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Research on the Impact of Knowledge Integration on Collaborative Innovation between High Manufacturing & Tech-service Industry

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Abstract: Under the background that China takes innovation drive as the main battlefield, this paper used Vensim DSS software to simulate and analyze the change trend of knowledge potential energy, knowledge innovation rate and knowledge transfer rate of high manufacturing & tech-service industry based on dynamic system theory and innovation synergy theory. Taking Hengqin in Zhuhai as the case object, the paper selected five factors, including knowledge demand of manufacturing enterprises, knowledge absorption capacity, government incentive mechanism, financial investment and talent construction, to analyze the impact of knowledge integration, and the sensitivity of its innovation rate. The conclusion was that the knowledge innovation rate and knowledge transfer rate of high manufacturing & tech-service industry increase with knowledge potential energy' increasing, that mean the five factors had an optimistic effect on the innovation rate. The application of the research results would help promote the knowledge integration in key regions of China and the development of high-end high manufacturing.

1. Introduction

Under the new economic normal, China's high manufacturing had become the main battlefield driven by innovation, and is undergoing a process from big to strong, which is crucial to sustainable economic growth. The strategic plan of "made in China 2025" proposed that China should build economic growth' original power, shape core competitive advantages in the world, and concentrate the high manufacturing to enhance its core competitiveness. Through the organization and implementation of "made in China 2025", we will strive to cultivate key and common technologies with independent intellectual property rights, strive for the leading power in the development of advanced high manufacturing, and lead and drive a new round of manufacturing development in China. Knowledge management is the key to enhance the core competitiveness of organizations. In the face of various environmental changes, all organizations should carry out knowledge management activities such as knowledge creation, dissemination, updating and application to enhance the core competitiveness. At the same time, how to effectively acquire knowledge and reduce innovation risks is a key challenge for the research and development of new technologies and products. With the expansion of the scope of technological innovation, technology will become more complex and more vulnerable to internal and external changes in the organization. Therefore, the requirements for knowledge acquisition, knowledge sharing and knowledge support are also stronger. To build a national innovation system, we need to constantly strengthen strategic tech forces, support the transformation of scientific research achievements, and accelerate the high-level integration of innovation subjects. In the context of the made in China 2025 strategy, the innovation awareness of China's high manufacturing & tech-service industry is far from enough, and the internal driving force of knowledge integration on collaborative innovation is insufficient.

2. Literature Review

2.1. Knowledge Integration and Related Industrial Relations

Andrew (1998) divided the tech-service industry into transportation tech-service industry and financial tech-service industry, and established the capital market investment amount, labor cost, and the function of tech-service industry and each connecting department in the input-output table [1]. By analyzing the data of six countries, it was concluded that tech-service industry has a significant positive supporting effect on each department. Brescia (2000) analyzed the knowledge transfer process closely related to the interactive interface by studying the organizational knowledge transfer model [2]. After studying the connection and communication mechanism between KIBS and enterprises, Strambach (2001) concluded that the high manufacturing is difficult to make progress and enhance its core competitiveness only by relying on its own experience and knowledge. Knowledge generation and dissemination are very important for the development of the high manufacturing [3]. Wong (2002) established a regression verification model by some questionnaire data of companies in Southeast Asian countries, and concluded that knowledge fusion provides necessary information services for the high manufacturing, which was conducive to the realization of technology transformation within enterprises, and the high manufacturing also provided a platform for knowledge application scenarios. The relationship between the two is mutually reinforcing [4]. Smirnov (2016) believed that multi-agent modular collaboration is the mainstream innovation mode of generic technology research and development in the high manufacturing. The performance of collaborative knowledge chain determined the performance of collaborative research and development and organizational competitiveness [5]. Stephen (2016) analyzed the development process of the interaction and integration of knowledge intensive service industry and equipment high manufacturing, divided it into three stages, and summarized the influencing factors of the interaction and integration of knowledge intensive service industry and equipment high manufacturing [6]. Petrovich (2018) and others pointed out that the closer and more persistent the interaction between knowledge intensive service industry and users, the more likely it is to perfectly combine the skills of organizational technology with the innovation strategies of enterprises, and at the same time profoundly affect user innovation [7]. Sudhindra (2017) proposed that simple knowledge transfer is not the whole process of consultants providing services to enterprises. KIBS enterprises could accept tacit knowledge in the process of service, and this knowledge would be widely used in enterprises [8].

2.2. Exploration of Knowledge Fusion Method

Alberto (2003) proposed a knowledge information cooperation model based on complex formulas and characteristic screening, which effectively improves the correctness of cooperation of diverse knowledge bases [9]. Akhlaghi (2018) expressed knowledge in the form of triples, extracted and fused them to form a knowledge base [10]. Daniela (2017) constructed an emergency decision knowledge model based on knowledge elements, and proposed a new fusion method considering the fuzziness of knowledge to solve the problem that the existing methods may cause the fusion results to conflict with the objective reality [11]. Wu (2019) summarized the current status of the identification framework, methods, multiple relationships and the application of in-depth content level analysis methods of the current research frontier through content analysis, divided the types of research frontier and constructed a forward-looking index system [12]. Anthony (2019) adopts the semi-automatic string matching method through the ontology editor to combine the ontology of the high manufacturing and consulting, strengthening the knowledge connection between multi industry developments [13]. Usama (2021) pointed out that ontology, as one of the main knowledge modes of knowledge fusion, can effectively represent heterogeneous knowledge in the field and allow other experts and users to access and use it. Unlike precise ontology, fuzzy ontology used the concept of fuzzy set to describe the relationship between individuals and concepts, and refined the fusion source semantically, making knowledge representation more objective and flexible [14]. Miao (2021) used bibliometrics and visualization software to analyze and summarize the current achievements of the integrated growth of productive services and manufacturing. The research Condensed in this direction of manufacturing service, producer services agglomeration, technological innovation, threshold effect, service outsourcing, intelligent manufacturing, etc., while supply side reform, industrial agglomeration, manufacturing service and total factor productivity have become the current research frontier [15]. Hu (2021) proposed information mixing method by confused ontology to solve the problem that a large amount of uncertain and inaccurate information in large group emergency decision-making is difficult to express and store, so as to build a large group emergency knowledge base to query the optimal scheme [16].

To sum up, scholars have done a large number discussion of connection among knowledge integration and manufacturing and service industries, and the mathematical methods of knowledge integration, which has laid a good research foundation, but there is insufficient research on the essence of industry progress under the background of knowledge integration. Therefore, this paper converge on some work on the internal driving force of knowledge integration in the innovation and development of high manufacturing & tech-service industry.

3. Mode Design

3.1. System Description of Knowledge Fusion Collaborative Innovation System

The innovation subject directly affected the realization of innovation synergy in the collaborative innovation system, which is the core of the system. All the influence effects were realized through the behavior of the innovation subject, and the behavior of the innovation subject had tremendous influence in procedure and results of innovation synergy. Theirs innovation subjects in this paper were high manufacturing & tech-service industry. And innovation behavior from these two industries was the key research object. Knowledge fusion could be introduced into the system to analyze how knowledge innovation could realize collaborative utilization and promotion in the two industries. The process of knowledge integration between high manufacturing and tech-service industry was shown in what knowledge transfer of tech-service industry promotes some improvements of knowledge potential energy from high manufacturing. Integrating the transferred knowledge with its own knowledge could ameliorate the knowledge innovation rate of enterprises. These knowledge accumulation of manufacturing enterprises could be applied to the tech-service industry, which is conducive to the targeted knowledge integration and knowledge re innovation of the tech-service industry. Through knowledge fusion, function with 1+1 > 2 was created, and the amplification effected of the functions of each part was realized. The principle that manufacturing and service industries work together was the construction of new knowledge systems. Through knowledge accumulation, transfer and reengineering, they could achieve business integration and collaboration, and promoted a virtuous cycle of knowledge innovation. The function of the system depended on internal information transmission and feedback, so it was necessary to define the internal and external boundaries and department boundaries of the system. Referring to the documents of Chris (1996) and Fu (2022), this paper took the main elements of innovation, government elements and environmental elements as components, so as to determine the boundary of the knowledge fusion innovation system of high manufacturing and tech-service industry, analyzed the information transmission and feedback between various subsystems, and clarified the mechanism of action between them [17,18].

3.2. Knowledge Fusion Collaborative Innovation System Dynamics Model

3.2.1. Causal Analysis of Collaborative Innovation

Combined with the existing research results, this paper established a feedback mechanism for the knowledge fusion innovation of tech-service industry and manufacturing companies, and put forward a complex open system with multivariable and multi loop formed by the mutual coupling of three subsystems of "tech-service industry innovation system - manufacturing enterprise innovation system - external environment system". The independent relationship existed between the innovation system from tech-service industry and these innovation system of manufacturing enterprises. A feedback loop of reciprocating circulation was formed between the two industries. The two systems also existed in the social and market environment. Influenced by government policies and knowledge market demand, government support could promote the efficiency of knowledge creation and knowledge transfer. Figure 1 showed the causal relationship of establishing collaborative innovation between the two industries based on relevant research results. In Figure 1, the left half represented these subsystem from knowledge innovation in tech-service industry, then right half represented the subsystem of knowledge innovation in manufacturing enterprises. Knowledge potential energy difference and transfer threshold were the boundary values that affect whether knowledge transfer can continue.

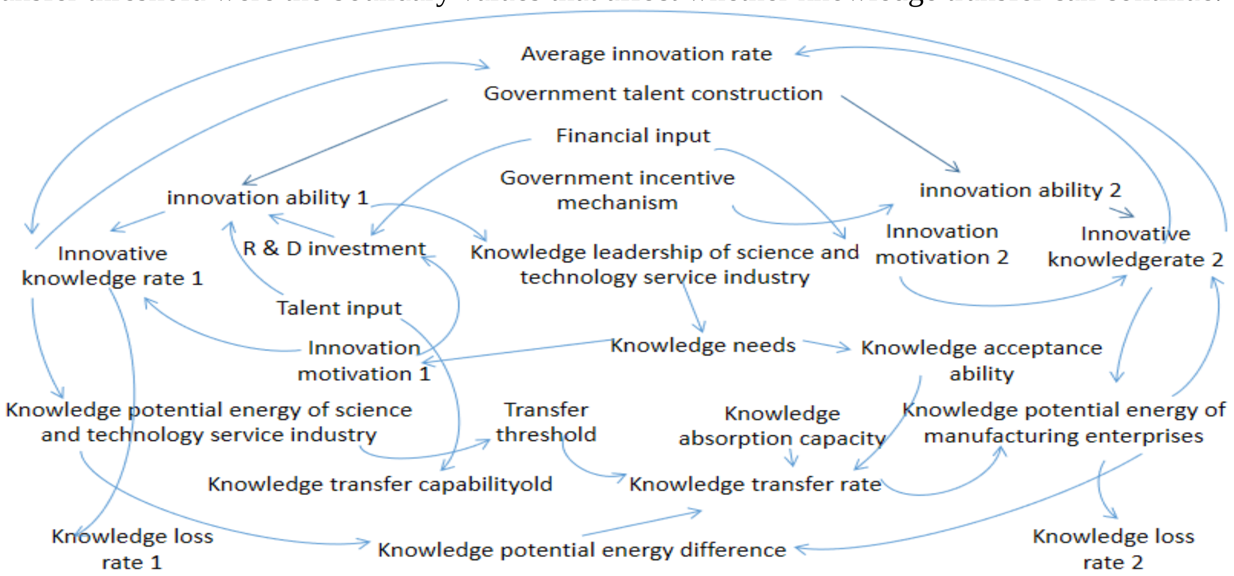

Figure 1: Causal relationship between collaborative innovation in high manufacturing & tech-service industry

Figure 1 showed important evolution path from collaborative innovation in high manufacturing & tech-service industry through knowledge integration. Knowledge migration built a bridge for the knowledge integration from high manufacturing & tech-service industry. Experience could break through the original boundary and realized a virtuous cycle of system elements. It was explained in detail in Table 1.

Table 1: Path and explanation

PATH	EXPLANATION
Innovation path of tech-service industry: knowledge innovation rate 1 - knowledge potential energy of tech-service industry - knowledge potential energy difference - knowledge transfer rate - knowledge potential energy of manufacturing enterprises - innovation motivation 1 - R & D investment - innovation ability 1 - knowledge innovation rate 1; Knowledge innovation rate 1 - knowledge potential energy of tech-service industry - knowledge potential energy difference - knowledge transfer rate - knowledge potential energy of manufacturing enterprises - knowledge innovation rate 2 - knowledge innovation rate 1	Manufacturing enterprises have invention and innovation with production needs, and have unique knowledge advantages and core competitiveness among innovation subjects; The innovation knowledge of manufacturing enterprises spills over to the tech-service industry, which plays a role in the progress of the tech-service industry. The self owned knowledge of both sides realizes the integration and innovation under the new service system.
Innovation path of high manufacturing: knowledge innovation rate 2 - knowledge potential energy of manufacturing enterprises - innovation motivation 1 - R & D investment - innovation ability 1 - knowledge innovation rate 1 - knowledge potential energy of tech-service industry - transfer threshold - knowledge transfer rate - knowledge potential energy of high manufacturing - innovation ability 2; Knowledge innovation rate 2 - knowledge potential energy of manufacturing enterprises - innovation motivation 1 - Talent Investment - innovation ability 1 - knowledge innovation rate 1 - knowledge potential energy of tech-service industry - transfer threshold - knowledge transfer rate - knowledge potential energy of high manufacturing - innovation ability 2	tech-service companies own a flexible mechanism for transform knowledge, and can design a matching innovation mechanism for manufacturing enterprises. Knowledge potential can be improved in tech-service industry. Manufacturing companies can utilize knowledge fusion to break through existing knowledge barriers.

3.2.2. Flow Chart of Collaborative Innovation System

This paper introduced condition variables, speed variables, subsidiary variables and constants to transform Figure 1, and the collaborative innovation system of high manufacturing & tech-service industry included 2 state variables, 5 speed variables, 12 auxiliary variables and 5 constants. Seen Figure 2 for details.

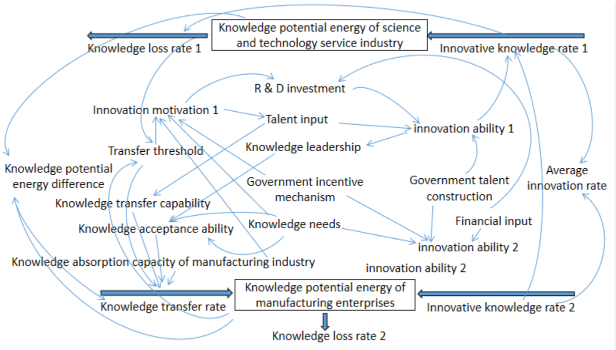

Figure 2: Collaborative innovation system flow of high manufacturing & tech-service industry

3.2.3. Equation Formulation of Collaborative Innovation System

According to the above analysis, let KPES represented the knowledge potential energy from tech-service industry, KPEM represented knowledge potential energy from high manufacturing, KIR represented the knowledge innovation rate, KLR represented the knowledge loss rate, KTR represented the knowledge transfer rate, INTEG represented the integral formula, IA represented the innovation ability, TI represented the talent investment, RI represented the R & D investment, GTC represented the government talent construction, TT represented the transfer threshold, KACM represented knowledge absorption capacity, KTC represented the knowledge transfer capacity, KAC represented to knowledge acceptance ability, and KPED represented to knowledge potential energy difference. The equation of collaborative innovation system was shown as:

$$\mathrm{KPES} = \mathrm{INTEG}(\mathrm{KIR1} - \mathrm{KLR1}, 80) \quad (1)$$

Formula 1 indicated that the initial value of knowledge potential energy of tech-service industry was 80, which was the integral of the difference between knowledge innovation rate and knowledge loss rate.

$$\mathrm{KPEM}=\mathrm{INTEG}\ (\mathrm{KIR2}+\mathrm{KTR}-\mathrm{KLR2},\ 20) \quad (2)$$

Formula 2 indicated that the initial value of knowledge potential energy in high manufacturing was set to 30, which was the integral of the sum difference relationship among knowledge innovation rate, knowledge transfer rate and knowledge loss rate.

$$\mathrm{KLR1} = \mathrm{STEP}(0.1 \times \mathrm{KIR1} + 0.3, 8); \mathrm{KIR2} = \mathrm{STEP}(0.1 \times \mathrm{KIR2} + 0.2 \times \mathrm{KTR} + 0.15, 8) \quad (3)$$

At this time, the knowledge loss rate was a step function of the knowledge innovation rate and knowledge transfer rate, and the step occurs at 8.

$$\mathrm{IA1} - \mathrm{TI} \times \mathrm{RI} \times \mathrm{GTC} \quad (4)$$

The innovation ability of tech-service industry was some product function from talent investment, R & D investment and government talent construction.

$$\mathrm{TT} = \mathrm{KPEM}/\mathrm{KPES} \quad (5)$$

The transfer threshold is calculated by the ratio of knowledge potential energy of high manufacturing to what of tech-service industry.

$$\mathrm{IA2} = \mathrm{GTC} \times \mathrm{KPEM} \times \mathrm{KACM} \quad (6)$$

The innovation capacity of high manufacturing was calculated by the product of government talent construction, manufacturing knowledge potential energy and manufacturing knowledge absorption capacity.

$$KTR = DELAY1I(IF\ THEN\ ELSE(TT < 0.8, KACM \times KTC \times KAC \times KPED, 0), 2, 0) \quad (7)$$

Knowledge transfer rate was an increasing function of manufacturing knowledge absorption capacity, knowledge transfer capacity, knowledge acceptance capacity and knowledge potential energy difference. The first-order delay function was used to simulate knowledge transfer rate, and the transfer threshold was used as the valve of knowledge transfer process. Set the delay time as 2 and the initial value as 0. When the knowledge potential energy difference exceeds the transfer threshold, the manufacturing enterprise will be difficult to absorb the knowledge to be transferred, and the knowledge transfer process will stop.

4. Collaborative Innovation Simulation and Sensitivity Analysis

The data adopted the overall situation of Zhuhai statistical yearbook, Guangdong science and Technology Yearbook from 2020 to 2021 and the collaborative innovation growth of Hengqin high manufacturing & tech-service industry. Their initial value and parameters in Zhuhai Hengqin knowledge integration collaborative innovation were set as: manufacturing knowledge absorption capacity (KACM)=0.25; Government incentive mechanism (GIM) =0.35; Knowledge demand (KD) =0.15; Financial input (FI) =0.3; Government talent construction (GTC) =0.25.

4.1. Collaborative Innovation Simulation Analysis

In this paper, Vensim DSS software software was used for the simulation prediction of knowledge fusion and innovation collaboration. The simulation prediction needed to give the prediction period in advance, and then calculated according to the time series. In this study, for the sake of conforming to the growth of China's high manufacturing 2025 and Hengqin, this time target was set at 2025, and the data used was 2021. Therefore, the simulation time was set at 4 years that was 48 months. Therefore, we could use data and software to simulate the results of knowledge potential energy, knowledge innovation rate and knowledge transfer rate of high manufacturing & tech-service industry of Zhuhai.

4.1.1. Analysis of Changes in Knowledge Potential Energy and Knowledge Innovation Rate

Figure 3 and Figure 4 showed that the technology service industry had improved its knowledge potential due to knowledge transfer. After the index reached 200 in the 34th month, the increase effect was more obvious. By the 48th month of the prediction period, the index reached 434. It showed that the integration of transferred knowledge and their original knowledge would improve their knowledge innovation ability and knowledge innovation rate. Therefore, with the increase of knowledge potential energy in tech-service industry, innovation rate within enterprises was also rising. It could also be found that the knowledge potential energy and knowledge innovation rate of tech-service industry were significantly higher than that of high manufacturing, indicating that tech-service industry was some foundations for manufacturing knowledge integration. Only when the knowledge of tech-service industry was better integrated, could the technological upgrading of high manufacturing be brought about. Tech-service industry itself relied on experience accumulation as well as transfer to maintain its competitive position. Tech-service industry had unique advantages of knowledge production. The tech-service industry itself relied on bring forth new ideas to increase knowledge to maintain its competitive position. Manufacturing enterprises attached importance to the production of products, mainly using knowledge transfer to increase knowledge potential energy, but also using knowledge innovation to increase knowledge potential energy. Therefore, the knowledge potential energy and knowledge innovation rate of tech-service industry were higher than that of enterprises, which was in line with the actual cognition.

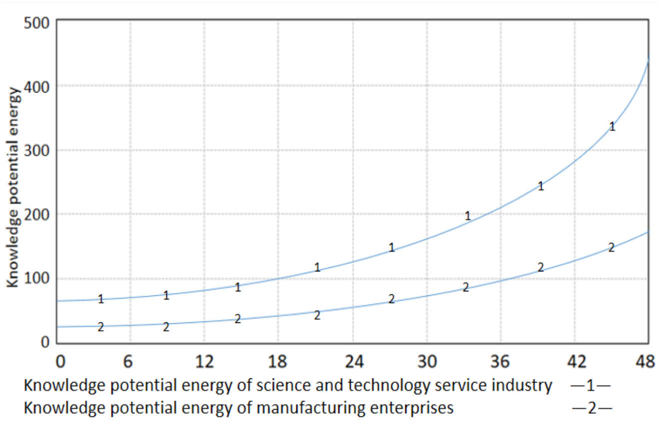

Figure 3: Knowledge potential energy of Hengqin tech-service industry and high manufacturing

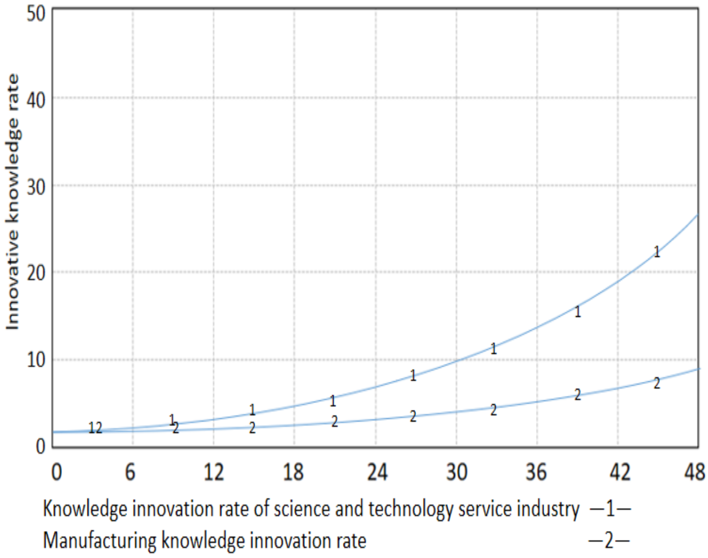

Figure 4: Hengqin tech-service industry and high manufacturing knowledge innovation rate

4.1.2. Analysis on the Change of Knowledge Transfer from Tech-service Industry to High Manufacturing

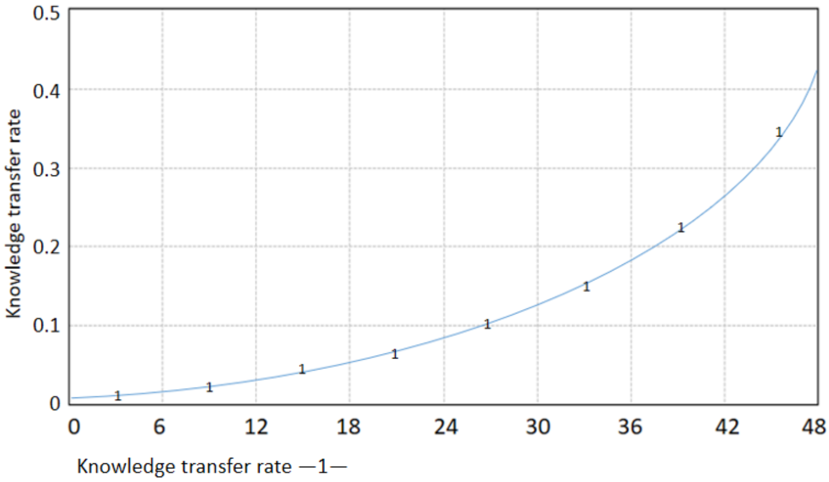

Figure 5: Simulation of knowledge transfer rate of Hengqin tech-service industry

Knowledge transfer rate was an important manifestation of knowledge fusion. As could be seen from Figure 5, it broke through 0.1 at 26 months, 0.2 at 37 months, 0.3 at 44 months, and 0.4 at 47 months. In the 48 month simulation prediction interval, the knowledge transfer rate was accelerating. With the progress of knowledge transfer, the knowledge transfer rate of tech-service industry to manufacturing enterprises was increasing. Growth rate of knowledge potential energy and innovation rate of tech-service industry were higher than that of manufacturing enterprises, which would increase their knowledge potential energy difference and promote the progress of knowledge transfer. The knowledge transfer rate would continue to increase, forming a virtuous circle, and realizing the knowledge integration and collaborative innovation development between high manufacturing & tech-service industry.

4.2. Collaborative Innovation Sensitivity Analysis

4.2.1. Sensitivity Analysis of Knowledge Fusion Factor

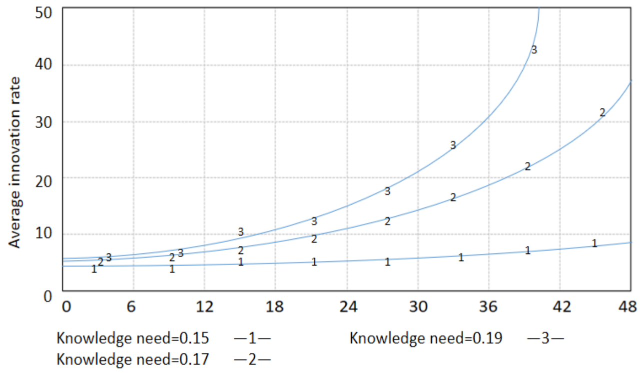

Figure 6: Sensitivity analysis of knowledge demand factor

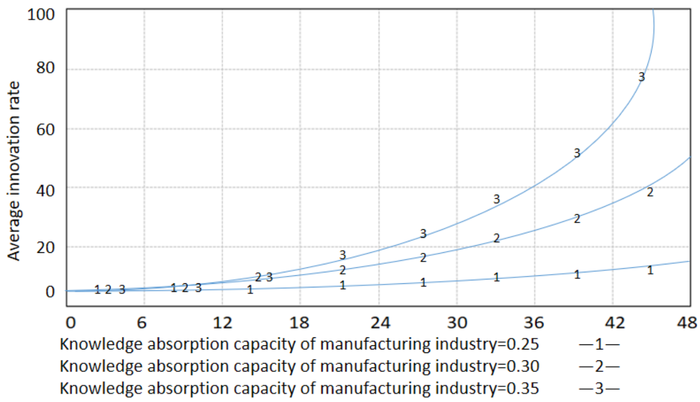

Figure 7: Sensitivity analysis of manufacturing knowledge absorptive capacity factor

Collaborative innovation was produced by knowledge fusion, so knowledge fusion factors included knowledge demand factors and manufacturing knowledge absorption capacity factors. According to the actual situation of Hengqin, this paper set Special value of knowledge demand factor as 0.15, 0.17 and 0.19, took the value of manufacturing knowledge absorption capacity factor as 0.25, 0.30 and 0.35, and run the change of the average innovation rate of high manufacturing & tech-service industry in Hengqin. Simulation results were shown in Figure 6 and Figure 7. The value of knowledge demand factor and manufacturing knowledge absorptive capacity had no effect on the trend of average innovation rate. With the increase of knowledge demand and manufacturing knowledge absorptive capacity, the average innovation rate would increase. From the comparison between Figure

6 and Figure 7, knowledge demand has a higher sensitivity to the average innovation rate. The greater the demand of manufacturing enterprises for knowledge, the more it could stimulate the knowledge innovation motivation of science and tech-service enterprises and high manufacturing, then improved this average innovation rate of the two industries; With the improvement of knowledge absorption capacity of high manufacturing, the average knowledge innovation rate of manufacturing enterprises and tech-service industry had increased significantly. The knowledge absorptive capacity from manufacturing enterprises could promote the effect of knowledge transfer and improve the average knowledge transfer rate.

4.2.2. Sensitivity Analysis of Policy Factors

Policy factors mainly referred to three factors: government incentive mechanism, financial investment and government talent construction. While keeping other parameters in the system unchanged, combined with the actual situation of Hengqin, the government incentive mechanism factors were set to 0.35, 0.40 and 0.45, the financial investment factors were set to 0.30, 0.35 and 0.40, and the government talent construction factors were set to 0.25, 0.30 and 0.35. Through the operation of three factors, we can get the sensitivity simulation analysis results of the average knowledge innovation rate of tech-service industry and manufacturing enterprises in Zhuhai, as shown in Figure 8, Figure 9 and Figure 10. With the improvement of incentive mechanism, talent construction and financial investment, the average innovation rate of high manufacturing & tech-service industry had become higher as well as faster, and average innovation rate had increased exponentially. It could be concluded that the system had high sensitivity to incentive mechanism, talent construction and financial investment.

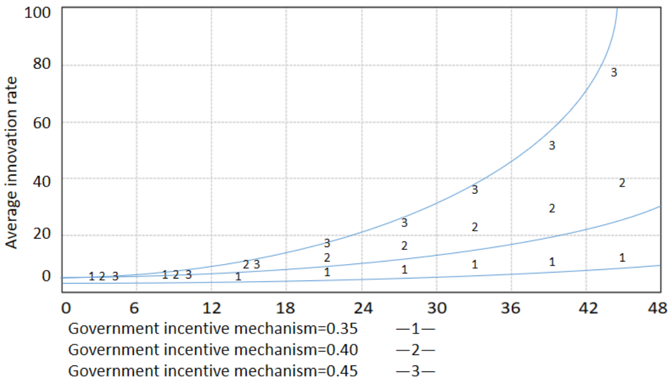

Figure 8: Sensitivity analysis of government incentive mechanism factors

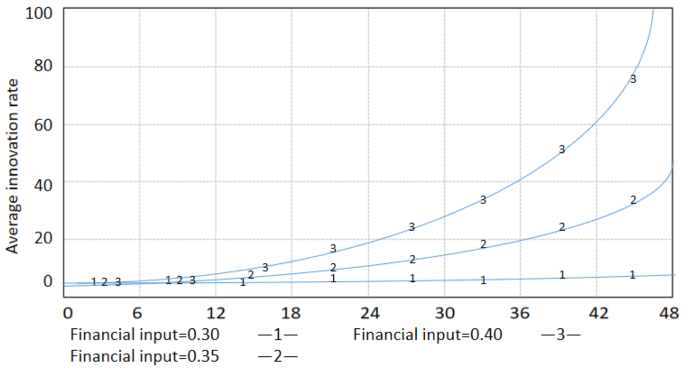

Figure 9: Sensitivity analysis of financial input factors

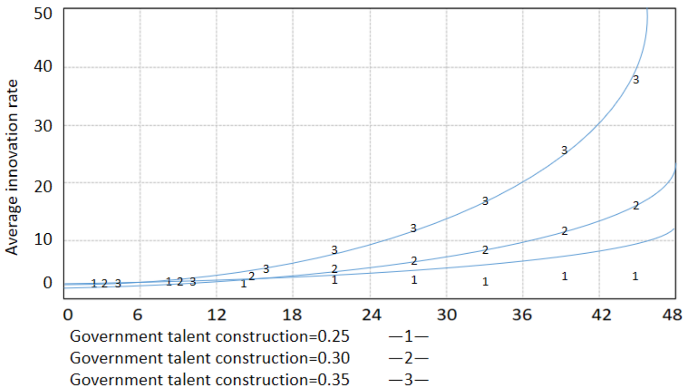

Figure 10: Sensitivity analysis of government talent construction factors

To sum up, the collaborative innovation system had high sensitivity to the knowledge demand and knowledge absorption capacity of manufacturing enterprises, as well as the incentive mechanism, financial investment and talent construction of the government. These variables were positively related to knowledge innovation in high manufacturing & tech-service industry. Knowledge demand could stimulate the innovation motivation of the two industries, enhanced the integration of knowledge, enhanced the innovation ability of enterprises, and then stimulated the innovation motivation of tech-service industry. Government support might stimulate the knowledge innovation ability of the two industries.

5. Suggestions on Improving Level of Collaborative Innovation

5.1. Improve Innovation Ability of Knowledge Integration

The knowledge absorptive capacity of manufacturing enterprises was an important factor affecting the effect of knowledge transfer. The quality of knowledge absorptive capacity directly determined the success or failure of knowledge acquisition and innovation, and would also reduce the innovation motivation and innovation efficiency of tech-service industry. Some knowledge demanded from enterprises directly affects knowledge transfer between high manufacturing & tech-service industry. The market as well as government could stimulate and encourage the scientific and technological innovation of manufacturing enterprises to increase their demand for advanced knowledge and promote the knowledge transfer and innovation of enterprises.

5.2. Improve the Government Incentive Mechanism

The government shall vigorously advocate the science and technology and knowledge innovation of high manufacturing & tech-service industry, and encouraged the cooperation and sharing of knowledge resources between the two industries. This incentive mechanism would promote the demand of manufacturing enterprises for knowledge, stimulate the knowledge innovation ability of tech-service industry, promote the knowledge transfer between two industries, as well as realize the coordinated development of the two industries.

5.3. Government Increases Financial Input

Government financial support was the fundamental guarantee to improve the efficiency of knowledge creation and knowledge transfer. The increase of financial investment would enable the two industries to allocate more funds for R & D investment in knowledge. The increase of R & D investment could not only display the ability of high-quality talents, but also stimulate the innovative behavior of talents, thus to boost improvement of talents' knowledge innovation ability.

5.4. Government Strengthens Talent Construction

High quality talents were important resources for the tech-service industry and manufacturing companies to improve their innovation ability. The government shall pay attention to cultivating local high-quality leading talents or attracting foreign high-quality leading talents, pay attention to the construction of scientific and technological innovation teams, then ensure the stability development of scientific and technological innovation teams.

6. Conclusion

Process of knowledge transfer between tech-service industry and manufacturing companies was also a procedure of continuous integration and innovation from knowledge. Through knowledge transfer, the knowledge potential energy and knowledge innovation ability of manufacturing enterprises were increased, and the innovation motivation and innovation ability of tech-service industry were also increased. Knowledge integration blaze new trails shall take enhancing the knowledge absorption capacity of enterprises, stimulating the knowledge demand of manufacturing enterprises, strengthening the government incentive mechanism, increasing financial investment and paying attention to talent construction as a breakthrough, so as to realize the knowledge integration and collaborative innovation development of tech-service industry and manufacturing enterprises. This study could provide a theoretical basis for tech-service industry and manufacturing establishment to improve their knowledge innovation ability and make better use of knowledge resources to achieve collaborative innovation. In reality, the knowledge transfer between high manufacturing & tech-service industry was a more complex and abstract process than this paper. Its influencing factors were numerous and changeable, so it is difficult to fully take into account the influencing factors when building the model. Therefore, this model had some limitations, which need to be optimized and improved in the upcoming day.

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