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Research on the Roles of Chinese Universities from the Perspective of the Triple Helix Model

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Abstract: *At present, the world is in the superposition period of the innovation business cycle. Disruptive technologies are constantly emerging, and new industries, new formats and new models are booming. As an important part of the national innovation system, universities are one of the important sources of knowledge innovation and technological innovation. Through theoretical analysis, this paper systematically expounds the triple helix theory, innovation theory of business cycle, scientific paradigm revolution, endogenous economic growth theory and other related theories. Using qualitative research methods, this paper analyzes the cases of Zhangjiang iFLYTEK, Zhangjiang Pharma Valley, quantum communication and Hefei's development, and explores the role behavior of universities in the revised Government-Industry-University (GIU) Triple Helix Model. The research results include: (1) Research-oriented universities, applied science and engineering universities and higher vocational institutions have different roles in GIU Triple Helix Model. (2) In GIU Triple Helix Model, research-oriented universities provide non-exclusive knowledge. (3) In GIU Triple Helix Model, applied science and engineering universities play special roles in applied research, patents and other technological innovations, providing exclusive and competitive knowledge. (4) In the GIU Triple Helix Model, higher vocational institutions mainly play a role in cultivating innovative talents and serving scientific and technological innovation.*

Keywords: *Innovation Theory, GIU Triple Helix Model, Role of Universities*

1. Introduction

1.1. Research Background and Research Problem

In today's world, science and technology are developing with each passing day, technological change is accelerating, major scientific and technological innovations are constantly emerging, and scientific and technological achievements are increasingly applied to production and practice, which is gradually changing people's way of living, production methods and even thinking modes. From the perspective of world science and technology development, a new wave of scientific and technological revolution and industry reform are reshaping the global innovation landscape and the global economic structure. Science and technology have had an unprecedented impact on the future and destiny of a country and people's lives. Science and technology, with their basic, leading and strong permeability, have become the key factors in the national strength competition of big economies. China's economy has changed from a high-speed growth stage to a high-quality development stage, and is in the key period of transforming the development mode, optimizing the economic structure and transforming the growth momentum. The key to this is innovation-driven and holistic innovation. That is to say, innovation is not limited to the basic research in the ivory tower of universities. Although such innovations have the potential and possibility to promote development, they are not realistic and timely.

The benign interaction among universities, industry, and the government is not only the key to innovation but also the inexhaustible driver for economic growth and social development. Innovation activities need the participation of universities, industry, and government, which makes the triple helix interaction among universities, industry, and government become the core power of the innovation system. Economic development has different stages; especially economic development driven by innovation has obvious stage characteristics. Innovations will play different roles in different stages of development, and their intensities and modes will also be different, so we cannot treat them in the same

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way. All subjects exist in certain fields with specific cultural, national and policy attributes; that is, the subjects are national, so they are special because of the national history, culture, system, economic foundation, development level, etc., which will inevitably make the application of GIU Triple Helix Model unavoidable and legitimate localization.

In addition, the way out of the traditional GIU Triple Helix Model lies in the establishment of "entrepreneurial universities", which can be used for reference in China, but it is far from enough. In the framework of China's national innovation system, the mission of innovation has been attributed to multiple subjects based on national conditions. After all, compared with other countries, Chinese enterprises have not yet formed universal consciousness and competencies of scale in scientific and technological innovation. China's higher education system and research institutions' organization system have not yet formed a close and direct connection with national production and life; especially entrepreneurial universities that focus on scientific and technological transformation and production application have not yet formed a deep consensus and practice at the conceptual and factual levels. Such a national condition determines that we need to make an in-depth study on the roles and functions of different types of universities in triple helix innovation theory.

1.2. Research Objectives

The first is to revise the GIU Triple Helix Model. Based on China's practical experience, the author found that the traditional GIU Triple Helix Model cannot fully explain some innovation phenomena, so he got the idea of revising the theory based on practice. The premise is that innovation has become the core driver of economic development and the GIU Triple Helix Model is known as an important way to generate innovation at present. Schumpeter's business cycle theory clarifies the era value of innovation and the cyclical economic development it causes. GIU Triple Helix Model confirms the production path of innovation by government, industry and university. According to endogenous economic growth theory, knowledge, technology and human resources are the core elements supporting the GIU Triple Helix Model. Thus we can clarify the internal relations among the three theories, and then introduce Kuhn's paradigm revolution and transfer theory to revise the traditional GIU Triple Helix Model theoretically.

The second is to analyze typical cases guided by the GIU Triple Helix Model theory, including enterprises, industries and cities, which can not only highlight the universal applicability of the GIU Triple Helix Model theory but also highlight the role of different universities and how they interact with "governments" and "industries" in different typical cases.

The third is to explore the functions and roles of universities at different stages (different levels of U) in GIU Triple Helix Model under the theoretical framework of the GIU Triple Helix Model based on innovation theory and through case analysis and literature combing, which leads to the change of management objectives and strategies of universities (organizations).

1.3. Research Content

Part I: Introduction. This part elaborates on the research background and proposes the research content, objectives, and structure of the paper.

Part II: Theoretical foundation. This part reviews the relevant theories and research status of the triple helix theory, innovation and business cycle theory, and endogenous economic growth theory.

Part III: Research methods. On the basis of literature analysis, this part elaborates on the research methods and uses the government-industry-university triple helix theory constructed in this paper to analyze iFLYTEK, Zhangjiang Pharma Valley, China's quantum communication and Hefei's urban development.

Part IV: Research conclusions. This part integrates theoretical research and case studies and summarizes different roles and operating mechanisms of different types of universities in the government-industry-university triple helix.

Part V: Discussion. This part summarizes the research results, limitations and prospects for further research.

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2. Literature Review

There are a lot of theories with innovation as the core concept and theme. However, each theory only focuses on a certain aspect of innovation. For example, the Triple Helix Innovation Theory pays attention to the generation mechanism of innovation, and the innovation theory of business cycle focuses on the function of innovation, especially the same frequency resonance function on the economic development cycle. However, they pay less attention to overall innovation and its application. Besides, under the realistic situation that innovation drives economic development, any single theory inevitably has the risk of bias in guiding practice, so the appropriate theoretical integration is particularly critical. This part focuses on combing the triple helix innovation model theory, the innovation theory of business cycle and the endogenous economic growth theory. The reason why these three theories are selected among many innovation theories is to complete the construction of specific components for the innovation theory of this study. Among them, the GIU Triple Helix Model dedicated to the mechanism of innovation is the main component, the innovation theory of business cycle is the definition of the stage in which innovation plays a role, and the endogenous economic growth model is the emphasis on the innovation field and the independent "endogenous development" of the subjects.

2.1. Literature review on innovation theory of business cycle

Schumpeter's innovation theory of business cycle is mainly expressed in his monographs Economic Development Theory—An Investigation of Profit, Capital, Credit, Interest and Business Cycle and Business Cycle: Theoretical, Historical and Statistical Analysis of Capitalist Process. In these two books, he constructed the economic cycle theory with innovation theory as the core, or the innovation theory of business cycle. Drucker, the father of modern management, predicted that Schumpeter would become an economist who had the greatest influence on the development of the world economy in the 21st century. Rosenberg even emphasized that the 21st century would be the Schumpeter era of economics.

Based on Schumpeter's concept of innovation, the theory of "technological innovation" appeared in the early 1960s. This theory is known as "New Schumpeter School" in Western economics. Some of the famous figures are Edwin Mansfield, Morton L. Carmine, Nancy Schwartz, Richard Levin, G.K. Helena, etc.

In China, “Schumpeter's ‘Multi-Level’ Business Cycle Theory and ‘Technological Innovation’” published by Tan Hui in 1988 was the first to study Schumpeter's innovation theory of business cycle in China. In this paper, she introduced Schumpeter's “multi-level" business cycle theory, pointing out that this theory is "based on ‘technological innovation’”, which has two meanings: First, the emergence or formation of business cycle comes from "technological innovation". Because in Schumpeter's view, the introduction of "technological innovation" is not continuous and smooth; instead, it is sometimes high and sometimes low, sometimes "clustered" and sometimes sparse, which produces business cycles. Second, the "multi-level" business cycle and the different lengths of various business cycles also come from "technological innovation". She pointed out that the thoughts of Schumpeter on business cycle are influenced by Karl Marx to some extent.

With the deepening of theoretical research, Schumpeter's innovation theory of business cycle is constantly challenged by Chinese scholars. Liang Jie (2006) pointed out that in recent decades, the mainstream economic paradigm studying business cycles has changed from Keynesianism to business cycle theory, but both theories have many problems in explaining real data. Sun Liang and Wei Sen (2020) reviewed Schumpeter's innovation drive theory and pointed out that Schumpeter's business cycle theory with innovation as the core has limitations. First of all, although Schumpeter described five categories of "innovation", from the content of his writings, he mostly focused on the application of new production technology as the explanation tool for long-term economic fluctuations, and he somehow absolutely believed that innovation was the only factor leading to the business cycle, while ignoring the factors such as population and labor, investment, distribution relationship and property rights. Secondly, Schumpeter contended that both recession and depression belong to the automatic adjustment process from the old equilibrium to the new equilibrium, and emphasized that recession is necessary and depression is unnecessary. Thirdly, in the business cycle theory, capital is assumed to be a non-scarce resource, and the only factor causing economic growth is innovation. According to Schumpeter's logic, without innovation, no matter how abundant funds are, economic development is impossible. In the face of today's economic fact that capital is king, this is obviously problematic. He concluded that "although currently 'innovation' has got more attention than ever, it is the corresponding business cycle that deserves more attention."[1]

2.2. Literature review on GIU Triple Helix Model

In the early 1950s, the concept of triple helix appeared in the field of biology. Richard Lewontin, an American geneticist, was the first to use triple helix to simulate the relationship between genes, tissues and the environment. In his book *Triple Helix: Genes, Organisms and the Environment*, he pointed out that "the relationship among genes, organisms and the environment is a complex one. The three are like three helices intertwined, and all of them have a causal relationship at the same time. Both genes and environment are the causes of the organism, while the organism is also the cause of the environment, so genes mediated by the organism become the cause of the environment. "[2]

In 1995, inspired by the triple helix model of biology, Henry Etzkowitz (1993) and Leydesdorff (1995) co-authored *Universities and the Global Knowledge Economy: Triple Helix of University-Industry-Government Relations*. Through the practical investigation and research of Silicon Valley cases in the United States, they condensed the GIU Triple Helix Model of universities, industry and government, and applied it to study the complex dynamic interaction among universities, industry and government. In the same year, they published a paper entitled "Triple helix --- relationship among universities, industries, and governments: the knowledge-based lab for economic development", which explains the transformation from the dominant industry -- government binary relationship in industrial society to the growing triple relationship between universities, industries and governments in the knowledge society[3]. In the knowledge society, the potential for innovation and economic development is to enable universities to play more prominent roles and to combine the elements of universities, industries and governments to create new institutions and social forms for production. Their follow-up research further pointed out that the driving force of social and economic development comes from the mutual cooperation and mutual promotion among universities, industries and governments, which enriches the research foundation for innovation, entrepreneurship and economic development. Different from the traditional innovation system theory which emphasizes the single role of enterprise or government as the core element of the innovation system, the Triple Helix Innovation Theory emphasizes the close cooperation among GIU and collaborative innovation, which holds that the "overlap" of university, industry and government is the core unit of the innovation system, and its triple connection is an important factor to promote knowledge production and dissemination. In the process of transforming knowledge into productivity, the three parties interact with each other, thus promoting the helix of innovation. Since then, the GIU Triple Helix Model theory has been regarded as a new paradigm in innovation research and "innovation in innovation"[4], which mainly means that under the background of the knowledge economy, universities, industries and governments should strengthen the sharing and exchange of resources and information through structural arrangement and system design, so as to improve the efficiency and benefit of scientific and technological resources utilization. [5]

Chinese scholars began to study Triple Helix Model in 2000, when Xue Lan first mentioned triple helix in an article published in *Chinese and Foreign Science and Technology Information*. In 2003, Fang Weihua formally introduced the GIU Triple Helix Model theory from the West and systematically explained it. The paper pointed out that the essence of GIU Triple Helix Model lies in "emphasizing the cooperative relationship among the industry, academia and government, and emphasizing that the common interest of these groups is to create value for the society in which they live". Zhou Chunyan (2006) translated Henry Etzkowitz's book *Triple Helix: The Three-in-One Innovation Model of University, Industry and Government*. In his book review, he pointed out that the previous innovation theories are mostly studied from the perspective of economics, while triple helix studies the organization and realization of innovation activities from the perspective of sociology. University, industry and government are regarded as the roles of social activities, which are not only the elements of innovation, but also the main bodies of activities. After more than 20 years of development, great progress has been made in the theoretical research of GIU Triple Helix Model in China, which is manifested in the endless publication of articles on relevant topics, the deepening of research contents, from the introduction of early theories to the current practical application, and to the emergence of localized innovation. To a certain extent, research on triple helix is characterized by diversification, practicality, localization and innovation. The application of GIU Triple Helix Model theory in China mainly focuses on regional innovation and development, GIU cooperation mode and mechanism, university education and so on.

2.3. Literature review on endogenous economic growth theory

Endogenous economic growth theory, also known as the new economic growth theory, was proposed in view of the neoclassical economic growth model (Solow model). Solow founded the neoclassical growth model, which is based on the Cobb-Douglas production function with labor input and material capital input as independent variables, and takes technological progress as exogenous factors to explain economic growth, so he got the conclusion that long-term economic growth stagnates when factor income decreases. Specifically, there are three main differences between endogenous economic growth theory and neoclassical economic growth theory: First, the assumptions are different. Neoclassical economic growth theory assumes that the marginal benefit of capital is diminishing, while endogenous economic growth theory assumes that the marginal benefit of capital is unchanged. Neoclassical economic growth theory assumes that technology is exogenous, while endogenous economic growth theory maintains that technology, like capital, is endogenous. Second, the model forms are different. In the model of endogenous economic growth theory, the production function is Y=AK, where Y is output, K is capital stock, and A is constant, representing technology. In the neoclassical economic growth theory model, the production function is Y=F (L, K), where L is labor input, K is capital deposit, and the Cobb-Douglas production function is often selected in the model of Y=F (L, K), and the return to scale is assumed to be constant. Third, the conclusions are different. The conclusion of endogenous economic growth model is that the economic growth rate is endogenous, that is, the factors that promote economic growth are determined by the model, and savings and investment will cause long-term economic growth. The conclusion of neoclassical economic growth theory is that economic growth depends on exogenous technological progress, while savings will only lead to temporary economic growth, and the law of diminishing marginal benefits of capital finally makes economic growth only depend on the stable state of exogenous technological progress.

Romer (1986) put forward the first economic growth model in his paper "Increasing Income and Long-term Growth", which is an economic growth model under the condition of complete economic competition. Romer believed that from the vertical investigation of the economic growth of various countries, it can be seen that with the passage of time, the economic growth rate of a country has an upward trend; from the horizontal comparison of countries in the world, the gap between developed countries and most developing countries is widening rather than narrowing. According to this basic fact of economic growth, Romer came to the conclusion that production has increasing benefits. He believed that knowledge and technology research and development are the sources of economic growth.

The study of the endogenous economic growth theory began in China at the end of the 20th century. Yang Hongru (1991) compared Arrow's "learning by doing" model, growth model including human capital, technology externality model, specialization and trade-led economic growth model, and pointed out that the economic growth process in the four models does not depend on exogenous variables, and the production process can accumulate and develop itself. [6] On this basis, Chinese scholars have done a lot of valuable research from two aspects: the understanding of endogenous economic growth theory and the application of the theory.

After all, endogenous economic growth theory is a relatively new theory, and there is room for further development. However, what is particularly helpful to this study is that, endogenous growth theory puts forward the role of knowledge, technology and human resources in promoting economic development, and Schumpeter's business cycle theory puts forward the core role of innovation in economic development. Knowledge, technology and human capital have inherent consistency with innovation, or innovation depends on knowledge, technology and human capital, and knowledge, technology and human capital are the carriers of innovation. Therefore, the endogenous growth theory and Schumpeter's business cycle theory have the same goal through different paths, both pointing out the important role of education in economic and social development from different aspects! Then, increasing investment in education and improving people's education level are all investments in knowledge, technology and human capital, as well as in innovation. The classification of knowledge and technology and the classification of human capital also provide a theoretical basis for the different roles that different universities should assume in GIU Triple Helix Model.

3. Methodology

This study adopts a mixed research method, including constructing hypotheses and research framework by theoretical research and verifying and revising theoretical framework by empirical

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research. The two correct and support each other, serving this study completely.

3.1. Theoretical research

Table 1: Different roles of GIU in innovation-driven business cycles.

Stage	Characteristics	Representation	Government	Enterprises	University
Science and technology innovation period	New scientific theory paradigm revolution, scientific theory thought	Industrial revolution stimulated by scientific revolution	Policy making, basic research investment	Participation in research	Scientific research, establishing a new paradigm
Innovation growth period	Disruption of science and technology, innovating paradigm	Industrial revolution, new industry Leading to the revolution of industrial organizations and even the revolution of production mode, lifestyle and social mode	Determining the direction of innovation, led by science and technology, and supporting GIU to integrate innovation	Accelerating the transformation of scientific and technological achievements, strengthening the construction of common technology platforms, and promoting the integration and innovation of the middle and lower reaches of the industrial chain, and large, medium and small enterprises	Forward-looking basic research, key generic technology, cutting-edge leading technology, modern engineering technology research and development
Normal growth period	Diffusion and application of knowledge Updating of the improved knowledge Improvement and growth of technology Breaking down, subdividing and deepening of industries Cross-boundary knowledge	Normalized innovation In mature GPT, new applications, new markets, growing technology Efficient business model Knowledge deepening, expanding combination New market space	Creating and maintaining an environment that encourages innovation, integrating innovation resources, and promoting the progress of applied science and technology and corresponding industries	Quickly transforming scientific and technological products, developing industrial clusters, opening up new business models and expanding new markets	Constantly confirming and improving the theory, innovating the talent training mode, and providing knowledge, intelligence, technology and special talents
Anomalies (period) Dilemmas, imbalances	Reflections on challenges, imbalances and dilemmas Applicability technology, sustainability Discovering new opportunities, judging, and abandoning traditional thinking patterns Preventing pseudo-innovation Element recombination	Unbalanced, non-repetitive Contradictory dilemma, implying the miracle of innovation Traditional livelihood industry being impacted and transformed High-tech-empowered production Development, cultivation and transformation of emerging industries Capital-empowerment, investment	Giving full play to the government's public finance role and adjusting the industry policy in a timely manner	Implementing austerity strategy, reducing costs and investment, accelerating asset recovery, and developing promising businesses and markets	Exploring new knowledge, studying new theories and exploring new scientific paradigms

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In this study, theoretical research is the main research method, including literature analysis and philosophical speculation. Specifically, theoretical research is mainly used to analyze business cycle theory, endogenous economic growth theory, GIU triple helix theory and paradigm theory, and to study the internal relevance of these theories, so as to put forward a revised theoretical model of government-industry-university triple helix system.

Traditional GIU Triple Helix Model put forward an important path of innovation, but it lacks the background of innovation, the requirements of the times for innovation and the driving force of innovation. After fully investigating the requirements of economic cycle development for innovation, we introduced the endogenous economic growth theory to supplement the driving force and source of innovation. This study constructs a GIU Triple Helix Model based on innovation theory.

In the GIU triple helix model, as the base of knowledge production, the university (abbreviated as U) ensures the source of new knowledge and new technology, and it is the productivity factor of knowledge economy; industry or business (abbreviated as I) is the place of production, producing products and providing services; government (abbreviated as G) regulates and maintains the contract relationship participants in the market by means of legislation, etc., and ensures the stable interaction and reciprocal exchange. Based on Kuhn's paradigm revolution, the innovation business cycle can be divided into four stages: science and technology innovation period, innovation growth period, normal growth period and anomalies. According to the economic endogenous growth theory, the governments, enterprises and universities play different roles in these four stages, as it is shown in Table 1.

The economy develops cyclically and spirally. Everything develops in a nonlinear spiral dynamic way. The economy also fluctuates periodically and grows in a spiral way. Sometimes it accelerates and sometimes it decelerates and even regresses. In most cases, economic growth is gradual, and sometimes it may be radical or revolutionary. Innovation is the driving force of economic spiral development. Many factors affect the periodic (spiral) development of the economy, but the only driving force is innovation. This periodic (spiral) characterization mechanism is related to General Purpose Technology (GPT), such as steam engine, internal combustion engine, electric motor, IT, or general disruptive technological revolutions, such as ships, navigation, automobiles and computers. The invention and creation of this kind of GPT lead to revolutionary breakthrough development, while the mature applied innovation (product, process, etc.) of this kind of GPT promotes the gradual development and prosperity of the economy.

G, I, and U are the producers, transformers and distributors of innovative elements such as resources and products, especially innovative elements such as intelligence, knowledge and technology. G, I, and U create and produce intelligence, knowledge and technology, and combine general element resources with intelligence, knowledge transformation and institutional elements, thus becoming the driving force for promoting economic and social development. In the economic cycle, positions and functions of G, I, and U are independent of each other, and meanwhile they blend with and transform into each other. Therefore, GIU Triple Helix is not a mixture of each development path and track of G,I, and U. Healthy and effective GIU relationship is a triple helix structure, which is equivalent to a gene helix structure.

3.2. Case study

Case study is another important method to support this study besides theoretical research. Taking the development planning of iFLYTEK, biomedical industry, quantum communication and Hefei City's development plan as examples, this study analyzes the theoretical support and practical guiding value of GIU Triple Helix Model, and clarifies the different roles and operational mechanisms of different types of universities in the GIU triple helix. Especially, under the guidance of GIU Triple Helix Model based on innovation theory, Hefei Information Technology University has carried out management reform and achieved good effect.

iFLYTEK was founded at the end of 1999. Its predecessor was a startup company established by 19 university graduates of USTC. The entrepreneurial team was born out of the man-machine voice communication laboratory of the Department of Electronic Engineering of USTC. Speech synthesis technology, the core technology on which iFLYTEK relies for starting a business, is the technology of converting arbitrary text information into speech by synthesizing human voice with machine. In 2008, iFLYTEK became the first listed startup company founded by college students in China and the only listed company in the voice industry in China. In the same year, iFLYTEK's business expanded from speech synthesis to speech recognition, and began to study deep learning. In 2010, the voice cloud platform was launched; in 2014, the IFLYTEK Super Brain Program was launched; in 2017, it became

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an open innovation platform for a new generation of artificial intelligence in intelligent voice.

In August 1996, the Ministry of Science and Technology, the former Ministry of Health, the former State Food and Drug Administration, the Chinese Academy of Sciences and the Shanghai Municipal People's Government launched a comprehensive plan of "co-construction of ministries and cities" to jointly build the "National Shanghai Medical Science and Technology Industrial Base" in Zhangjiang High-tech Park, Shanghai. After more than 20 years of development, Zhangjiang's biomedical science and technology industry has developed from an industry factor cluster to an industry cluster, forming a biomedical industry cluster with complete industrial chain and first-class R&D capability in China: Zhangjiang Medicine Valley. Zhangjiang Pharma Valley is positioned as a high-end product R&D center, R&D outsourcing and service center in biopharmaceutical industry. The base focuses on tumor immunotherapy, cell therapy, gene therapy, innovative medical equipment and next-generation gene sequencing. After years of development, Zhangjiang Pharma Valley has now entered the stage of evolution and development of network innovation, bringing together more than 500 R&D and manufacturing institutions covering all aspects of new drug R&D. It has initially formed a cluster of talents, R&D innovation and innovative projects, and is entering a new stage of industrialization, marketization and international development.

The pilot application of quantum communication in China started late but developed rapidly. In 2007, University of Science and Technology of China realized the first optical-fiber quantum phone in Beijing, and then successively established several metropolitan quantum communication demonstration networks, financial information quantum communication technology verification lines and quantum communication hotlines among key departments in Beijing, Jinan, Wuhu and Hefei. In 2014, the quantum communication project "Beijing-Shanghai Trunk Line" passed the review and the construction started. It is planned to build the first international long-distance optical-fiber quantum communication backbone line between Beijing and Shanghai with a distance of over 2000 km based on cryptographic relay of secure credit nodes. The strategic pilot project "Quantum Science Experimental Satellite" was led by the Chinese Academy of Sciences with the cooperation of University of Science and Technology of China, Research Institute of the Chinese Academy of Sciences and the Eighth Research Institute of China Aerospace Science and Technology Corporation.

Hefei is located in East China, between central Anhui and Jianghuai, surrounded by Chaohu Lake. It is a sub-center of Yangtze River Delta urban agglomeration, a comprehensive national science center, a strategic dual-node city of “the Belt and Road Initiative” and Yangtze River Economic Belt. Hefei is a member city of the World Science and Technology Cities Alliance, the city that loves reading most in China, a central city of integrated circuits in industry, a national science and technology innovation pilot city and one of the four major science and education bases in China. In 2013, Anhui Education Department and Finance Department began to implement the Higher Education Revitalization Plan. High-level universities are the "engine" of urban economic transformation and development, which provides an important engine for urban economic development by cultivating and gathering outstanding talents, producing and transforming high-level scientific and technological achievements. The typical two representatives of high-level universities in Hefei are University of Science and Technology of China and Hefei University of Technology (HFUT). These two universities represent the top education level in Hefei and even Anhui Province, and they are mainly responsible for scientific research and applied technological innovation.

4. Findings

Universities are important bases for knowledge innovation, which have the necessary conditions and talent advantages for engaging in basic theory and scientific and technological research, and are the main force of basic research. Knowledge innovation is the foundation of technological innovation. Technological innovation refers to the process of producing new technology through the research, improvement, renewal and transformation of science and technology. The main bodies performing this function are mainly enterprises, higher education institutions and scientific research institutions. The dissemination of science and technology in the innovation system is a process in which people acquire new science and technology through the transfer and training of new knowledge and technology, and at the same time shoulder the task of cultivating human resources with solid theoretical foundation, skilled specialized technology and creative thinking ability. Higher education institutions and scientific research institutions are the main bodies to realize this function, with enterprises and scientific and technological intermediary organizations widely involved. In the process of knowledge innovation and knowledge dissemination, colleges and universities are in the core position.

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In view of the fact that the classification of university types has not been standardized, systematized, refined and unified at present, this study, combined with the characteristics of GIU cooperation in serving the social economy, divides universities into three categories: research-oriented universities, applied science and engineering universities and higher vocational institutions. This study also makes an in-depth analysis of the characteristics of different types of universities and their roles and mechanisms in GIU cooperation.

4.1. Roles of research-oriented universities in GIU Triple Helix

Research-oriented universities focus on the dissemination, production and application of knowledge, aim at producing high-level scientific research achievements and cultivating high-level elite talents, and play important roles in social development, economic construction, scientific and educational progress and cultural prosperity. Research-oriented universities put research first and are engaged in high-level personnel training and scientific R&D. Their basic characteristics are reflected in high-grade teachers and high-quality students, sufficient research funds and high-level research achievements, and training of high-level talents through scientific research. [7] In China, the main part of research-oriented universities is "Project 985" universities, "Project 211" universities and provincial key undergraduate institutions, which focus on basic theoretical research, major research projects and training academic and entrepreneurial talents based on scientific research in various professional fields, such as Peking University, Tsinghua University and University of Science and Technology of China.

Research-oriented universities play an important role in GIU cooperation with its advantages of high personnel training level, strong scientific and technological R&D strength, good social service ability and the most extensive national exchanges. It is mainly reflected in exploring unknown fields, carrying out major research projects, serving incubation enterprises and so on.

4.1.1. Cultivating innovative talents and leading the innovation system

Research-oriented universities are the center of national knowledge innovation and technological innovation, and an important birthplace of science and technology. With strong strength in basic research, they can produce significant original research results. Universities with the abilities to catch up with the advanced academic level in the world are regarded by any country as the core force to build an innovative country, and they have a decisive influence on a country or region to occupy a favorable position in the increasingly fierce global and regional economic, technological and cultural competition.

Research-oriented universities not only provide research results and technologies that can be transformed and applied for various innovative enterprises in the whole national innovation system, but also provide them with direct producers to a large extent -- a large number of researchers, engineers and technicians, scientific managers and scientific consultants. These outstanding talents with innovative spirits and abilities serve the society through scientific discovery, knowledge innovation, technological innovation and knowledge dissemination. They are the basic guarantee for the ultimate realization of knowledge diffusion and innovation performance of the national innovation system.

4.1.2. Exploring unknown fields and innovating theoretical knowledge

Research-oriented universities, based on their strength, relying on the financial advantages of enterprises and combined with that new trend of social development, undertook the national key projects and carry out innovative research and industrial development, giving full play to the advantages of talents and science and technology of the universities. With the strategic needs of industry and enterprise development, guided by major scientific research projects, the major common key technical problems that restrict the development of enterprises and industries have been solved emphatically, and the technological innovation chain from technology source to product development and technology promotion has been formed and improved. At the same time, a new talent training mode has been constructed, which provides human resources guarantee for the development of the industry.

Knowledge innovation mainly includes basic research and applied research, which is a process of acquiring new knowledge in basic science and technical science. The purpose of knowledge innovation is to pursue new discoveries, explore new laws, create new theories and new methods and accumulate new knowledge, which is a revolutionary force to promote scientific and technological progress and economic growth. As the main body of higher education, research-oriented universities play important roles in providing new theories and methods for human beings to understand and transform the world.

For example, Zhejiang University has established a "government-industry-university-research" four-wheel drive model. Government plays a leading role in university development by formulating strategic plans and incentive policies and providing resource conditions. Industry provides a stage for the transformation of achievements, education and training. University is the main body of university service development. Research, i.e. research institutions, provide knowledge innovation achievements and are the carriers of universities' service development. [8] Under the guidance of this model, the National Genetically Modified Experimental Base, the National Plant Gene Research Center Base, the Animal Husbandry Ecological Community of the Ministry of Agriculture and the Zhejiang Genetically Modified Crop Experimental Base have been established in the Agricultural Experimental Station of Zhejiang University. At the same time, Zhejiang University has pushed the scientific and technological achievements of the Institute to the society to serve the energy conservation, emission reduction, transformation and upgrading of enterprises. The series of achievements of "General Boiler Thermal Calculation System" developed by him have been applied to thousands of boilers in more than 30 class-A boiler enterprises in China, and have created new output value of nearly 4 billion yuan and new profits and taxes of nearly 700 million yuan for related enterprises. At the same time, driven by knowledge innovation, universities are exploring and trying the system, which provides a strong guarantee for knowledge innovation.

4.1.3. Carrying out research and obtaining patent equity

According to the development needs of the social market, after enterprises evaluate their capabilities, they may turn to universities for help if they cannot develop by themselves or the projects are the existing inventions of universities. The cooperation forms mainly include technology transfer, technology development, etc., so as to realize the economic and social value. Among them, technology transfer means that, through technology transfer, technical cooperation, technical consultation and technical service, etc., enterprises outside universities purchase the technology in universities with potential commercial value, thus realizing the social function of universities as "high-tech radiation sources".[9] Technology development includes contractual research, joint technology research, entrusted development, etc. Its remarkable feature is to carry out applied research and development research centered on the needs of enterprises or markets. [10]

In terms of technology transfer, Peking University Founder Group Corp. is the most typical one. In 1986, Peking University invested to establish Founder Group, which owns and creates core technologies that are crucial to the development of IT, medical and pharmaceutical industries in China. It is a state-owned enterprise wholly invested by Peking University. With the later development, Founder has rapidly grown into a large holding group with comprehensive strength ranking among the top three in the industry. The technical strength of Founder Group is backed by the Institute of Computing, State Key Laboratory, State Engineering Research Center and other units under the leadership of Wang Xuan. The relationship between Founder and them is not the grafting of scientific research institutions and production enterprises in the organization, nor is it a simple technical cooperation or transformation relationship. Rather, it is a real combination mechanism of economic interests and functions that meets the needs of market economy, and it is an organic connection of interdependence, coexistence and common prosperity. [9] At the beginning of its business, Founder Group began to cooperate with Shandong Weifang Computer Factory in the form of "technology transfer" in order to bring the world-leading Chinese laser phototypesetting system to the market. However, in the process of technology transfer, faced with many unstable factors, Peking University decided to transfer the technology of its institute to Peking University New Technology Company (the predecessor of Peking University Founder Group). Since then, Peking University New Technology Company has cooperated closely with the Institute of Computer Science and Technology. New Technology Company is responsible for technical services, sales and training, while the Institute is responsible for developing new technologies. "Scientists with market minds" and "entrepreneurs with scientific minds" have been combined, and the roles of enterprises and research institute personnel have begun to penetrate each other. [9]

In terms of technology development, in addition to USTC and iFLYTEK and QuantumCTek Group that it hatched, Tsinghua Tongfang Co., Ltd. is also a typical one. In 1997, with the planning of Tsinghua University and Tsinghua Enterprise Group, five outstanding school-run companies owned by Tsinghua University, including Tsinghua Artificial Environment Engineering and Information Technology, jointly established Tsinghua Tongfang Co., Ltd., and successfully got listed on Shanghai Stock Market. The subjects of enterprises are basically professors or a professional research group. Companies are often wholly-owned enterprises, and some of their business behaviors are jointly decided by scientific research and development personnel. With the standardization of the market,

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under the guidance of national policies, independent enterprises derived from universities began to form group enterprises under the direction of the scientific research departments of universities. After that, with the continuous development of scientific research achievements in universities and the expansion of the strength of group enterprises, universities began to integrate the operating assets of the whole university with capital as the link, and established modern company management systems. The operation mode of technology transfer + capital investment has become the strategic choice for the existing derivative enterprises to continue the development, and the shareholding system has become the realization mode of this strategic choice. After Tsinghua Tongfang went public, the enterprise took the high-tech business incubator as the core of its technological innovation and offered technical transfer for the university. [9]

4.1.4. Serving incubation enterprises and cooperating in development research

Relying on the original resources, universities position themselves as incubators connecting knowledge innovation sources and knowledge application terminals, so as to realize the connection between the science and technology chain and the industrial chain. University science parks are the most typical. They are the high-tech invention and development area of universities and enterprises. In the university science parks, high-tech laboratories, research centers and enterprises have become the basic components. The university science parks build platforms for cooperation between enterprises and universities. The platforms can provide a suitable growth environment for scientific and technical personnel, their scientific and technological achievements, and the transformation and industrialization of projects. The platforms can also provide a perfect public service system and a perfect investment and financing system for the whole process and multi-directional services, so that enterprises can reduce initial investment and reduce growth risks, and can directly invest in new technologies and develop and apply them to accelerate the growth. University science parks can integrate government policy resources, university innovation resources, industrial capital and social resources, and provide incubation goods and services and a power system with a benign operation for new enterprises. By effectively binding the three parties of GIU Triple Helix Model together, knowledge (technology) can be continuously updated for existing enterprises, or innovative technology (knowledge) can be directly transformed into new derivative enterprises to participate in the social and economic system. [9]

As a form of incubator, TusPark integrates almost all the service functions in the process of innovation. It is the product of the interaction among GIU and an advanced stage in the derivative organizational structure of the triple helix. The government plays an important role in the knowledge innovation system by participating in the construction and management of TusPark. The Ministry of Science and Technology, the Ministry of Education and the Beijing Municipal Science and Technology Commission give certain preferential policies to TusPark in terms of infrastructure construction, talent introduction, fiscal and taxation management, etc. to promote the sound development of enterprises in the park. Similarly, TusPark has been actively strengthening its ties with the government. By giving full play to the advantages of being close to enterprises, the park assists the government in formulating relevant industry policies, feeds back the effect of policy implementation, and guides the government resources to tilt towards Tus Park. As a form of incubator, TusPark integrates almost all service functions in the process of innovation, which is the product of interaction among GIU and an advanced stage in the derivative organizational structure of the triple helix. [9] TusPark has embarked on a new road with Chinese characteristics in promoting the deep aggregation of innovative elements such as government, industry, university, research, finance, mediation, trade and media, and exploring the establishment of a new GIU cooperation model. A series of explorations and practices in TusPark have proved that university science parks can not only become an effective link connecting innovative resources such as government, enterprises, universities and mediation, but also achieve multi-win results on the basis of integrating these resources, and become an important force to promote the transformation of regional industry and enhance innovation ability. [11] In addition, Shenzhen Tsinghua University Research Institute operates according to the mode of "GIU-capital integration" and successfully established the incubator brand. The Institute has set up venture capital companies, international technology transfer centers and enterprise technology service centers in stages. It has provided an incubation area of about 17,000 square meters, incubated more than 90 companies, and graduated more than 20 companies with another more than 60 in incubation, thus realizing the benign interaction between incubating enterprise and incubated enterprise. [12]

4.2. Roles of applied science and engineering universities in GIU Triple Helix

Applied science and engineering universities are the product of technological development, economic development and educational development. Applied science and engineering universities are new universities that can integrate higher education and vocational education [13], with cultivating applied science and engineering talents as the characteristics and serving local economic and social development as the principle. They not only have the commonness of higher education to cultivate students' general ability but also have the engineering nature of vocational education to train professional, applied and technical talents. While becoming a source of cultivating applied science and engineering talents, and a cradle of tens of millions of technological forces in the process of training and reserving economic transformation and upgrading, applied science and engineering universities should also become a source of technological application and technological innovation, and become a member of an industry or regional technological innovation system. It has become an important part of the integrated development of the industrial chain, innovation chain and talent chain[14]. That is, relying on the superior disciplines and majors of the university, we should carry out scientific and technological breakthroughs and applied research to solve practical problems and important and difficult problems in production and life.

During the development, applied science and engineering universities gradually form a triple helix structure with governments and enterprises, and they jointly train high-level applied science and engineering talents, develop social economy and construct industries, hoping to enhance students' development potential and employment competitiveness, and solve practical problems such as the disconnection between school education and social needs, and between theoretical knowledge and practical application[15]. GIU cooperation requires applied science and engineering universities to undertake important responsibilities combined with the characteristics of school development, sum up experience in practice and seek the internal development mechanism.

As educational institutions, applied science and engineering universities need to train talents that meet the needs of social development through education and teaching. As higher education institutions, they need to serve social development and promote better and faster economic development. As applied science and engineering higher education institutions, they need to give full play to the role of technology in personnel training and social development. In GIU cooperation, applied science and engineering universities have played important roles in offering applied science and engineering undergraduate talents, carrying out key and difficult scientific and technological research, and serving the local economy.

4.2.1. Based on the market demand, offering applied science and engineering undergraduate talents

In the current society, enterprises like applied science and engineering talents. On the one hand, enterprises conform to the future economic development trend and put forward new requirements for personnel training specifications. While talents are transforming from theoretical type to skilled and compound type, enterprises expect students to have team spirit, coordination ability, practical ability, ideological and political quality and professional and technical quality. The survey results of 300 enterprises and institutions in Nanhua Vocational College of Industry and Commerce show that "enterprises need talents with rich work experience, solid professional skills, high professional ethics and good communication skills in professional exchanges"[16]. On the other hand, the applied science and engineering talents are close to the needs of regional economic structure, and can realize the transfer and application of knowledge in the region. According to a survey in Germany, "the local working rate of graduates from applied science and engineering universities is relatively stable, with 80% of graduates from big cities staying to work locally, while the rate in small cities also reaches 60%".[17] The high stability of employment reserves a large number of applied science and engineering talents for local economic development, avoids excessive loss of talents, and makes the cultural capital and social capital carried by talents circulate in the region to exert their economic effects.

Talent training is a complex systematic project. As specialized talent training institutions, universities have advantages in virtue cultivation, knowledge inheritance and professional ability development. Based on the development needs of the knowledge economy, applied science and engineering undergraduates are committed to "building a training system for science and engineering applied and innovative talents oriented by market demand and quality improvement, cultivating high-level skilled talents with high comprehensive quality, solid theoretical knowledge, strong practical ability and innovative and entrepreneurial spirit, and serving local economic and social development through the training of skilled innovative talents and applied technology R&D." [18] The core lies in improving students' comprehensive quality, cultivating their theoretical and practical ability, and cultivating applied science and engineering talents with entrepreneurial and innovative consciousness. In GIU cooperation, the talent training of applied science and engineering universities emphasizes promoting students' understanding of knowledge, learning of industry and strengthening majors through practice and research, and improving students' ability to find, analyze and solve problems. [19]

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The core of training applied science and engineering undergraduate talents guided by market demand lies in dealing with the relationship between "demand" and "application". It is required that the trained talents have strong ability in professional application, which is mainly reflected in taking social needs as the guide, setting up majors that match the occupations and posts of social needs, and realizing the synchronization between talent training and market demand. For example, Shanghai proposes to give priority to the development of advanced manufacturing and service industries, which puts forward new demands for the training specifications of talents. Under the guidance of the concept of "connecting discipline chain and major chain with industrial chain", Shanghai University of Engineering Science has successively set up disciplines such as "machinery manufacturing and automation" and "material processing engineering" related to manufacturing industry, and focused on building disciplines such as "social security" and "logistics management" around service industry. Here is another example. Taizhou plastic mold industry is one of the local characteristic industries. Taizhou University has focused on building materials physics and other majors according to its characteristics. On the one hand, it met the needs of local plastic mold enterprises for talents; on the other hand, under the support of local developed plastic mold industry, it indirectly promoted its material physics to become a national characteristic major and a provincial superior major[20], thus realizing the industry's feedback to education.

4.2.2. Making use of universities' resources to carry out important and difficult scientific and technological research

UNESCO divides scientific research into three types: basic research, applied research and development research. Applied science and engineering universities focus on applied basic research and technology development research. The core lies in the research of "technology". By rationally utilizing and allocating all kinds of knowledge, science and technology and human resources of the university, we can carry out scientific and technological research work with the advantages and characteristics of the university, and establish a scientific and technological research and innovation system of science and technology application-oriented universities that adapts to the development of modern science and technology, economy and society and mainly meets the needs of local regional innovation. [19] Unlike research-oriented undergraduates who pay attention to research achievements such as thesis and patents, applied science and engineering undergraduates pay more attention to the application of technology in production and life. That is to say, the practical orientation of research is placed before the academic orientation, and the application of research can not only focus on research itself. Technology research promotes the cultivation of applied science and engineering undergraduate talents through the education, teaching and scientific research activities of universities. At the same time, through the joint discussion and research of technical problems in production practice by teachers and students, it breaks through technical barriers, provides substantial help for the production, technology manufacturing and product innovation of enterprises, and maximizes their interests. [16]

In the framework of GIU Triple Helix and under the background of local social and economic development, applied science and engineering undergraduate institutions cooperate with enterprises to carry out scientific and technological research and innovation to serve local development. For example, Chongqing University of Technology closely focuses on the macroeconomic environment and development trend of the military industry and the pillar industries such as automobiles and motorcycles in Chongqing and the southwest region as the whole, and is committed to building a scientific and technological platform, jointly carrying out scientific and technological research, and enhancing the independent development and innovation capability of Chongqing's local pillar industries. The Heavy Industry and Vehicle Engineering Institute was jointly established with Southwest Military Industry Bureau and its affiliated enterprises, which has become an important pillar of Chongqing "two vehicles" development and research. The university has also signed a series of cooperation agreements on science and technology education projects with Bishan County and Dazu District of Chongqing, which has made great contributions to the economic development of the district and the county. [21] Also, Chongqing University of Science and Technology takes "one institute and two centers" as the carriers to build GIU cooperative development brand. One institute refers to Chongqing Waste Incineration Power Generation Technology Research Institute; Two centers refer to the Oil and Gas Well Control and Safety Technology Research and Training Center and the Aerospace Functional Magnetic Materials Research and Development Center. On the basis of existing work, GIU cooperation focuses on the R&D of core technologies with independent intellectual property rights, providing manpower guarantee and scientific and technological support for the adjustment of industry structure and breakthroughs in key technologies and key processes of enterprises, and promoting the development and progress of cooperative enterprises. [22]

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The technological research of applied science and engineering undergraduate universities is based on their abundant resources. First of all, applied science and engineering undergraduate universities have gathered a highly professional team of teachers. On the one hand, the universities have teachers with solid theoretical knowledge; on the other hand, they have introduced a group of engineers with practical experience through cooperation with enterprises. Secondly, the applied science and engineering undergraduate universities have established innovative platforms and bases with the advantages of university characteristics and regional characteristics, such as various key laboratories and engineering technology research centers. Platforms and bases can continuously strengthen their own capacity building by actively undertaking various scientific research projects at all levels. At the same time, they can be applied to the key and difficult scientific and technological research of enterprises, and realize the organic combination of theory and practice. Finally, with the promotion of scientific and technological research for education and teaching, they have trained a large number of applied science and engineering undergraduate talents with research ability. Young people's active thinking, innovative ability and exploratory courage play a catalytic role in scientific and technological research and tackling key problems.

4.2.3. Incubating technology industry and serving local economy

Incubation of technology industry is "the main way for universities to tap the scientific and technological achievements and the advantages in talents to industrialize knowledge and capitalize technology,[19] and to realize the effective transformation of scientific and technological achievements by establishing scientific and technological enterprises. "The transfer and innovation of technological achievements is the key to accelerating the transformation of scientific and technological achievements into real productive forces and promote the combination of science and technology and economy".[19] At present, Chinese enterprises have not yet reached the requirements of becoming the main body of scientific and technological innovation, which still needs several years of development. This requires universities to give full play to their advantages, go beyond the single mission to educate and teach, move from behind the scenes to the front to directly participate in social services, and jointly promote the transformation of scientific and technological achievements with enterprises, thus becoming an important driving force for promoting social and economic development. The applied science and engineering undergraduate universities with "application" as the core need to undertake the important responsibilities of serving the society, especially promoting the industrialization of high and new technology and revitalizing the regional economy while completing their mission. However, the scientific and technological achievements of applied science and engineering undergraduates are mostly in the laboratory state, and it will take some time to directly serve the social and economic development. On the one hand, because the transformation of scientific research achievements is a professional process, it needs a lot of capital investment, so universities itself cannot afford it. On the other hand, the main task of universities is talent training,[23] so breaking through this function and directly investing in social production and service requires the renewal of ideas and systems. Therefore, it is a feasible way to transform scientific and technological achievements through the "science and technology innovation incubator" founded by university-enterprise cooperation.

Science and technology innovation incubator is a strategic, value-added intervention control and business support shared space facility for incubating enterprises. It forms a trinity organizational mechanism with enterprises as the main body, universities and research institutes as technical support, and modern enterprise system as the standard, and is an extension of applied science and engineering undergraduate function. Applied science and engineering undergraduate universities, as the technical support for enterprises in incubators, while helping enterprises solve key technical problems and reserve technologies and projects, should carry out secondary development of relatively mature scientific research achievements in enterprises,[23] so as to promote the transformation of scientific and technological achievements, help incubate high-tech enterprises, and serve social and economic development indirectly or directly. For example, Nanjing Institute of Technology closely combines the advantages of professional disciplines, vigorously carries out applied research, scientific and technological development and incubation of scientific and technological enterprises for large mechanical and electrical industries, strengthens the organic link of "R&D base -- incubation base -- industry base", and constructs three platforms, namely, "scientific and technological innovation, transformation and engineering of scientific and technological achievements, industrialization of scientific and technological achievements and incubation of high-tech enterprises". They enhance the ability of universities to directly serve the society, at the same time, embody the important supporting role of "scientific research promoting teaching", and improve the training quality of applied science and engineering talents[23].

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4.3. Roles and operational mechanisms of higher vocational institutions in GIU Triple Helix

In 2011, the Ministry of Education issued Several Opinions of the Ministry of Education on Promoting the Reform and Innovation of Higher Vocational Education and Leading the Scientific Development of Vocational Education, which pointed out that higher vocational education has dual attributes of higher education and vocational education, and its main task is to train high-end skilled professionals in the front line of production, construction, service and management.[24]In Chinese mainland, higher vocational education includes two educational levels: junior college and undergraduate. Compared with ordinary higher education which cultivates academic talents, higher vocational education focuses on cultivating applied talents of higher technology and science and engineering. Higher vocational education is mainly at the junior college level in Chinese mainland. In terms of characteristics, it equips students with the necessary theoretical knowledge and scientific and cultural foundation, enables students to master the main technology skillfully, and focuses on practical application. Also, it cultivates students' ability of expression, communication and cooperation, pays attention to practical knowledge, and strengthens the training of vocational skills. Its goal is to cultivate technical talents with practicality as the key, which is to cultivate a group of talents with university knowledge and certain professional skills on the basis of a complete secondary education.

In the process of GIU cooperation, the participation of higher vocational education has injected new vitality into GIU cooperative education in China. After several years' practice and exploration, GIU cooperation in schools has become the necessary path, establishment foundation, training foundation and development source of Chinese higher vocational institutions. Through local financial support and other policies and measures, the enthusiasm of enterprises to participate in higher vocational education has been mobilized, and the university-enterprise cooperation of higher vocational education and the institutionalization of the combination of government, industry and university have been promoted. Due to the advantages of cooperative education in talent training and the strong support of the government, cooperative education has gradually developed widely in China's higher vocational institutions. In practice, according to the specific situation of the university and the actual needs of local economic construction, higher vocational institutions have innovated a variety of cooperative education models, such as the "comprehensive cooperation model with local economy" represented by Shenzhen Polytechnic, "order-based government-industry-academic talent training mode" represented by Wuhan Vocational and Technical College, "2 +1" GIU cooperative mode represented by Henan Mechanical and Electrical Higher Vocational School, "GIU cooperative education mode of work-study combination and two-way intervention between schools and enterprises" represented by Chengde Petroleum Higher Vocational School, etc. [25]

4.3.1. Connecting enterprises and building characteristic disciplines

Major construction is the bridge and link between higher vocational education and social development and industry needs. The major construction of vocational education aims at serving the regional social and economic development. It must rely on the employment market of professional talents and the needs of enterprises to set up majors, and always position the majors and development based on industrial development and the needs of professional posts for majors. [26] Creating one characteristic brand major in one university is an important condition for higher vocational institutions' development, and it is also an advantage in GIU cooperation.

With the development of market economy, higher vocational institutions gradually get in line with the society. While abandoning the traditional teaching discipline construction in the past, they carry out industrial or professional research based on local economic development, enterprise demand and market development, adopting flexible modes according to market status and talent demand trends, and working out professional talent training programs together with industries (enterprises) to realize the connection between majors and industries (enterprises). Especially in GIU cooperation, they gradually get rid of the passive situation in the past. They take the initiative to innovate, build majors with university characteristics, and connect professional curriculum content and professional standards. For example, the Software College of Liaoning Institute of Technology opened the "Building Intelligent Engineering Technology" major in time after learning about the gradual popularization of information-based residential quarters, and added the "Automotive Electronic Technology" major after learning about the popularization of automotive electronic technology. With the GIU cooperation and bold reform and innovation, teaching work is closely combined with production practice, as well as the transformation, application and popularization of new technologies, so as to cultivate high-quality workers who "spread and apply technologies".[27]

At the same time, due to the different regional economies, geographical environments and school conditions and advantages in higher vocational institutions, the schools should combine the regional economic development needs when setting up majors. They should carefully build high-quality majors, concentrate on cultivating long-term majors and carefully develop short-term majors, thus forming their own characteristics and brands. For example, Zhenjiang College focuses on the development trend of Zhenjiang's industry structure of the 12th Five-Year Plan, docks the nine major industries in Zhenjiang. According to the 12th Five-Year Plan for Major Construction and Development of Zhenjiang College and the needs of regional economic development, based on the principle of "social demand, university-enterprise co-construction, innovative development", the platform determines the professional construction orientation of "keeping close to the development of local industry and social undertakings, strengthening and expanding engineering majors", and connects with Zhenjiang's leading industry and key industries in the aspects of "facing modern equipment manufacturing industry, electronic information industry, green chemical and pharmaceutical industry", striving to improve the ability to serve the modern industry and better serve the industry economy. [28] See Figure 1 for details.

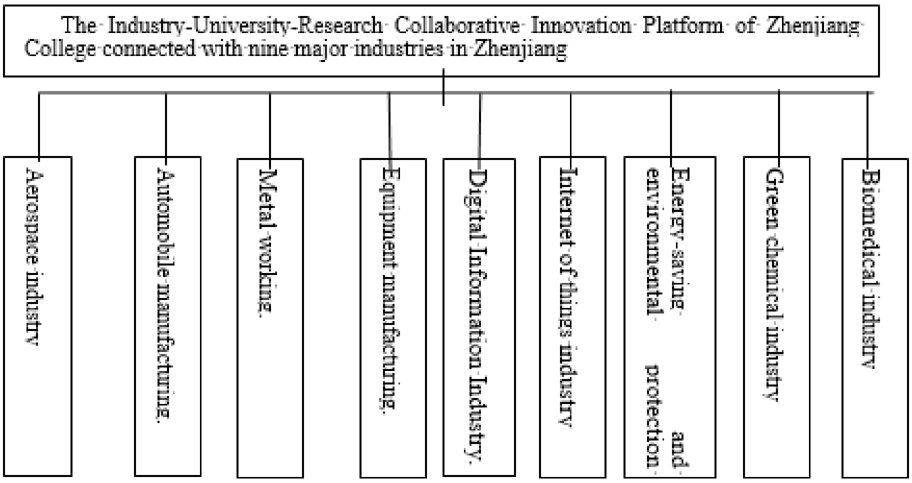

Figure 1: Zhenjiang College connecting industries on the GIU collaborative innovation platform.

4.3.2. Order-based training to improve the employment rate of students

Table 2: SWOT analysis of both parties in university-enterprise cooperation.

Main items	S (Strength)	W (Weakness)	O (Opportunity)	T (Threat)
Universities	① The training room and training equipment are fully equipped; ② License training software is configured in place; ③ Enterprise orientation training can be provided for students; ④ Teachers have experience in vocational training	① The connection between curriculum and industry and enterprise is weak; ② Students' professional skills and professional qualities are poor; ③ Teachers' professional cognition is disconnected from industries and enterprises	① Enterprises need universities to train talents with professional practicality and basic professional qualities; ② Enterprises need universities to participate in project R&D and horizontal projects; ③ Enterprises need universities to provide orientation training for new employees	① How to reform the curriculum ; ② How to reform teaching ; ③ How to cooperate with industries and enterprises
Enterprises	① Practical engineering models and data; ② Practical engineering experience; ③ Horizontal projects of enterprises and industries; ④ University teachers go to the enterprise practice point	① Lack of high-quality talents in cost specialty; ② Lack of standardized process of calculation; ③ The high cost of training new employees	① Universities need enterprises to participate in teaching; ② Universities need enterprises to provide research projects and horizontal projects; ③ Universities need enterprises to participate in the joint development of personnel training standards	① How to attract and retain talents; ② How to improve work efficiency; ③ How to develop and innovate

In terms of talent training, higher vocational institutions and enterprises jointly formulate talent training plans according to the needs of society and market and sign employment orders. They cooperate in terms of teachers. According to the needs of society and market, they jointly formulate personnel training plans, sign employment orders, and cooperate in terms of teachers, technology and school-running conditions. Through the "work-study alternation" mode, teaching is carried out in universities and enterprises respectively, and students go directly to the enterprises after graduation. [29]

For example, after analyzing the advantages of universities and enterprises, the Suzhou Institute of Construction and Communications establish contact with enterprises, provide personnel training for them, and train enterprise employees in the student internship stage. According to the requirements of enterprises, the school formulate relevant standards such as the talent training plan for order classes of cost enterprises, the skills training standards for internship students, and the short-term skills training standards for enterprise employees. At the same time, "Engineering Cost Vocational Skills Training Manual (Staff Skills Quality Standard)" has been developed, which can not only provide enterprise order training for cost consulting units, but also provide short-term skills training services for employees, and really train practical talents of cost consulting enterprises. At the same time, the practical requirements of enterprises are used to guide the training of cost competitions at all levels, so as to realize the integration of competitions with actual business. [30] See Table 2 below for details.

4.3.3. Relying on higher vocational institutions to set up comprehensive service platforms

With the country's emphasis on higher vocational institutions, training bases have been established inside and outside them to train high-skilled talents. Thanks to those training bases, students of higher vocational institutions can have real hands-on practice in the actual engineering environment, gain real experience, practice real skills, and get relevant professional abilities. Meanwhile, universities have also formed a corresponding long-term mechanism for the base construction to ensure that the base can be afforded and can be used conveniently and effectively.

University's technology industry is an experimental base for transforming scientific research achievements into real productivity, and is also a comprehensive service platform for university-enterprise cooperation. In the process of transforming scientific research achievements into real productivity, it is necessary to carry out intermediate experiments and production experiments with certain difficulties and risks. University's technology enterprises have become the most direct and convenient bases for these experiments. [27]

With the support and guidance of local government and enterprises, higher vocational institutions redesign and rebuild the training room on campus according to the post requirements and scenes of enterprises to build an integrated teaching venue that can not only meet the theoretical teaching, but also have the function of full-process professional skills training, providing students with real learning conditions to experience the actual working process, and improves their learning interest and learning effect through the organic combination of reality and virtuality. For example, in 2008, the Department of Electronic Information Engineering of Suzhou Vocational University established the "Handa Industrial Automation Technology Research Center of Suzhou Vocational University" with local enterprises, which was market-oriented and project-based and used teachers as the development team to further tap the scientific and technological potential of the university. [31] On April 7, 2017, the South China Vocational Education GIU Cooperative Experimental Base was inaugurated in Zhongshan Torch Polytechnic, which was jointly established by the Institute of Vocational and Technical Education Center of the Ministry of Education, the Guangdong Provincial Department of Education and the Zhongshan Municipal People's Government. The base adheres to the principle of "government guidance, resource pooling, coordinated promotion and market operation". Through the coordinated promotion of "government, industry, university and research", vocational education reform research and innovation-driven practice go hand in hand, build "one institute" and "seven centers", aggregate the superior scientific and technological resources of higher vocational education, and strengthen the horizontal connection with Zhongshan enterprises, industries and universities, so as to achieve the goals of incubating high and new technology, cultivating scientific and technological enterprises, promoting the transformation of scientific research achievements, the growth of scientific and technological talents, the introduction and cultivation of scientific and technological projects, and promoting the high-quality development of the regional economy. [32]

5. Discussion

5.1. Different roles of different types of universities in GIU Triple Helix

In the GIU Triple Helix Model, universities are the main force of innovation while the government

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and enterprises play auxiliary roles in guidance and assistance. As for economic development driven by innovation, this research has identified its periodic stages from a theoretical perspective. Based on the existing research and our case study, we also found that at different stages, universities play different roles in innovation. Furthermore, such differences will be projected on different types of universities, such as research-oriented universities, applied science and engineering universities, and higher vocational institutions. They play different roles in different stages of the innovation period. Table 3 below shows:

During the period of the innovation revolution, research-oriented universities were mainly engaged in basic research. At this time, scientists had found that science could not be well explained and applied to reality, so they concentrated on basic scientific research and took theoretical breakthroughs to establish a new paradigm as their research purpose. Applied science and engineering universities in this period mainly focused on transforming science into technology. It is necessary to know that science and technology are not equal, and the gap between them needs to be filled by research. In this period, higher vocational institutions mainly focused on transforming the current science and technology into students' skills and abilities, so as to cultivate innovative craftsmen.

Table 3: Roles of different types of universities in innovation-driven economic development.

Stage	University type		
	Research universities	Applied science and engineering universities	Higher vocational institutions
Stage 1 Innovation revolution period (Paradigm revolution)	Breakthrough in basic science. Establishment of new paradigm.	Exploration on the application of scientific achievements. Science-technology transfer.	Training innovative craftsmen and dual-innovation talents.
Stage 2 Innovation growth period (Innovative technology, paradigm shift)	Breakthroughs in basic science -- high-end technology research, and the transformation of science and technology accelerated.	Technology-market transformation, technical engineering innovation research, new materials and new tools.	Transformation of engineering and technological achievements, training of applied talents in new industries and fields.
Stage 3 Normal growth period (Incremental innovation)	The theory is constantly confirmed and perfected, and the explanation and solution of difficulties and puzzles as well as falsification begin to appear.	Development of engineering, process and craft products as well as training of talents	New product development, new market development and application scope expansion in industry, continuing education and new knowledge.
Stage 4 Anomalies period	Accumulation of basic research, questioning of paradigm, exploration of new knowledge, high-end basic research talents, adjustment of traditional disciplines, and emergence of new disciplines.	Studies on engineering and technical difficulties, breakthrough seeking, and discipline adjustment in science and engineering.	The transformation of traditional industry requires the knowledge transformation of skilled craftsmen.

In the innovation growth period, research-oriented universities made breakthrough research in basic science and high-end technology by inevitable chance, and set out to apply new scientific theoretical breakthroughs to technology. At this time, while participating in the research of science and technology transfer in research-oriented universities, applied science and engineering universities mainly assumed the role of finding the market for new technologies, and began a series of engineering explorations of applying new technologies to industry, such as technological engineering innovation research, developing new materials and creating new tools. And the function of higher vocational institutions was relatively clear; that is, to speed up the transformation of engineering and technological achievements and train applied talents in new industries and fields.

In normal growth period, the deepening of research-oriented universities' basic research has enabled the theory to be continuously confirmed and improved. The difficulties and confusion encountered in the application of the new theory have forced the revision and improvement of the theory, but at the same time, the seeds of questioning have been planted, and falsification has begun to appear within a certain range. Applied science and engineering universities' main energy at this time was to put in scientific and technological innovation under the guidance of mature theory, including engineering, process, craft product development and personnel training. Higher vocational institutions would focus on the industry, explore new products brought by new technologies, and then open up markets to expand the application scope as much as possible. At the same time, it would continue to cultivate diversified applied talents who can apply new knowledge and possess new skills to adapt to the new industry.

In the anomalies period, the new theory obtained from the previous stage of exploration encounters a general dilemma. Under its guidance, the productivity transformation ability of new science and technology has dropped sharply. Research-oriented universities once again devote themselves to the accumulation of basic research, launch research on paradigm questioning, and explore new knowledge. Moreover, the phenomenon of adjustment of traditional disciplines and the emergence of new disciplines may occur in universities. At this time, applied science and engineering universities also focus on the research of engineering and technical difficulties in order to seek a breakthrough. Higher vocational institutions, on the other hand, will face the transformation of traditional industry, adjust the knowledge structure of applied talents trained according to the transformation, and promote the knowledge transformation of skilled craftsmen.

6. Limitations and prospects

The main limitation of this study is that all the data used come from relevant databases and the data published by the National Bureau of Statistics and the Ministry of Science and Technology, with papers and patent data as the main ones.

In the future, we can strengthen the empirical research on triple helix. Big data should be fully used to search empirical research data and perfect data research methods. Database technology and visualization technology should be used to process and analyze data, so as to improve the scientific and comprehensive research. We can also study the Triple Helix Model in different types. Different countries and different periods have widely different contexts in politics, economy, culture and society. Therefore, according to different countries and specific periods, we can dynamically revise and expand the GIU triple helix model to promote the full play of the main functions of triple helix innovation, the mutual penetration of functions and the rational allocation of resources in the innovation system.

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