talent innovation, and collaborative financial innovation.

4.1. Strategic Collaborative Innovation Model

TUS-EST and Tus-Clean Energy are both independent parts of Tus-Holdings; each has an independent and complete business system and conducts business independently. TUS-EST focuses on the comprehensive management of the environment, and Tus-Energy focuses on the transformation of scientific and technological achievements in the field of clean energy. In 2018, Tus-Holdings proposed the strategic concept of "energy + environmental protection". Through the organic combination of the two blocks of business of TUS-EST and Tus-Clean Energy, it achieved the strategic goal of "permanent cure by energy treatment and temporary solution by environmental protection" and built a leading energy and environmental integration group in China. In September 2018, Mr. Wen Hui, Chairman of Tus-Clean Energy, began to serve as the director of the ninth board of directors and secretary of the General Party Branch of TUS-EST. In April 2019, Wen Hui, Chairman of Tus-Clean Energy, was elected as Chairman of the ninth Board of Directors of TUS-EST. At the same time, he announced the overall upgrading of the main industry strategic layout direction and industrial planning orientation and promoted the integration and coordination of the overall operation and strategy of the company. In January 2019, Tus-Clean Energy Research Institute and TUS-EST Research Institute merged to form Tus-Energy and Environment Joint Research Institute so as to promote the integration of energy and environmental protection technologies and realize the collaborative innovation of energy and environmental protection technologies. In July 2019, TUS-EST changed from "Tus-Sound Environmental Resources Co., Ltd. (Beijing, China)" to "TUS-EST", reflecting the strategic layout of "energy + environmental protection". At the same time, the company is positioned as an integrated environmental management service provider of integrated energy and environmental protection. Under the strategic framework of energy and environmental protection integration, TUS-EST and Tus-Clean Energy achieve strategic

synergy by distinguishing strategic positioning: TUS-EST as a leading enterprise in the environmental protection industry orients "zero carbon and waste-free city builder", and in the business model, it mainly invests in environmental protection projects and other forms of heavy asset investment; as a platform for the transformation of scientific and technological achievements in the field of energy, Tus-Clean Energy is positioned as the "global clean energy messenger". In the business model, technological innovation services and other forms of light asset operations are given priority. In September 2019, TUS-EST and Tus-Clean Energy jointly established Beijing Tus-Energy Zero Carbon Technology Co., Ltd. (Beijing, China), focusing on clean, comprehensive energy services and zero-carbon energy business areas, giving full play to the synergistic innovation role of the two. By August 2020, Beijing Tus-Energy Zero Carbon Technology Co., Ltd. invested a total of four holding subsidiaries, with an investment amount of 70 million yuan, and the integration strategy of energy and environmental protection has been rapidly implemented.

Tus-Holdings has recombined the environmental sector and the energy sector through collaborative innovation to create advanced domestic energy and environmental protection integrated group. Through differentiated strategic positioning, concurrent chairmanship, integrated technology research, and joint business investment, the strategic combination was quickly implemented. The characteristics of strategic collaborative innovation mode and collaborative surplus can be summarized as follows: Under the guidance of major strategic objectives, the enterprise group takes the executive subjects represented by the chairman and vice president as the core and combines the optimization and combination of internal strategic resources of the enterprise group. It uses strategic positioning adjustment, high-level personnel mobilization, technical research integration, joint business investment, and other methods to obtain the collaborative surplus: rapid realization of strategic objectives and rapid formation of strategic advantages in the core business field.

4.2. Strategic Customer Collaborative Innovation Model

In May 2019, Qingdao Municipal People's government and Tus-holdings held the signing ceremony of the strategic cooperation agreement in Qingdao Municipal Organization Conference Center (Qingdao, China). The two sides conduct in-depth cooperation in the fields of civil–military integration, artificial intelligence, marine science and technology, energy and environmental protection, education and training, as well as building an industrial incubation system, building a science and technology park, and promoting international scientific and technological cooperation. Under the framework of strategic cooperation between the two sides, Tus-Holdings relies on its own advantages of a diversified business system to concentrate resources and provide a package of cross-market services for strategic customers through collaborative innovation, so as to help the Qingdao municipal government to upgrade in an all-round way. As of July 2020, there are more than 70 companies and projects invested and introduced by Tus-Holdings in Qingdao. The landing business involves the field of digital security, talent education, fund, rural revitalization, marine fishery, etc., which provides the best practice cases for Qingdao to carry out clustering and industrial chain investment. The key projects are shown in Table 1.

As a new science and technology "department store", Tus-Holdings uses a diversified business system to provide self-selection services for strategic customers. When facing strategic customers, it provides cross-market, comprehensive, and integrated services for strategic customers through diversified business collaborative innovation so as to provide services for strategic customers at the strategic level, improve customer experience and obtain a high evaluation from strategic customers. The characteristics of the market collaborative innovation model and collaborative surplus can be summarized as follows: The enterprise group relies on its advantages of multiple business systems, with the general manager, deputy general manager, and market director as the main executives and middle managers' special groups, through matching resources with the strategic objectives of customers, providing a cross-market package of services for strategic customers from the strategic level, accurately docking the internal business of the enterprise group with the specific needs of strategic customers, helping the realization of strategic customer objectives, providing customers with super expected service experience to win customer trust, and improving brand awareness.

Table 1. List of cooperation projects between Tus-holdings and Qingdao.

Time	Important Issues
May 2019	Qingdao Municipal Government and Tus-Holdings signed a Strategic Cooperation Agreement
June 2019	Jimo District and Qingdao Blue Valley signed 14 key projects with the subsidiaries of Tus-Holdings, involving clean energy, science and technology education, biomedicine, marine industry, big data, artificial intelligence and other fields.
July 2019	Chengyang District of Qingdao City and Tus Triple Helix Co., Ltd. (Beijing, China) held a signing ceremony. Tus Triple Helix will move its headquarters to Chengyang after the signing of the contract. Iimo District and Tus-Holdings signed 5 project cooperation agreements, covering industrial parks,
August 2019	energy, sports technology, new materials, science and technological innovation services and other fields. The Qingdao branch of Tus Business School was unveiled at the same time and settled in Tus-Holdings Building
September 2019	Huatong Group and Tus-Holdings subsidiary companies signed a strategic cooperation agreement. The two sides will carry out in-depth cooperation in the fields of civil–military integration, artificial intelligence, marine science and technology, big data operation, education and training, etc, as well as building industrial incubation system, building science and technology park, and industrial funds.
September 2019	Qingdao Laixi Municipal Government's Economic Development Zone, Education and Sports Bureau, Culture and Tourism Bureau, Health and Health Bureau, and City Investment Office respectively signed 5 enterprise landing agreements and four cooperation framework agreements with Tus-Holdings subsidiaries.
September 2019	Qingdao North District and Tus-Holdings hold a comprehensive project doking meeting and signing ceremony of the strategic cooperation framework agreement. The two sides will cooperate around in artificial intelligence, robots, big data, cloud computing, block chain, intelligent manufacturing, civil–military integration, biomedicine, new energy and new materials and other strategic emerging industries.
October 2019	Qingdao North District Government, the Fourth Highway Engineering Bureau of CCCC and Tus-subsidiaries signed a framework cooperation agreement on the construction of an artificial intelligence industrial park.
February 2020	Tus-Holdings and Qingdao City Co-Resistance Epidemic: Tus Cloud established an intelligent monitoring and management system for isolated personnel in Chengyang District of Qingdao. Tus Guoxin provided overall solutions for remote mobile office for medical personnel and government personnel. TUS-EST responded to the epidemic by carrying out medical waste and kitchen projects in Qingdao. Tus Hailiang assisted the unattended urban management in north District through the dual-propaged approach of intelligent temperature measurement and video. Al
May 2020	Tus Middle School was approved to establish three campuses in Laoshan, Shibei and Chengyang, and the spring teacher recruitment examination was completed.
July 2020	Tus-Tech City Group Co., Ltd. (Beijing, China) participated in the mixed-ownership reform of Double Star Group, and obtained 35% equity of Double Star Group by means of capital increase and equity expansion.

4.3. R&D Collaborative Innovation Model

In order to seize the opportunity of the coal-to-clean energy policy and open the heating market of household biomass heating furnaces, Tsinghua Solar Co. Ltd. (Beijing, China) uses its own solar thermal utilization and resource accumulation in the coal-to-electricity market to achieve new business expansion by developing new types of household biomass furnaces. Tsinghua Solar Co., Ltd. has accumulated rich experience in government relations, product promotion, engineering installation, and other fields through its own development. However, due to its late involvement in the research and development of biomass stoves, its accumulated experience is not rich enough; the independent research and development time is long and difficult. Beijing Nowva Energy Technology Co., Ltd. (Beijing, China) is a technology company focusing on the development and efficient solid fuel energy utilization technology and the implementation of the project. It has a full understanding of the combustion characteristics of biomass fuels and has rich experience in the field of furnace core structure design. In the early stage, Beijing Nowva Energy Technology Co., Ltd. has invested a lot of research and development manpower and material resources in the field of biomass heating furnaces and carried out relevant technical reserves, but it has not been successfully promoted to the market for various reasons. In May 2019, Tsinghua Solar Co., Ltd. decided to expand the business of biomass combustion stoves. In order to speed up the input of new products, it released the demand for collaborative research and development of new products within Tus-Holdings. In July 2019, Tsinghua Solar Co., Ltd. and Beijing Nowva Energy Technology Co., Ltd. reached a collaborative R&D intention through contact and communication and signed a technology development agreement. After the collaborative R&D matters were determined, the two sides established a collaborative R&D team to carry out R&D work for household biomass heating furnaces that meet the latest standards. Tsinghua Solar Co., Ltd. Company is responsible for the research and development of biomass fuel, smoke exhaust system, and thermal cycle system, while Beijing Nowva Energy Technology Co., Ltd. is responsible for the research and development of combustion system and fire sealing system. The coordination group held regular discussion meetings to inform each other about the R&D situation, communicate with each other on key points and difficulties in a timely manner, discuss the work arrangements in the next stage, determine detailed work plans, and ensure that both parties complete relevant R&D work according to the time node. In case of major emergencies, the collaborative R&D team will hold a special meeting on emergency issues for special treatment to ensure R&D efficiency. The collaborative R&D division of the two sides is shown in Table 2.

Table 2. Division of collaborative R&D.

Collaborator	R&D Achievements	Collaborator
Tsinghua Solar Co., Ltd. Tsinghua Solar Co., Ltd. Tsinghua Solar Co., Ltd.	Biomass Fuel Smoke Exhaust System Thermal Cycle System	
	Combustion system	Beijing Nowva Energy Technology Co., Ltd.
	Fire sealing system	Beijing Nowva Energy Technology Co., Ltd.

After one year of collaborative research and development, in July 2020, Tsinghua Solar Co. Ltd. successfully launched a biomass combustion stove with intellectual property rights. After testing by a qualified third-party testing organization, the product meets the requirements of the national standard GB-13271-2014 in terms of particulate matter, sulfur dioxide, nitrogen oxide, and other air pollutants emissions. At the same time, it also meets the current standards of the National Energy Administration in terms of thermal efficiency and cooking power. Compared with the existing products, it has the characteristics of sufficient combustion and more environmentally friendly emissions, showing strong competitiveness.

Tsinghua Solar Co., Ltd. and Beijing Nowva Energy Technology Co., Ltd. have successfully developed biomass combustion stoves for only one year through the research and development of a collaborative innovation model. At the same time, all core indicators are in line with the current standards of the National Energy Administration and are superior to existing market products. They have participated in the formulation of NB/T 34006-2020 "Technical Conditions for Clean Heating Stoves" issued by the National Energy Administration and established the leading position in the industry. Tsinghua Solar Co., Ltd. and Beijing Nowva Energy Technology Co., Ltd. successfully realized the research and development of new products through complementary R&D technology. Collaborative R&D not only greatly shortens the R&D cycle of Tsinghua solar co. for its new products but also revitalizes the reserve technology of Beijing Nowva Energy Technology Co., Ltd., and realizes the win–win cooperation. The characteristics of the R&D collaborative innovation model and collaborative surplus can be summarized as follows: with the help of abundant

R&D resources in the group, when the member enterprises of the enterprise group face market opportunities, the staff joint working groups, the middle-level managers with R&D director, and R&D personnel as the main force, give full play to their respective advantages and uses complementary advantages to obtain collaborative surplus: revitalize reserve technology, shorten the R&D cycle of new products, and quickly establish the leading industrial status of technology leadership.

4.4. Management Collaborative Innovation Model

Hot Spring Project Department and the Xian'an Project Department are two independent project departments with urban sanitation as their core business. The two project departments are independently managed and independently accounted for. Since the business of the two project departments is highly similar, the requirements for personnel, mechanical equipment, and operation methods are the same. In order to meet the operating requirements, the two projects are equipped with a variety of operating equipment and multi-post operators. Due to the limited operating area, the personnel are bloated, the work is not full, the operating machinery costs are high, the idle time is long, and the project performance is poor. At the end of 2018, the two project departments began to explore management collaborative innovation in order to achieve performance improvement. Management collaborative innovation is mainly carried out from two aspects: personnel streamlining and job optimization: (1) The two project departments are optimized and adjusted into a management team, readjust the organizational structure, optimize management responsibilities, sort out and reengineer the process, reduce duplication of work, and improve work efficiency. As of 30 June 2019, the cumulative optimization of 22 managers, including 10 captains and 12 managers, reduced management costs by 980,000 per year. By increasing the salary of front-line workers and encouraging front-line workers to take on more jobs, the "three-person, four-salaries and five-posts" model was explored, and a total of 30 front-line workers were optimized, including 9 drivers, 4 car attendants, and 17 cleaners. The annual labor cost was reduced by CNY 1.05 million, and the total cost was reduced by CNY 2.03 million through the optimization of managers and front-line workers. (2) After the two project departments carried out collaborative management innovation, the scope of mechanical operation is adjusted from small regional operations to large regional operations, and the vertical division of labor is adjusted to comprehensive, collaborative operations. The sprinkler and sweeper routes are optimized in the overall region to improve the operation efficiency of mechanical equipment, reduce the number of equipment used, and reduce the idle time of mechanical equipment, thereby reducing the cost of equipment procurement and maintenance. By June 2019, the number of mechanical equipment decreased by 5, and the idle time of mechanical equipment decreased by 50%. The first-line operation mode is adjusted from the original independent operation of sprinkler, cleaning, and dust suppression to collaborative operation. The three types of operators form a collaboration group to achieve seamless connection through the three-dimensional operation method. Road sprinkler, cleaning, and dust suppression are completed at one time to ensure the quality of road operation, reduce the frequency of rework operation and improve the operation efficiency. Through the optimization of operation mode, the quality of operations has increased significantly: in the first half of 2019, the cumulative deduction of environmental sanitation operation service assessment was 99,000 yuan, which was 73% lower than the deductions of sanitation operation service assessment of 368,000 yuan in 2018. The overall management collaborative innovation effect of the two project departments is shown in Table 3

Through collaborative innovation, the two project departments enhance the overall management level and carry out work from two aspects of personnel streamlining and job optimization, achieving a significant decline in management costs, labor costs, and assessment deductions, thereby significantly improving performance. The characteristics of management collaborative innovation mode and collaborative surplus can be summarized as follows: With the help of advanced management experience sharing, the management

personnel of the enterprises affiliated to the enterprise group can improve the management level and change the business thinking. The front-line employees can achieve one specialty and multiple abilities by improving the comprehensive quality so as to obtain the collaborative surplus by optimizing and simplifying redundant personnel and changing the operation mode: the management cost, labor cost, and assessment deduction are reduced so as to improve the business performance.

Table 3. Achievements of management collaborative innovation.

Туре	Management Cost	Labor Cost	Assessment Deduction
Improved	decreased by	decreased by	decreased by
amount	¥980,000	¥1,050,000	¥269,000

4.5. Talent Collaborative Innovation Model

The appointment and appointment of the board secretary of the vertical system of the board secretary of the Tus-Holdings are jointly and jointly managed by the Department of Strategic Planning and Investment Development (hereinafter referred to as "the Department of Strategic Investment"), and it is an important function to cultivate and reserve excellent expatriate board secretaries for the group member enterprises. The expatriate board secretaries need to have the comprehensive professional ability in strategic planning implementation, investment evaluation implementation, risk control management, and so on and need to have good communication and coordination ability, so they have higher requirements for employees. From 2017 to 2019, the strategic investment department of Tus-Holdings appointed the secretary of the board of directors to the members of Tus Blockchain Group, Tus-Clean Energy Group, Tus Triple Helix Group, Tus New Materials Group, and Tus Digital Group and other enterprises. All these expatriate board secretaries are graduated from 985/211 colleges and universities, most of them have a master's degree or above and have an excellent comprehensive ability. At the same time, because their tenure in the strategic investment department is more than one year, they have a global vision and are familiar with the overall situation of the group so as to better help subordinate enterprises. By sending the secretaries of the board of directors to export exports high-end talents for member enterprises, Tus-Holdings improves the management level, thereby promoting the overall management level of the group. In 2019, the TUS-EST began to layout the park area for energy business development under the integrating energy and environmental protection strategy. None of the senior managers are involved in the park area, so they need to introduce relevant personnel. Tus Science and Technology City Group is a professional platform for Tus-Holdings in the planning, construction, and operation of science and technology parks. Its senior managers have rich industry experience and industry resources in the park area. In June 2020, the executive vice-president of Tus Science and Technology City Group was transferred to the executive vice-president of TUS-EST, responsible for business expansion in the park area. The business of Guangxi Fangchenggang Company (Fangchenggang, China) is power distribution services. In order to meet the needs of business development, a certain number of professionals are needed. Because it has not been able to recruit suitable personnel for a long time, which affects the business development, it seeks collaborative support from Tus member enterprises. In order to support Fangchenggang Company in carrying out business, Tus member enterprises have successively delivered one chief engineer, one financial director, one senior financial supervisor, one engineering supervisor, and three electricians to it. Fangchenggang Company has completed the formation of a professional team in a short period of time through personnel coordination among member enterprises, saving a lot of time and personnel recruitment and training costs for the rapid development of the business. The EBA project of Tus-Holdings Business School has been held for six consecutive years and has trained more than 300 middle and high-level managers for Tus-Holdings. Each period, EBA students will undergo 9 months of training. Tus-up member enterprises distributed

around the world provide field visits, research, and other collaborative support for the training students. For example, in the sixth period, students, through the collaborative support of member enterprises, have successively entered the Tus business landing areas such as Hangzhou, Xi'an, Heze, Zhengzhou, Beijing, Liuzhou, Tengchong, and Moscow for exchange and learning.

Through collaborative talent innovation, the vertical and horizontal flow of talents is realized within the Tus-Holdings, which promotes the improvement of the management level of member enterprises and reduces the cost of talent acquisition. Selecting talents at all levels within the group for a centralized training mechanism promotes the exchange and integration of talents. The characteristics of talent collaborative innovation mode and collaborative surplus can be summarized as follows: With the help of abundant talent resources within the group, the member enterprises of the enterprise group solve the problem of high-end talent recruitment of the subordinate enterprises through the outpost of the group, realize the optimal matching of personnel and posts and the sharing of human resources in the vertical and horizontal flow of talents within the group, and promote the exchange and integration of talents by means of training. The listing measures cover all the subjects, such as executives, middle managers, and employees, and obtain the collaborative surplus: maximize the value of talents, improve the management level of member enterprises, reduce the cost of talent acquisition, and provide effective support for performance improvement.

4.6. Financial Collaborative Innovation Model

Tus-Holdings as the group headquarters to play the role of fund collection and collaborative distribution. In 2019, Tus-Holdings collected funds from five enterprises, such as Hefei Tus Technology Industry Center Management Center (Limited Partnership) (Hefei, China), paid interest of 57,668,700 yuan, and loaned funds to five enterprises, such as Nanjing Tus Smart Technology City Investment and Construction Co., Ltd. (Nanjing, China) with interest income of 118,358,100 yuan [54], as shown in Table 4.

Table 4. Capital occupation of related parties of Tus-holdings.

Affiliated Parties	Trading Content	Amount
Nanjing Tus Intelligent Technology City		
Investment and Construction Co., Ltd.	Interest income	¥63,006,422.41
(Nanjing, China)		
Beijing Tus Legend Film Media Co., Ltd.	Interest income	¥8,575,663.52
Yadu Technology Group Co., Ltd.	Interest income	¥11,522,510.48
(Beijing, China) Shaanyi Tus Science Park Development Co. I td		¥2,420,152.78
(Xi'an China)	Interest income	
Tusinceie Technology City Investment Group	T	¥32,833,333.33
Co., Ltd. (Beijing, China)	Interest income	
Hefei Tus Technology Industry Management	Interest exchange	¥28 254 947 56
Center (Limited Partnership)	interest exchange	120,231,717.30
Enlightenment Huizhi (Beijing) Investment	Interest exchange	¥115,058.49
Management Co., Ltd. (Heter, China)	0	,
Suzhou Saide Investment Management Co., Ltd.	Interest exchange	¥46.650,555.55
Oibong United Enterprise Management (Tianiin)		
Partnership (Limited Partnership)	Interest exchange	¥4.838.028.79
(Tianjin, China)	interest cheminge	11,000,020
Qitong Jiarong (Zhuhai) Equity Investment Fund	Interest exchance	V24 460 711 10
(Limited Partnership) (Zhuhai, China)	merest exchange	124,400,711.10

Superior companies provide guarantees for subordinate companies so as to help them more easily obtain loans from financial institutions. For example, Tus-Holdings provides guarantees for Tuspark Forward Co., Ltd. (Cayman Islands) and Tus-Technology Services Co., Ltd. (Beijing, China), and Tus-Tech City Group Co., Ltd. (Beijing, China) provides guarantees for Jurong Tus-Tech Development Co., Ltd. (Jurong, China) TUS-EST (000826) signed a loan agreement with the controlling shareholder Tus Technology Services Co., Ltd. on 17 November 2017, 8 December 2018, 28 March 2019, and 23 January 2020, respectively. The single loan amount is up to 1.5 billion yuan, and the loan interest rate is not more than 6.5%. Borrowing does not require any form of guarantee such as guarantee, mortgages, and pledges from the TUS-EST. Borrowing provided by the controlling shareholder timely supplements the liquidity required for the daily operation of the TUS-EST. The TUS-EST moved to Tsinghua Science and Technology Park and its surrounding areas as a whole in 2018. By cooperating with Tus-Holdings, Tus-Clean Energy, Huaqing Property, and other Tus-Holdings member enterprises to own or lease property, the relocation was realized in a short time, and the related intermediary costs were saved. In order to solve the problem of insufficient vehicles in the company, Tus Qingyun leased vehicles from brother companies with the help of Tus-Holdings controlling members. Joint investment is also an important part of financial coordination. In November 2019, Tus-Techology City Group Co., Ltd. and TUS-EST jointly invested in Hebei Xiong'an Tus-Zero Carbon Technology Co., Ltd. (Xiong'an, China) in Xiong'an New District, with a registered capital of 10 million yuan. The main business is new energy technology promotion services, environmental protection engineering construction, environmental protection consulting, environmental engineering special design services, environmental protection testing, etc.; Zhengzhou Tus-Donglong Science and Technology Development Co., Ltd. (Zhengzhou, China) and TUS-EST jointly invested in Henan TUS-EST Energy Development Co., Ltd. (Zhengzhou, China) in Zhengzhou in November 2019. The registered capital is 1 billion yuan, and the main business is new energy technology, urban domestic waste removal and transportation, power engineering design and construction, etc.

Through the financial collaborative innovation model, Tus-Holdings improves the efficiency of capital utilization by collecting and allocating funds at the group level. Subsidiary companies are more likely to obtain funds through shareholder guarantees and shareholder funding, and other ways, and asset sharing and joint investment are realized among member enterprises. It can be seen that the financial collaborative innovation model realizes the efficient use of funds and assets within the group. The characteristics of the financial collaborative innovation model and collaborative surplus can be summarized as follows: The members of the enterprise group make use of the advantages of financing at the group level and various financing channels to collect and distribute funds within the enterprise group, shareholder assistance, mutual guarantee, asset sharing, joint investment, etc., to obtain collaborative surplus: help members of the enterprise to obtain low-cost financial support, timely supplement operating funds, reduce investment risk, and realize the efficient use of funds and assets within the group.

5. Research Conclusions and Enlightenment

5.1. Research Conclusion

Through a longitudinal case study, this paper systematically studies and analyzes the collaborative innovation mode of Tus-Holdings, and constructs the path framework for obtaining the collaborative surplus of enterprise groups (as shown in Figure 2). Through the research on the collaborative innovation mode of strategy, customer, business, R&D, management, personnel, finance, and other factors, this paper analyzes the main types, characteristics, and manifestations of collaborative innovation modes and draws the following conclusions:



Figure 2. Collaborative Innovation model of enterprise group.

- (1) The main types of enterprise group internal collaborative innovation model are strategic collaborative innovation model, strategic customer collaborative innovation model, business collaborative innovation model, R&D collaborative innovation model, management collaborative innovation model, personnel collaborative innovation model, financial collaborative innovation model. As a concentrated reflection of systematic collaborative innovation activities, the collaborative innovation mode has both technical innovation and non-technical innovation [8], which runs through the whole collaborative innovation system of enterprise groups.
- (2) The internal collaborative innovation model of enterprise groups shows nonlinearity and diversity. In order to achieve the goal of collaborative innovation, the enterprise group invests in collaborative innovation activities by executives such as the chairman, supervisors and other middle managers, employees, and other subjects. Using the internal resources of the enterprise group, such as strategy, market, technology, management, talent, finance, and so on, combined with strategic combination, unified market, joint research and development, management improvement, personnel mobility, financial sharing, through nonlinear combination, a variety of collaborative innovation models are formed.
- (3) Collaborative surplus performance is closely related to collaborative innovation mode; different collaborative innovation modes will produce a different collaborative surplus. Various collaborative innovation models have created multiple collaborative surpluses, such as reducing the time cost of strategic transformation, improving strategic customer satisfaction, improving business operation efficiency, reducing R&D costs, reducing talent acquisition and training costs, and improving capital and asset efficiency. These collaborative surpluses cannot be realized by a single enterprise, so collaborative innovation enhances the internal competitiveness of enterprise groups, improves the performance of enterprise groups, and wins the competitive advantage at the group level. This conclusion supports that the collaborative innovation model is an important path for enterprise groups to obtain collaborative surplus [14].

5.2. Theoretical Contribution and Practical Significance

The theoretical contribution of this paper mainly lies in the following three aspects: First, the research on collaborative innovation within enterprise groups in this paper enriches the collaborative innovation theory. The existing collaborative innovation research mainly focuses on the collaborative innovation mode and mechanism among different actual controllers [3–7]. The research in this paper makes up for the lack of research attention in the field of collaborative innovation of enterprise groups in recent years. It is a good supplement to the strategic alliance model [55] and the industry-university research model [56] formed between different controllers and contributes to the research results of collaborative innovation theory. Second, this paper contributes new cases and knowledge to comprehensive innovation management theory. According to the comprehensive innovation management theory proposed by Xu Qingrui and other scholars based on the long-term research on Haier's innovation activities [36], this paper takes Tus-Holdings as the research object, summarizes the collaborative innovation model of enterprise groups, and puts forward the collaborative residual acquisition framework. This study is not only the development of the "five-stage comprehensive collaborative process model" proposed by scholar Zheng Gang [37] but also the supplement of 'technical elements as the core, and the non-technical elements collaborative model' [8]. It contributes new cases and knowledge to the comprehensive innovation management theory and verifies the universality of the theory. Third, this paper provides a new idea for the subsequent research on the performance evaluation of collaborative innovation. The selection of existing achievements for collaborative innovation performance indicators mainly focuses on the speed of technological development, the success rate, the degree of upgrading, and the number of new products as the core indicators of collaborative innovation performance, while ignoring the non-technical factors, such as the collaborative innovation achievements in the fields of strategy, customer and management, which leads to the incomplete research perspective. However, some scholars have realized the existence of this problem, selected new or improved products, new or improved processes, new or improved management practices, new or improved marketing methods, and the other indicators as collaborative innovation performance [2]. The results of this study support this evaluation standard and further refine the evaluation index of collaborative innovation, which provides a valuable reference for subsequent collaborative innovation performance research.

Although our empirical study is situated in the context of China, the research findings may also apply to a larger scale of emerging economies because China is representative of a wide range of emerging economies [57,58]. The practical significance of this paper is as follows: through in-depth analysis of the collaborative innovation model formed by Tus-Holdings in the long-term enterprise practice, this paper reveals the path to obtain collaborative residuals, and vividly demonstrates the manifestation of collaborative residuals of enterprise groups, providing case reference for other enterprise groups: (1) Enterprise groups can learn from the collaborative innovation model of Tus-Holdings, and form special collaborative innovation committees through organizational structure optimization [59], such as Strategic Collaborative Innovation Committees, Market Collaborative Innovation Committees, and Technical Collaborative Innovation Committees, through the top-level design and guidance, explore the collaborative needs within enterprise groups, and organize and implement collaborative innovation activities; (2) By combining their own resource endowments, business groups uses the flow and combination of factors such as strategy, market, technology, management, talent, finance to form collaborative innovation mode, optimize the collaborative innovation process and improve the collaborative innovation efficiency through process reengineering [60]; (3) Enterprise groups should unswervingly promote collaborative innovation strategy, carry out comprehensive and systematic design through the adjustment and distribution of internal resources, encourage full collaborative innovation through system construction and incentive mechanism design [61], stimulate full collaborative innovation enthusiasm, explore potential collaborative innovation opportunities, and obtain more collaborative surplus, so as to enhance the overall competitive advantage of enterprise groups.

5.3. Limitations and Future Research Directions

Although this study tries its best to select representative enterprise groups in the field of collaborative innovation practice for typical analysis, due to the limitations of the case study itself, the universality of the conclusions of this study has become one of the limitations that cannot be ignored. Future research can be expanded from the following aspects: on the one hand, future research can expand the research background to other enterprise groups with collaborative innovation as the core competition through multicase studies to verify the universality of the research conclusions; on the other hand, the efficient identification of collaborative innovation opportunities within enterprise groups is an important part of collaborative innovation capability, and it is also the basis for the formation of collaborative innovation model. Subsequently, the identification model of collaborative innovation opportunities is constructed through relevant research to further enrich the research results in the field of collaborative innovation.

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