INSTITUTO
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The Making of Core Enablers and Their Joint Actions for Clusters of Innovation in the Biotechnology and Healthcare Industry: A Case-Based Research

TANG Minchao

Doctor of Management

Supervisors:
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Abstract

With the country's rapid development, the advent of the bioeconomy, and the wide application of biotechnology, the Chinese government attaches great importance to the development of the biotechnology and healthcare industry. As a consequence, hundreds of cities have been planning and constructing biotechnology and healthcare industrial parks, with many facing considerable problems such as homogenization of planning, difficulty in investment promotion, low transformation rate of innovation outcomes, and inability to integrate into the global innovation network coupled with risks such as "path dependence" and "low-end lock-in". How can these parks be transformed and upgraded into "clusters of innovation" to gain momentum for sustainable development?

Based on the case of Guangzhou International Bio Island, this study conducted field surveys, formal interviews, and expert focus groups along five years, from 2019 to 2023, with a total of 170 interviews with the heads of 151 organizations (including 29 foreign ones), resulting in 13,410 minutes of audio recordings and 3,577,687 words in English and Chinese. The study summarizes the core enablers for the formation and development of biotechnology and healthcare industry clusters of innovation and how these enablers interact with each other to promote innovation. The study further proposes the concept of "core enablers" and puts forward a distinction between "explicit enablers" and "implicit enablers" as well as the forms and mechanisms of the interaction of these enablers. It was also found that international exchanges and cooperation have a positive impact on clusters of innovation.

Keywords: Innovation; Industrial clusters; Clusters of Innovation; Innovation ecosystems; Guangzhou International Bio Island; Case study

JEL: I15, O36

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Resumo

Em consequência do rápido desenvolvimento do país, com o advento da bioeconomia e da generalização aplicada da biotecnologia, o governo chinês atribuiu grande importância ao desenvolvimento da indústria da saúde e centenas de cidades chinesas têm vindo a planear e a construir parques ligados a essa indústria. Muitos destes parques enfrentam problemas incluindo homogeneização de planeamento, dificuldade na promoção dos investimentos, baixa taxa de conversão dos resultados de investigação e incapacidade de integração em redes internacionais de inovação. Estes parques sofrem também dos riscos de dependência histórica e de bloqueio. Como podem estes parques ser transformados em “clusters de inovação” para que possam ganhar impulso para um desenvolvimento sustentado?

Tendo como base o parque “Guangzhou International Bio Island”, esta tese realizou um estudo empírico, combinando entrevistas formais e grupos de análise com especialistas. Ao longo de cinco anos (2019-2023) realizaram-se 170 entrevistas com responsáveis de 151 organizações (incluindo 29 estrangeiras), resultando em 13.410 minutos de gravação e 3.577.687 palavras em inglês e chinês. A investigação permitiu identificar os elementos centrais para a formação e desenvolvimento dos clusters de inovação na biotecnologia e indústria da saúde e como estes elementos interagem uns com os outros para promover a inovação. A tese propõe o conceito de “facilitadores principais” e sugere a distinção entre “facilitadores explícitos” e “facilitadores implícitos” bem como formas e mecanismos de interação entre os facilitadores. Conclui-se ainda que os intercâmbios e a cooperação internacional têm um impacto positivo nos clusters de inovação.

Palavras-Chave: Inovação; Clusters industriais; Clusters de inovação; Ecossistemas de inovação; Guangzhou International Bio Island; Estudo de caso

JEL: I15, O36

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摘 要

随着国家的快速发展，生物经济的出现和生物技术的广泛应用，中国政府高度重视生物技术和健康产业的发展，中国数百个城市都在规划和建设与该产业相关的园区。许多园区面临着规划同质化、招商引资难、科研成果转化率低、无法融入国际创新网络等问题。这些园区还存在历史依赖和锁定的风险。如何将这些园区转化为〞创新集群〞，使其获得持续发展的动力？

本论文以“广州国际生物岛”园区为基础，结合正式访谈和专家焦点小组，开展了实证研究。在五年的时间里（2019-2023年），对来自151家机构（包括29家外国机构）的管理人员进行了170次访谈，记录了13,410分钟的访谈内容和3,577,687个中英文单词。通过研究，确定了生物技术和健康产业创新集群形成和发展的核心使能要素，以及这些要素如何相互作用以促进创新。论文提出了“核心使能要素”的概念，并提出区分“显性使能要素”和“隐性使能要素”，以及使能要素之间的相互作用和机制。论文还得出结论，国际交流与合作对创新集群具有积极影响。

关键词：创新；产业集群；创新集群；创新生态系统；广州国际生物岛；案例研究

JEL: I15, O36

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Acknowledgements

In 1998, I attended the first fully English-taught MBA program in China, organized by Virginia Trigo and Nelson António, and received my master's degree in 2002. This was my first immersed experience in Western education, where I gained knowledge about the learning methodology and experienced the interactive teaching approach, built an entrepreneurial mindset with a global vision, and started career planning, all of which had a great impact on my life. I became the youngest departmental cadre in the history of Guangzhou, and later on, I shifted my career from a government official to an entrepreneur, promoting several "International Bridge" projects. I fell in love with education from the moment I discovered how much education could influence human beings. Believing that there is no greater endeavor than helping others grow and succeed, I made education my lifework and was striving to get myself prepared for it. After learning from Virginia about the program of Doctor of Management in Healthcare, I was fortunate to become a participant in 2018. From 2018 to 2023, going from practice to theoretical research, it was a process of learning and applying "research methodology theories". I have learned and acquired a systematic and global approach to research and developed the ability to conduct independent research.

Thanks to Southern Medical University (China) and ISCTE (Portugal) for giving me such a valuable learning opportunity.

Thank you, Virginia, for giving me another opportunity for development and for providing me with all-around help throughout my study and research, she gave me the advice to read a lot of literature related to my study. During the five years, I immersed myself in theoretical studies and research and engaged in extensive reading around the topic of my thesis, an average of 175-200 paperbacks per year, plus thousands of articles. There was not much Chinese literature on clusters of innovation in the biotechnology and healthcare industry, and it was very difficult to obtain international literature. In this regard, I am especially grateful to Virginia for her help.

I would like to thank my supervisor, Nelson António, for his careful supervision of my thesis. I am most impressed by his heuristic guidance. Instead of telling you what to do, he pointed out the problems and let you think about how to solve them.

Mr. Liu Yuanli from Peking Union Medical College, Chinese Academy of Medical

Sciences, gave me valuable comments, especially emphasizing that I should make efforts to write three articles: a national article, an academic article, and a translational article (easy-to-understand, impressive, applicable).

My thanks also go to Prof. Wang Jici. When I read literature on clusters of innovation, I found that her studies were cited in most Chinese literature. I managed to contact her and received a lot of help from her, especially on the theories of innovation, industrial clusters, and clusters of innovation.

I would like to thank Ms. Ou Weiyan and Ms. Wang Sihan for their guidance on the format and layout of my thesis.

My thanks also go to Prof. Binkang Wang, Ms. Manjun Jiang, and Ms. Jiaojiao Yao for their assistance during my thesis writing.

Thanks to all the students of Intake 2018 for their trust and for unanimously electing me as the class president on the evening of the welcome ceremony. I have done far from enough for you. I hope that in the future, I can further contribute to the group, the school, and of course, the cause of education!

致 谢

我早在1998年就参加了Virginia Trigo和Nelson António在中国大陆举办的第一个全英文授课的MBA项目，在2002年获得了硕士学位。这是我第一次系统地接受西方教育，掌握了学习方法论以及互动教学的模式，建立了全球化思维和企业家思维，接触并开始了职业生涯规划，这些都给我的人生带来巨大的影响和改变。我成为了广州市历史上最年轻的处级干部、后来又从官员变为创业家、推动多个“国际桥”合作项目……从当我感受到教育对人的影响如此巨大，从此我爱上了教育——坚信“没有比帮助别人成长和成功更伟大的事业”，将教育事业视为自己的终身事业，为之积极准备。后来从Virginia那了解到南方医科大学/葡萄牙里斯本大学学院公共卫生政策与管理博士学位项目（Doctor of Management in Healthcare Program）并有幸成为了2018年班学员。从2018年至2023年的学习和研究期间，本人开始从实践走向理论研究，可以说是一个从学习“研究方法理论”到“研究方法实践”的过程，初步掌握了较系统的国际化的研究方法论。具备了一定的独立研究能力。

多谢南方医科大学和葡萄牙里斯本大学学院给了我一个宝贵的学习机会。

感谢Virginia又给了我一次提升的机会，而且在整个学习和研究期间，她对我的帮助是360度全方位的，Virginia鼓励我要多读文献。这5年期间，我沉浸于理论学习和研究，围绕着博士论文主题，进行大量的相关多元化的阅读，平均每年阅读175本-200本纸质书，以及数千文献。由于我研究的主题涉及生物技术和健康产业创新集群，在国内著作和文献较少，且非常难找到国外的著作和文献。这方面特别感谢Virginia给予了我许许多多的帮助。

感谢我的导师Nelson António给予我论文悉心指导，他给我印象最深的是启发式的指导，他不是“要你怎么做”，而是把论文存在问题指出来后，让你自己思考怎么改善。

中国医学科学院北京协和医学院刘远立老师，给我论文多次点指导，尤其是强调我做好三篇文章：国情篇、学术篇和转化篇（看得懂、记得住、用得上）。

感谢王缉慈教授，我阅读有关创新集群文献时，几乎绝大部分的中国学者都有引用她的文献，因此我设法找到她且得到她的诸多帮助，尤其向她学习到了有关创新、

产业集群和创新集群的专业理论体系，给予我非常大的帮助。

感谢欧玮艳老师、王思涵老师对我论文格式和排版上的指导。

感谢王斌康教授、姜满珺女士、姚姣姣女士对我研究工作的支持。

感谢2018班的全体同学的信任，在开学礼当天晚上一致推选我担任班长，我为大家做的远远不够多，希望学习结束后仍然可以为本班和学校做出更多积极贡献。同时，为教育事业多做贡献！

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Chapter 1: Introduction

Owing to globalization since the 1990s, numerous industrial clusters have been formed in areas with industrial agglomeration (usually in national and provincial development zones) in China. Enterprises in these clusters received outsourcing orders from Western countries, leveraging industrial agglomeration’s advantage of low cost. Through mutually beneficial cooperation with foreign firms, they have integrated themselves into the global value chain. However, the comparative advantages of these clusters, which are based on low-cost manufacturing, are weakening in the face of fierce international competition and change. To maintain an enterprise or a city/country’s competitiveness and high-quality development in the complex and constantly changing international environment, it is imperative to realize the transformation and upgrading from low-cost manufacturing to high-technology innovation and build clusters of innovation with global competitiveness and influence. In recent years, the Chinese government has put forward the goal of building “a new national system, national strategy, and technological power” and “Healthy China, Healthy Cities”, incorporated biotechnology and healthcare in its national strategy, and vigorously promoted the development of the biotechnology and healthcare industry, resulting in A large number of biotechnology and healthcare industrial parks have been constructed and developed in various regions in China, but most of these parks still follow the concepts and ideas of construction and development, investment promotion and business management of traditional industrial parks, and thus only a very small number of them have been able to successfully develop into clusters of innovation of biotechnology and healthcare industries. Biotechnology is a typical high-tech and knowledge-intensive industry, which is fundamentally different from industrial clusters based on low-cost manufacturing. Transforming and upgrading industrial clusters into clusters of innovation (COIs) to realize the high-quality development of the biotechnology and healthcare industry is a new challenge and new opportunity for all cities and regions in China.

1.1 Background of COIs in the biotechnology and healthcare industry

Many countries have incorporated biotechnology and healthcare industry development plans into their national development strategies. COIs have been formed in the gathering place and source of biotechnology and healthcare innovation. In the following, we will analyze the background of the development of COIs in the biotechnology and healthcare industry.

1.1.1 The global prosperous development of COIs in the biotechnology and healthcare industry

As the birthplace of the world's high-tech center, Silicon Valley, in the early 20th century, pioneered technological innovations in history. In the 1950s, a high-tech industrial base was established surrounding Stanford University in the form of the Stanford-Silicon Valley Industrial Park (Castells & Hall, 1994). Over the years, Silicon Valley has had an enormous impact on the world as a successful COI. Many countries have referred to or even "copied" the model of Silicon Valley to establish their technology industrial parks and develop them into industrial clusters and COIs. Especially in the 21st century, with globalization and a knowledge-based economy, as well as the emergence of new industries and technologies, such as the Internet and biotechnology, governments all over the world are formulating national strategies and economic and social development strategies around technological innovation. It has further accelerated the development of high-tech industrial parks, which provide research institutions, enterprises, and talents with better production and living conditions, improved infrastructure, and a beautiful environment. At the same time, the rapid flow of talents, knowledge, technology, information, enterprises, and capital fosters the overall development of the parks. Therefore, the economic behavior of modern enterprises manifests characteristics of spatial agglomeration and clustering. That means, industrial clusters and COIs are indispensable for industrial development and are crucial to the economic growth of a region and even a country.

In developed countries, some major cities have formed biotechnology industry COIs leveraging the advantages of universities, research institutions, talent intensity, entrepreneurial spirit, and venture capital. The following is a summary based on relevant literature and field research. The United States is not only the birthplace of modern biotechnology but also the global "leader" in biotechnology. At present, ten biotechnology clusters have been formed, including Boston, San Francisco, and San Diego. In Europe, the formed biotechnology clusters include the London-Oxford-Cambridge bioscience "golden triangle" in the United Kingdom, the "biological valley" of Munich and the Upper Rhine River Delta in Germany, the "Medicon Valley" of Northern Europe (Stockholm-Uppsala and Malmo-Lund of Sweden and Copenhagen of Denmark), the Gothenburg region in Sweden, Helsinki and Espoo in Finland, the Paris "Gene Valley" and the Lyon Biotechnology Park in France, Brussels in

Belgium, Dublin in Ireland, and the life sciences cluster in Switzerland (including sub-clusters with distinct characteristics such as BioAlps, Biopolo Ticino, BioValley Basel, and Zurich MedNet) (Q. Lin et al., 2020). According to the data provided by the Swiss Investment Agency, the largest life science clusters in Asia are in Japan and Singapore. The clusters mentioned above have become sources of innovation and development for the global biotechnology industry.

The World Intellectual Property Organization (WIPO) ranks the top-level innovation capabilities of countries and economies around the world every year. On September 20, 2023, WIPO released the Global Innovation Index (GII) Science and Technology Cluster Ranking 2023 (see Figure 1.1).

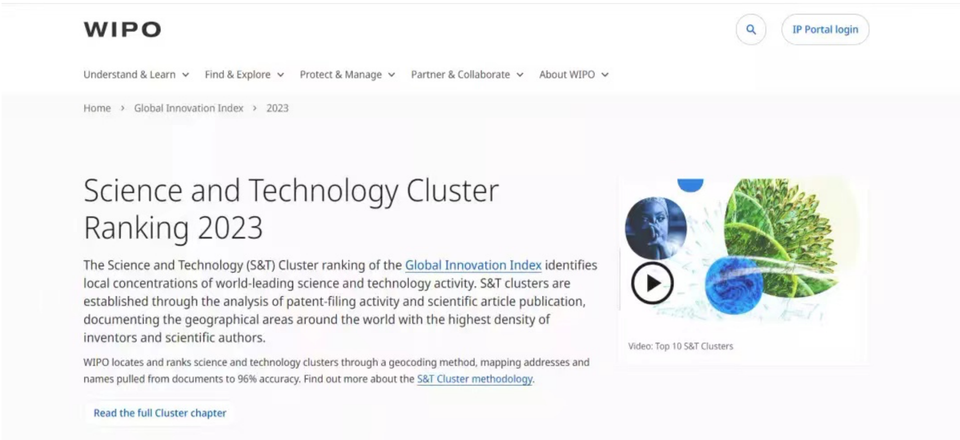

Figure 1.1 GII Science and Technology Cluster Ranking 2023

Source: WIPO (2023)

The ranking shows that China is the country with the largest number of science and technology clusters, currently having 24 clusters (see Figure 1.2).

经济体 Economy	经济体名称 Economy Name	百强集群数目 Top 100 clusters
CN	中国 China	24
US	美利坚合众国 United States of America	21
DE	德国 Germany	9
JP	日本 Japan	4
CA	加拿大 Canada	4
IN	印度 India	4
KR	大韩民国 Republic of Korea	4
FR	法国 France	3
GB	联合王国 United Kingdom	3
AU	澳大利亚 Australia	3

Figure 1.2 Economies with over three Top 100 science and technology clusters in 2023

Source: WIPO (2023)

Tokyo-Yokohama (Japan) topped the list as the world's largest science and technology cluster, followed by Shenzhen-Hong Kong-Guangzhou (China), Seoul (South Korea), Beijing (China), and Shanghai-Suzhou (China). The top five clusters are all located in East Asia, and the sixth is the San Jose-San Francisco cluster of the United States (see Figure 1.3).

排名 Rank	集群名称 Cluster name	所属经济体 Economy
1	东京-横滨 Tokyo–Yokohama	JP
2	深圳-香港-广州 Shenzhen–Hong Kong–Guangzhou	CN/HK
3	首尔 Seoul	KR
4	北京 Beijing	CN
5	上海-苏州 Shanghai–Suzhou	CN
6	加利福尼亚州圣何塞-旧金山 San Jose–San Francisco, CA	US
7	大阪-神户-京都 Osaka–Kobe–Kyoto	JP
8	马萨诸塞州波士顿-剑桥 Boston–Cambridge, MA	US
9	加利福尼亚州圣地亚哥 San Diego, CA	US
10	纽约州纽约市 New York City, NY	US
11	南京 Nanjing	CN
12	巴黎 Paris	FR
13	武汉 Wuhan	CN
14	杭州 Hangzhou	CN
15	名古屋 Nagoya	JP

Figure 1.3 Top 15 GII science and technology clusters in 2023

Source: WIPO (2023)

It can be seen from the above rankings that China has made great progress in fostering the development of COIs since it defined scientific and technological innovation as a national strategy. It could not be achieved without the great attention and strong efforts of the government.

1.1.2 The era: Bioeconomy accelerated the development of the biotechnology and healthcare industry

The biotechnology and healthcare industries are the most vibrant and far-reaching emerging industries of innovation in the 21st century. Biotechnology is widely applied in green manufacturing, biomedicine, healthcare, agriculture, energy, and environment, as well as other key fields closely related to the national economy, people's livelihood, and national security. Due to its close relationship with economic development, "bioeconomy" has garnered widespread attention. In 1980, Toffler predicted that socioeconomic development would transition from an agricultural and industrial economy to an era of information economy and bioeconomy (Toffler, 1980).

The concept of bioeconomy was proposed by Davis and Meyer (2000). We are now in the middle of the information economy era, and by the end of the 2020s, people will usher in the next economic era: the bioeconomy era. In the near future, the bioeconomy will be 10 times as big as the information economy. The widespread use of cheap chips and wireless technology marks the information economy's transition from maturity to decline, and human society will eventually be taken over by a bioeconomy in development (Davis & Meyer, 2000). The bioeconomy had already been in its nascent stage before the information economy reached maturity. The discovery of the DNA double helix structure by Francis Crick and James Watson in 1953 marked the beginning of the incubation period of the bioeconomy. The completion and publication of the decoding of the human genome symbolized the end of the incubation period, and currently, the bioeconomy is already in the growth stage (Davis & Meyer, 2000). However, only when the bioeconomy reaches a mature stage can we call it a bioeconomy era. This bioeconomy era is predicted to arrive in the mid-2020s when biotechnology is widely applied in the abiotic world (X. Deng & Gao, 2006) (see Figure 1.4).

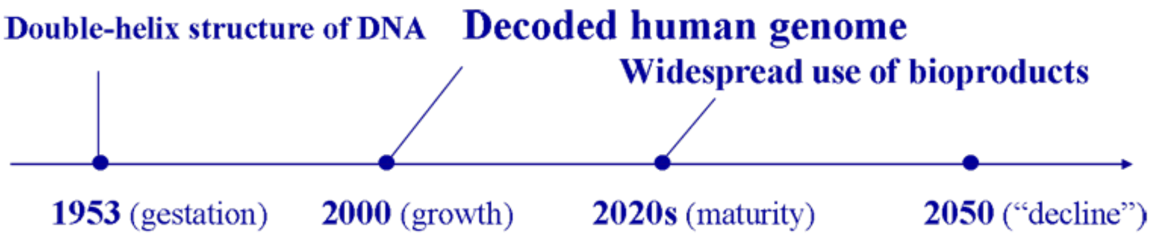

Figure 1.4 Stages of bioeconomy development and the signs

Source: Davis and Meyer (2000)

It is anticipated that approximately half of the most significant innovations in the future will rely on biotechnology. Considering factors such as scientific and technological progress, industrial development, and demand growth, it is expected that around 2030, human society will usher in a period of the prosperous development of bioeconomy, and the importance of biotechnology to human society will, to a certain extent, surpass that of information technology (J. Jiang, 2022).

In May 2009, the Organization for Economic Co-operation and Development (OECD) released *The Bioeconomy in 2030*, which comprehensively analyzed the future development trend of agriculture, health, and industry, the three sectors with the greatest potential impact on biotechnology. It pointed out that the contribution of biotechnology to global GDP would surpass 2.7% by 2030 (B. Li, 2022).

1.1.3 The policy: The development of the bioeconomy and biotechnology industry as a national strategy

Each breakthrough or major advancement in science and technology will inevitably lead to significant industrial transformation and structural adjustments, thereby propelling substantial development and leaps forward in a nation's economy and even the global economy.

Developed countries around the world have included the bioeconomy in their national strategy, increasingly focusing on this area through government policies and support. In the *National Bioeconomy Blueprint*, the U.S. government regarded "support[ing] research to establish the foundations for a 21st century bioeconomy" as a priority in its science and technology budget. In *Innovation for Sustainable Growth: A Bioeconomy for Europe*, the European Union defined the bioeconomy as a key element of its Europe 2020 Strategy for smart and green development, and the *Industrial Technology Roadmaps* were released. Germany, in its *National Bioeconomy Strategy*, proposed to improve Germany's global competitiveness in the economic and scientific fields through vigorous development of the bioeconomy (National Development and Reform Commission of China, 2016). Russia formulated *The Comprehensive Program for the Development of Biotechnology in the Russian Federation* (2012-2020). India announced the *National Biotechnology Development Strategy*. South Korea formulated the *Framework Plan for the Promotion of Bioeconomy* ("Bio-Vision 2016"). The Japanese government took "innovation in life science" as the national strategy. All of these countries are racing for the dominant position in biotechnology and accelerating the revolutionary development of the biotechnology industry (Ministry of Science and Technology of China, 2017).

China, from the state to local levels, has attached greater importance to the development of the biotechnology and healthcare industry, implemented a series of policies to encourage basic research and the transformation of research outcomes, and increased investment in R&D, thereby expediting the industrialization of innovations, accelerating the transformation and upgrading of science and technology industrial parks, and facilitating the development of industrial clusters and COIs. From the "*10th Five-Year Plan*" (2001-2005) to the "*14th Five-Year Plan*" (2021-2025), the bioindustry has been identified as one of the key strategic emerging industries. The "*14th Five-Year Plan*" officially proposed the goal of scaling up and enhancing the bioeconomy (J. Du, 2022).

1.1.4 Market demand: Rapid growth in consumption in China's healthcare industry

In recent years, the Chinese government has placed an unprecedented level of importance on the healthcare agenda. On October 26, 2016, the *Outline of "Healthy China 2030" Plan* was issued and implemented, which was the first time that China announced a medium- to long-term plan in the health sector.

According to the results of the *National Health Literacy Monitoring* released on the official website of the National Health Commission of China, the health literacy level of the Chinese population has been increasing year by year. Compared to 2015, Chinese people's health awareness doubled by 2020 (Z. Jin, 2022). Consciousness drives demand, and demand drives purchasing power. Correspondingly, the overall revenue of China's big health industry continues to rise, with the market size reaching RMB 7.4 trillion yuan (approximately 958 billion EUR) in 2020. According to the *Review and Outlook of M&A Activities in China's Big Health Industry from 2013 to the First Half of 2021* released by PwC, thanks to the release of medical consumption demand and the policy guidance for the healthcare system, China's big health market has reached RMB 13 trillion yuan (approximately 1.68 trillion EUR) with the compound annual growth rate being 13% from 2013 to 2021, and China has become the world's second-largest market. The big health industry includes sub-sectors such as pharmaceutical distribution and retail, medical services, and consumer healthcare. Among them, medical services, which include in-hospital and out-of-hospital health management, digital healthcare, and medical information technology, is the subsector with the largest market size, reaching RMB 4.7 trillion yuan (approximately 609 billion EUR) (PwC, 2021). In 2023, the market size of China's big health industry will reach RMB 14.48 trillion yuan (approximately 1.88 trillion EUR).

As people's incomes increase and their living standards improve, spending on health and medical care will also increase. According to the "Healthy China 2030" plan of the National Health Commission of China, it is expected that the scale of China's healthcare industry will expand significantly, totaling RMB 16 trillion yuan by 2030 (Xinhua News Agency, 2017).

1.1.5 Globalization: All-round strengthening of international cooperation in science and technology innovation

From the global spread of the COVID-19 pandemic, we can see that no country in the world can be spared in dealing with major infectious diseases and other major diseases that endanger human life and health. International exchanges and cooperation are imperative.

In recent years, driven by economic globalization, innovation enablers, with knowledge, technology, and talents as the core, have been flowing rapidly around the world. Chinese President Xi Jinping (2016a) highlighted that “science and technology are global and contemporary, and to develop science and technology, a global vision is necessary”; efforts should be made to enhance the capability of integrating global innovation resources and actively construct a “Belt and Road” science and technology innovation community (R. Qu & Yang, 2019). In the *2023 Government Work Report of China*, there is a specific mention of promoting international scientific and technological exchanges: “[We should] advance the construction of international and regional science and technology innovation centers,… strengthen intellectual property protection, motivate innovation, and promote international scientific and technological exchanges” (The State Council of the People's Republic of China, 2023). On September 10, 2023, Chinese President Xi Jinping sent a congratulatory letter to the 2023 Pujiang Innovation Forum, pointing out that the current unprecedented major changes are accelerating, and the world is witnessing a new round of technological revolution and industrial transformation; further development of technology innovation is a critical force for mankind in coping with risks and challenges and promoting peace and development; China will adhere to an opening strategy for mutual benefits, continuing to increase efforts in high-level opening-up, promote international scientific and technological exchanges and cooperation with open mindset and incentives, build an open innovation ecosystem with global competitiveness, and work with other countries to create an open, fair, and non-discriminatory environment for scientific and technological development (Xinhua News Agency, 2023).

1.2 Research problem

Industrial parks (including all types of science and technology parks) in China are the main carriers for the formation of industrial clusters and COIs, but only some of them can form industrial clusters, with very few being able to upgrade to COIs. In China, even biotechnology parks in developed cities are facing the dilemma of attracting investment and upgrading and transforming into COIs. The progress of international cooperation and exchanges is slow, which is a practical problem that China needs to address promptly. The following sections will present some common phenomena and challenges in biotechnology and healthcare industry parks in China.

1.2.1 "Race to the bottom" leading to "policy-driven tenants" and "bad money driving out good"

The clusters that are most prone to decline are those relying solely on low prices in competition, having a low level of organizational systems and low entry barriers, and lacking a technological innovation system and an adequate service system (Y. Pang, 2006). In order to attract investment and solve the problem of property lease, these parks do not adhere to the industrial requirements and criteria, and thus the resident enterprises may not be qualified, having varied quality and level. Many enterprises settle in the park solely for the purpose of enjoying tax benefits and rent incentives provided by the government to attract investment and enterprises. In other words, they are "policy-driven tenants". That often leads to vicious competition among parks in different cities. In the middle to later stages, these parks may face two dilemmas.

First, when preferential policies expire, local costs rise, or when competitors (parks in competing cities) engage in a "race to the bottom" and erode the policy advantages, cost-sensitive enterprises may relocate to regions with lower costs.

Second, the phenomenon of "bad money driving out good". "Bad money drives out good", also known as Gresham's Law, was proposed by Thomas Gresham, Master of the Royal Mint under Queen Elizabeth in 16th century England. It is a well-known economic law that describes such a historical phenomenon: In the era of coinage, when coins of lower weight or purity, known as "bad money," enter circulation, people tend to hoard coins of higher value and quality, known as "good money"; eventually, the good money is driven out of circulation, leaving only the bad money in the market. Such phenomenon is not only observed in currency circulation but also in various aspects of economics and social life. For example, high-quality enterprises are unwilling to settle in the same park along with enterprises of lower quality and levels.

1.2.2 The dilemma of "the existence of enterprises without an industry" making parks fail to develop into industrial clusters or COIs

Another phenomenon is insufficient or even no connections among the enterprises in the park. In this case, the park is merely a provider of office and production spaces for enterprises. At the same time, these enterprises lack core technology, have insufficient innovation capabilities and limited market competitiveness, and fail to generate sufficient industry-related connections, resulting in the phenomenon of "the existence of enterprises without an industry".

There is no industrial linkage or industrial chain, and the park fails to form industrial clusters. Without collaborative innovation, the park cannot integrate into international innovation networks, not to mention forming COIs or establishing a sustainable industrial innovation ecosystem. When resident enterprises with limited competitiveness face survival or development difficulties, it will hinder the sustainable development of the park and may lead to its decline.

1.2.3 Sticking to the real estate profit model and lacking a specialized system for technological innovation and industrial service

The root cause of the aforementioned phenomena lies in the fact that some parks, despite being named biotechnology parks, are essentially businesses with a real estate, "industrial property", or "technological property" profit model, relying on rental income, property sales, and land appreciation. The input in park infrastructure and fixed assets far outweighs the speed and quality of investment attraction. They prioritize "hardware" over "software" and fail to establish specialized and efficient service systems. Park operators primarily provide property management services rather than value-added services related to the biotechnology industry.

1.2.4 The "lock-in effect" and "path dependence" in the park

Biotechnology industrial parks are mainly located in high-tech zones, many of which are newly established biotechnology industry areas based on the existing economic and technological development zones and other industrial zones. Most of these economic and technological development zones and high-tech zones in China were established under the leadership of the government. In the early stages of development, they relied on preferential policies, low-cost land, and cheap labor to attract enterprises, primarily owing to the offshoring and outsourcing of manufacturing by multinational companies from developed countries to developing countries for cost reduction in the 1970s and 1980s. These parks mainly undertook manufacturing and processing in the low-end segments of the industrial chain and were barely engaged in R&D.

Even now, many park administrators remain stuck in the old model, accustomed to attracting manufacturing projects (factories) from large enterprises and multinational corporations. Therefore, they continue to use the "manufacturing parks" mindset in operating and developing "high-tech parks", attempting to attract and serve high-tech projects and enterprises by using the approach for manufacturing-based projects and enterprises. Alternatively, in the pursuit of output value and tax revenue, they focus on attracting large enterprises and listed companies to move their headquarters (including regional headquarters) to the park, which has little association with fostering innovation. Meanwhile, compared to large enterprises, small and medium innovative enterprises receive less attention and support due to their limited value creation and tax contribution in the short term.

That can lead to three problems: a) When large enterprises perform poorly or relocate elsewhere, it will impact the operation, survival, and development of the park. b) The "lock-in effect". The "lock-in effect" is essentially a kind of "path dependence" phenomenon of industrial clusters during their life cycle evolution. Using the Ruhr region in Germany in the 1960s and 1970s as an example, Grabher (1993) proposed the concept of regional lock-in in old industrial areas. He pointed out there are three categories of lock-in effects: functional lock-in, cognitive lock-in, and political lock-in. c) The "path dependence." Path dependence was first proposed by Paul David in his book *Technical Choice, Innovation, and Economic Growth*, referring to the inertia present in the technological evolution or institutional change in human society. That is, once a particular path is taken (regardless of being "good" or "bad"), due to factors such as economies of scale, learning effects, coordination effects, and adaptive expectations, the development will continue along that path, becoming locked into it. The force of inertia will continue to reinforce this choice, making it difficult to deviate from the path.

1.2.5 The traditional investment promotion model is no longer suitable for the current trend of clustered industrial transfer

As mentioned above, initially, the primary task of establishing industrial parks in China was to attract investment, more specifically, foreign direct investment (FDI). These parks provided special policy incentives to multinational companies and foreign-invested enterprises, encouraging them to establish manufacturing and processing factories in traditional sectors such as food and beverage, consumer goods, steel, and automobile manufacturing. However, in the biotechnology and healthcare industry, currently, the industrial transfer is trending towards a more clustered form, encompassing manufacturing, R&D, and services, thus imposing higher requirements on industrial parks in terms of the environment, infrastructure, supporting facilities, investment promotion, and industrial services. In this case, the traditional investment promotion model of the production-driven parks can no longer meet the demands for industrial transfer in the biotechnology and healthcare industry.

1.2.6 Conceptual bias and policy-oriented bias

In many Chinese cities, local governments and biotechnology industrial parks' administrators have introduced various support policies, but they often overly focus on technological innovation and lack incentives for management innovation, market innovation, and business model innovation. Both technology policies and talent policies tend to prioritize innovation-oriented leading scientific and technological talents (research and technical personnel), with insufficient attention to the importance of entrepreneurial talents in the transformation of research outcomes and industrial innovation. When enterprises' leaders (e.g., chairmen and general managers) receive talent support benefits, they are often identified as scientists or research personnel rather than entrepreneurs. The root cause is the social bias of the "original sin" perception towards entrepreneurs. This study has found that many leaders of local government and state-owned parks even hold the assumption that "state-owned enterprises will not have integrity risks, while private enterprises may have, and private entrepreneurs are dishonest".

Furthermore, the role of intermediaries and professional service providers has not been effectively evaluated and recognized, and there is a lack of effective incentives for them. Although some local governments have introduced relevant policies, their implementation is inadequate due to the lack of an effective evaluation system.

1.2.7 Lack of talent training system and mechanism and insufficient talents for park operation and management

Industrial parks' operation, management, and investment promotion teams vary greatly in service quality, and there is a lack of professional talents (especially leading talents) with international vision and expertise in investment promotion and industrial operation and management. There is currently no specific discipline dedicated to this field in universities, and there is a significant lack of professional training in society regarding high-tech zones, industrial clusters, and COIs. This deficiency is particularly evident with the rapid development of high-tech zones, biotechnology industrial parks, and COIs in various regions.

1.2.8 Insufficient understanding of COIs and inadequate integration of theory and practice constraining the development of COIs

In recent years, terms such as "industry chain", "financial chain", "innovation chain", and "talent chain" are frequently seen in Chinese government work reports and policy documents.

It indicates that park administrators and policymakers still think in linear terms and have not developed the innovation ecosystem mindset. The top-level design and positioning of the park are ambiguous, with severe homogenization and lack of differentiation; the industrial planning is rather general and comprehensive, lacking precise segmentation, professionalism, and farsightedness.

There is also a lack of theoretical and practical innovations that are tailored to the Chinese context. The COI theories developed based on developed countries may not be entirely applicable to the Chinese context. It is necessary to identify a development path for Chinese COIs taking into account local circumstances with references to the relevant theories from developed countries. The theory can guide practice, and innovation in practice can, in turn, promote theoretical advances. However, currently, a lot of Chinese scholars go "from theory to theory," with insufficient integration of theory and practice. The research on clusters focuses more on traditional industries, and there is a lack of empirical research on strategic emerging industries, especially the biotechnology and healthcare industries. In China, theoretical research on clusters is dominantly at the level of "industrial clusters" rather than "COIs", and sometimes, the two were referred to interchangeably.

On the other hand, due to the lack of systematic theoretical guidance, the operators and managers of industrial parks can only rely on experiential learning in practice. Many practical experiences have not been developed to the theoretical level, hindering the ability of future operators of the parks to learn quickly and innovate based on existing knowledge. To some extent, it hampers the transformation and upgrading of technology industrial parks and the high-quality development of COIs.

1.2.9 Limited understanding and capabilities of international cooperation and insufficient integration into global innovation networks leading to the "closed container" trap

In today's era, a country's ability for scientific and technological innovation largely depends on its capability to integrate global innovation resources. As China accelerates the construction of an innovative nation and a world leader in science and technology, it needs to plan and promote innovation with a global vision and comprehensively strengthen international cooperation in science and technology innovation (J. Xi, 2022).

It is urgent to improve China's independent innovation ability in the biotechnology and healthcare industry. To address this question, it is essential to understand where and how innovation can take place. Therefore, the focus is to understand the source of innovation.

Comparing the biotechnology industry COIs in developed countries and the biotechnology industrial parks in China, the former is the birthplace of technological innovation, paying great attention to international exchanges and cooperation, the integration of local and international innovative thinking, and building innovation institutions, cultures, and ecosystems, while the latter are still stuck in the traditional “investment promotion” model and are keen on the projects that can immediately generate output value and tax revenue, usually manufacturing or service outsourcing projects. Even if the parks can attract foreign enterprises to establish companies and factories locally, the primary purpose of many of them is to address market access issues. They may engage in simple processing or even simple assembly (“the last mile” of the production journey), do not organically integrate into the local regional economy, and do not contribute to localized technological innovation or the enhancement of local enterprises’ innovation capabilities.

China is one of the world’s largest consumer markets. To meet the huge market demand for healthcare products, it is highly urgent to introduce international mid- to high-end biotechnological innovations to China for commercialization. However, apart from a few first-tier coastal cities such as Guangzhou and Shanghai, the majority of biotechnology industrial parks in China excessively rely on local networks, are not aligned with the global arena, and fail to integrate into the global innovation network, thus falling into the trap of a “closed container.” This may ultimately lead to increased entropy and chaos. Clusters should not be closed containers, but rather open systems connected to the external world. Overemphasis on local connections can lead to excessive rigidity in the local network, which will adversely affect the long-term competitiveness of the industry. Moreover, there are issues to be addressed in international exchanges and cooperation, such as intellectual property rights, administrative efficiency, and the legal environment, which still need to be improved and enhanced.

1.3 Research questions

There has been extensive research on COIs worldwide. However, the enablers of the formation and development of COIs and their joint actions are different in different times and spaces. From a temporal perspective, different historical stages have given rise to varied research and theories. The question arises as to whether the theories of the past can be applied to today. From a spatial perspective, it is worth considering whether Western theories are applicable to the Chinese context. Moreover, in terms of the integration of theory and practice, it is important to assess whether the theories can effectively guide practice.

This study is based on the case of Guangzhou International Bio Island (hereinafter referred to as the "Bio-Island"), aiming to provide valuable insights for governments, enterprises, investment institutions, and park operators and administrators in addressing challenges in the development of biotechnology and healthcare industrial parks and identifying paths for the parks' upgrading, transformation, and sustainable development. The study explores how to enhance the competitiveness of industrial parks and COIs in biotechnology and healthcare and foster the high-quality development of the industry.

The research questions are:

1) What are the core enablers of COIs in the biotechnology and healthcare industry and how do their joint actions foster the formation and development of COIs?

2) Do international exchanges and cooperation have a positive impact on the formation and development of COIs?

1.4 Research innovation

This study is based on the case of Guangzhou International Bio Island. We first conducted a literature review of Chinese and international studies on concepts and theories related to industrial clusters and COIs, the core components, and the relationships among the components. Following an analysis of the policy background for the formation of COIs in the biotechnology and healthcare industry, we collected the historical data of Bio Island, conducted field research and formal interviews, and invited experts to participate in focus group discussions, in an attempt to identify the core enablers that foster the transformation of Bio Island into a COI and explore how these enablers have joint actions to drive innovation. For instance, which drives and fosters innovation: the "invisible hand" (the market) or the "visible hand" (the government)? Universities, research institutions, or enterprises? The "entrepreneurs" or "scientists"? The "organizations" or "institutions"? Or are there other forces (actors and behaviors) at play? Additionally, the study aims to investigate the means and methods by which these enablers (innovation actors) establish connections and effective joint actions (innovation activities), facilitating the integration of the internal and external resources of the park, thereby driving innovation behaviors and technology diffusion and application. Furthermore, the study explores the impact of international exchanges and cooperation on the formation of COIs. In the context of China's reform and opening-up policy and Guangzhou's aspiration to build an international innovation hub, this study will also discuss how Bio Island proactively integrates into the global innovation network and achieves internationalized innovation.

Chapter 2: Literature Review

Research on clusters of innovation (COIs) naturally involves research on "innovation". Therefore, this chapter will conduct a literature review of innovation theories and the theoretical evolution of COIs as the theoretical basis of this study. We will also review studies dedicated to industrial parks and COIs of the biotechnology and healthcare industry in China.

2.1 Theories on innovation

Schumpeter (1912) was one of the earliest to point out innovation's important role in economic and social changes. He believes that economic development is a process of qualitative change driven by innovation in a certain historical period.

However, people often have some misunderstandings regarding innovation. First, they may mistakenly regard invention as innovation while ignoring the transformation of innovations, customer experience, and market value, without realizing that only when products are accepted by customers and the market can they be considered innovations. Moreover, they may mistakenly consider technological development as the source of value creation, believing that innovation is equal to technological innovation, failing to recognize the importance of model innovation. Chesbrough (2003a, 2006) showed that business models were crucial for releasing the potential value of new or existing products. Technology itself has no economic value; only when technology development and commercialization are completed with the assistance of a business model can the economic value of technology be realized (Vanhaverbeke, 2017). Furthermore, people may regard innovation as a linear process, failing to recognize its nature as a system.

Therefore, through literature research, we attempt to understand the concept and nature of innovation, the evolution and theoretical development of the innovation process and paradigm, the innovation process and its underlying logic, and the classification and theoretical evolution of innovation systems. All these have significance on studies of COIs.

Research on innovation spans many fields of social sciences and humanities, such as management, economics, geography, sociology, politics, psychology, and history. Innovation often occurs at the edge of disciplines, industries, and regions. The task of enterprises and entrepreneurs is to turn "technological innovation" into "product innovation". However, from the government's perspective, for national, municipal, or regional development, the innovation process goes beyond that and should also include the pathway from "product innovation" to "industrial innovation".

2.1.1 The definition of innovation

Schumpeter (1912) *The Theory of Economic Development* first put forward the concept of "innovation" and its role in economic development. Schumpeter (1934) recognized the entrepreneurial spirit as a crucial factor of production that drives output increases by altering the production function. It is essentially a process of innovation. Schumpeter defined innovation as a "new combination" of existing resources, which involves introducing previously non-existent production factors and conditions to the production system to develop new production capabilities, including but not limited to the introduction of new products or a new quality of product, the adoption of new production processes or methods, the exploration of new markets, the discovery of new sources of raw materials, and the realization of new forms of organizations within firms.

Schumpeter (1934) identified five types of innovation: a) the development of new products or new categories of existing products, b) the adoption or sales of new production methods (not yet confirmed by the industry), c) the opening of new markets (not yet represented by industry segments), d) the discovery of new sources of supply of raw materials or half-manufactured goods, and e) the establishment and implementation of a new organization of the industry, such as the creation or destruction of monopoly position.

According to Schumpeter (1934), anyone in the pursuit of profit should undertake innovation, which implies a different use of the existing production means in the economic system. Schumpeter regarded innovation as the basic driving force of competitiveness (Porter & Stern, 1999) and economic dynamics (Hanusch & Pyka, 2007). He also considered innovation as the center of economic change, leading to "creative destruction" (Schumpeter, 1942). According to Schumpeter (1942), innovation is a process of industrial mutation, constantly changing the economic structure from the inside, disrupting the old structure, and creating new structures. Schumpeter's theory divided the innovation process into four dimensions: invention, innovation, diffusion, and imitation (Burton-Jones, 1999).

When analyzing the diffusion of innovation, Schumpeter (1939) highlighted the clustering trend of innovation in a certain industry or period (and the resulting growth effect), as well as the possible role of such "clusters" in promoting the formation of economic cycles and "long waves" in the global economy. Schumpeter believed that the occurrence of "innovation" or the "new combination" of production factors is not continuously and evenly distributed along the timeline as predicted by the general principles of probability. Instead, it occurs intermittently with fluctuations, sometimes in groups, and other times in sparsity, resulting in "business cycles" or "economic cycles".

Schumpeter's theoretical logic is: entrepreneurs - new combination (innovation) - economic development. According to him, the emergence of entrepreneurs in large numbers is the sole reason for prosperity. Schumpeter placed great emphasis on the role of individuals, specifically "entrepreneurs," in the development of capitalism. For Schumpeter, the importance of entrepreneurs exceeded that of material factors such as technology or industries.

Drucker (1995) highlighted that scientific research itself is a form of "social innovation". He argued that innovation is not solely a technological term, but rather an economic or social term. Innovation entails changing the output of resources and should be defined from a demand perspective rather than a supply perspective. Specifically, it refers to changing the value and satisfaction that resources provide to consumers. Innovation serves as a unique tool for entrepreneurs, who perceive change as an opportunity to create new ventures or services by using this tool. Innovation, as a discipline, can be shared with the public, studied by individuals, and applied in practical settings. Entrepreneurs should actively seek the sources of innovation, identifying changes and signals that indicate opportunities for successful innovation. They should also understand and apply the principles of successful innovation.

At present, "innovation" is generally regarded as the outcome of a process and is defined based on two characteristics: the novelty of change and the usefulness or application success of new things. The concept of "new" or "novelty" can be understood as new to the world, new to a country, or new to a company (Granstrand & Holgersson, 2020).

2.1.2 Technological innovation

Academic circles generally believe that the theory of technological innovation has been developed on the basis of Schumpeter's innovation theory through a long period of research (F. Zhang et al., 2010). Some Chinese scholars have categorized technological innovation into narrow and broad senses. Narrow-sense technological innovation refers to the process by which companies, guided by market demand, utilize scientific and technological R&D to create products that better meet potential market needs, production processes that are more efficient and cost-saving, and managerial methods that are more scientific and appropriate, thereby optimizing the use of resources and enhancing the efficiency, productivity, and cost-effectiveness of production activities. Broad-sense technological innovation encompasses not only narrow-sense technological innovation but also innovation diffusion, transfer, penetration, and market development (X. Wang, 2006).

Schumpeter’s concept of innovation is more in an economic sense rather than a purely “technological” sense. However, in China, the role of technological innovation has been exaggerated and even absolutized (S. Xing, 2016). People excessively focus on technological innovation while ignoring the need for technology to be “transformed” into new productivity. Therefore, the fundamental meaning of innovation is to create new products or services and realize their market value (J. Wang et al., 2019).

Enos (1962) was the first to explicitly define technological innovation. He believed that technological innovation is the joint outcome of various behaviors, including invention selection, capital investment guarantees, organization establishment, planning, workforce recruitment, and market development.

Freeman (1973) defined technological innovation as a comprehensive process covering technology, processes, and commercialization, which leads to the market realization for new products and the commercialization of new technologies, processes, and equipment. Later, Freeman (1982) further defined technological innovation as the first commercialization of new products, new processes, new systems, and new services.

The Organization for Economic Co-operation and Development (OECD, 2005) also defined technological innovation as the innovation of products and processes, including the introduction of new technologies, products, and processes, as well as significant improvements in technology-related products and processes. It encompasses a range of activities related to science, technology, organization, finance, and commerce.

2.1.3 Industrial innovation

In the mid-1960s, the academic community began to explore the ways and means by which technological innovation impacts industrial structure, industrial efficiency, and industrial evolution. They discovered the fundamental trajectories and development directions of industrial innovation induced by technological advancement. The theory of industrial innovation mainly addresses the study of technological revolutions, while the theory of innovation component aggregation represents the mainstream in research on industrial innovation, bringing together related theoretical and empirical research outcomes from various disciplines.

2.1.3.1 Proposal of industrial innovation

Cunningham (1960) was the first to define the scope of the term "innovation" and discussed the difficulties and obstacles that may arise during innovation dissemination within economic cycles. He proposed solutions for the differentiated problems faced by different industries during their development, the determination of performance criteria based on industry characteristics, and the establishment of inter-industry connections. This work laid the foundation for subsequent research on industrial innovation by establishing a basic conceptual framework, language paradigm, and line of thinking.

2.1.3.2 Empirical studies of industrial innovation

In the 1960s, American economist Schmookler (1966) conducted early empirical research on industrial innovation. Regarding the sources of technological innovation, Schmookler highlighted that innovation is driven by the pursuit of economic profits.

Mansfield (1988) conducted comparative research on industrial innovation in Japan and the United States and identified the characteristics of the Japanese mode and the American mode. Japan focused more on technological accumulation and upgrading through comprehensive integration, and their approach involved organized technology transfers to quickly bring products to the market and achieve rapid internationalization. In contrast, the United States emphasized the commercialization of R&D outcomes, through financing, particularly securities markets and venture capital, supporting university laboratories to transform their outcomes into products or even industries.

In the 1970s, Freeman and Soete (1974) conducted empirical research on innovation in multiple industries. Taking a historical perspective, he concluded that industrial innovation encompasses technological and skill innovations, product innovation, process innovation, management innovation (including organizational innovation), and market innovation. The content of innovation varies across industries, and innovation is a systemic concept. Systemic factors play a decisive role in the success of industrial innovation. Among them, technological innovation encompasses the entire process of technology development and commercialization, enabling the realization and maximization of market value for new products. The system of innovation will be discussed in detail further in this chapter.

2.1.3.3 Enhancing the competitiveness of traditional industries through industrial innovation with the innovative factors highly agglomerated in industrial parks

Research on industrial innovation in China started upon China's reform and opening up. The prominence of industrial innovation across regions is reflected in the high agglomeration of innovation components in industrial parks. Many Chinese scholars started paying attention to the relationship between regional economic development and industrial innovation, analyzing and exploring industrial innovation from multiple perspectives, such as technological innovation, organizational innovation, institutional innovation, and service innovation. They paid special attention to the driving forces of industrial innovation, innovation mechanisms and policies, and key success factors and barriers (L. Zhou & Zhang, 2017).

Industrial innovation represents a comprehensive integration of technological innovation, product innovation, and market innovation, among others. It is the highest-level and ultimate goal of enterprise innovation and is the process in which enterprises break free from the constraints of structured industries, reshape existing industry structures, or create entirely new industries by employing technological innovation, product innovation, market innovation, or a combination thereof (G. Lu, 2003).

2.1.4 "Knowledge spillover" and "innovation diffusion" in the innovation process

Knowledge is one of the decisive factors for innovation. In 1996, the OECD put forward in *The Knowledge-based Economy* that contemporary innovation activities are driven by the interaction between producers and users in exchanging explicit knowledge and tacit knowledge (OECD, 1996). In the classic work *The Tacit Dimension*, Michael Polanyi (1966) used "We can know more than we can tell" (the so-called "Polanyi paradox") to describe the difference between tacit knowledge and explicit knowledge (or codified knowledge). Explicit knowledge can be clearly explained and disseminated through magazines, project reports, raw materials, and other tactile media. In contrast, tacit knowledge, with a high degree of uncertainty and obscurity, can hardly be articulated accurately and requires face-to-face contact and communication; thus, commercial activities often take place in locations with geographical proximity. Innovation is a social process. Contemporary innovation requires interdisciplinary and industrial integration. Therefore, people with expertise in the same or related industries need to have adequate communication and interaction with each other in a diversified innovation environment. Such internal and external communication and interaction across organizations, industries, and regions is conducive to the mutual learning and reference of information, knowledge, and technology. It is a process of gaining inspiration and creating new ideas and a process of disseminating innovation. Moreover, this social process also forms new innovation networks and communities on the basis of the existing social networks. Therefore, the "knowledge spillover" and "innovation diffusion" in the innovation process are crucial for the study of innovation and COIs.

2.1.4.1 Knowledge spillover

With the increasing complexity of technology, individuals have fewer opportunities for invention and innovation, making collective learning and knowledge spillover increasingly needed. The knowledge spillover in the process of innovation is critical to economic growth.

The concept of knowledge spillover can be traced back to the economic externalities highlighted by Marshall (1890). He believed that industrial districts were conducive to knowledge dissemination and technology diffusion among enterprises. Subsequently, economists Arrow (1962) and Romer (1986) expanded upon the concept of knowledge spillover. Glaeser et al. (1992) synthesized the perspectives of Marshall, Arrow, and Romer on knowledge spillover and coined the term "Marshall-Arrow-Romer (MAR) spillover". According to the MAR spillover, the distance between enterprises within the same industry can influence the dissemination of knowledge among them. It is highlighted that knowledge transfer among enterprises in the same industry within the region will foster innovation and economic growth. Closer proximity between enterprises can result in greater MAR spillover effects. The exchange of ideas primarily occurs through communication among employees, more specifically, the sharing of thoughts on new products or new production methods among technical personnel from different enterprises in the same industry, which will lead to innovation. For example, many semiconductor companies intentionally locate their R&D facilities in Silicon Valley to leverage the MAR spillover effects. Additionally, the film industry in locations such as Los Angeles, California relies on the geographical concentration of professionals (e.g., directors, producers, screenwriters, and set designers), gathering all resources of film production to create the final product.

That is different from the view of Jacobs (1961), an urban planner, who regards industrial diversity in cities as a mechanism of knowledge spillover. Her view is that the differentiation and diversification of the urban economy foster the cities' development. According to Jacobs, the proximity of enterprises from different industries influences the diffusion of knowledge among them, thus promoting innovation and growth. That is different from the MAR spillover effect. MAR spillover focuses on enterprises within the same industry, while Jacobs' diverse proximity spillover emphasizes the gathering of ideas among individuals with different perspectives to encourage intellectual exchange and foster innovation within an industrially diverse environment. In other words, according to Jacobs, the most important sources of knowledge spillovers come from the external of industries.

Despite the differences between the MAR paradigm and the Jacobs paradigm in terms of industry specialization and diversity, both acknowledge the importance of knowledge spillovers for innovation and economic growth. That involves two interactive processes, namely, knowledge production and development. If one attempts to explain economic growth through innovation, then spillovers are merely a necessary condition. Only when commercialized and utilized can knowledge be transformed into higher levels of competitiveness, thereby promoting economic growth (L. Zhou & Zhang, 2017).

2.1.4.2 Innovation diffusion

Rogers (1962) pointed out that the diffusion of innovations was influenced by the characteristics of the innovation, the communication channels, time, and the social system.

Rogers (1962) conducted a detailed analysis of the factors that impact innovation diffusion and the formation of diffusion networks. Using the innovation diffusion curve, the multi-step innovation flow theory, and the innovation adoption curve, he described the process of innovation diffusion and proposed that the diffusion of innovation involves five steps: cognition, persuasion, decision, implementation, and confirmation. He categorized the adopters of innovations into five groups: a) innovators 2.5%, b) early adopters 13.5%, c) early majority 34%, d) late majority 34%, and e) laggards 16%.

Rogers (1962) pointed out that innovation diffusion always relies on certain social networks. During the spread and diffusion of innovations within a social system, information technology can effectively provide relevant knowledge and information. However, interpersonal communication is more direct and effective in persuading people to accept and use innovations.

Rogers' contribution lies in his emphasis on the formation of networks. As his work highlighted how information exchange occurs within networks and in geographical space, some scholars consider him a pioneer in the perspective that innovation should be seen as an interactive process (Fagerberg et al., 2013). However, the innovation diffusion approach views innovation as a linear process and does not fully recognize its systemic nature.

In Lundvall (2013) research, innovation is conceptualized as an interactive process that involves multiple components and expands over time. It involves the interaction between individuals with heterogeneous skills and organizations with heterogeneous capabilities. Information exchange, problem-solving, and mutual learning are often considered integral parts of innovation. In this process, relationships are established, which can be interpreted as the formation of organizations, networks, clusters, and even "innovation systems." The core of this innovation theory assumes that it is meaningful to regard innovation as a process that starts by combining existing knowledge elements and ends by generating new knowledge. Innovation can be considered as a "new combination" of more or less different knowledge elements. The more distinct the elements, the more radical the innovation.

2.1.5 The evolution of innovation paradigm

Perez (2002, 2010) believed that each technological revolution would produce a new economy, new production methods, new consumption modes, and new regulations of social and economic life. A new technological revolution is a new "techno-economic paradigm", which means the emergence of interrelated new technologies, industries, and infrastructure.

With the increasing importance of innovation capability to the competitiveness of enterprises, industries, regions, and countries, the innovation paradigm has evolved from the linear paradigm to the innovation system paradigm and is now entering the era of the innovation ecosystem, as shown in Table 2.1.

Table 2.1 Comparison of the three innovation paradigms

	Linear paradigm	Innovation system	Innovation ecosystem
Innovation actors (relationship)	Emphasis on enterprises	Industry - university - research collaboration	"Symbiosis" of industry - university - research - user
Innovation strategic focus	Independent R&D	Collaborative R&D	Creative design & user relationship
Value realization vector	Products	Service + Product	Experience + Service +Product
Innovation-driven model	Demand + Research (Double Helix)	Government + Enterprise + Academia, Demand + Research + Competition (Triple Helix)	Government + Enterprise + Academia + Users, Demand + Research + Competition + Symbiosis (Quadruple Helix)
IT support	Web 1.0 Network access	Web 2.0 Interconnection	Web 3.0 Cloud platform/Big data

Source: Shanghai Institute for Science of Science (2015)

Twenty to thirty years ago, when innovation shifted from a linear paradigm (increasing investment and promoting economic growth) to the innovation system paradigm, countries and regions around the world began establishing national/regional innovation systems to drive their economic development. In the 21st century, the innovation paradigm underwent another transformation on a global scale, transitioning from an engineered and mechanized innovation system to an ecological and organic innovation ecosystem.

In 2013, the European Union officially released the report *Open Innovation 2.0: A New Paradigm* (Curley & Salmelin, 2013). The report pointed out that the first stage of the innovation paradigm was based on a linear model (i.e., closed innovation), while the second stage was based on the innovation system theory and “Open Innovation 1.0” (innovation sources are not limited to internal sources, but also include external sources). The third stage is based on the innovation ecosystem. Through *Horizon 2020*, the European Union focuses on “Open Innovation 2.0”, which is based on the “quadruple helix” that includes government (public institutions), enterprises (industry), universities (research institutions), and users (citizens). The report also emphasized the diversity of collaborators. Innovation occurs in ecosystems or networks far beyond the boundaries of conventional organizations. The network formed by the cooperation of multiple stakeholders, including organizations, individuals, universities, and governments, can create joint value, which cannot be achieved by any single organization alone (Shanghai Institute for Science of Science, 2015).

The rise and development of the innovation ecosystem mark the entrance into the third generation of innovation paradigm: the “structural innovation paradigm”, which is consistent with the development of the industrial economy, is evolving into the “embedded innovation paradigm” that is in line with the knowledge economy (Simanis & Hart, 2009). This evolution highlights that users are no longer passive targets of producer-led innovation, but rather deeply engaged in the innovation process to co-create value with producers, forming an embedded innovation paradigm. In the future, the deep engagement of users will fundamentally change the internal structure of the innovation process (Shanghai Institute for Science of Science, 2015).

2.1.5.1 From “closed innovation” to “open innovation”

The concept of open innovation was proposed by Chesbrough (2007) to describe the innovation process where companies develop and acquire external knowledge through interaction with the external environment. Open Innovation is the source of collaborative innovation. Regardless of the size of an enterprise or organization, it is challenging to achieve efficient innovation solely through internal efforts, which is referred to as “closed innovation”. Chesbrough (2007) defined “open innovation” as the purposeful use of inbound and outbound knowledge flows to accelerate internal innovation and expand external markets for the use of innovation.

Chesbrough (2003a) suggests that more and more enterprises are reevaluating the earlier approach of relying solely on internal R&D efforts for innovation. To accelerate internal innovation, it is essential to leverage external wisdom. Many well-known large enterprises have carried out open innovation practices by utilizing resources from other enterprises, universities, or research institutions. Furthermore, in the internet era, every consumer has the opportunity to participate in production and R&D, being potential drivers of technological innovation. Consumers are now an integral part of enterprises' production systems, marking the era of co-production with consumers.

Open innovation has also played a crucial role in the service sector. Similar to product open innovation, service innovation also benefits from a specialized division of labor. Through "outside-in" open innovation, by leveraging external ideas, creativity, and technology, service companies can achieve economies of scope. On the other hand, through "inside-out" open innovation, by sharing core processes with other enterprises, service companies can achieve economies of scale. Additionally, one of the most effective approaches is constructing open business platforms based on open innovation that can attract upstream and downstream enterprises and partners (Chesbrough, 2011). Figure 2.1 compares the process of closed innovation and open innovation. We can see that open innovation is conducive to breaking through enterprise boundaries, introducing and integrating external innovation resources, discovering new technologies and projects, and opening up new markets.

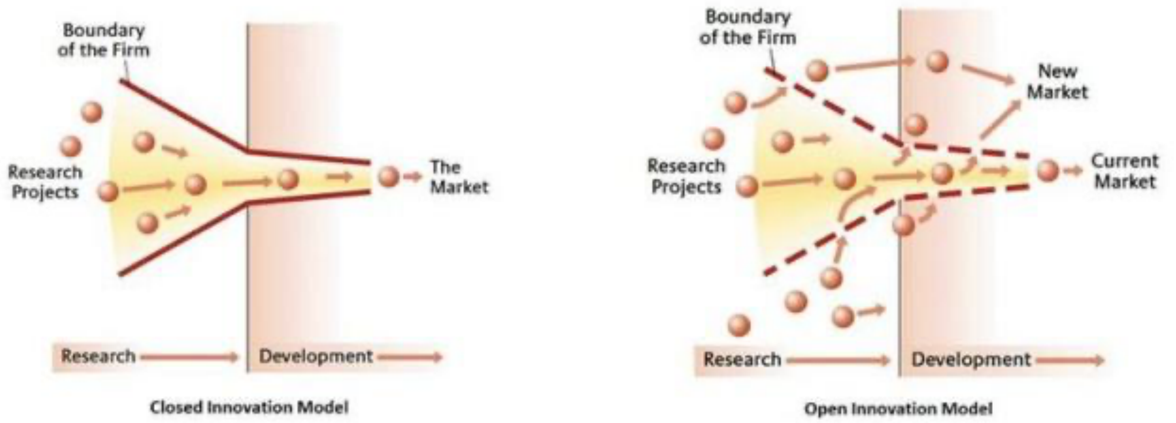

Figure 2.1 Closed innovation and open innovation

Source: Chesbrough (2003b)

At the economic level, results of the Community Innovation Survey showed that under the same conditions, institutions with more external knowledge channels performed better in innovation (Laursen & Salter, 2006). A survey among 125 large enterprises found that, by comparison, enterprises that adopt open innovation were better off at innovation outcomes (Chesbrough & Brunswicker, 2014). However, Vanhaverbeke (2017) argued that small and medium-sized enterprises should not simply copy the practice of large enterprises. The open innovation of small enterprises takes the network form, whose management mode is quite different from that of large enterprises' innovation networks. Relying on private relationships and personal trust, rapid decision-making, and informal communication are the main features of the exchange and cooperation between small companies and their innovation collaborators. That is quite different from large enterprises' management of open innovation.

2.1.5.2 From the "Triple Helix" model to the "Quadruple Helix" model and "Quintuple Helix" model

In the mid-1990s, Etzkowitz and Leydesdorff (1995) proposed the renowned government-industry-academia Triple Helix theory, which addresses the novel joint actions among the government, industry, and universities in the knowledge economy era. It is considered to have pioneered a new field and new paradigm for innovation research.

The Triple Helix theory highlights the close cooperation and interaction among universities, industry, and the government, thereby enhancing overall collaborative innovation and ultimately improving regional innovation efficiency (X. Zhang & Huang, 2013).

The theory does not intentionally highlight any particular innovation actor; rather, it emphasizes the three parties' joint value creation for society, in which the government, industry, and universities can all act as leaders, organizers, and components within the dynamic system. They have joint actions and benefit each other, with their functions overlapping.

According to the endogenous growth theory, enterprises, universities, and research institutions are regarded as the main actors of knowledge creation and spillover. Enterprises excel in technological innovation, while universities have an advantage in knowledge innovation (basic research) (Hewitt-Dundas, 2013). Although knowledge has the attributes of a public good, no organization can acquire all the knowledge required for its development solely through internal efforts. Innovation requires organizations to continuously exchange resources, information, and potential energy with the external environment (Chyi et al., 2012).

However, in reality, there is often a disconnect between knowledge innovation and technological innovation. Universities and research institutions tend to stay in the knowledge innovation stage, while enterprises' technological innovation is mainly limited to internal R&D. To address this issue, since the 1960s, various countries (regions) have explored best practices of industry-university-research collaboration, as seen in benchmark high-tech parks such as Silicon Valley in the United States, Cambridge and Oxford Science Parks in the United Kingdom, Tsukuba Science City in Japan, the Jurong Industrial Park in Singapore, and the Hsinchu Science and Industrial Park in Taiwan, China. These parks share some common features: they provide an environment for the formation of industrial clusters and the creation of a collaborative innovation network, enabling enterprises, universities, and research institutions to mutually promote knowledge and technological innovation, thereby driving regional economic growth. In this context, the academic community began researching collaborative innovation from industrial clusters to COIs, expanding research on industrial innovation.

More and more innovation practices have shown that "user-oriented innovation" is increasingly important. Carayannis and Campbell (2009) put forward the "Quadruple Helix" theory, addressing the relationship among the government (public institutions), enterprises (industry), academia, and users (citizens). Taking the public or civil society as the fourth helix, they indicated various formal and informal ways to foster social innovation. They believed that the Triple Helix model was not capable of analyzing the cross-sectional cooperation in contemporary entrepreneurship and highlighted that the Quadruple Helix model was particularly useful for analyzing the role of civil society (including entities such as citizens, economic organizations, and social organizations) in the innovation process. Therefore, the fourth helix introduces a mechanism for the participation of all members of society, making innovation a borderless activity, that is, open innovation. According to EU's *Open Innovation 2.0*, the Quadruple Helix innovation paradigm is characterized by integrated cooperation, joint value creation, construction of innovation ecosystems, and release and rapid adoption of technology with exponential growth. Under the Quadruple Helix paradigm, besides R&D components, innovation also involves non-R&D components that were regarded as irrelevant to innovation in the industrial era (Curley & Salmelin, 2013). For example, innovative crowdfunding websites raise funds for creativity, design, R&D, and entrepreneurship, and innovative crowdsourcing websites enable integrated APP development that includes R&D, investment, manufacturing, and application (Carayannis & Campbell, 2009).

Some scholars proposed and developed the Quintuple Helix model based on the former Triple Helix theory and the Quadruple models. However different scholars have proposed different components of the Quintuple Helix model. For example, Carayannis and Campbell (2010) adds the "natural environment" as the fifth component. Calzada (2016) have proposed the "Social Entrepreneurs" as the fifth components. Tonković et al. (2015) have proposed the Penta Helix model is made up of (1) Academics, (2) Entrepreneurs, (3) Government, (4) Non-Governmental Organizations and (5) Diaspora.

According to the literature review, we found that knowledge in "Helix-Conceptions" is key enabler of innovation and progress, which lead in the field of sustainable development.

The basic innovation 'core model' of the Triple Helix focuses on the knowledge economy. Quadruple Helix already brings in the perspective of the knowledge society (and of knowledge democracy). From the point-of view of the Quadruple Helix innovation model, it is evident that there should be a coevolution of the knowledge economy and of knowledge society (Dubina et al. 2012). The Quintuple Helix finally emphasizes the socioecological perspective of the natural environments of society. Social ecology focuses on the interaction, co-development and co-evolution of society, and nature (Carayannis & Campbell, 2010, p. 59). The pivotal question of the Quintuple Helix defines itself in the following way: "How do knowledge, innovation and the environment (natural environment) relate to each other? (Carayannis & Campbell, 2010, p. 42)".

2.1.5.3 From the linear innovation paradigm to innovation systems

Innovation theories in the 1960s and 1970s suggested that the entire process, from the generation of new ideas by individual inventors to product development, production, and sales, occurred within an enterprise. When other enterprises adopted these new ideas or products, it was considered innovation diffusion. In geographical location analysis, based on this linear view of innovation, assuming that enterprises possess complete information about location conditions, one could assess whether enterprises' decision-making regarding spatial strategies is rational. Consequently, it was concluded that changes in location conditions led to innovation's hierarchical structures in the geographic space: during the early stages of product innovation (i.e., R&D) and innovation diffusion, enterprises clustered in developed core regions; however, during the later stages of innovation (process innovation) and product adoption, enterprises were dispersed in less developed peripheral areas.

In an influential article, Kline and Rosenberg (1986) criticized the "linear paradigm" account of innovation, which assumes that innovation must go through the stages of "research - development - production - marketing", where the research is easily regarded as a key factor. This paradigm has two problems. First, it is only applicable to the causal chain of a few innovations. Although some significant innovations do originate from scientific breakthroughs, this is not the case in most scenarios. Enterprises usually innovate; due to business needs, they usually innovate by leveraging existing knowledge. They would not consider investing in scientific research until this does not work. In fact, in many cases, user experience rather than science is the most significant source of innovation (Lundvall, 1988; Von Hippel, 1988). Secondly, the "linear paradigm" ignores many feedback and cycles that occur between different stages of the innovation process, whereas the problems and failures may make innovators reconsider the earlier steps, thereby leading to innovations.

As scholars and practitioners have realized the mistake of regarding innovation as a linear process, there has been a lot of research on innovation systems, which conceptualizes innovation as an interactive process that involves multiple components and expands over time. The participating individuals or organizations possess heterogeneous capabilities. Information exchange, problem-solving, and mutual learning are considered integral parts of innovation. In the process of innovation, relationships are established and may develop into organizations, networks, clusters, or even innovation systems. Therefore, the innovation process is a process that starts by combining existing knowledge elements and ends by the generation of new knowledge as output. Innovation can be seen as a "new combination" of more or less distinct knowledge elements. The more distinct the elements, the more radical the innovation (Lundvall, 2013). The concept of innovation systems was defined by Freeman (1987, p. 1) as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies".

At any point in time, an innovation system can be characterized by the relationships between its components. The innovation process reflects these relationships and will drive the continuous construction, proliferation, and destruction of such relationships (Lundvall, 2013).

By the 1980s, it was recognized that innovation was a long-term, uncertain, and dynamic process. Technological innovation efficiency was improving, product lifecycles were shortening, and the process and spatial patterns of innovation were becoming unprecedentedly complex. Innovation was no longer confined to R&D and was no longer a linear path from invention to diffusion; instead, it could emerge from various sources within the value chain of an enterprise, including raw material supply, production, and sales. Besides improving and disseminating existing technologies, innovation can also create new production and consumption methods, being an incremental and sustainable process.

In modern complex and large technological systems (e.g., transportation and high-speed rail systems), innovation is no longer a linear process. Instead, it emerges within a network environment with fair competition and cooperation through continuous user feedback. In the face of intense global competition, local enterprises selectively form long-term, stable, and mutually beneficial relationships with other enterprises and organizations. These network relationships include both formal relationships (e.g., joint ventures and strategic alliances among multinational corporations) and informal information exchanges (e.g., frequent face-to-face contact in meetings, social gatherings, or sports games). Bonding people with different skills into cross-functional teams is crucial for contemporary innovation. The stronger an enterprise's internal capabilities, the more effective its external connections. Successful innovative enterprises can synergize internal capabilities with specialized knowledge from external sources (J. Wang et al., 2019).

2.1.6 Components, functions, and activities of the innovation system

Organizations and institutions are often considered primary components of an innovation system (Edquist, 2009). Organizations are consciously created formal structures with clear purposes (Edquist & Johnson, 1997, pp. 46-47). They are the components (actors) of innovation behaviors. Important organizations in the innovation system include enterprises, universities, venture capital firms, and public institutions responsible for innovation policies, competition policies, or drug regulation (Edquist, 2009). Institutions are a set of shared habits, norms, routines, customs, regulations, or laws that regulate the relationships and joint actions between individuals, groups, and organizations - they are the game rules (Edquist & Johnson, 1997, p. 46). Among them, enterprises are often regarded as the most important organizations. However, the specific definitions of organizations and institutions can vary across different innovation systems (Edquist, 2009).

X. Liu and S. White (2001) pointed out a fundamental weakness in the research on national innovation systems - the lack of systemic explanations. To address this issue, they focused on "activities" within the innovation system, which are linked to the creation, diffusion, and development of technological innovations. They identified five fundamental activities in the innovation system: R&D, application, end-use, education, and linkage.

Bergek and Jacobsson (2003, pp. 2-4) highlighted that for a system to support the growth of an industry, it must undertake certain functions, such as providing resources. They suggested that when describing and analyzing a technological or product innovation system, its "functional mode" should be considered, for example, how these functions are undertaken. They indicated five functions: generating new knowledge, guiding research, providing resources, creating positive external economies, and facilitating market formation.

Rickne (2000, p. 175) identified 11 essential functions for technology-based enterprises: creating human capital, creating and diffusing technological opportunities, creating and diffusing products, incubating (providing facilities, equipment, and administrative support), establishing rules that may facilitate market expansion and market access, legitimizing technology and firms, creating markets and disseminating market knowledge, enhancing network connectivity, guiding technology-market matching and partner search, facilitating financing, and establishing a labor market available for technology-based firms.

Clearly, there is no consensus on which specific functions or activities should be included in an innovation system, which provides opportunities for future research. The following approach can be used to describe what happens within an innovation system. At a general level, the principal function of an innovation system is to facilitate the innovation process. The activities within the innovation system are the factors that influence the development, diffusion, and application of innovations. It is important to study these activities (e.g., their causes and determinants) in a systematic way (Edquist, 2009, pp. 189-190). The following activities are considered critical in most innovation systems:

1) Provision of R&D and creation of new knowledge, primarily in sectors of engineering, medicine, and natural sciences.

2) Capacity building of the workforce (education and training, creation of human capital, upskilling and reskilling, and individual learning) for innovation and R&D activities.

3) Creation of new markets for products.

4) Understanding the quality demand of new products.

5) Creation and transformation of organizations to meet the needs of new areas of innovation, such as fostering entrepreneurship to create new ventures, enhancing intrapreneurship for the diversification of existing enterprises, and establishing new research organizations and policy agencies, among others.

6) Establishment of networks through markets and other mechanisms, including interactive learning (potential) among different organizations in the innovation process. This involves integrating knowledge elements from external sources and different parts of the innovation system with enterprises' existing knowledge.

7) Creation and transformation of institutions, such as intellectual property laws, tax laws, environmental and safety regulations, and R&D investment norms, which may incentivize or hinder innovation organizations and processes.

8) Incubation activities, such as providing infrastructure, equipment, and administrative support for innovative activities.

9) Funding the innovation process and other activities that are conducive to the commercialization and application of knowledge.

10) Provision of consulting services related to the innovation process, such as technology transfer, business information, and legal services (Edquist, 2009, pp. 190-191).

2.1.7 Classification and evolution of innovation system and innovation ecosystem

"Ecosystem" was first proposed by Tansley (1935) to describe the complex physical system formed by the interaction between organisms and the environment. In the 1990s, scholars began to carry out research on innovation systems from an ecological perspective, and the ecosystem was introduced into the study of economic management, implying the dynamic interaction between economic components and their environment. The mainstream research gradually fell into three types: business ecosystem, innovation ecosystem, and platform ecosystem (Jacobides et al., 2018). Jacobides et al. (2018) pointed out that modularity is the premise of the emergence of the innovation ecosystem. It allows a group of different but interdependent organizations to coordinate without complete hierarchical commands. The core of the ecosystem lies in non-commonality and complementarity, as well as the creation of character sets facing similar rules. The concept of an ecosystem originated in the field of ecology, with the flow of matter and energy conceptualized. According to Granstrand and Holgersson (2020), the innovation ecosystem consists of a group of evolving components (actors), activities, and artifacts, as well as organizations and relationships (including complementary and alternative relationships). It is essential for the innovation performance of the component(s). Through the review of the 21 classical definitions of innovation ecosystems, Granstrand and Holgersson (2020) pointed out that “actor” is a word that appeared in all definitions; the term “collaboration/complements” appeared 16 times; the term “activities” appeared 15 times; the term “co-evolution/co-specialization” appeared seven times (X. Liu, 2022).

The difference between the innovation system and the innovation ecosystem is shown in Table 2.2.

Table 2.2 Differences between innovation system and innovation ecosystem

	Innovation system	Innovation ecosystem
System model	From the perspective of engineering, it emphasizes the input and output of the system and the unity of the model.	From an ecological perspective, it emphasizes the input and output of the system and pays attention to the enhancement and regulation loop, that is, feedback and attribute differences.
Innovation components and their relationships	The boundary of components is relatively clear; the relationship between components is complex; it highlights industry-university-research collaboration and the “triple helix” structure of government, enterprises, and academia (open innovation).	The components are more diverse, heterogeneous, and varied; the relationship between components is more complex; it emphasizes the “symbiosis” of industry, university, research, and users, and the “quadruple helix” structure of government, enterprises, academia, and users (embedded innovation).
Government functions	The government mainly provides framework policies such as R&D investment, tax incentives, and intellectual property rights; it emphasizes the importance of	It emphasizes the joint driving force of government, market, and society; innovation governance demand-side policy, science of science policy (SoSP), and innovation performance have become

	industry-university-research collaboration.	important topics.
Operating mechanism	It pays less attention to the analysis of “evolution mechanism”.	It attaches great importance to “selection mechanism”, such as the selection and adaptation between innovation components and innovation environment (ecosystem).
Understanding of users	No attention paid.	It considers society, innovation governance, and demand-side policies; political and institutional changes can help ecosystems develop in new ways to meet new demands.

Source: Shanghai Institute for Science of Science (2015)

Innovation systems are typically classified into national innovation systems, regional innovation systems, sectoral innovation systems, and corporate innovation systems (see Figure 2.2).

Concept:	National innovation system	Regional innovation system	Sectoral innovation system	Corporate innovation system
Innovation system				

Figure 2.2 Classification of innovation systems

Source: Granstrand and Holgersson (2020)

2.1.7.1 From national innovation system to national innovation ecosystem

The concept of the “national innovation system” was first explicitly introduced by Freeman (1987, 1988). In Lundvall (1992), the national innovation system was defined as a set of components and relationships that have joint actions in the production, diffusion, and use of new and economically valuable knowledge. In a narrow sense, they include organizations and institutions related to research and exploration, such as R&D departments, technological institutes, and universities; in a broader sense, they also encompass economic structures and institutions that influence learning and research, such as production, marketing, and financial systems. The efficiency of a national innovation system is measured by the efficiency of innovation diffusion and economically valuable knowledge use. The key to understanding innovation systems lies in studying and exploring how they operate within the economic system to generate economic benefits (Shanghai Institute for Science of Science, 2015). According to Lundvall (1992), the core of a national innovation system is the learning activities of producers and users in their joint actions.

Based on that, Nelson (1993) further developed the concept and formulated the theory of the national innovation system. According to Nelson (1993), the national systems that support technological innovation in 15 countries and regions (e.g., the United States and Japan) were analyzed and compared. It was pointed out that due to the specific conditions of each country and the innovation systems’ inherent institutional and technological behavioral factors, different systems may involve different actors, and there is no unified model for national innovation system construction. For example, the main characteristic of the United States' national innovation system is collaboration between industry and universities, with less government intervention. However, in Japan, the government intervenes directly in technological innovation activities through planning and coordination, with policymakers playing the role of innovation organizers. The process of scientific and technological innovation is full of uncertainties, and the only effective way to deal with that is through diversification of technological innovation, while maintaining resilience and flexibility in the institutional arrangements of the national innovation system. Regardless of the adopted model, according to this school of thought, the core of the national innovation system is to connect all the components of innovation (e.g., enterprises, universities, research institutions, government, and market intermediaries) through a set of institutional arrangements, enabling them to collaborate and function as a whole to improve innovation efficiency (X. Wang, 2018).

In a broader sense, a (national) innovation system includes all factors that can influence the development, diffusion, and use of innovations, including economic, social, political, organizational, institutional, and other important factors (Edquist, 1997).

The OECD (1997) considered that a national innovation system primarily consisted of four complementary components: innovation institutions, organizations, resources, and environment. The key to studying innovation systems lies in understanding how learning and exploration can be combined within the economic system to create economic benefits. The OECD emphasized the importance of technological collaboration and joint actions between enterprises, universities, research institutions, and other relevant organizations, in which the government plays a crucial top-down role.

In the United States, the innovation ecosystem was first proposed in *Science in the National Interest*, the first official presidential report on science policy initiatives released by the Clinton administration in 1994: "Today's science and technology enterprise is more like an ecosystem than a production line" (Clinton & Jr. Gore, 1994). In 2004, The President's Council of Advisers on Science and Technology (PCAST, 2004a, 2004b) of the United States published two reports, titled *Sustaining the Nation's Innovation Ecosystem: Information Technology Manufacturing Competitiveness* and *Sustaining the Nation's Innovation Ecosystems of our Science and Engineering Capabilities*, highlighting that the economic prosperity and global leadership of the United States owes to a well-crafted innovation ecosystem. To maintain its leadership as an innovative nation, it is crucial to keep the innovation ecosystem dynamic and updated. It consists of several key components: inventors, technologists, and entrepreneurs; a proactive and skilled workforce; world-class research-oriented universities; effective R&D centers (industry-funded or federally funded); a vibrant venture capital industry; and government support for basic research in high-potential areas. Among the joint actions of this dynamic innovation system's key enablers (including enterprises, government, workforce, and academia), the following three are essential requirements: the overall quality of the talent, societal risk tolerance (particularly for long-term investment risk), and infrastructure and organizational mechanisms that can meet future innovation needs (Shanghai Institute for Science of Science, 2015). *A Strategy for American Innovation* (National Economic Council & Office of Science and Technology Policy, 2015) put forward the strategies for building and maintaining a national innovation ecosystem in order to enhance national innovativeness and competitiveness from the perspective of public base, private sector, innovating crowd (users), and innovation environment. This newly proposed national innovation ecosystem included two more dimensions: the creativity of the population and the importance of the innovation environment, indicating that fostering innovation and entrepreneurship among the population is an important factor in the innovation ecosystem. The national innovation ecosystem is an institutional and organizational system resulting from the history of national development. Its function is to promote innovation and entrepreneurship among people and organizations and to enable organizations to form mutual promotion, interdependence, and joint evolution (X. Liu, 2022).

Japan has also placed emphasis on the development of innovation ecosystems in its recent transformation efforts. In *25 Strategies for Innovation*, issued in 2015, the Industrial Structure Council of Japan introduced the concept of a national innovation ecosystem and proposed shifting the focus of policies from technology policies to ecosystem-based innovation policies. In 2012, Indian Prime Minister Manmohan Singh proposed the establishment of an innovation ecosystem to bridge the gap between research and the market, and to enhance collaboration between the scientific community and the business sector in order to facilitate the transformation of innovations into productivity (Shanghai Institute for Science of Science, 2015).

2.1.7.2 From regional innovation system to regional innovation ecosystem

The concept of a regional innovation system first emerged in the early 1990s, inspired by the concept of a national innovation system and based on similar principles with a focus on territorially based innovation systems (Asheim & Gertler, 2009).

The concept of a regional innovation system was proposed and advocated by Cooke et al. (1997), Braczyk et al. (1998), Cooke (2001) and Asheim and Isaksen (2002) (Edquist, 2009, p.

184). In their words, any functioning regional innovation system comprises two subsystems: one is the knowledge application and development subsystem, mainly owned by enterprises in the vertical supply chain network; the other is the knowledge generation and diffusion subsystem, primarily consisting of public organizations (Asheim & Gertler, 2009).

At the regional level, the introduction of innovation ecosystems has raised attention to environmental factors in innovation activities, maintaining system stability through mechanisms such as diversity and static equilibrium. The influencing factors include technology, market, ecological environment, institutions, and policies (L. Huang, 2003).

Based on the ecological theory and drawing on the definition of the regional innovation system and the ecosystem, a regional innovation ecosystem refers to a self-organizing system with the characteristics of symbiosis, cooperation, and dynamic evolution, in which different innovation species, populations, and communities, based on the common value proposition, realize value co-creation through the exchange of materials, knowledge, and information with the innovation environment within a certain geographical space (W. Li et al., 2014). As the regional innovation ecosystem is a self-organizing system where different innovation populations realize value co-creation (X. Liu et al., 2020), it shows the following characteristics in its dynamic evolution: proximity, diversity, self-organization, and openness (X. Liu, 2022).

The regional innovation ecosystem is an organic system formed within a specific space, where innovation components and related organizations with compatibility and functional complementarity have joint actions. It fosters interdependence, mutual constraint, and adaptation among the innovation components, thus promoting their proactive and dynamic capabilities, ultimately driving regional innovation performance. This adaptive symbiotic relationship among innovation populations and communities is gradually formed through self-organization and exhibits ecological balance at the regional level. The regional innovation ecosystem responds actively to continuous external environmental disturbances and constantly evolves during the dynamic process of balance - imbalance - new balance. An example of a vibrant and successful regional innovation ecosystem is the Silicon Valley (Shanghai Institute for Science of Science, 2015). The key is to promote the flow of knowledge and information in the region, enhance the joint actions among innovation actors, and improve the innovation capability of the region by building a regional innovation ecosystem.

2.1.7.3 From industrial innovation system to industrial innovation ecosystem

In addition to geographical dimensions, innovation systems can also be classified from the perspective of "industries" (Edquist, 2009). "Industries" refer to an activity community consisting of associated product groups with shared common knowledge with the aim of meeting specific or emerging needs (Malerba, 2009). An industrial innovation system can be defined as a group of enterprises that are actively involved in the development, manufacturing, creation, and utilization of the industry's technologies (Breschi & Malerba, 1997).

The transformation of an industrial system is a result of the joint action of various components during co-evolution. The industrial system framework focuses on three aspects: knowledge and technology domain, actors and networks, and institutions. The knowledge and technology domain refers to the specific knowledge base, technologies, and related inputs of each industry. Actors and networks encompass heterogeneous individuals and organizations within an industry. The individuals include consumers, entrepreneurs, and scientists, among others. The organizations include both business (e.g., producers, suppliers, and users) and non-business entities (e.g., government, universities, technology societies, commerce associations, and financial institutions), as well as departments of large organizations (e.g., research or production departments) and organization groups (e.g., industry associations). In an industrial innovation system framework, innovation can be viewed as a systematic interactive process involving numerous components with the aim of creating, exchanging, and commercializing innovation-related knowledge. Institutions refer to the established norms, conventions, common practices, regulations, laws, and standards that influence the cognition, behavior, and joint actions of components within the industry. Over time, an industrial system undergoes change and transformation through the co-evolution of its components (Malerba, 2009).

The most appropriate units for analyzing an industrial system are not the enterprises but individuals (e.g., scientists who have found a new biotechnology company), subunits of enterprises (e.g., research or production departments), and enterprise clusters (e.g., industrial clusters) (Malerba, 2009). In response to the rapidly evolving technological-economic environment, industries adopt strategies similar to "swarming" in biological populations, creating a system for value creation among member enterprises, namely, an industrial innovation ecosystem. This ecosystem focuses on the collaborative joint action, open circulation, and co-evolution among the innovation actors (e.g., enterprises, universities, research institutions, and intermediaries) that are linked organically along the industry and value chains, as well as their joint actions with the innovation environment. It values communication, connections, exchange, and cooperation among enterprises (Shanghai Institute for Science of Science, 2015).

2.1.7.4 From enterprise innovation system to enterprise innovation ecosystem

The enterprise innovation system is an extension of the concept of national innovation system, regional innovation system, and industrial innovation system to the enterprise level. An enterprise innovation system is a complex network of different innovation components within the enterprise around the enterprise development strategy, composed of internal and external, technical and non-technical knowledge in a nonlinear manner with feedback paths. It is an organism that operates according to a set of rules and a systematic institutional arrangement based on knowledge elements and their combination to support and safeguard enterprise innovation activities (C. Zhao et al., 2018). Many scholars believe that the concept of the enterprise innovation ecosystem is traced back to Moore (1993), who first introduced ecological principles into business, indicating that the ecosystem is conducive to mutual interdependence and co-evolution among small and medium-sized enterprises and can enhance their survival capabilities. Drawing an analogy between market competition in enterprises and “predators and prey” in natural ecosystems, Moore (1993) viewed the business ecosystem as an economic community and a business organism based on joint actions among organizations and individuals. Its components include consumers, producers, competitors, and other risk-takers, as well as trade groups, unions, financial institutions, government, and other relevant organizations. However, the business ecosystem focuses on “value capture” rather than “value creation”, which is emphasized in the innovation ecosystem.

Facing the rapidly changing global market, enterprises must establish a value relationship network to collaborate closely with relevant enterprises and organizations - that is exactly the enterprise innovation ecosystem. By integrating innovation resources and establishing value distribution rules, core enterprises can achieve sharing and interdependence with other enterprises and organizations in terms of information technology channels, so as to adapt to the environment and gain competitive advantages. Such a highly open system and model facilitate the transformation of relationships both among and within enterprises, shifting innovation resource allocation from internal circulation to external circulation, and enabling more specialized division of labor in the innovation process.

“One of the striking facts about innovation is its variability over time and space. It seems, as Schumpeter pointed out, to ‘cluster’, not only in certain sectors but also in certain areas and time periods" (Fagerberg, 2009, p. 14).

2.2 "Spatial agglomeration" of innovation: Theoretical studies of COIs

Human progress and social development depend on scientific and technological innovation, and national/regional economic development relies on industrial innovation. With the increasing complexity and diversity of technology, innovation research continues to expand and increasingly focuses on the regional level rather than the national level, as local innovation culture, infrastructure, resources, and conditions greatly affect the success of innovation activities. From literature research, it has been found that Western COI theories have evolved from "industrial agglomeration" to "industrial cluster" and then to "clusters of innovation (COI)". The two widely recognized theories in the literature are the industrial district theory and the industrial cluster theory. In the 1980s, the Italian scholar Becattini (1978) revisited the industrial district theory of Marshall, a British economist who had conducted related studies more than 100 years ago. The American scholar Porter (1990) discussion on the extreme importance of industrial cluster location for enterprise innovation and national competitiveness created a great impact. Both theories are centered on the promotion of technological innovation. In recent years, Engel and other scholars (Engel, 2014, 2015, 2022; Engel & Del-Palacio, 2009, 2011) across the globe have conducted a large number of theoretical and case studies on COIs around the world.

Thus, the "spatial agglomeration" account of industrial clusters and COIs, through observing and conceptualizing the phenomenon and developing its theory, can better explain where innovation occurs and has been adopted by many international organizations and states as a policy tool to improve the regional/national innovation capacity.

The following sections will compare different accounts of COIs and present the evolution of COI theories, aiming to gain insights into the internal mechanism of the formation of COIs and clarify the ideas and objectives of the development of Chinese industrial clusters and COIs. In order to provide a more comprehensive presentation of the concepts and theoretical revolution of COIs, in addition to the above two mainstream theories, we will also present and compare the results of other representative studies.

2.2.1 Industrial agglomeration theories

The global economic geography pattern is a dynamic system composed of industrial agglomeration regions and their trade flows from all countries. Industrial agglomeration occurs in all stages of industrialization and can foster industrialization. Even in the post-industrialization period, regional development still relies on agglomeration to promote technological innovation and cultural innovation. Many value chain segments are separated geographically, leading to spatial agglomeration of related enterprises in both upstream and downstream activities.

2.2.1.1 Marshall's external economic theory (Marshall's industrial district theory)

The earliest research on industrial agglomeration can be traced back to Marshall (1890) research on industrial districts. From 1873 to 1877, Marshall researched pottery production in Staffordshire, hat production in Bedfordshire, chair production in Buckinghamshire, and cutlery production in Sheffield, among others. In his work *Principles of Economics*, Marshall (1890, p. 271) discussed local industries, namely specialized industries agglomerating in specific locations, which were referred to as industrial districts.

The Marshallian industrial district was also revisited by Castells and Hall (1994), who wisely used the industrial district theory from the 19th century for analysis when demonstrating the discovery of the efficacy of vertical separation production systems and flexible specialization. In cities with high innovation capabilities (e.g., Tokyo, Paris, and Los Angeles), similar to Silicon Valley in the United States, enterprises are prominently connected by networks, which is in line with the classical process demonstrated by Marshall. Castells and Hall (1994) included a quotation from (Marshall, 1890, p. 271), indicating that when an industry chooses a place for itself, it may stay there for a long time; often, the benefits that people in the same skill industry get from geographical proximity are huge. The craft of the industry will no longer be a secret; however, because these secrets exist in the environment, children can naturally acquire many of them. Good work will receive fair evaluation; any invention and improvement of machinery or processes, as well as the practice of general business organizations, will be widely spread immediately. If anyone puts forward a new idea, others will adopt it and combine it with their own thinking to turn it into a new source of thought. The auxiliary trade service industry will develop nearby, supplying equipment and raw materials, organizing transportation, and providing solutions for raw materials saving.

Industrial districts were viewed by Marshall (1919) as relatively stable communities with shared local culture and specialized industrial knowledge. When workers transition between job positions within the district, their expertise will remain a part of the district's collective resources, what Marshall referred to as the "air" (later replaced with "atmosphere" by Marshall [1919]) of the industrial district. Individuals flowing between enterprises and workers and employers residing in the same community all benefited from the “secrets of the industry in the air” (Becattini, 2017; Pyke et al., 1990).

Marshall broke the limitations of the neoclassical equilibrium analysis and even “foresaw” the vitality of Schumpeter’s ideas on innovation because he correctly recognized that the innovation process was not what Schumpeter called the heroic act of “new man” (J. Wang et al., 2019).

When analyzing organization as a production factor, Marshall (1890: Part IV, Ch. X) touched upon the topic of industrial agglomeration. According to Marshall, industrial districts possess the following characteristics: a) the existence of auxiliary industries, b) an industrial atmosphere in the community, c) an imperfect competition market, d) the coexistence of competition and cooperation, e) a local banking system based on trustworthiness, and f) convenience in shopping. These factors drive enterprises to agglomerate in the pursuit of external economies of scale (J. Wang et al., 2019).

Marshall’s research was groundbreaking as he not only explained enterprise agglomeration, a significant economic phenomenon, but also explored the competition and cooperation between agglomerated regions, laying the theoretical foundation for research on industrial clusters. However, Marshall focused on the “partial equilibrium theory” and did not systematically explore the conditions and operational mechanisms of industrial clusters, thus having certain historical and theoretical limitations (L. Zhou & Zhang, 2017).

2.2.1.2 Weber’s industrial location theory

In the 20th century, Alfred Weber (1909) studied the geographical characteristics and operational patterns of the industrial agglomeration. He categorized industrial location factors into “localization factors” and “agglomeration factors.” According to Weber, enterprises choose to agglomerate because the benefits of agglomeration outweigh the costs. If this condition is not met, agglomeration will not occur. Weber also divided industrial agglomeration into two stages. The first stage involves the expansion of enterprise business within a region, leading to a trend of industrial concentration, which is the initial stage of industrial agglomeration. The second stage represents a more advanced form of industrial agglomeration with large enterprises as the center and the gathering of more similar enterprises, ultimately leading to industrial clusters. By systematically developing the concepts, principles, and theorems, Weber provided a comprehensive theoretical framework of industrial location, which has had a significant impact on research in fields such as economic geography and regional economics. Following Weber’s theory of industrial location, numerous scholars conducted extensive research on the effects of industrial agglomeration. These studies accentuate the interconnectedness of economic activities between regions in a specific geographical scope, including production, operations, information and technology sharing, and marketing. As a result of industrial agglomeration, enterprises and industry organizations form a complex value network. These studies serve as the theoretical groundwork for research in economic geography and industrial competitiveness (J. Wei, 2010).

2.2.2 The industry district theory

The industry district (ID) theory, also known as the Italian ID or the new Marshallian ID, constitutes an important branch of the cluster theories (Amin & Thrift, 1992). The theory of Italian ID was developed by the Regional Economic Planning Institute of Tuscany (Instituto Regionale Programmazione Economica Toscana) during their study of the Tuscany region in Italy. Inspired by the Marshallian ID, they found the ID concept particularly suitable for explaining the efficient industrial growth in Tuscany (also known as the "Third Italy", which refers to the northeastern and central parts of Italy, including seven regions such as Emilia-Romagna). By researching several IDs in Tuscany, especially after analyzing the woolen textile ID in Prato, Becattini (1986) pointed out that the economic characteristics of IDs include externalities in the labor division, joint actions between enterprises within the district, and strong social and cultural support. Therefore, theorists (especially in the field of economic geography) generally refer to the industrial district concept developed from the experience of the "Third Italy" based on Marshall's thoughts as the "new industrial district" (or "new Marshallian industrial district") or "Italian industrial district".

A Handbook of Industrial Districts (Becattini et al., 2009) was edited by three generations of renowned Italian scholars who have studied IDs: Becattini, Bellandi, and De Propris. It compiled 53 articles by scholars around the world.

According to Becattini's (1989, p. 126) definition, ID is "a socio-territory entity, which is characterized by the active presence of both the community of people and populations of firms in one naturally and historical founding area in this history community and firms tend to inter-penetrate".

According to Pyke et al. (1990), Pyke and Sengenberger (1992), the new ID refers to a geographically bounded production system, where enterprises, with specialized division of labor, are in different production stages, engaging in production of the same type of product in different ways. Its development requires entrepreneurs' entrepreneurial spirit and innovation capacity, enterprises' flexible production methods, and close connection and cooperation among enterprises.

The economic prosperity in the new IDs, contrary to the prevailing economic downturn at the time, was reinterpreted by Piore and Sabel (1984). They argued that the IDs in the "Third Italy" were able to compete with regions dominated by large corporations because of their high degree of specialization and strong collaboration and synergies among enterprises. The new IDs consist of small and medium-sized enterprises serving domestic or international markets, which have formed stable cooperative networks through intermediaries, thereby promoting technological innovation and regional development. The contemporary world economy is composed of such flexible production systems (J. Wang et al., 2019). The new ID highlights trust and commitment, which enable enterprises to create synergies and obtain benefits while maintaining a high degree of flexibility. The main economic actors in these IDs are small and medium-sized enterprises.

Embeddedness, innovativeness, and institutional comprehensiveness are fundamental criteria for identifying a new ID. Embeddedness refers to that economic behaviors are deeply embedded in social relationships. The strength of specific relationships between traders provides a solid foundation for the functioning of the economic system. The most distinctive feature of the new ID is the special balance between cooperation and competition among its enterprises. Cooperation is manifested in shared public services provided by local organizations, enterprises' compliance with competition rules, and a high level of mutual trust (Lorenz, 1992). The presence of industry associations is an important indicator for identifying a new ID.

Hirst and Zeithlin (1997) referred to the case study on Italy (central and northeastern regions) and Germany (mainly southern regions) as an ideal model, which is characterized by small enterprises, cooperation, and input-output regionalization. The new ID theory is conducive to a better understanding of the local environment and policies for enterprise innovation. However, the ID model with a purely local network is challenged by globalization and has received some criticism.

Some scholars have pointed out the limitations of the research that primarily focused on the division of labor and the delineation of industrial eras represented by Piore and Sabel (1984) (Whitford, 2001). In addition, Morgan and Cooke (1998) insisted on the view that big corporations must win. Amin and Robins (1990) reminded people that multinational corporations are still the shakers of the world economy.

The limitations of the ID theory also include:

a) Insufficient discussion of transnational corporations (in reality, both large and small enterprises collaborate not only locally but also internationally, as seen in the new IDs such as Silicon Valley);

b) Inadequate consideration of state intervention;

c) Incomplete characterization of the roles of universities and other non-profit organizations (including chambers of commerce);

d) Neglect of the importance of cross-regional flow of mature technology and labor in the formation of IDs;

e) Insufficient consideration of environmental factors (when pursuing production efficiency, it is necessary to maintain harmony with the environment and use new resources and technologies to reduce environmental damage).

2.2.3 Porter's industrial cluster theory

Porter (1990) formally introduced the concept of industry clusters and highlighted the significance of geographic clustering for the global economy. Clusters are considered determinant factors to enhance productivity and innovation capabilities and are conducive to a nation's competitiveness. Terms such as innovation, upgrading, competitiveness, and productivity frequently appeared in Porter's work. Competitiveness stems from the geographic clustering in the region, and such cluster advantages can hardly be replicated and imitated in other locations.

Porter (1998) explained the role of cluster locations in enhancing enterprises' competitiveness in the global economy. According to Porter, a cluster refers to a concentration of interconnected companies and organizations within a specific geographic area, including a group of entities that play a crucial role in competition, such as suppliers of specialized input (such as components, machinery, and services) and providers of specialized infrastructure (including both "hard" and "soft" infrastructure, with "soft" infrastructure referring to all the organizations needed to maintain the economic, cultural, and social fabric, such as the financial system, education system, healthcare, government services, law enforcement, and emergency services). Clusters also often extend downstream to customers and laterally to manufacturers of complementary products and companies related to technology or investment. They also include government and other organizations that provide specialized training, education, information research, and technology support, such as universities, standard-setting organizations, think tanks, vocational training providers, and chambers of commerce.

According to Porter and Ketels (2009), clusters are defined based on three dimensions:

First, the geographical dimension. Clusters arise due to externalities caused by geographical proximity and therefore, they usually occur in specific areas within larger countries, often in a city/town. Second, the activity dimension. Clusters include product- and service-related business activities of different industries that are mutually linked and are valued by customers. Third, the business environment dimension. Clusters are environments shaped by specific conditions, involving individual or collective actions of companies, government agencies, universities, and other public and private entities. The complexity of competition for enterprises within a specific geographic location is greatly influenced by the quality of the local business environment. Therefore, a healthy cluster is vital for the well-being of enterprises.

Porter (1998) cluster theory has made a significant impact on policy-making. It views clusters as specialized knowledge and skills-based infrastructure and supportive industries that naturally contribute to improving productivity. Clusters are driven by competition knowledge spillovers and learning effects, rather than being defined by creating relationships among activities in a given location through a specific pathway.

The production factors that industrial clusters possess form the foundation of their competitive advantage. The advantage derived from resource endowments can only lead to low-end static competitiveness, while advantages derived from technological agglomeration can bring high-level dynamic competitiveness (Porter, 1998). However, Porter did not explain why, in some clusters, there may appear new industries that do not align with the original industrial concentration. Porter's cluster theory is not without limitations. While highlighting the importance of clusters for competition, he failed to address complex issues such as the source and nature of technology, the social embeddedness of production, the role of power, and the complexity of network relationships. His theory is primarily based on empirical evidence from developed countries where an innovative business environment is created for product and service exportation to other countries. It may not be understood or applicable to countries or regions in the early or middle stages of industrialization with imperfect institutions. Furthermore, the concept of cross-industrial clusters is not aligned with standard industrial classification systems, which often leads to the underestimation or neglect of the importance of clusters (J. Wang et al., 2019).

2.2.4 The concept of clusters of innovation (COIs)

Organizations such as the United Nations Industrial Development Organization and World Bank actively promote industrial cluster strategies in developing countries. As a result, the term “cluster”, with its meaning significantly different from the standardized concept of industrial clusters, frequently appears in international research reports. From a global perspective, clusters generally fall into two categories.

First, COIs. These are successful industrial clusters that play a significant role in economic growth in regions like Europe and the United States, representing high-road and innovation-based clusters. COIs can be further divided into three subcategories based on industrial characteristics: consumer goods COIs, high-tech COIs, and cultural and creative COIs. This thesis primarily focuses on high-tech COIs. Second, production clusters. They represent low-road and low-cost-based clusters and manifest certain characteristics of industrial clusters, thus also known as “quasi-clusters” (J. Wang et al., 2010). These clusters are at an initial stage of development (H. Wei, 2008).

After the proposal of the National Innovation Systems (NIS) (OECD, 1997), the OECD further developed the concept of “cluster” and formally put forward the idea of “clusters of innovation” (COIs) in the report *Innovative Clusters: Drivers of National Innovation Systems* (OECD, 2001). However, the report did not directly define COIs. The OECD believed that clusters were economic phenomena where enterprises gradually aggregate through joint actions to enhance competitiveness. Innovation is no longer considered simply the outcome of progress in basic scientific research; instead, the innovation concept should be developed within the framework of industrial cluster theory.

Engel and Del-Palacio (2009) provided a definition of COIs. They followed the core components of Porter’s industrial cluster theory and further expanded it: Industrial concentration is not defined primarily by industry specialization but by the innovation development stage of cluster components, and Silicon Valley is a prototype of such a cluster. Their research identified key characteristics of the environments that facilitate the creation and development of high-potential entrepreneurial enterprises: increased mobility of resources (primarily personnel, capital, and information, including intellectual property), enhanced flow of resources (including the flow of intellectual property), and increased flow intensity of resources. The increased flow of resources can accelerate business development, and a culture of mobility can foster an affinity for collaboration and robust relationships (Engel, 2014).

To explain the new innovation and commercialization patterns within existing or emerging COIs and their global connections, Engel and Del-Palacio (2011) defined COIs as favorable business environments with high potential and entrepreneurial spirit, characterized by high mobility of resources (including personnel, capital, and information). They found that COIs are symbiotic on a global scale. COI networks will be formed, and components of these networks are interdependent, leading to the emergence of super COIs.

As the economy becomes more knowledge-intensive, the trend of COIs becomes more prominent, and the geographical concentration of innovation becomes increasingly evident over time (Cortright & Mayer, 2002).

According to Panori (2016) from the Economist Intelligence Unit, COIs are vital laboratories for creating and applying new tools, technologies, and processes. They are not only contexts for innovation but also dynamic organisms where each component is indispensable.

2.2.5 Formation and evolutionary stages of COIs

Clusters, like industries, are dynamic and have life cycles (Menzel & Fornahl, 2007). The formation of COIs is essentially the process of joint actions and networking among various components within the industrial cluster, rooted in the regional social, economic, cultural, and institutional context, leading to the creation of a strong and resilient innovation network and a favorable regional innovation environment, which is manifested in a continuous upward movement along the global value chain. The evolution of clusters generally falls into four stages: the nascent stage, growth stage, mature stage, and decline stage (Fornahl & Hassink, 2017).

Nascent stage: In this stage, enterprises begin to aggregate geographically and technologically. The enterprises within the cluster start to outperform those outside due to reduced cognitive distance and lowered technological barriers resulting from mutual learning and joint actions in the specific regional environment. The aggregation leads to the emergence of a nascent cluster. However, the economy of the region will not be efficient or effective unless there is stable cooperation among enterprises and a specialized labor market that leads to a high level of division of labor and specialization. When there emerges a leading innovative enterprise that acts as the “nucleus” of the cluster and attracts other enterprises to join, the cluster enters the nascent stage. In this stage, the infrastructure of the cluster is basically accomplished, but entities such as enterprises, universities, research institutions, and specialized intermediaries are not yet part of the cluster. The cluster’s innovation network only consists of a simple industrial chain, while value chains and knowledge chains have not yet formed. Nascent clusters are vulnerable to external environments and may not naturally evolve into the growth stage. They may decline or disappear due to enterprises’ relocation or insufficient or improper policy support.

Growth stage: During the growth stage, the specialization level within the region increases, with numerous enterprises flocking to the cluster, leading to the cluster's rapid expansion. Government, universities, research institutions, and specialized intermediaries start joining the cluster, and an innovation culture gradually takes shape, leading the COI into to a growth stage. This specialized and functional growth cluster may create various innovation networks, quickly form supply-demand relationships among enterprises and specialized markets, and foster rapid development and growth of the local economy. Growth clusters generally show a stable development momentum and high productivity (Pouder & St. John, 1996), primarily facilitated by leading enterprises within the cluster.

Mature stage: At this stage, the industrial cluster continues to expand, with more diversified components, a refined collaborative innovation network, and a mature innovation culture. When the COI enters the mature stage, enterprises have formed stable networks within the cluster and have established relatively long-lasting and open network connections with external enterprises and organizations, resulting in a stable knowledge flow internally and externally. Enterprises in the cluster have formed knowledge, value, and innovation connections among themselves and with other components, leading to the emergence of learning organizations. Through the innovation network in the cluster, enterprises' growth, technological innovation, outcome transformation, and industry planning are further enhanced, thereby enabling the cluster to gain dynamic competitive advantages. Mature clusters may evolve in two directions: a) decline, when over-specialization leads to diminishing returns or the cluster is constrained by a fixed political-economic framework, or b) further growth. if enterprises actively adapt to new environments, consciously explore new channels and platforms for knowledge exchange, and develop new industry pathways and new growth opportunities (Martin & Sunley, 2006).

Decline or renewal stage: If a mature cluster evolves into a cluster with static advantages that is heavily dependent on a single market, technology, or labor force, with homogeneous enterprises, rigid network development, insufficient connections with the outside world, and incapability to create new knowledge, technologies, or industry pathways (innovation paths), it tends to be "locked in" a decline state (Grabher, 1993). That will reduce the cluster's vitality, innovation awareness, and innovation capacity. With a reduced growth rate of new technologies, new patents, and new products, the COI enters the decline stage. Declining clusters will witness a reduced number of enterprises due to enterprise exit or bankruptcy, decreased labor force, insufficient driving force for the cluster's development, and reduced economic benefits.

However, there are two possible outcomes for declining clusters: death or transformation/upgrading. To achieve the latter, there are two ways. The first is to initiate transformation internally by breaking through bottlenecks and identifying new growth opportunities. The second is to seek transformation externally. For example, with government policies' guidance and support, COIs can continuously innovate and optimize innovation mechanisms, culture, and environment, where governments, enterprises, universities, research institutions, and specialized intermediaries form a community of shared values and shared future through the COI ecosystem, generating a continuous driving force for making breakthroughs and gaining dynamic competitive advantages. As a result, the COI continuously upgrades from the low-end to the mid-to-high-end along the global value chain, eventually achieving sustainable development.

2.2.6 COI key components and their joint actions

Taking the United States as an example, nine regions, including Boston metropolitan area, San Francisco Bay, San Diego (California), North Carolina Research Triangle, Seattle-Tacoma, New York - North New Jersey, Philadelphia (Pennsylvania) - Wilmington - Atlantic City, Los Angeles, and Baltimore (Maryland) - Washington, accounted for more than 60% of the grants provided by the National Institutes of Health (NIH) of United States and nearly 66% of biotechnology-related patents.

For all biopharmaceutical clusters in the United States, their success is closely related to local renowned universities and research institutions and the support and funding from the government (see Table 2.3).

Table 2.3 The top 10 biotechnology clusters in the United States

Cluster name	Number of patents	Number of employees	NIH funds (million USD)	Venture capital funds (million USD)	Laboratory area (10,000 square feet)
Boston/Cambridge	6,496	86,235	1,055	3,060	1,990
San Francisco	10,312	67,738	520.6	800	100
Santiago	4,383	63,730	352.9	650	29.3
North Carolina	928	35,073	349	14	70
Seattle	1,887	24,320	374.4	169	460
New York	3,208	127,308	787.3	132	1,270
Philadelphia	1,365	53,614	389	125	640
Los Angeles	1,479	120,688	337.4	-	200
Washington	4,108	39,145	271.4	146	950
Chicago	1,143	53,054	252.5	69	350

Source: Q. Lin et al. (2020)

The London life sciences cluster in the UK also shows that the close relationship with local government, universities, and research institutions fosters the formation and development of COIs. With the government's support, the London life sciences cluster has become a COI centered on the Francis Crick Institute (the largest single laboratory in Europe) that integrates resources of many renowned universities, such as Imperial College, University of London (UCL), and King's College London (KCL), and London's largest biomedical research institutions, including National Institute for Health Research and Cancer Research UK.

2.2.6.1 Key success factors of international COIs

Panori (2016) studied the life cycles and success factors of five COIs located at Silicon Roundabout (UK), Bangalore (India), Boulder (United States), Singapore, and Estonia.

It was pointed out that each cluster was unique, and there was no simple and quick formula for clusters' success. The report concluded on six key factors of success: a) a skilled workforce, b) accommodating policy frameworks, c) the infrastructure imperative, d) luck and serendipity, e) low-cost structure, and f) livability.

According to the report, COIs are crucial laboratories where novel tools, technologies, and processes are created and applied. They are not just the "context" of innovation; they are dynamic organisms closely related to everything that happens within their "walls".

2.2.6.2 Actors (or components) of COIs

The main constituents of an innovation system are organizations and institutions, among which, enterprises are often considered the most crucial organizations (Edquist, 2009). The innovation capacity of industrial clusters in developing countries relies more on the internal value network structure, while in developed countries, cluster innovation is primarily achieved through the innovation and diffusion of enterprises (Martin, 1994). It can be seen that enterprises are the main components of innovation.

The OECD (2001) has pointed out that COIs consist of various components, including enterprises, research institutions, universities, venture capital firms, and intermediary service providers. Through industry chains, value chains, and knowledge chains, they form strategic alliances and achieve various forms of cooperation, leading to the creation of technology-economic networks with competitive advantages, agglomerating economies, and extensive knowledge spillovers.

Engel (2014) pointed out that traditional industrial clusters often resembled industrial supply chains, with specialized resources available at the doorstep, such as knowledgeable workers, experienced service providers, professionals, managers, appropriate financing, supportive government policies, and opportunities to access appropriate transportation, distribution, and end customers. The components of COIs tend to adapt to new technologies, create new markets, and target large global markets. These components include entrepreneurs, mature companies, universities, industry resource centers, venture capital, service providers, management, and government.

Engel (2022) defined the components of COIs in a more refined manner and found it meaningful to distinguish between core components and supporting components. The core components include entrepreneurs, venture capitalists, and incumbents of major enterprises, which serve as the main driving forces in mature COIs. The supporting components include universities, management, professionals (legal, accounting, recruitment, consulting), and government. Additionally, Engel and his team introduced a new component called “hybrid components,” which bridge gaps and facilitate the innovation process. This category includes incubators, research parks, accelerators, public-funded venture capital, corporate venture capital (CVC), angel investors (individuals), and service organizations.

2.2.6.3 Behaviors of COIs

The concept of COIs is based on Porter’s model but goes beyond the industrial cluster concept. COIs focus on development stages and the nature of innovation rather than industry specialization. The behaviors that can distinguish COIs from others are as follows: the mobility of key resources; the process of entrepreneurial management; the pursuit of big opportunities for rapid expansion; the compensation and reward systems that can ensure that the interests of entrepreneurs, investors, and other stakeholders are aligned with the overall success of all the participants (to maintain enterprises’ commitment to its promises during the cluster’s development); and the tendency of forming alliances with similar entities in the environment (to respond swiftly to opportunities and challenges) (Engel, 2014).

Behavior represents how components of the COI and the COI ecosystem create and respond to stimuli. It describes how members of the community interact with each other. It is a binding actor that brings individuals and enterprises together. It can be a lubricant that facilitates movement or a “grain of sand in the gears” that slows things down (Engel, 2022). Behavior not only reflects the explicit actions of components within the COI but also serves as a means of conveying, reinforcing, disseminating, and imparting tacit knowledge (Hannan & Freeman, 1984). From a sociological perspective, behavior reflects the culture and values of a COI (Engel, 2022). Behavior is not fixed or entirely predictable in a given context, but violating behavior can have long-term consequences for individuals and groups who operate against the widely accepted norms. COIs can be regarded as subcultures, in which certain members (components) play predefined roles (component types), and each member is expected to operate in certain ways within certain constraints (behavioral norms).

2.2.7 The impact of international exchange and cooperation on the formation and development of COIs

A country cannot gain international competitive advantages in all sectors but can succeed in some characteristic industries. The R&D activities, industrial design, and marketing activities of these characteristic industries are geographically agglomerating in certain areas of the country, forming COIs. Meanwhile, production activities diffuse to low-cost regions within the country or are replicated in developing countries, exhibiting spatial agglomeration with production clusters formed, as is the case of the iPhone, which is designed and developed in the COI in California, the United States but manufactured in production-oriented clusters in developing countries such as China, India, and Vietnam.

COI is not a "closed container" and needs to actively integrate into the global innovation network. For the constantly increasing economic activities, global knowledge networks and knowledge flows are the essential sources of ideas (MacKinnon et al., 2002). Bathelt et al. (2004) believe that in addition to the knowledge generated and shared locally in a specific region, enterprises also need to obtain knowledge from non-local sources as a supplement. These authors used "local buzz and global pipelines" to describe such duality of the spatial distribution of innovation. Especially in the biotechnology industry, all enterprises rely on knowledge from external sources.

Therefore, COIs need interaction and cooperation across regions and clusters. There are many such cases in the world. For example, the series of cluster strategies issued by the federal government of Germany have emphasized the importance of local cluster technology networks and global cluster cooperation networks. They are conducive to the formation of a highly networked local interaction and exchange mechanism among geographically proximate and clustered enterprises and organizations. In addition, the strategies also highlighted the positive role of clusters' openness and international cooperation in creating the synergy between government, industry, and academia and in promoting regional COIs' growth.

Germany's "new high-tech innovation strategy" emphasized the importance of regional COIs and cluster networks in the construction of the national innovation system. The "High Tech Strategy 2025" suggested making full use of knowledge and innovation networks and prioritizing their development. The establishment of cross-cluster partnerships is an important part of Germany's "Go-Cluster" program, which has funded 18 inter-cluster collaboration projects, including 8 regional interdisciplinary inter-cluster collaborations, 7 domestic cross-regional inter-cluster collaborations, and 3 cross-border inter-cluster collaborations, involving a total of 44 clusters. The establishment of these cross-cluster partnerships has made a positive and far-reaching impact on the development of cluster components, especially small and medium-sized enterprises. For example, in Germany, Dresden and its surrounding region Saxony have developed into the largest microelectronics and ICT cluster in Europe, “Silicon Saxony”, which is the fifth largest in the world. At the same time, the pharmaceutical industry in this region has developed along and formed the “BioSaxony” cluster as part of Germany’s “Go-Cluster” program. At present, it has more than 300 enterprises dedicated to biotechnology, medical equipment, or pharmaceuticals and more than 30 research institutions. On the regional level, “BioSaxony” and “Silicon Saxony” have established and maintained cross-sectoral inter-cluster collaborations; on the cross-regional level, “BioSaxony” has established cross-regional collaboration with BioRegio STERN Management GmbH, a cluster in Stuttgart (China Center for Information Industry Development, 2019).

2.3 Biotechnology and healthcare COIs and industrial parks in China

In recent years, the Chinese government has proposed “Healthy China, Healthy Cities” and included strategic emerging industries such as the biotechnology industry in the national strategy, encouraging the formation of biotechnology industrial clusters with biotechnology industrial parks as the carrier, thereby vigorously promoting the development of the biotechnology industry. How to build a COI with global competitiveness and realize the high-quality development of the biotechnology industry is currently a new opportunity and a new challenge faced by cities and districts. For countries and regions, the most critical thing is to build clusters with global competitiveness, so as to create high-quality employment and promote economic growth in the complex and volatile international environment.

Various biotechnology or biomedical industrial parks in China serve as carriers for the development of biotechnology and healthcare COIs. Most of these parks are located in national or provincial/municipal development zones. The formation of biotechnology COIs is closely related to economic and technological development zones and high-tech industrial development zones.

2.3.1 Biotechnology and healthcare industrial parks in China

The formation and development of China's biotechnology and healthcare industrial clusters and COIs are primarily facilitated by biotechnology or biopharmaceutical industrial parks, which were mainly established and developed based on various development zones.

To foster urbanization and industrialization following China's reform and opening up, by establishing "development zones", China has created an effective institutional environment to safeguard property rights and contract enforcement, thereby attracting investment and promoting economic growth. "National-level development zones" is a collective term referring to various development zones in urban planning areas that are authorized by the State Council with specific preferential policies implemented, such as national-level economic and technological development zones, national-level high-tech industrial development zones, national-level exportation and processing zones, and national-level bonded zones. In addition to national-level zones, there are also provincial-level and municipal-level development zones. The formation of biotechnology COIs is closely related to economic and technological development zones and high-tech zones.

From 1984 to 2021, there were 232 national-level economic and technological development zones in China. With the industrial upgrading, many of them planned bio-industrial areas or biomedical industrial parks.

From 1988 to the end of 2019, there were 169 national-level high-tech zones in China, with its GDP reaching RMB 12.14 trillion yuan in 2019 (around 1.57 trillion EUR), equivalent to 12.3% of the national GDP. The internal R&D expenditure ratio in GDP of enterprises in national-level high-tech zones was three times higher than the national average (Torch High Technology Industry Development Center & Institute for Strategic Consulting of Science and Technology, 2021).

The rapid development of various high-tech industrial parks has created huge economic and social benefits. Biotechnology industrial parks are important carriers for developing the biotechnology and healthcare industry and promoting the regional economy (National Development and Reform Commission of China et al., 2021).

At present, there are 35 national-level biotechnology industrial bases in China (Lin et al., 2020). In the *Notice on Accelerating the Construction of Strategic Emerging Industry Clusters*, National Development and Reform Commission of China (2019) announced the first 66 national strategic emerging industry clusters, 17 of which are related to the biopharmaceutical industry. Nearly half of the national-level high-tech zones and economic development zones are in the biopharmaceutical industry (Qianzhan Industrial Research Institute, 2020). As of the end of 2019, there were nearly 500 provincial or national-level bio-industrial parks in China (Z. Wu, 2019).

Industrial parks in China play a significant role in promoting the formation of industrial clusters, but some parks fail to eventually form clusters, not to mention COIs. In China, the numerous biotechnology and healthcare industrial parks of various categories show varied development status. Even some biotechnology parks in developed cities are facing the dilemma of attracting investment and upgrading and transforming to COIs, with extremely slow progress in international exchange and cooperation, which is a pressing issue that China needs to address promptly.

Some common phenomena and challenges in Chinese biotechnology and healthcare industrial parks were listed in §1.2. Local governments and park managers must have a proper understanding of the concepts, components, and development laws of industrial clusters and COIs and formulate clear development goals and action plans. Only after cultivation and accumulation for a certain amount of time can these parks develop into COIs, which indicates the significance of this study.

2.3.2 Studies of industrial clusters and COIs

China is currently in a period of economic development transition, facing the challenges of structural adjustment and development pattern change for sustained economic growth, which imposes a significant demand for technological innovation, making the improvement of industrial clusters' innovation efficiency a crucial task for turning China into an innovative nation. Various types of industrial clusters have become important carriers for China's economic structural adjustment and industrial upgrading. All industrial clusters, regardless of the development stage or the industry (traditional or high-tech), entail complex innovation processes, which are interactive and synchronized with industrial development.

Chinese scholars have conducted extensive research on industrial clusters and COIs from different perspectives.

According to J. Chen and Z. Tang (2002), an industrial cluster is a network structure composed of numerous region- and industry-related organizations, bridging individual enterprises with the market.

F. Yue (2009) stated that when industrial clusters reach a certain stage of development, they may encounter technological and institutional lock-ins due to product/technology convergence, increased factor costs, and excessive competition. To overcome these lock-ins, the industrial cluster's upgrading is imperative.

Thus, promoting industrial clusters' continuous upgrading and cultivating their sustainable dynamic competitive advantages is essential. Research on cluster upgrading lays the foundation for guiding the formulation of strategies and policies, addressing clusters' lock-ins and decline, fostering dynamic competitive advantages characterized by innovation, and achieving clusters' sustainable development (L. Wang, 2014).

Z. Ma (2010) identified three types of lock-in states during cluster upgrading and proposed three corresponding paths for cluster upgrading. The first is to obtain division-of-labor advantages by embedding into high-end segments of the global value chain through technological innovation, thus forming high-end industrial clusters with regional comparative advantages; the second is to obtain market advantages by developing the service industry through market innovation, accelerating the establishment of specialized markets, and creating a unified domestic market; and the third is to gain institutional advantages by improving government services and institutional environment through institutional innovation, thus creating favorable conditions for nurturing innovative entrepreneurs.

The studies mentioned above all indicated the importance and urgency of industrial clusters' upgrading. The upgrading of industrial clusters to COIs is one of most the important upgrading directions.

Apart from a few leading scholars like Wang Jici, most Chinese scholars do not explicitly differentiate between industrial clusters and COIs. No consensus has been reached regarding their definitions.

One reason is that many Chinese scholars lack sufficient reading of international literature and thus fail to distinguish between industrial clusters and COIs. Secondly, Chinese cities, parks, and industrial clusters are in an upgrading and transformation stage in tandem with the development of the Chinese economy. Previous research mostly focused on clusters in traditional industries, such as the footwear cluster in Dongguan, the furniture and ceramics cluster in Foshan, the gold and jewelry cluster in Shenzhen, and the lighter cluster in Wenzhou. To begin with, there are only very few successful cases of clusters upgrading into COIs. For practitioners, the most important is considering how to do it, how to formulate policies and measures, and how to design development plans. For scholars without government working experience, discussing cluster governance will be like engaging in idle theorizing (J. Wang et al., 2010).

A few scholars have addressed the differences between COIs and industrial clusters. While exhibiting common cluster features (e.g., geographical proximity or spatial agglomeration, networks, embeddedness, and openness), they show significant differences in terms of the formation background, characteristics, components, innovation modes, and organizational structures. For example, the views of C. Wang (2012) are summarized in Table 2.4.

Table 2.4 Differences between industrial clusters and COIs

	Industrial clusters	**COIs**
Background and conditions	globalization	knowledge economy and information age
Essential characteristics	interplays of value chains or supply chains	proliferation of new products, knowledge-intensive exchange, and innovation connections
Outputs	products of mature technology	new technologies and new patents
Components	enterprises are the core components of innovation, with universities and research institutes playing a supporting role	universities and research institutions are sources of innovation
Production or knowledge systems	production system	knowledge system
Learning process	adaptive learning	generative learning
Organizational structure	process-based	technology-based
Embeddedness	strong	relatively weak
Position in value chain	medium and low-end	high-end
Influence on the peripheral economies	weak	strong

Source: C. Wang (2012)

Industrial clusters and COIs differ in their definitions and variable characteristics. The core of an industrial cluster lies in the coexistence of various enterprises within the same industry with a specialized division of labor and geographical proximity. However, in many cases, cooperation between enterprises is not regular and is just incidental. Sometimes, cooperation may not take place among the enterprises in the same park or with geographical proximity. Even if entrepreneurs live and work in the same region, they may rarely communicate or share information, and enterprises may experience vicious competition (J. Wang, 2023). COIs focus on the formation of local innovation networks and the integration into global innovation networks, thus creating conditions for joint actions between components and resources within and outside of the COI. The formation and expansion of innovation networks are conducive to the realization of "information sharing" and "resource sharing" among innovation actors in the COI, including the dissemination of "tacit knowledge". The "cross-border cooperation" across organizations, industries, and regions is conducive to "cross-border innovation" and "collaborative innovation".

COIs represent the advanced development stage of industrial clusters, and industrial clusters are the core inducement and intrinsic basis of COIs (J. Wang, 2004). The continuous emergence of new technologies and industries requires collaboration among different components and joint actions between different industries and disciplines to promote knowledge spillover. Innovation often occurs at the boundaries of industries. The cross-sector collaboration and integration are crucial for fostering innovation. The complex connections that exist or may emerge in the future can hardly be planned in advance. For complex products, it is unlikely that all segments in the industrial chain can be completed within the same province or city, or even within the same country (J. Wang, 2021). For example, the biotechnology and chemical-pharmaceutical industries are highly complex and cannot be operated by an individual enterprise alone. These industries are not limited to a single discipline; instead, they often develop through cross-disciplinary cooperation or interdisciplinary studies. Hence, to form COIs, close cooperation among multiple actors is imperative. It is necessary to avoid merely relying on low costs and scale expansion for building industrial chains and industrial clusters and abandon the mindset that common social and cultural values within the cluster will inevitably promote enterprise cooperation, that clusters are inevitably innovation hubs, and that clusters as static industrial organizational forms and closed systems. Additionally, we must change the mindset of using theories from developed countries to guide China's practices. It is imperative to cultivate authentic COIs and make them a site for China's independent innovation practice and a source of international competitiveness (J. Wang et al., 2010).

China is still in a period of economic development transition and faces the challenges of structural adjustment and development pattern change for sustained economic growth. There is a tremendous demand for technological innovation. Strengthening technological innovation capacity and implementing a national innovation strategy to improve the quality of economic growth has become the consensus of academia and government decision-makers (B. Li et al., 2012). In order for the region to gain new advantages, it is necessary to transform and upgrade industrial clusters into COIs. Meanwhile, improving COIs' innovation efficiency will be a crucial task in building an innovative country.

2.3.3 Evolutionary stages of biotechnology and healthcare COIs in China's high-tech zones

Currently, there is a lack of representative research focusing on biotechnology industry parks. As the majority of China's biotechnology parks fall under the category of high-tech development zones and are sometimes planned as "biotechnology industry areas" within these high-tech zones, their development shows certain commonalities. Hence, this study takes the research on the evolution and key factors of COIs in high-tech zones as a reference for investigating the biotechnology and healthcare industrial clusters.

Some Chinese scholars have categorized the development of high-tech zones into four stages: the factor-driven cluster stage, industry-dominance stage, innovation breakthrough stage, and wealth accumulation stage (Y. Zhou & Wang, 2003).

Inspired by C. Wang (2012) and insights from other scholars and taking into account the researcher's practical experience, we identified four evolutionary stages of China's biotechnology industry COIs: enterprise flocking together, industry aggregation, industrial clusters, and COIs.

2.3.3.1 Stage of enterprise flocking together

The early stage of China's high-tech zone construction was driven by factors such as policy incentives, land development and allocation, and fixed asset investment (e.g., infrastructure). The goal was to achieve the agglomeration and integration of technology, enterprises, and industries within a park, serving as a demonstration. However, in reality, some high-tech zones have continued the functions of economic development zones with traditional investment promotion models in their early stage of development, and have attracted a number of Chinese manufacturing enterprises or foreign-funded manufacturing plants through low-cost inputs and policy advantages. These enterprises often do not bring advanced technology or core technology), resulting in the phenomenon of "enterprises without technology (referring to the lack of core technology and leading technology in the industry)".

These "special zones" attracted enterprises and investors with special policies such as favorable land prices, tax incentives, and financial returns to enterprises. In this stage, enterprises drawn to these industrial parks are seeking "excessive policy benefits" (commonly known as "policy-driven tenants"), rather than being attracted by the proximity to industry chains and markets. The spatial agglomeration of enterprises in this stage can only be described as "enterprises flocking together", with limited interconnectivity among enterprises in the park. The case of relying on special policies to attract enterprises and investments is particularly evident in underdeveloped cities and sometimes is even found in immature industrial parks and incubators in developed coastal cities. These parks are typically characterized by "having enterprises" but "lacking industry" (they have not yet formed associated industry chains and industrial agglomerations).

2.3.3.2 Stage of industrial agglomeration

After the initial stage of enterprises flocking together, some of China's biotechnology industrial parks began to transition to the stage of "industrial aggregation." What factors promoted this upgrading?

Enterprises are more willing to settle in parks with greater policy incentives. As the park attracts more and more enterprises, it gains recognition and reputation, which helps increase enterprises' trust in the park, making them believe that their legitimate rights and interests can be effectively protected. For example, some national-level development zones are more likely to gain enterprises' trust compared to town-level development zones, as they have comparative advantages in infrastructure, transportation, communication, and tax incentives.

Results of market-oriented agglomeration research show that agglomeration is the result of accidental concentration of enterprises, with its continuous external positive effects accumulating and strengthening the agglomeration. However, most of China's parks are not naturally formed; they are developed under the guidance of government policy. Initially, many enterprises are merely "policy-driven tenants." Since they choose to settle in these parks for the purpose of survival and development, do they also play a role in promoting local suppliers and talent markets? Do high-tech parks, such as biotechnology parks follow the same pattern and path of industrial agglomeration as traditional industrial parks? Is industrial agglomeration driven by transnational corporations and large enterprises, or the concentration of small and medium-sized enterprises? The field research and case study in Chapter 4 will attempt to answer these questions.

2.3.3.3 Stage of industrial cluster

It is essential to note that industrial agglomeration does not necessarily equate to an industrial cluster. Industrial agglomeration is a necessary but not a sufficient condition for the formation of an industrial cluster. An industrial cluster has higher requirements; geographic concentration alone may not create interdependence among enterprises. In order for an industrial cluster to leverage its advantages, it must form a symbiotic mechanism and organic whole within the region to create interconnectivity and interdependency among enterprises within the cluster. Enterprise agglomeration refers to enterprises clustering at the site of operation, while an industrial cluster represents enterprises clustering at the site of interaction. Innovation is achieved through interactions, especially knowledge exchange (J. Wang et al., 2010). In this stage, if the cluster fails to establish an industrial culture of trust among enterprises, enterprises will be mainly in competition but barely in cooperation. In addition, internal knowledge sources in these parks, such as technology research institutions and information consulting agencies, are generally very scarce. Enterprises' knowledge and information mainly come from external sources, and in this case, external information and knowledge exchanges become enterprises' primary learning channel. Neglecting the establishment of intrinsic linkages among enterprises and industries may lead to the failure of the park's industrial development strategy and hinder its sustainable development.

In recent years, China's various industrial clusters have played a significant role in sustaining high-speed economic growth. However, with the great adjustments in the global economy, some industrial clusters show signs of decline, extensive development, insufficient innovation, redundant layout, excess production capacity, low international competitiveness, and low resilience to risks (Z. Liu, 2015).

According to Y. Tian (2011), as globalization and the knowledge economy continue to deepen and evolve, the development of industrial clusters faces new problems and challenges, such as inadequate cluster governance mechanisms, insufficient scientific and technological innovation capabilities, lax intellectual property protection, missing innovation system environment, and incomplete ecosystem development. After reaching a certain stage, industrial clusters may face the risk of being locked into low-end segments of the value chain (including technological, division-of-labor, market, and institutional lock-ins) due to issues such as product/technology homogeneity, rising factor costs, and excessive competition, which may lead to reduced competitiveness or decline of the industrial cluster. Therefore, it is imperative for industrial clusters to transform and upgrade.

2.3.3.4 Stage of COIs

According to J. Wang (2010), "COIs are developed in certain industries based on the synergy of local enterprises and relevant organizations. Through cooperation and joint action, they generate external economies and reduce costs. Through integrity between enterprises, based on certain regulations, their cooperation can foster knowledge spillover, industrial integration, and industrial innovation. These clusters have both trade and non-trade interdependencies, which require a sound institutional environment, including intellectual property protection. COIs are open innovation communities that foster a trust-based innovation culture construction locally." Industrial parks do not necessarily lead to the formation of industrial clusters, and not all industrial clusters are COIs. Industrial innovation often occurs in locations with industrial agglomeration, but industrial agglomeration does not necessarily foster industrial innovation. In high-tech industries, the success of low-end activities may not lead to the success of high-end activities.

Some industrial clusters become local production systems rather than innovation systems, remaining in the categories of "low-road" and "low-cost-based" clusters or production clusters. Industrial clusters and COIs differ in their concepts and variable characteristics. The former is based on production systems, while the latter is based on "knowledge systems" and "innovation systems" - the "high road". COIs emphasize cross-industrial integration and technology intersection, which leads to emerging industries and radical innovations. Therefore, it is particularly important to form collaborative innovation networks for technological cooperation between industry, universities, and research and exchange networks of "tacit knowledge" in COIs.

2.3.4 Key conditions for high-tech zones' transformation and upgrading into COIs

To transition from the stage of enterprises flocking together to industrial aggregation and eventually become COIs, high-tech zones need certain transformational conditions.

Firstly, to progress from the stage of enterprises flocking together to industrial agglomeration, it is crucial to establish interconnections among enterprises within the park (cluster). This can be achieved through various means, such as joint recruitment to attract talent more effectively, lower recruitment costs, and increase efficiency. Additionally, enterprises within the park can engage in mutual procurement of each other's products at lower prices, capitalizing on the advantages of proximity to reduce transportation costs. As enterprises recognize these benefits, the enterprises already present in the park will spontaneously contribute to investment promotion (which was previously led by government investment promotion departments) and attract upstream and downstream supporting enterprises (e.g., suppliers and distributors), thereby the positive external effects brought about by enterprise agglomeration continuously reinforce the agglomeration, creating a virtuous cycle.

Secondly, after realizing the expansion of scale, high-tech zones should adhere to their original goal, realizing the transformation and upgrading from "factor-driven" to "innovation-driven".

Once the spatial agglomeration reaches a certain level, if supporting, complementary, and related industries emerge and establish connections among them, it can accelerate enterprises' mutual learning and improvement, leading to a continuous increase in product quality and cost efficiency, resulting in product or process upgrading. At this point, an industrial cluster starts to be formed within the region.

Thirdly, the development of high-tech industries that are technology-dependent and highly specialized, such as the biotechnology industry, has a high demand for exchange and cooperation among cluster components (innovation actors), including collaboration between industry, universities, and research institutions and formal/informal communications (e.g., forums, seminars, and even conversations in cafes and restaurants). Therefore, being able to build innovation networks and innovation ecosystems is the primary condition for the transformation of industrial clusters into COIs. An innovation network is a complex of formal and informal relationships that are relatively stable and can accelerate technological innovation, formed through continuous joint action and collaborative innovation among COI components (enterprises, universities, research institutions, financial institutions, and intermediaries) within a certain geographic area.

In summary, in the transition from “enterprises flocking together” to “agglomeration”, the connection between enterprises is the key; from “agglomeration” to “cluster”, the realization of industrial linkage is the key; from “cluster” to “COI”, the formation of an innovation network and an innovation ecosystem by integrating various innovation elements is the key (C. Wang, 2012).

C. Wang (2012) proposed the four stages of COI development and the three “key factors” of its transformation and upgrading, which are valuable insights, but he did not specify how the enterprise connections, industrial linkages, innovation networks, and ecosystems are realized. This study, through the case study of Guangzhou International Bio Island, will examine whether China's high-tech zones, especially biotechnology and healthcare industrial parks, have gone through the same four stages of evolution, and what methods and means have been used to realize the transformation and upgrading of the zones into COIs. What are the core enablers in this process? How do these core enablers have joint actions to integrate the park's internal and external resources, thereby promoting innovative behaviors, including the diffusion and application of technology? What is the impact of international exchanges and cooperation on COIs? Through the empirical case study, we attempt to create a theoretical framework for COIs.

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Chapter 3: Research Method

This chapter mainly addresses the selected research methods, the research plan, and the research process, including data collection and processing.

3.1 Selection of methods

This thesis used the qualitative approach (interviews, focus groups, and case study).

Qualitative research is the counterpart of quantitative research. Its specific purpose is to delve into the specific characteristics or behaviors of the research subjects and further explore the reasons behind them. Unlike quantitative research, qualitative research does not rely solely on statistical data or numbers to draw conclusions. It is a scientific inquiry into the essential attributes of things and is one of the fundamental steps and methods in scientific research. It examines whether the research subject possesses certain attributes or properties and explores the relationships between them through observation, experimentation, analysis, and other relevant processes. As it focuses on finding out the qualities of the research object, it is called qualitative research. This study gathered data from natural contexts through historical data review, literature analysis, interviews, observations, and participatory research and conducted data analysis by non-quantitative means to obtain conclusions. Qualitative research emphasizes the meaning, experience (often through verbal communication), and description (Denzin & Lincoln, 1994).

According to Miles and Huberman (1994), data analysis in qualitative research typically consists of three steps: data reduction, data display, and conclusion drawing. Data reduction refers to the process of selecting, coding, and categorizing data. Data display refers to the methods used to present the data, such as direct quotations or using matrices, graphs, and charts to uncover the underlying patterns. These tools assist researchers (and ultimately readers) in understanding the data. Conclusions are drawn based on the data display (patterns of the dataset) (Sekaran & Bougie, 2013).

3.1.1 Case study

Regarding the research paradigm, a case study is a type of empirical research. It is a method for tracking the behaviors of an individual or group. It involves collecting and recording the information of one or several cases, and the production of case reports. If data is collected on-site, it is called “field research” and typically employs instruments such as observation, interviews, document collection, descriptive statistics, tests, questionnaires, photographs, and videos. In the early stage of the industrial organization theory, case analysis was widely applied, with research subjects covering various industry sectors. Currently, the case study method is also applied in studies on the development of specific industries, especially new phenomena and trends in industrial development (e.g., the impact and penetration of the new industrial revolution on traditional industries; the influence of new technologies, new business models, and new patterns on industrial development). The case study enables us to gain insights from specific cases and obtain valuable research findings, despite constraints such as limited data (X. Bai & Du, 2021).

The case study method, also known as the case history method, has the advantages of typicity, in-depth analysis, and feasibility. However, it also has certain limitations. For example, the case may not be universally generalizable but can serve as a source of inspiration and reference; case studies can be time-consuming and resource-intensive, as historical data may not always be accessible, and gathering internal information may impose challenges. Given that this study aims to explore the development and evolutionary stages of biotechnology industrial parks, identify the core enablers and their joint actions for the formation of COIs, and find out the impact of international cooperation and exchange on COIs through examining the development process of the Bio Island, the case study method is deemed suitable. Data was collected from field research, direct observation, internal documents, and historical records. We also obtained primary data from face-to-face interviews, as described in the following section.

3.1.2 Interviews

The interview method is a commonly used approach to collect data. It involves guided and purposeful conversations between two or more individuals to obtain relevant information of interest. Interviews can be conducted face-to-face, over the phone, or through online platforms (Sekaran & Bougie, 2013). The main advantage of the interview method is that it allows to obtain in-depth information that may be difficult to gather through questionnaires. However, it can be time-consuming, costly, and limited by the sample size (H. Li, 2004).

In this study, face-to-face interviews were chosen as the primary method, and the interviewees consisted of executives of the operating agencies of Bio Island, senior officials from relevant government authorities overseeing Bio Island and the biotechnology and healthcare industry, founders and decision-makers of the company, and Chinese and international experts in COI research. We ensured the diversity of interviewees to obtain in-depth information from multiple perspectives. The interview questions were a combination of structured questions, unstructured questions, and semi-structured questions. During the actual interview, structured questions were posed initially, gradually followed by semi-structured and unstructured questions to gain insights into the actual status and obtain valuable perspectives.

3.1.3 Focus group

Focus group research, also known as group interview, is a collective term for any research that investigates how people discuss a clearly defined topic (Sekaran & Bougie, 2013). Focus groups are a commonly used qualitative research method in social sciences and are a form of group interview. Typically, a trained researcher facilitates the discussion using a semi-structured approach (i.e., the interview questions were partially pre-defined), engaging with a group of participants. It focuses on the interaction and shared construction of meaning within a specific group (Bryman & Bell, 2012). An expert panel is a group of individuals specifically convened by researchers to obtain knowledge and opinions on a particular topic. The inclusion criteria vary among different studies, and expert panels are typically composed of independent experts (Sekaran & Bougie, 2013).

The main purpose of focus groups is to listen to participants' views on the research questions, and the participants are selected from the overall population of the study. The advantage of focus groups lies in the unexpected discoveries that often arise from free discussions. Focus groups impose high demands on the facilitator, who introduces the topic, observes, and records the discussion. The facilitator is not a participant in the discussion but rather guides panel members to provide relevant information and helps them overcome any potential impasses. The facilitator should also ensure that all members participate in the discussion and prevent any member from dominating the discussion (Sekaran & Bougie, 2013). Additionally, note-taking and information collation are also essential tasks of the facilitator.

3.2 Research process

3.2.1 Data collection

3.2.1.1 Site visits and internal data collection

To prepare for the interviews, we gathered relevant internal information about Bio Island from its governing units, including the Guangzhou Development Zone Administration Committee, the Bio Island Administration Committee, and the Bio Island Company (Bio Island's operator). Special attention was paid to historical materials (e.g., the major events) to gain an understanding of the development process of Bio Island. This helps in conducting well-informed interviews.

3.2.1.2 Interviewee selection and interview planning and implementation

The data was collected in two parts: formal interviews and focus group discussions. The timeframe spanned from 2019 to 2023. In the first part, the primary interviewees were executives of the organizations directly associated with Bio Island. It took five stages, all involving site visits to the interviewees' respective units for field research and interviews. In the second part, the participants comprised Chinese and international scholars with expertise in research on industrial clusters and COIs. This part included two stages of focus group discussions. The first stage took place in Beijing in 2020, all discussions were held at the same location. The second stage occurred in 2022 as an online video conference format.

In total, involving 170 individuals from 151 organizations (including 29 foreign organizations), resulting in 13,410 minutes of audio recordings and transcripts of 3,577,687 Chinese characters or English words. In total, the two parts involved 21 government authorities, 11 research institutions, 5 industry associations, 25 universities, 66 companies, 14 investment institutions, and 9 intermediary service agencies, as shown in Table 3.1.

Table 3.1 Data collection summary

Parts	Data Source	Stages	Organizations	Sessions	Recordings (min)	Transcripts (words)
1st Part	Formal interviews	1st	53	53	4,770	1,210,944
		2nd	9	9	810	89,600
		3rd	12	12	1,080	123,751
		4th	42	42	3,780	1,218,610
		5th	27	27	2,400	682,576
		Subtotal	143	143	12,840	3,325,481
2nd Part	Focus group discussions	1st	12	15	300	132,740
		2nd	9	12	270	119,466
		Subtotal	21	27	570	252,206

3.2.1.3 The first part: interviews

In the first part, 143 sessions of interviews were conducted with interviewees from 131 different organizations (12 organizations were interviewed for a second time after the outbreak of the COVID-19 pandemic). When selecting interviewees, we took into account industrial clusters' and COIs' essential components and actors identified in the literature, such as the government, universities, research institutions, enterprises, investment institutions, intermediaries (industry associations and alliances), and third-party service providers. We selected organizations that were representative organizations directly related to Bio Island. Approximately 8% of the interviewees were officials from government authorities overseeing Bio Island, 80% were executives of resident organizations in Bio Island, and the rest were from organizations that had business with Bio Island or expressed interest in establishing a presence there. The selected interviewees were from different levels and showed diversity. For instance, (i) the selected government authorities covered multiple levels, including provincial, municipal, and district-level departments; (ii) the selected universities and research institutions included both local ones and those from other regions that were interested in collaborating with Bio Island; (iii) the selected enterprises showed diversity, including multinational corporations, foreign-funded enterprises, and Chinese (state-owned and private) enterprises, covering both large and small-and-medium enterprises (including start-ups). As enterprises of different types or at different stages have different needs and viewpoints, this approach enabled a comprehensive and in-depth understanding of diverse perspectives.

The research spanned a period of five years, which is relatively long. The interviews were conducted one stage per year. See Table 3.2 for the detail of the first stage of formal interviews, Table 3.3 for the second stage of formal interviews, Table 3.4 for the third stage of formal interview, Table 3.5 for the fourth stage of formal interview, and Table 3.6 for the fifth stage of formal interview.

To balance "consistency" and "diversity," the interview framework and main topics were designed as follows. The interview mainly comprised four parts, including but not limited to the following questions:

1) Please provide an overview of the organization, including its history, current status, core business, products and services, and the development strategies and plans for the next three years.

2) Please explain the reasons for choosing Bio Island as its location, identify the core enablers within Bio Island (park/cluster) that are conducive to enterprise development and

innovation, and rank them according to their importance. What are the organization's specific needs during its development in Bio Island? Which needs have been met, and which ones are yet to be fulfilled? What additional services would the organization hope to see in the park?

3) Has the organization established any exchange or cooperation relationships with other organizations within Bio Island? If so, describe the types of joint actions and point out which are the common and preferred types. Can these joint actions foster the enterprise's innovation and higher-quality development, and how (please provide specific examples if possible)?

4) Please share any needs and experiences for international exchange and cooperation. Is Bio Island (the park) conducive to international cooperation and exchange? Describe how you participate in international exchanges and collaborations. In your opinion, what impact does international exchange and cooperation have on local innovation? Do you believe it can foster local innovation?

Table 3.2 Name list of the first stage of formal interviews (in 2019, about 1.5 hours/interviewee)

Interviewee	Position	Organization
CC	Executive	G-SWD-GWH (an administration authority)
CJ	Chairman	C-SZ (enterprise specializing in pathogenic microbiology detection services)
CJD	Head of department	G-GZ-FG (an administration authority)
CL	Founder	C-EB (a company that conducts internationally leading R&D of innovative vaccines and biologics with unique technology for adenovirus genetic modification)
CLH	General Manager	C-YY (a national high-tech enterprise specializing in the R&D, production, sales, and third-party testing services of animal disease in vitro diagnostic products)
CM	Director of Academic and Technical Ventures	U-UK-IL (a collage in the UK)
CV	Head of Business Development/External Investment	G-UK-I (a local investment promotion agency in the UK)
DW	Former CEO	R-UK-R (a council in the UK)
FW	Head of department	G-GD-YJ (a local administration authority in China)
GQ	Chief Scientist	C-GWQ (a world-leading biphotonic research company)
HHX	Board Member	I-XN (a capital company)
HK	Head of Health, Life Sciences, and Bioeconomy Affairs	G-UK-B (an administration authority in the UK)
JHX	Partner	S-DS (one of the most polycentric law firms in the world)
JJJ	General Manager	C-NT (an industrialization enterprise for the creation of new nucleic acid drugs)
JS	Head of life sciences industry in the UK	N-UK-UC (an association in the UK)
JY	Former Consul General	G-I-CG (Israel Consulate General in China)
KA	CEO	C-A (a company developing bioresorbable heart stents)
KK	Board Member	S-CE (a global commercial real estate services and investment company)
KK	Founder	N-UK-M (a medical device alliance in the UK)
LWH	Managing Director	S-SS (one of the world's leading real estate service

		providers)
LXF	Founder	C-HX (an enterprise with the largest respiratory virus resource library in China and providing respiratory virus diagnostic products)
LY	Founder and CEO	C-SN (a leading pharmaceutical company in anti-tumor RNA therapy)
LYM	Executive Director	C-RSB (a manufacturer specializing in portable respiratory function testing devices and catheters)
LYM	Chairman	C-JY (one of the market leaders in China's third-party medical testing industry)
LYQ	Secretary-General	N-GZ-B (a local bioindustry alliance in China)
MM	Head of Healthcare & Life Sciences	G-UK-CG (British Consulate General in China)
PG	CEO	C-CT (a medical imaging and diagnostic company providing clinical trials and second medical opinions)
PSL	Former Vice Chancellor	U-CN-HG (a university in China)
PT	Deputy Dean, Faculty of Biology	U-UK-BF (a university in the UK)
QY	Partner	S-PC (one of the world's largest professional services providers)
RB	President	U-UK-WE (a university and health technology innovation center in the UK)
RJL	Executive Deputy Director	R-SWD (a local laboratory in China)
RW	Executive Director	N-UK-M (an association in the UK)
S	Deputy Head	G-UK-B (an administration authority in the UK)
SB	CEO	C-V (an international company that adopts advanced tissue engineering therapy based on stem cell regenerative medicine technology)
SQ	CEO	C-CP (a crystallization and particulate engineering company that uses proprietary supercritical fluid technology to improve drug performance)
SXW	Executive	G-GDD-GWH (an administration authority)
SY	Partner	I-LAV (a preeminent venture fund focused on life sciences and healthcare)
TJ	Head of Life Sciences and Digital Health	G-UK-CG (British Consulate General in China)
TJ	Provost and Vice President	U-UK-BM (a university in the UK)
WHW	Chairman	C-RT (a high-tech enterprise specializing in the R&D, production, and sales of orthodontic biomaterials)
WTC	Founder	C-BJ (a CRO+CDMO that provides "one-stop" services for the whole process of R&D and production of drugs and medical devices for Chinese and international pharmaceutical companies)
XAL	President (former member of the Bio Island Planning Expert Group)	U-CN-B (a Chinese medicine university in China)
XZ	Head of department	G-GD-FG (an administration authority)
YDW	Board Member	I-HK-I (Hong Kong-Ireland funds)
YJH	Chairman	C-JT (China's leading high-tech enterprise dedicated to providing overall solutions for biological laboratories)
ZH	General Manager	I-CI (an Israel-China joint venture and a secondary enterprise of C-SWD)

ZL	Founder	C-HX (a biotechnology company that provides total solutions for spinal health)
ZMQ	Managing Director	C-AG (a global leading biotechnology company)
ZNS	Division Head	R-GZ-HX (a research center in China)
ZR	General Manager	C-HYS (industry-university-research operating unit of a respiratory diseases research center)
ZW	Chairman	C-SWD (operating agency of an industrial park)
ZXB	Executive	G-GZ-GX (an administration authority)

Note: G - government authority; R - research institution; N - (NGO) industry association; U - university; C - company; I - investment institutions; S - intermediary service agencies.

Table 3.3 Name list of the second stage of formal interviews (in 2020, about 1.5 hours/interviewee)

Interviewee	Position	Organization
DXF	Chairman	C-HYSHW (a medical device manufacturing company of R&D and application of medical infrared technology)
HJ	Former principal	U-CN-JN (a university in China)
LL	Deputy General Manager	C-HYSSWAQ (a high-tech enterprise focusing on biosecurity projects with epidemic prevention technology)
LZR	General Manager	C-WL (an innovative company engaged in medical signal processing and computer-aided diagnostics)
PT	Chairman	C-HNYM (an innovative R&D enterprise focusing on recombinant protein nanoparticle vaccines)
WXH	Senior Partner	S-GX (a legal services provider in the Guangdong-Hong Kong-Macao Greater Bay Area)
YHB	Chairman	C-AJ (a high-tech enterprise centered around the R&D and industrialization of biomedical products)
YSH	Professor	U-CN-HS (a university in China)
ZF	Chairman	C-AZD (a globally renowned CDMO+CRO+CSO company in the medical device industry)

Note: G - government authority; R - research institution; N - (NGO) industry association; U - university; C - company; I - investment institutions; S - intermediary service agencies.

Table 3.4 Name list of the third stage of formal interviews (in 2021, about 1.5 hours/interviewee)

Interviewee	Position	Organization
CK	Head of the International Life Sciences Innovation Park and Regional Innovation Center	C-AZ (a science-led and patient-centric global pharmaceutical company)
HD	Head of Operations in China	C-BS (global CRDMO with over 27 years of history)
JJ	Managing Director	S-HQ (an IP service platform)
LJ	CEO of Innovation Center	C-BJSZ (a global biotechnology company focused on developing and commercializing innovative and affordable anti-tumor drugs)
LKL	General Manager	S-LHYC (a headhunting company focusing on high-end talents in the biological industry)
ML	CEO	I-XH (a technology group)
QHO	Chairman and General Manager	S-DWQ (a science and technology innovation service center)
RJL	Vice President (Asia)	C-PTI (a renown proton therapy technology manufacturer for transforming cancer treatment)
YHL	Chairman	C-FH (a company that provides technologies and services such as neonatal genetic metabolic disease detection and genetic diagnosis, childhood immunodeficiency disease detection, and pre-eclampsia detection for women)

YJF	General Manager	C-KZ (a company that provides medical devices and overall solutions for psychiatric and neurological rehabilitation)
YSH	Chairman	C-GS (a R&D company of new medical imaging equipment and services)
ZNS	Division Head	R-GZ (a biotechnology laboratory in China)

Note: G - government authority; R - research institution; N - (NGO) industry association; U - university; C - company; I - investment institutions; S - intermediary service agencies.

Table 3.5 Name list of the fourth stage of formal interviews (in 2022, about 1.5 hours/interviewee)

Interviewee	Position	Organization
AF	Partner	S-DE (one of the world's leading comprehensive professional services providers)
CJ	General Manager	I-GY (a capital company)
CL	Founder	C-EB (a company that conducts internationally leading R&D of innovative vaccines and biologics with unique technology for adenovirus genetic modification) ■
CWQ	Executive	G-GDD-KJ (an administration authority)
CWY	President	I-DGX (an investment group)
CXW	Dean	R-ZKYGZ (a local institute of biomedicine and health in China)
CY	Secretary-General	N-GZ (a science and technology incubator)
DY	President	I-SD (a capital company)
FBL	General Manager	C-CS (an enterprise engaged in biomedical materials R&D, biomedical materials technical services, and biotechnology services)
GF	Deputy Director	R-GD-HN (a provincial center for new drug creation in China)
GHC	Chairman	C-AQ (one of the earliest Chinese enterprises engaged in the overall construction of laboratories)
HD	CEO	I-GY (an investment group)
HQ	Executive	G-GZ-SW (an administration authority)
HSJ	Executive Director	C-AG (a CDMO engaged in pharmaceutical, clinical, and production base integration)
HWJ	Executive	G-GDD-TC (an administration authority)
HZF	Chairman	I-YH (a real estate investment company)
LJ	Head of department	G-GZ-KJ (an administration authority)
LLQ	Chairman	C-YD (a biomedical in vitro diagnostic company integrating R&D, production, and sales of clinical laboratory reagents and instruments with scientific research and technology testing services)
LM	CEO	C-JS (a global CRO for circular RNA innovative therapeutics)
LWY	Chairman	C-FHQ (an operating agency of a local state-owned incubator in China)
LWY	Chairman	C-KJ (A local state-owned holding company that promotes the integration of technology and finance)
LXC	Executive Director	C-PDLX (a company engaged in the development and production of biomedical materials technology)
LXF	Founder	C-HX (an enterprise with the largest respiratory virus resource library in China, providing respiratory virus diagnostic products) ■
LYL	Chairman	C-HJ (a company providing high-quality scientific research outsourcing technical services and scientific research products for biomedical enterprises, universities, research institutions, hospitals, and individuals)
LYM	Executive	C-RSB (a manufacturer specializing in portable respiratory

	Director	function testing devices and catheters) ■
MWN	Board Member	C-YZ (an innovative company focusing on gene delivery technology)
PMM	Investment Director	I-CT (a local production and investment group and a state-owned investment institution focusing on locally promoted industries)
PZG	General Manager	C-WAK (a professional technical service enterprise specializing in R&D and testing of pharmaceutical preparations)
SJ	Executive Director	C-TY (a company that provides a one-stop preclinical R&D platform)
TGK	Executive	G-GD-GX (an administration authority)
WBY	Founder	C-ASD (a national high-tech enterprise engaged in life science and biotechnology)
WK	CEO	C-BW (a national high-tech enterprise specializing in the R&D, manufacturing, and marketing of high-end human vaccines)
WM	Managing Director	I-FJ (FX Pharma's first new drug innovation fund with incubation model)
WXX	General Manager	C-BX (a developer and supplier of innovative technologies and products for molecular probes and epigenetics)
WY	Deputy General Manager	C-JN (a CRO that provides a full range of clinical development services in line with international standards)
XYT	Chairman	C-BK (a new drug R&D company oriented to clinical needs that applies a variety of technologies to upgrade new and old drugs)
YGM	Former Vice Chancellor	U-CN-ZS (a university in China)
YGM	Chairman	C-WRT (an anti-cancer drug R&D enterprise committed to the clinical transformation of M1 virus to treat tumors)
YXM	General Manager	C-BG (a high-tech enterprise focusing on medical epigenetics and transcriptional regulation research)
ZF	Chairman	C-AZD (a globally renowned CDMO+CRO+CSO company in the medical device industry) ■
ZJX	General Manager	I-NY (an investment fund)
ZR	General Manager	C-HYS (industry-university-research operating unit of a respiratory diseases research center) ■

Note: Organizations with "■" had a second formal interviews.
G - government authority; R - research institution; N - (NGO) industry association; U - university; C - company; I - investment institutions; S - intermediary service agencies.

Table 3.6 Name list of the fifth stage of formal interviews (in 2023, about 1.5 hours/interviewee)

Interviewee	Position	Organization
*HFC	Academician	R-ZH (a local institute of medical research in China)
*JC	Founder	C-YQXXW (a knowledge services platform in the field of scientific instruments)
CC	Executive	G-SWD-GWH (an administration authority) ■
DFD	Vice President of Internal Operations	C-RS (a pharmaceutical company specializing in tumor genetic testing and early cancer screening)
HK	Division Head	G-GD-WJ (an administration authority)
IP	Head of MedCity	N-UK-D (a local investment promotion agency in the UK)
LYD	Chairman	C-TYJS (a state-controlled listed company committed to the development of the pharmaceutical industry and human health, striving to build a Chinese flagship enterprise in the pharmaceutical and health industry)
LYD	General Manager Assistant	C-ZGTY (a state-owned backbone enterprise directly managed by the Chinese central government focusing on medicine and healthcare)

LYL	Executive	G-G (a local government in China)
LYM	Chairman	C-JY (one of the market leaders in China's third-party medical testing industry) ■
MD	Head of CEFC	U-CH-L (a university in Switzerland)
MT	Former Chairman	C-LSBIOP (one of the largest life sciences parks in Europe)
RJ	General Manager	C-SHXSY (an enterprise that invests in professional technical services and projects for the R&D of new drugs)
RJ	Chairman	C-WHGG (a R&D company for biomedical products)
SJB	Deputy Head	G-GDD-GWH (an administration authority) ■
SM	Consul General	G-UK-CG (British Consulate General in China)
TL	Chairman	C-BRTAG (a biomanufacturing process research and training center that provides training courses for local bio-enterprises and a platform for the cultivation of high-end pharmaceutical talents)
WY	Director	R-SH-HS (a local institute of microbiology and infection in China)
WY	Initiator	I-GZ-XJ (a healthcare foundation in China)
XAL	President (former member of the Bio Island Planning Expert Group)	U-CN-B (a Chinese medicine university in China) ■
XY	CEO	C-KF (a biopharmaceutical company dedicated to R&D, manufacturing, and commercialization of innovative antibody drugs affordable to patients worldwide)
XYM	General Manager	C-HB (a company that provides consumables related to laboratory analysis and testing instruments)
YHT	CEO	C-KY (a Hong Kong company that provides investors with early-stage investment opportunities in various categories of medical technology innovation projects)
ZNS	Division Head	R-GZ-HX (a research center in China) ■
ZNS	Division Head	R-GZ (a biotechnology laboratory in China) ■
ZW	Chairman	C-SWD (operating agency of an industrial park) ■
ZWH	Division Head	R-SH-CRB (a medical center in China)

Note: Interviewees with "*" were interviewed for 2 hours; organizations with "■" had a second formal interviews.
G - government authority; R - research institution; N - (NGO) industry association; U - university; C - company; I - investment institutions; S - intermediary service agencies.

3.2.1.4 The second part: focus group

In focus groups, we primarily adopted the approach of expert panel discussions, conducted with 27 experts from 20 different organizations. Chinese scholars and experts specializing in research on industry clusters and COIs were invited, along with a few international scholars. Taking advantage of the opportunity provided by the *Conference of Industry Clusters and Regional Development (ICRD)*, we conducted focus group discussions in two stages, on October 21, 2020 (offline, see Table 3.7 for the detail of the focus group in the first stage) and December 11, 2022 (online, see Table 3.8 for the detail of the focus group in the second stage). The topics included, but were not limited to, "bridging divides and rebuilding bonds: exploring the development of biotechnology and healthcare industrial clusters", "regional innovation systems and industrial cluster transformation and upgrading", and "international frontiers in industrial clusters and regional development." At the conference, the researcher of this thesis made a thematic presentation, introducing the case study of Bio Island and the preliminary interviews and research. It was followed by expert discussions on topics such as the upgrading and transformation of industrial clusters, the enablers of COI development in the biotechnology and healthcare industry and their joint actions, and international cooperation. The discussions were not limited to the Guangzhou International Bio Island. Cases of biotechnology and healthcare industrial parks and COIs in Suzhou, Shenzhen, Shanghai, and other locations were also mentioned.

Table 3.7 Name list of the focus group in the first stage (approx. 5 hours)

Name	Position	Organization
BQ	Fellow	U-CN-JN-F (an institute for monetary and economic studies)
CGZ	Director	U-CN-BJ-U (Department of Urban and Economic Geography, School of Urban and Environmental Sciences)
CQQ	Director of Investment Research	I-QKJX
DJJ	Professor	U-CN-SZ-B (Business School)
HD	Member of the Comprehensive Party Committee	C-SHZJ (a national high-tech park in China)
HYL	Professor	U-CN-ZYDX-A (School of National Administration)
LSG	Professor	U-CN-ZGHY-E (Faculty of Economics)
MLX	Associate Professor	U-CN-ZNCJZF-B (Faculty of Business Administration)
PFH	Associate Professor	U-CN-BJSF-G (Faculty of Geography)
TX	Associate Professor	U-CN-BJ-U (Faculty of Urban and Environmental Sciences)
WJC	Professor	U-CN-BJ-U (Faculty of Urban and Environmental Sciences)
WXB	Dean	R-ZGC (a local bioindustry research institute in China)
ZG	Professor	U-CN-HDSF-U (Institute of Urban Development)
ZHS	Professor	U-CN-BJSF-G (Faculty of Geography)
ZL	Deputy General Manager	C-DX (a national biomedical base in China)

Note: G - government authority; R - research institution; N - (NGO) industry association; U - university; C - company; I - investment institutions; S - intermediary service agencies.

Table 3.8 Name list of the focus group in the second stage (approx. 4.5 hours)

Name	Position	Organization
CXF	Associate Professor	U-CN-HN-H (Research Center for Yellow River Civilization and Sustainable Development)
GQL	Professor	U-CN-DH-M (School of Management)
HHH	Director, Professor	U-CN-DN-E (Group Economic and Industrial Organization Research Center, School of Business and Management)
IM	Professor	U-DE-B (a university in Germany)
LEL	Professor	U-CN-HN-G (Faculty of Geography and Environment)
MCH	Director, Professor	U-CN-HN-H (Research Center for Yellow River Civilization and Sustainable Development)
TX	Associate Professor	U-CN-BJ-U (Faculty of Urban and Environmental Sciences)
WJC	Professor	U-CN-BJ-U (Faculty of Urban and Environmental Sciences)
WS	Professor	U-CN-ZJ-E (Faculty of Earth Sciences)
YFM	Director, Professor	U-CN-GDDX-S (Department of Social and Ecological Civilization)
YHX	Former Dean,	U-CN-SD-M (School of Management)

ZZQ	Professor Fellow	R-ZKY (a science and technology strategy consulting institute in China)

Note: G - government authority; R - research institution; N - (NGO) industry association; U - university; C - company; I - investment institutions; S - intermediary service agencies.

3.2.2 Data Processing

3.2.2.1 Data compilation and initial processing

This step involves the collection and collation of information from official websites, mainstream media reports, internal documents, and historical archives related to Bio Island over the years. Additionally, audio recordings of all interviews (and focus groups) were transcribed into written text and translated into English.

3.2.2.2 Data categorization and analysis

The data were categorized based on the research questions. The results from multiple rounds of interviews/discussions were compiled, compared, and analyzed. We examined the developmental process of Bio Island and the evolutionary stages of the COI to find out key factors of upgrading and transformation in each stage. Based on the interview records, the enablers contributing to the formation of the COI in Bio Island were identified. The enablers mentioned by all interviewees in the five rounds of interviews and two rounds of focus group discussions were identified as core enablers. In addition, we compared the importance rankings of these enablers by different interviewees in an attempt to reveal the reasons behind the variations.

3.2.2.3 Data coding and secondary processing

By comparing the COI components (actors) and behaviors (activities) mentioned in the literature (both Chinese and international studies) with those in the case of the Bio Island, we identified new enablers, changes in existing enablers (e.g., different characteristics and connotations), or differences in enablers' importance rankings, and attempted to find out the underlying reasons.

The Software Xmind was utilized for data coding, further data processing, and the creation of charts.

It is important to note that since Bio Island is a key state-owned bio-industrial base in China, desensitization prior to data processing is necessary, as required by the regulation regarding the processing of internal data of government departments, state-owned enterprises, listed enterprises, and foreign organizations.

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Chapter 4: Field Research and Case Study

We conducted a case study on Bio Island by collecting both external publicly available secondary data and primary data. The primary data was collected through field research, internal document retrieval, and formal interviews. The summarized findings are as follows.

4.1 Case study - Introduction to the Bio Island

Bio Island, with its full name as "Guangzhou International Bio Island", is situated on an island in the geographical center of Guangzhou (more specifically, in the southeastern part of the city downtown along the back channel development belt of the Pearl River) and covers an area of approximately 1.83 square kilometers (see Figure 4.1).

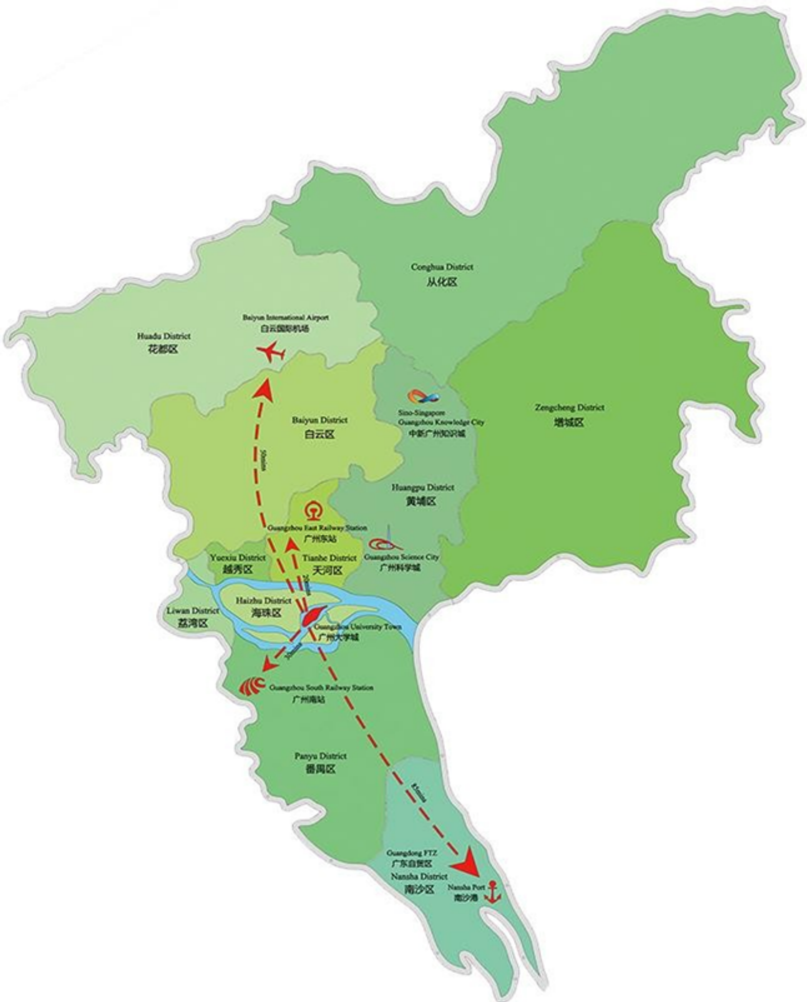

Figure 4.1 Location of Bio Island in the map of Guangzhou City

Source: Guangzhou International Bio Island (2015)

Its development was initially planned by the Guangzhou Municipal Government in 1999. The State Planning Commission (later reorganized as the National Development and Reform Commission) officially confirmed the establishment of this project in 2000, naming it Guangzhou International Bio Island (hereinafter “Bio Island”). In 2006, the National Development and Reform Commission approved it as one of the first national core biotechnology industrial bases. In 2008, the *Outline of the Reform and Development Plan for the Pearl River Delta Region* elevated the Bio Island project to a national strategic level. In July 2011, Bio Island was open officially, welcoming global investment. Its mission is to become a National Biopharmaceutical Policy Innovation Pilot Zone and a world-class R&D center for biopharmaceutical and biosecurity, with world-class standards as benchmarks, cultivating and introducing innovative enterprises, key technologies, and innovative products. Its vision is to become the “World’s Island for Life and Health”, as an innovation partner in the city center, an innovation platform for industrial policies, a carrier for global resource allocation, and an industrial ecosystem for world-class biotechnology innovation.

Since its official opening, Bio Island has gradually established an industry system of life safety, biosecurity, and biopharmaceuticals supported by five main pillars: drug development, stem cells and regenerative medicine, precision medicine, medical devices, and big health. It has become an emerging hub in the biotechnology and healthcare industry with international competitiveness.

Bio Island has gathered more than 500 biotechnology enterprises, including the headquarters of five listed companies: Guangzhou Shengnuo Bio-Pharmaceutical Technology Co., Ltd., Guangzhou Buring Rock Medical Testing Co., Ltd., Guangzhou King Med Testing Center Co., Ltd., Guangzhou Saliai Stem Cell Technology Co., Ltd., and Guangdong Quantum High-Tech Microecological Medical Co., Ltd. Eight Fortune 500 companies have also settled on the island. They are Thermo Fisher’s Precision Medicine Customer Experience Center, the Agilent (Guangzhou) Excellence Customer Experience Center, the Guangzhou Gilead-Richardson Joint Innovation Center, AstraZeneca Southern China headquarters, the Guangzhou Bioprocess Training Institute (the first Bioprocess Training Institute in China, co-established by Cytiva, National Institute for Bioprocessing Research and Training [NIBRT] of Ireland, and Guangzhou High-tech Zone Investment Group Co., Ltd.), the Guangdong-Hong Kong-Macao Greater Bay Area headquarters of Danaher Life Sciences, and the R&D Headquarters of Guangzhou Pharmaceutical Group (ranked 468th in Fortune 500 for 2021).

On Bio Island, there are currently nearly 40 research institutes, a total of 90 laboratories at the state or provincial level, and 36 pharmaceutical clinical institutions. These facilities include the Guangzhou Laboratory, the Bio Island Laboratory, the Human Tissue, Organ Transplantation, and Medical Big Data Center of the National Health Commission of China, the Human Cell Lineage Large Scientific Research Facility, the Guangdong Provincial Academy of Medical Sciences, the Guangzhou Respiratory Health Research Institute, the Life Health and Precision Medicine Research Institute of the First People's Hospital of Guangzhou, the Research Outcome Transformation Center of Sun Yat-sen Memorial Hospital, the Advanced Ophthalmic Diagnosis and Treatment Technology and Equipment Engineering Center in the Guangdong-Hong Kong-Macao Greater Bay Area (Zhongshan Ophthalmic Center, Sun Yat-sen University), the University of Hong Kong (Guangzhou) Innovation Institute, the Guangdong-Hong Kong-Macao Greater Bay Area High-Performance Medical Device Innovation Center, the BeiGene Innovative Center, the Lvye & Shin Nippon Regenerative Medicine Center, the Richardson Medical Mycology Laboratory, and the Merck China Innovation Hub.

Since 2017, Bio Island has been hosting the China Bioindustry Convention in Guangzhou. It has also initiated the Guanzhou International Bio Forum (referred to as the "Guanzhou Forum"), which has become a significant platform for biotechnology investment promotion, talent attraction, and industrial resource integration in Guangzhou or even the Guangdong-Hong Kong-Macau Big Bay Area. From 2017 to 2022, six forums have been successfully held, contributing greatly to promoting international exchanges and cooperation in the biotechnology and healthcare industry.

Bio Island has also established international cooperation platforms such as the "UK-China Bridge" and the "Israel-China Bridge". Through these platforms, it has engaged in technology and industry exchanges and collaborations with government institutions, industry alliances, associations, and companies from the United States, the United Kingdom, Canada, Israel, Germany, Switzerland, and Cuba.

It took as long as 12 years from the initial planning (in 1999) to the official announcement of Bio Island's opening (on July 8th, 2011), and until now (as of 2023), another 12 years have passed. How did Bio Island manage to achieve a breakthrough in attracting investment from "zero"? How did it evolve from 0 to 1, and then from 1 to N? What are the core enablers of the formation of a COI in the biotechnology and healthcare industry? How do these core enablers have joint action with each other to impact the formation and development of the COI? Furthermore, how do international exchange and cooperation positively affect the transformation and upgrading of the COI? To address these questions, this study conducted field research, formal interviews, and focus group discussions. The following section presents the analysis and discussion of the findings.

4.2 Analysis of research findings

Based on the information gathered from the "formal interviews" and "focus group discussions" conducted from 2019 to 2023, the following is an analysis of the findings.

4.2.1 Core enablers of the formation of the Bio Island COI and their joint actions

Regarding the "enablers of COI formation and development", the keywords mentioned by the interviewees include technology, enterprises, capital, talent, government, intermediaries and professional service providers, policies, innovation environment, universities, research institutions, industry associations and alliances, and international exchange and cooperation. According to their ranking, the top 6 enablers are knowledge and technology sources, innovative enterprises, innovative and entrepreneurial talents, technology capital and professional investors, entrepreneurial governments, and professional service providers. They received a high level of consensus and were thus considered indispensable "core enablers" for the formation of a COI (see Figure 4.2 and Figure 4.3).

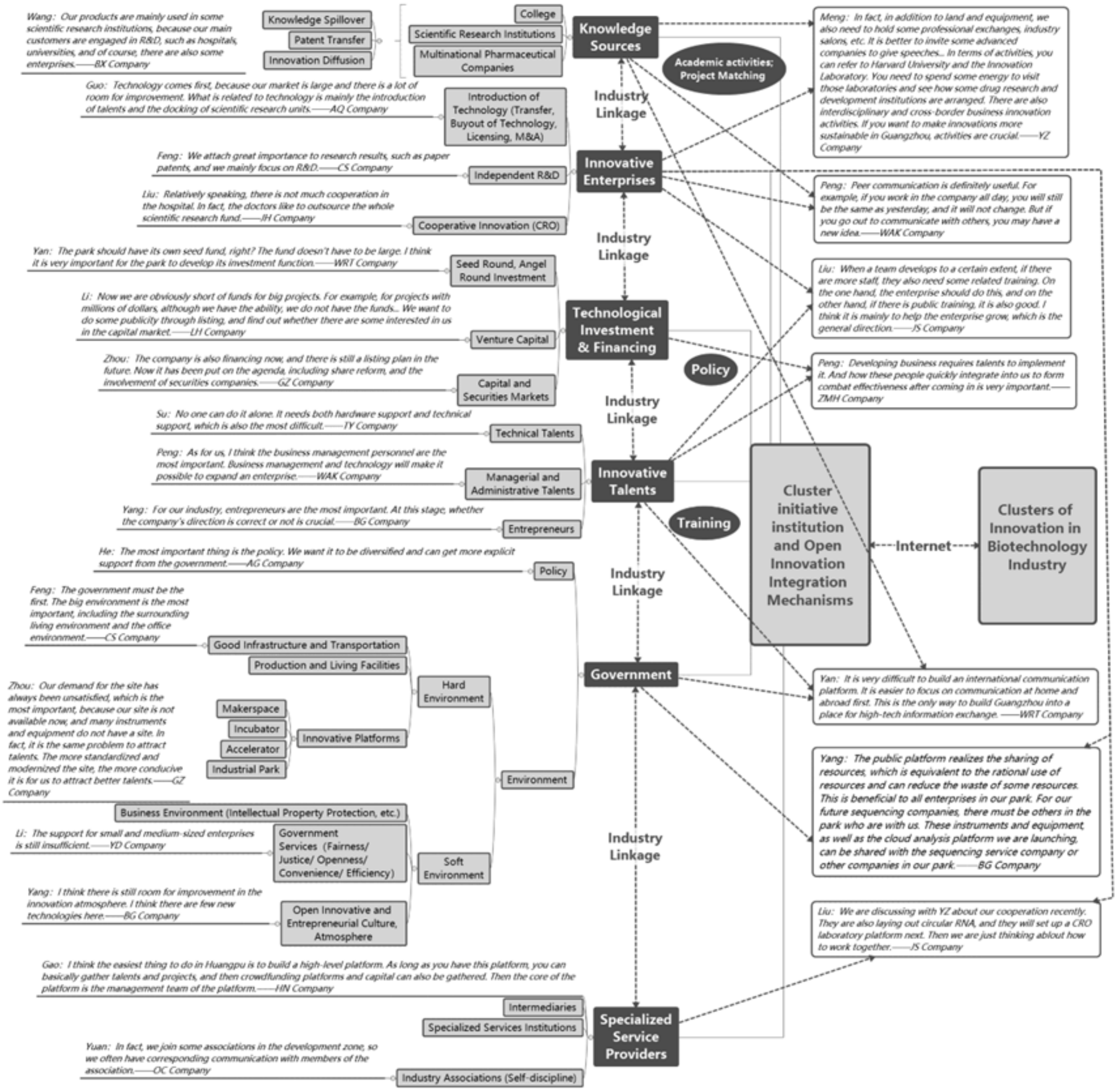

Figure 4.2 Core enablers of the COI and their joint actions

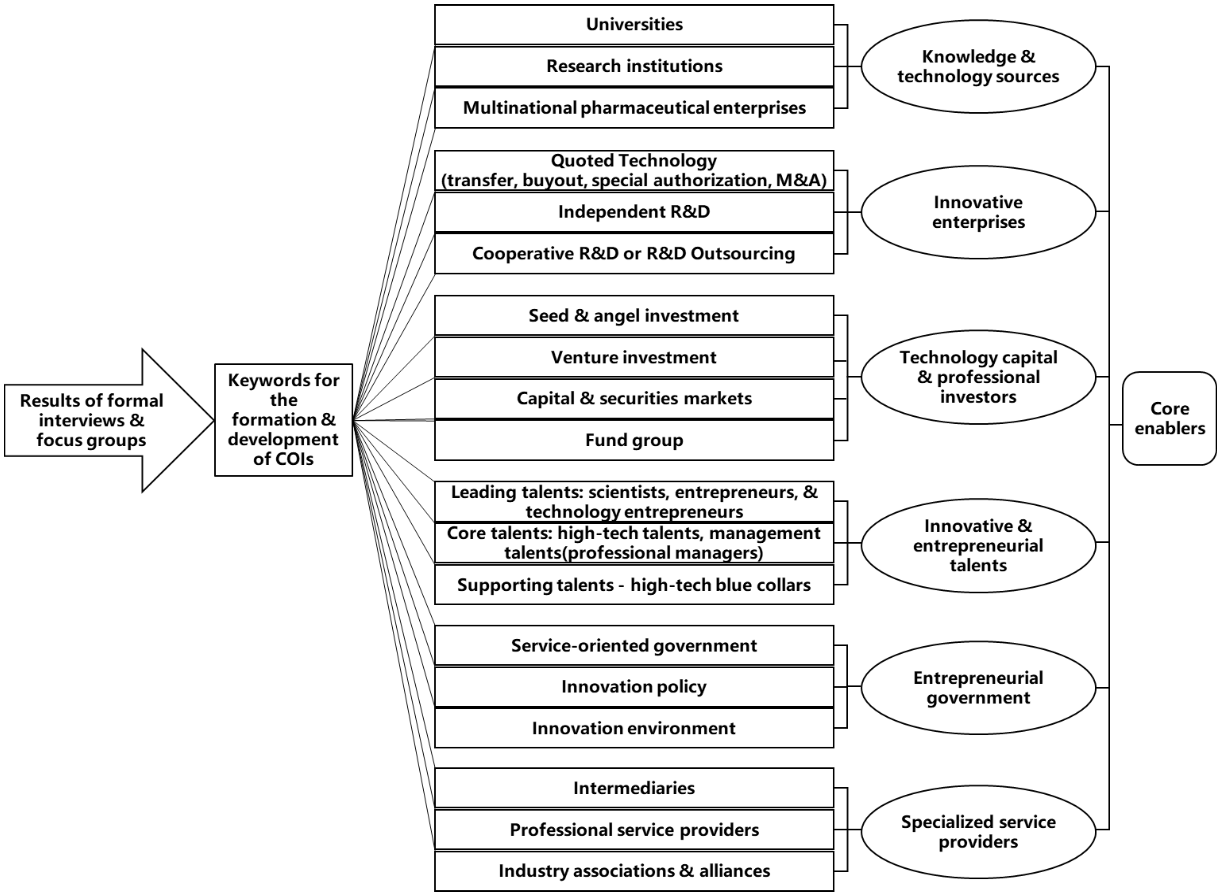

Figure 4.3 Indispensable “core enablers” for the formation of a COI

Due to the large number of interviewees, it is not possible to include all the views in one graph. Therefore, only some of the representative statements have been selected and quoted.

In the following, based on the views in formal interviews and focus groups, we will analyze each of the six core enablers for Bio Island’s transformation and upgrading into a COI.

4.2.1.1 Knowledge and technology sources

Interviewees from enterprises emphasized that “technology innovation” is pivotal for a company’s survival and development, regardless of whether these technologies are developed independently or obtained through external collaborations.

Interviewees with university and research institution backgrounds believed that the primary source of innovative technology comes from universities and research institutions. For instance, companies such as GS, JY, DA, and HY, which originated from prestigious universities in Guangzhou, obtained their initial technological basis from university licensing and have been in close collaborations with universities to this day.

Academician HFC perceived that “*innovation is a process of scientific discovery and knowledge creation. As a result, research institutions must collaborate closely with modern technology industrial parks that facilitate the commercialization and industrialization of* *research outcomes. This collaboration goes beyond the traditional research-only model of research institutions, nor the conventional model of production-oriented industrial parks. The exact approach to this integration and collaboration requires innovative exploration and experimentation*."

RJL stated in an interview that "*in Chinese public universities and research institutions, the emphasis on technological innovation is primarily from the perspective of basic research. Although some innovation is goal-oriented, a significant majority of these goals revolve around completing 'projects' (often funded by the government) and making publications. Universities and research institutions in China are mostly state-owned or non-profit organizations. They are led by non-academics and thus operate under various constraints, with bureaucracy often taking precedence over innovation. In recent years, the government has encouraged research personnel and teams that possess core technologies to engage in entrepreneurship, but there are still many institutional constraints. Consequently, there is a lack of market-driven incentives. Furthermore, many research personnel in public organizations lack experience in business and market-oriented practices.*"

CXW believed that "*national-level research institutions primarily invest in basic research. However, the key challenge lies in the transformation of research outcomes and enhancing the transformation rate. If invention and creation represent the leap from 0 to 1, then the successful transformation of research outcomes signifies the transition from 1 to N.*"

Professor WJC pointed out that "*innovation not only encompasses knowledge creation, technology innovation, and product innovation but also requires 'market value'. The process of transforming innovation outcomes into tangible results is accomplished by 'entrepreneurs' who serve as integrators of innovation resources. Enterprises are the driving force behind innovation. The sources of innovative technology are not only found in universities and research institutions but also in enterprises.*"

EB indicated that "*the sources of innovative technology for multinational pharmaceutical companies are substantial. In 2020, the total R&D expenditure of the top 10 pharmaceutical companies amounted to a staggering USD 96 billion, with an average R&D investment ratio of 20.23%, showing an increase compared to 2019 (USD 82 billion; 18.80%).*"

SY asserts that: "*due to the lengthy and capital-intensive nature of new drug development, especially the substantial investment and high risks associated with phase three clinical trials, multinational pharmaceutical enterprises have adjusted their strategies. In addition to independent R&D, they have begun to acquire innovation outcomes (technology and patent licensing) from small and medium-sized enterprises (SMEs). Sometimes they even utilize* *equity investments, mergers, and acquisitions to gain control over innovative technologies and talent pools. In this way, SMEs have also become significant sources of technological innovation. Multinational companies provide these SMEs with financial support and bring them benefits such as endorsement as industry leaders, accelerated project approvals by medical administration authorities, best practices in technology commercialization and industrialization, and access to global market channels.*"

In the interviews, enterprise directors generally agreed that "*only when technology is transformed into products and gains recognition from the market and customers, thus creating market and customer value, can it generate income and economic value*." However, interviewees from investment institutions expressed that "*entrepreneurial teams must pursue maximum technological innovation on the basis of pursuing maximum profit*."

4.2.1.2 Innovative enterprises

CC emphasized that "*in 2008, Bio Island was incorporated into the Outline of the Pearl River Delta Development Plan and became part of a national strategy.*" This plan explicitly highlights the significance of enterprises as the main actors of innovation. SXW further stated that "*the 20th National CPC Congress proposed 'reinforcing deep integration between industry, academia, and research with enterprises taking the lead, enhancing goal-oriented approaches, and raising the level of technology transformation and industrialization. This also entails bolstering the status of enterprises as the main force of technological innovation, with technology-driven key enterprises taking the leading and supporting role, creating a favorable environment for the growth of technology-oriented SMEs, and promoting the comprehensive integration of innovation chains, industrial chains, funding chains, and talent chains.*" These statements have highlighted the strategic importance of strengthening the role of enterprises in technological innovation, deepened our understanding of the law of innovation development, and refined the layout of the strategic system for innovation-driven development.

The director of a local government's science and technology department referred to the remarks made by Wang Zhigang, the former Minister of Science and Technology of China: The 20th National CPC Congress emphasized that "*enterprises are the main actors of technological innovation*." "*Enterprises are not only the main actors in technological innovation, responsible for solving technical problems; they are also at the forefront of scientific research and are expected to propose new methods, new scientific paradigms, new research areas, explanations for new phenomena, and strategies for transforming these into* *technology and high-tech industries*."

The term "enterprises" here does not refer to traditional production-oriented companies but rather to those dedicated to continuous innovation, with R&D investment exceeding the industry average, and possessing core and industry-leading technologies (domestically or even internationally). We refer to such enterprises as "innovative enterprises." This category includes domestic and foreign companies, multinational corporations, and SMEs in biotechnology. The classification is based on innovation capacity rather than company size.

4.2.1.3 Technology capital and professional investors

WK said that "*the biotechnology industry is a 'slow industry' with long product development cycles. Therefore, capital, especially venture capital, plays a crucial role in fostering innovation.*"

YHT believed that "*it is not sufficient to say capital or venture capital are enablers of a COI. That is because the actual contributors and decision-makers of some capital (funds) are from traditional industries. For example, funds from Hong Kong often have real estate backgrounds; they lack professional judgment regarding the characteristics of high-tech industries, especially the biotechnology industry, and do not have sufficient patience. In comparison, Singapore has more venture capital funds and professional investors focused on biotechnology and high-tech. Hence, it is not simply about capital or venture capital; differentiations should be made.*"

HHX shared a similar viewpoint: "*Many fund contributors were previously engaged in traditional industries such as real estate, retail, and foreign trade. After making a fortune, they shifted to 'capital operations,' often by establishing their own sole-funded fund companies or becoming 'Limited Partner (LP)' of a 'Private Equity (PE). They are not professional investors. In China, we refer to them as 'entrepreneur-investors'. On March 28, 2017, renowned financial writer Wu Xiaobo published a book titled From Today On, there is a Type of Entrepreneur Called Entrepreneur-Investor. The entrepreneur-investor is a new species combining 'entrepreneur' and 'investor'. They embody a dual-role nature, contributing to their beloved real industries for iterative progress and sustainable development, while also participating in the 'irrational prosperity' of the capital market, increasing their wealth through investment. They are unfamiliar with and do not understand biotechnology. They often apply their experience from traditional industries to biotechnology enterprises, resulting in situations of 'different trades, worlds apart' and 'outsiders guiding insiders,' impacting and intervening in the decision-making of professional fund management* *teams. Therefore, those truly promoting innovation are professional investors.*"

WM believed that "*promoting a COI cannot rely on just one or two funds, but rather a group of tech-funds, ranging from angel investments, series A, B, and C funds, to pre-IPO financing, to meet the financing needs of biotechnology companies at different stages and throughout their lifecycle, forming a seamless connection.*"

HD expressed that "*most managers in investment companies come from financial, accounting, and legal backgrounds, lacking expertise in biotechnology and healthcare. During the investment process, they may impose financial requirements and provide 'non-professional' advice to entrepreneurial and innovative teams, which cannot promote innovation and may sometimes even hinder it.*" YJH stated that "*some investors, after gaining control of biotechnology companies, drastically reduced R&D investments to cut costs, which led to a decline in the company's innovation capabilities and the exclusion of the founding team, serving as an example of hindering innovation.*"

SXW mentioned that "*over the years, Guangzhou Development Zone has formulated numerous policies to attract investments. The Three-Year Action Plan for High-Quality Development of the Biopharmaceutical Industry in Huangpu District and Guangzhou Development Zone (2021-2023) highlighted the focus on 'attracting high-quality investment institutions and investors and supporting outstanding entrepreneurs to transition into venture capitalists.' There are several such cases in the Guangzhou Development Zone, including companies like Daan Gene, XPH Pharmaceuticals, and Bio-thera. They are insider 'entrepreneur-investors' with professional knowledge.*"

JJJ mentioned that "*our company had previously been securing funding in the United States. However, since we settled in Bio Island, we have had more opportunities to engage with local investors. Our new drug for cancer treatment received an investment of RMB 40 million yuan (about 513 million EUR) from a local listed company.*" There are many cases like these in Bio Island.

ZH mentioned that "*during the early stages of Bio Island, to address enterprises' financing challenge, the management team of Bio Island drafted a policy proposal and submitted it to the Development Zone Administration Committee. After these policies were formulated and issued, they successfully attracted more than 70 technology and innovation investment fund companies from across China and overseas to settle in Bio Island, forming a 'tech-innovation investment fund cluster'.*" CC figured that "*Bio Island has evolved into a place of high interest for venture capital and professional investors. In the past, companies had to 'go out' to actively seek investors, but now investors are 'coming in' and proactively* *seeking projects within Bio Island. This suggests that compared to other high-tech parks, Bio Island offers more opportunities for companies to connect with investors and secure investments. Moreover, from the perspective of enterprises, the investors coming to Bio Island are specialized 'tech-innovation investment' capital with a focus on biotechnology investment. They possess a deep understanding of the biotechnology industry and abundant investment experience. Besides providing financial support, they can offer additional value to enterprises, such as assisting in finding and recommending partners, expanding market reach, and facilitating communication with the government. From the investors' point of view, Bio Island enforces the strictest approval criteria in Guangdong Province and rigorously screens incoming enterprises, resulting in a selection process that favors the best projects. Investors seeking projects within Bio Island benefit from this stringent selection process as they are choosing "the best among the best". Currently, investors scouting projects in Bio Island are not only from Guangzhou but from all across China and even other countries around the world, leading to the formation of a virtuous cycle where the integration of the "capital chain" and "innovation chain" is taking place.*"

4.2.1.4 Innovative and entrepreneurial talents

Throughout the interviews, the interviewees, regardless of being government officials, university and research institution representatives, or company directors, consistently emphasized the significance of talents. As LYL mentioned, "*President Xi Jinping pointed out that 'talents are the primary resource.' They can be categorized into three types: leading talents, core talents, and supporting talents.*"

According to the head of GDD, a technology administration authority, "*the Three-Year Action Plan for the High-Quality Development of the Biopharmaceutical Industry in Huangpu District and Guangzhou Development Zone (2021-2023) emphasized the promotion of talent aggregation and development in the biopharmaceutical sector. This involves vigorously introducing strategic scientists, highly skilled talents, and specialized core technology talents, enhancing collaboration between government, universities, and enterprises, and attempting to cultivate a group of scientific entrepreneurs with both expertise in science and technology and knowledge of business management.*

LJ pointed out that, the Ministry of Science and Technology's notification regarding the issuance of the *13th Five-Year Plan (2016-2020) for National Scientific and Technological Talent Development* emphasized the cultivation of a significant number of specialized technical talents, digital finance talents, and innovative entrepreneurs oriented towards the front lines of production in key industries that need to be developed urgently. The plan aims to create a high-level innovative talent pool for science and technology, strengthen the support for the development of strategic scientists, distinguished scientists, leading talents in technology, and innovation teams, and enhance the development of industrial technical talents, digital finance talents, and technology-driven entrepreneurs. The *14th Five-Year Plan (2021-2025) for National Talent Development* stated that during this period, talent development should have priorities and follow a phased advancement, with the aim to accelerate the establishment of global key talent centers and innovation hubs. From the government documents and talent development plans quoted by the interviewees, it is evident that at the national level, China is making efforts to cultivate and develop a multi-tiered innovative talent workforce.

Furthermore, it is noteworthy that the statement mentioned above regarding "the cultivation of a significant number of specialized technical talents oriented towards the front lines of production" aligns with the concept of "high-tech blue-collars" raised by an interviewee from Switzerland. MT, former chairman of the largest life science park in Europe, noted that "*among the top five global biopharmaceutical companies, two are in Switzerland. The Swiss Biotech Report 2023, which is an outcome of the collaborative efforts of the Swiss Biotech Association, Ernst & Young Consulting, and eight other partner institutions, concluded that as of the end of 2022, 20% of European biotechnology companies were headquartered in Switzerland. That is not solely due to the pool of high-end technological innovation talents in the country, but also because Switzerland has the world's highest density of high-tech blue-collars per square kilometer. In fact, when turning 'sample' into 'product', the blue-collars on the frontlines often play an 'unexpectedly pivotal' role in the process and technological innovation.*" This dynamic also constitutes a competitive advantage that Guangzhou and Bio Island should focus on cultivating (which may also be applicable to COIs in other Chinese cities).

In the interviews, directors of companies at different development stages showed varying opinions in subcategories of innovative talents and their ranking of relevance. For instance, those from startups considered technical talents the most significant, given that their products are still in the R&D stage. As companies grow in scale, progressing through stages such as pilot testing and production, the demand for managerial talents and high-tech blue-collars increases. Therefore, companies at later stages have a higher demand for talents in areas such as marketing, sales, business development, and customer services.

According to ZD, "*Those returned to China from overseas are also significant* *contributors to innovation. They constitute a special subgroup of the talent contributing to the COIs in the biotechnology industry.*" Since 1978, a cumulative total of 6.25 million individuals have pursued education abroad, and after completing their studies, nearly 5 million have decided to return to China for career development, accounting for around 80%. Since the 18th National CPC Congress (convened on November 8, 2012), the number of returned overseas students has been increasing notably, and approximately 3.41 million individuals have returned to China for career development, accounting for over 80% of the cumulative total number of returned overseas students of all times (Globalization Think Tank & Bank of China, 2022).

LYL mentioned his involvement in the founding of the China International Talent Exchange Meeting for Science and Technology (CITEMST) in Guangzhou in 1998. According to LXL, "*The event has been renowned as the 'Intelligence Canton Fair'. Incomplete records indicate that the successive sessions of the event have attracted nearly 50,000 high-level talents from both China and overseas, encompassing over 140 countries and regions globally. This initiative has led to the initiation of nearly 50,000 projects across China. Many of today's publicly listed enterprises were established by "returnees" who embarked on their entrepreneurial journeys years ago upon returning to China.*"

ZNS agreed that "*innovative talent is one of the core enablers of innovation.*" Firstly, what is innovation? In ZNS's view, only when the efforts of discovery and invention, throughout multiple stages, transform into tangible societal and economic benefits, both of which are indispensable, can it be called "true innovation".

Secondly, the "drive for innovation." There's a saying that "*passion is the best teacher, far exceeding a sense of duty.*" However, ZNS believed that this saying only captures half of the truth. He recounted the establishment of the malaria prevention drug research project in 1967 at Peking Union Medical College: "*The team led by Tu Youyou progressed from the discovery of artemisinin to collaborative advancements resulting in dihydroartemisinin, and eventually, the development of the fourth-generation artemisinin compound drug. This achievement led to the creation of a standard drug for malaria treatment benefiting the whole world, and Tu Youyou was awarded the 2015 Nobel Prize in Physiology or Medicine. It took 48 years of effort, and where did the drive come from? I believe it is from a sense of mission. Oftentimes, scientists develop curiosity in research, which evolves into a passion and then into a pursuit. Innovation takes place only when one perceives the mission of 'I must do it'. In the current international context, the motivation to enhance scientific qualities is not only curiosity but more importantly, a sense of mission.*"

Thirdly, speaking about the development of the capabilities of innovative talents, he believed that, "*Young people who merely focus on tasks may not be able to make great achievements. What I admire most is the ambition to continuously improve and the desire to make changes by seeking solutions - these are essential qualities and drivers. Once you have identified a problem or direction, you must keep going forward. To eventually achieve significant accomplishments, collaboration is crucial. Different entities possess distinct strengths. Great achievements can be realized only through coordination and collaboration.*"

4.2.1.5 Entrepreneurial governments

LYL pointed out, "*The government plays a vital role in guiding innovation and promoting economic growth. Entrepreneurial governments serve as both the formulators and promoters of national and regional innovation strategies. Governments have been playing a pivotal role in the development of many key technologies, which later turned into innovative breakthroughs with the engagement of private entities.*" Li Keqiang, Former Premier of China, articulated a discourse on the "entrepreneurial government": "*We are committed to building an entrepreneurial state, and the top priority is to streamline administration and delegate government powers. This will effectively give power to the market and reduce market entry barriers. It means constructing mechanisms that incentivize innovation, fostering an environment that safeguards innovation, and developing an innovation-driven economy*."

Many interviewees expressed that Bio Island's achievement of significant milestones over the past decade was due to "opportunities of the times" and "government's support." The development of the bioeconomy era has given rise to a technological revolution. China, from the central to local governments, has attached great importance to the development of biotechnology and the healthcare industry, issuing relevant plans and support policies. To foster the high-quality and high-speed development of China's bioeconomy and bio-industry, there is an urgent need for the transformation and upgrading of biotechnology industrial clusters. The following is based on interviews with various levels of relevant government authorities in biotechnology and healthcare, such as the National Development and Reform Commission, the National Medical Products Administration, the National Health Commission, the Ministry of Industry and Information Technology, and the Science and Technology Bureau. In addition to compiling the interview recordings, we also collected and analyzed relevant documents and information mentioned by the interviewees.

According to FW, "*On November 5, 2022, Mr. Bi Jingquan, former head of the National Medical Products Administration (NMPA) stated: 'Over the past decade, China has achieved* *significant accomplishments in biopharmaceutical innovation. The number of new drugs approved for market release in China accounts for about 15% of the global total. The number of new drugs developed by local enterprises accounts for around 33% globally. With more than 5,500 innovative biopharmaceutical projects in clinical trials, China has become an innovation-driven nation'."*

According to XZ, "*The ninth chapter of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China (2021-2025) and the Outline of Vision and Objectives for 2035 (referred to as the 14th Five-Year Plan) explicitly defined the objective of 'promoting the integrated, clustered, and ecologically sustainable development of strategic emerging industries, and increasing the added value of these industries to more than 17% of GDP'. On May 10, 2021, the National Development and Reform Commission officially released the 14th Five-Year Plan for the Development of the Bioeconomy, marking China's first top-level design in bioeconomy, aiming to steadily increase the contribution of the bioeconomy's value-added to China's GDP. The term 'innovation' appeared a total of 86 times throughout the entire text, highlighting the continuous dynamic of innovation-driven forces as a major focus for the development of the bioeconomy during the 14th Five-Year Plan period. The Plan also underscored 'advancing the development of national strategic emerging industrial clusters, establishing mechanisms for sound management and specialized advancement of industrial clusters, constructing comprehensive innovation and public service complexes, and creating a group of distinctive, complementary, and well-structured driving forces for the growth of strategic emerging industries'*."

According to LJ and CWQ, directors of local technology authorities, in 2013, the Ministry of Science and Technology of China officially launched the pilot project for innovative industrial clusters. By then, China had already established 109 such clusters nationwide, among which, 95 were located in national high-tech zones, accounting for 87% of the total. In April 2020, the Torch Center of the Ministry of Science and Technology issued the *Opinions on Promoting the High-quality Development of Innovative Industrial Clusters*, proposing the construction of 100 national-level innovative industrial clusters with trillion-yuan or billion-yuan scales, based on existing pilot projects and cluster cultivation efforts, giving full play to the clustering effect of national high-tech zones. These clusters are expected to possess key core technologies, have comprehensive industrial technology systems, foster integrated development of large, medium, and small enterprises, and hold leading positions in China and internationally.

According to TGK, "*In recent years, besides industries' development, the Ministry of*

Industry and Information Technology has also focused on the cultivation of industrial clusters, resulting in promising high-level and distinctive biotechnology industrial clusters and COIs in regions like the Beijing-Tianjin-Hebei area, the Yangtze River Delta, and the Pearl River Delta. China has built a strong foundation for accelerated development and advancement of the bio-industry. In 2020, Guangdong Province issued an action plan for 20 strategic industrial clusters, including the strategic pillar industrial cluster of biopharmaceuticals and healthcare. The Guangdong Province Action Plan for the Development of Strategic Pillar Industrial Cluster of Biopharmaceuticals and Healthcare (2021-2025) aims to achieve an industry revenue of RMB one trillion yuan by 2025 (about 129.88 billion EUR). During the 13th Five-Year Plan period (2016-2020), the annual average growth of Guangdong's biopharmaceutical industry reached 13.7%, surpassing the province's GDP compound annual growth rate for the same period. As of October 2022, Guangdong Province had over 90,000 operating enterprises in the biopharmaceutical industry chain. In 2022, the revenue of Guangdong's biopharmaceutical and healthcare industrial cluster reached RMB 411.28 billion yuan (about 53.42 billion EUR), a year-on-year increase of 14.71%, solidifying its national leading position in the biopharmaceutical industry."

Drawing from data provided by the Guangzhou Development and Reform Commission and the Guangzhou Municipal Bureau of Industry and Information Technology, the biopharmaceutical industry in Guangzhou has seen an average annual growth of around 10%. According to incomplete statistics, from 2019 to 2021, the number of biopharmaceutical enterprises in Guangzhou increased from over 3,800 to over 6,400, ranking third in China. In 2020, Guangzhou's biopharmaceutical and healthcare industry reached a value of RMB 131.8 billion yuan (about 16.87 billion EUR). According to the *14th Five-Year Plan for the Development of Strategic Emerging Industries in Guangzhou*, the added value of the biopharmaceutical and healthcare industry is targeted to reach RMB 210 billion yuan (about 27 billion EUR) by 2025. In terms of growth momentum, in recent years, Guangzhou's biopharmaceutical industry has maintained an annual growth rate of around 10%. Guangzhou's biopharmaceutical industrial cluster is the only strategic emerging industrial cluster in Guangdong Province that has received recognition and appraisal from the State Council for three consecutive years.

Entrepreneurial government serves as a driver for industry guidance, knowledge dissemination, innovation diffusion, and resource mobilization. Throughout the interview, we identified a highly representative comprehensive case. ZL, Chairman of HX Biotech Company, expressed that, "*In recent years, the government has consistently encouraged* *innovation and provided enterprises with clear directions for innovation. Initially, HX Biotech Company primarily engaged in the sales agency of anti-cancer drugs, possessing a sales network covering over 3000 hospitals across China. However, due to healthcare and procurement reforms in recent years, the company has embarked on a transformation journey. It has increased its investment in R&D while seeking new opportunities. We initially considered anti-cancer drugs but faced challenges with high investment costs and lengthy development cycles. After relocating the company's headquarters to Bio Island, we acknowledged that the island's industry planning favored the medical device segment, which inspired the company to shift its focus toward medical devices. Subsequently, we attended the 'UK-China Bridge' Open Innovation Workshop organized by Bio Island, where we were able to match a number of UK projects in a low-cost and efficient manner. Some collaborations involved patent licensing, while others were about establishing joint ventures. Through the 'UK-China Bridge' platform, the company also established connections with other biotechnology enterprises in Bio Island and the Guangzhou Development Zone, such as WL, a medical company with prowess in technical innovation. Our collaborations with WL Medical Company have led to significant achievements, particularly in the field of rehabilitation medical devices, enabling the creation of a closed loop encompassing R&D, production, and service. The integration of products and application scenarios has shifted the company's focus from mere product sales to a comprehensive 'product-service' approach."*

LZR, the founder of WL Medical, expressed that, "*I was previously serving as the Chief Engineer of a renowned state-owned enterprise. When embarking on the entrepreneurial journey, I experienced a period of confusion, pondering over how to effectively amalgamate our core competencies with market demands and select the right trajectory. The turning point came when we participated in the 'UK-China Bridge' event organized by Bio Island. During this event, executives of Bio Island and representatives of UK companies shed light on the developmental trends within the biotechnology and healthcare industries, which inspired us to leverage our existing expertise in digitalization and artificial intelligence to venture into the fields of medical devices and digital healthcare. At the event, we also got to know ZL, chairman of HX Company. Recognizing our strengths in R&D and weaknesses in marketing and sales, we found an ideal match for collaboration with HX Company, which resulted in great synergies where 1+1>2. This transition demonstrates a shift from technical innovation to business model innovation."*

The interviewees from enterprises commonly held the view that since the biotechnology and healthcare industry is strictly regulated, the government's stance on innovation plays a crucial role in the development of industrial clusters and COIs. A prevalent sentiment expressed is that the new product approval process is too long.

As CC mentioned, "*An entrepreneurial government should also be a service-oriented government, transitioning from a regulatory role to a service role to help businesses tackle challenges that arise during development*." The local government has formed a "special task force" to advance early and pilot implementation of innovation policies on Bio Island. On July 13th, 2023, the Guangzhou Development Zone signed the *Agreement on Jointly Promoting Reform and Innovation Cooperation and Construction of Biopharmaceutical Pilot Zone* with the Guangdong Medical Products Administration. With the signing of this agreement, three major technical support institutions of the Guangdong Medical Products Administration have converged within the Guangzhou Development Zone. This initiative ensured that enterprises within the zone could access pharmaceutical and medical device-related evaluation, inspection, and testing services conveniently, right at their doorstep. This is an innovative and pragmatic approach by local government to address business challenges.

Reflecting on the developmental journey of Bio Island, ZH noted, "*The formation of the COI in Bio Island has similar evolutionary stages of other high-tech parks in China: from 'enterprises flocking together' to 'industrial agglomeration', to 'industrial clusters', and to 'COIs'*." However, there is a difference in approach. When making strategic planning for Bio Island, the first General Manager of Bio Island Company had already acknowledged that the development of Bio Island could not merely rely on preferential policies. He put forth the idea that "*any successful project would require three key enablers - 'technology', 'capital', and 'talent'*", and that the development strategy needed to be based on a combination of "government-guided and market-led" principles, with a focus on "technology-driven, capital-propelled, talent-supported" approaches, emphasizing the adoption of a rigorous "investment promotion" strategy.

Bio Island's journey of over a decade has proven this decision correct. This approach has brought about at least three benefits: First, it prevented enterprises that were merely "policy-driven tenants". Second, through stringent screening, the projects and enterprises approved to enter Bio Island are indeed of top quality and have achieved sustained and positive growth. Third, these carefully selected enterprises have brought technology and attracted talent, capital, and suppliers to Bio Island, resulting in great synergies, which have significantly accelerated the transformation and upgrading of the COI. Thus, the strategic thinking of entrepreneurial government can largely determine the outcome of high-tech parks' development over the next decade and beyond.

4.2.1.6 Professional service providers

Professional service providers have become integral components of Bio Island and the COI. Many of them are providers directly related to the biotechnology enterprises and industry. For example, according to ZF's introduction, their company is a global medical device technology and service provider, and its mission is to facilitate and accelerate the R&D, clinical trials, product design, and manufacturing of medical devices by leveraging their expertise in the field and their global network. ZF strongly agreed with the vision articulated over a decade ago by Bio Island's first General Manager that "*China will become the global center for intelligent manufacturing of medical devices, with Guangdong at its heart.*" Recognizing Bio Island's focus and the formation of the COI in this segment, ZF's company decided to move its headquarters to Bio Island. At the same time, they also brought long-term partnership head-hunting firms and financial consulting firms to Bio Island in order to provide comprehensive services to their clients.

According to TL, C-BRTAG Training Center is a biopharmaceutical process talent training center jointly established by the local government, the National Institute for Bioprocessing Research and Training (NIBRT) of Ireland, and Company C, a leading company in the field of life sciences. More than 75% of the biopharmaceutical drugs approved by the FDA of the United States are produced using Company C's products and technologies. This training center began offering courses in March 2020 and has organized over 40 events until today. From the feedback of the trainees, it is evident that such professional service providers play a significant role in promoting technical innovation, process improvement, and talent development within the COI through hands-on training. Moreover, they facilitate "knowledge spill-over" and "innovation diffusion," acting as a hub centered around Guangzhou (Bio Island) that drives innovation in Southern China and the Guangdong-Hong Kong-Macao Greater Bay Area.

HD introduced that pharmaceutical CXOs are outsourcing organizations with high levels of expertise and specialization, mainly including CRO (contract research organization), CMO/CDMO (contract development and manufacturing organization), and CSO (contract sales organization), providing professional services for biopharmaceutical enterprises such as research outsourcing, production outsourcing, and sales outsourcing, respectively. CXOs in the COI not only function as professional service providers but also play a role in resource linkages. They benefit resident organizations and innovative enterprises in terms of clinical resources, production resources, outcome delivery, technical consultation, and knowledge repositories (knowledge clusters), facilitating the rapid assimilation of processes, lowering entry costs, and enabling access to market resources.

In addition to the highly specialized professional service providers mentioned above, there are providers of other commercial and technological services within the COI, such as services related to intellectual property protection, policy application support, talent recruitment, legal and accounting consulting, financing, and IPO, and even life-related services like assisting foreign executives with housing hunting and children's enrollment in international schools. Due to the limited space on Bio Island, these third-party service providers do not necessarily need to be located within the Island. Experts in the focus group discussion suggested that these third-party services of business and technology support benefit from the well-developed service industry in Guangzhou, a metropolitan area, and the Guangdong-Hong Kong-Macao Greater Bay Area, serving as necessary and valuable supplements to the COI's services.

4.2.2 International exchange and cooperation's impact on the formation of the Bio Island COI

During the interviews, we learned that China had become the second-largest pharmaceutical consumer market and the first-largest exporter of active pharmaceutical ingredients (APIs) in the world. More and more biotechnology enterprises from developed countries and globally renowned biotechnology enterprises are gradually transferring their upstream R&D sites and some medium- and high-end technologies to China, continuously intensifying their cooperation with China. At the same time, the Chinese government adheres to the opening-up policy, encouraging enterprises to "go out and bring in".

4.2.2.1 "International bridges"

Bio Island has established "international bridges" programs, initiating technological and industrial exchange and cooperation with various countries and regions, such as the UK, Israel, the US, Canada, Germany, Switzerland, and Cuba. In the following, we will focus on the "UK-China Bridge Open Innovation" program.

According to DW, Co-founder of the "UK-China Bridge", "*The UK has been in a leading position in life science research since 1953. Among the world's 100 most essential drugs, over a quarter have been discovered or developed in the UK. Currently, the UK has the second-largest biotechnology industry globally and is the second-largest exporter of pharmaceuticals. China is currently striving to be at the forefront of biotechnology development and is building* *an innovative system. The strengths of the two countries are complementary in this sense. Since the 2008 global financial crisis, many multinational pharmaceutical companies have adjusted their strategies. On the one hand, in order to cut costs, some companies closed their headquarters or R&D sites in Europe and carried out mass layoffs; on the other hand, after resigning or being dismissed, some former executives who were responsible for these technologies started spin-off companies, resulting in a large number of startups. The UK was also impacted at that time, and various UK (government) departments and (non-profit) organizations formed special task forces to seek funding, markets, and technology partners globally for these innovative projects and startups. The 'UK-China Bridge' program emerged in this context, as the UK government began to promote platform-based cooperation between China and the UK in technology innovation and business development, striving to commercialize and industrialize advanced medical and biotechnologies from the UK in China. The plan was to organize at least one 'UK-China Bridge Open Innovation' workshop each year, with the participation of outstanding entrepreneurs, scientists, and clinicians from both China and the UK, aiming to encourage innovation, establish mutual trust, and facilitate business collaboration through efficient and highly interactive conference formats."*

According to SQ (CEO of C-CP), "*In 2011, the UK team signed an agreement with Bio Island, designating the UK Investment and Trade Office (now known as the UK Department for Business and Trade) and the Guangzhou Development Zone Committee as guiding units, agreeing to hold the 'UK-China Open Innovation' workshop on Bio Island each year with a different theme, such as diagnostic technology, innovative technology for oncology treatment, and technology for elderly health.*" As of now, over 200 UK-China collaborative projects have signed memorandums of cooperation, and some have even resulted in joint ventures, engaging in cooperation across various areas, including technology R&D, clinical research, and market development. Furthermore, certain projects have received financial support from the governments of both countries and social capital investments. The "UK-China Bridge Open Innovation" program, as an international platform that assembles the UK's biotechnology and healthcare industry resources with China, aims to create an ecosystem that accelerates the development and commercialization of the UK's medical technologies, bringing new treatment options to patients in China and other countries.

4.2.2.2 The role of returned overseas students and high-level overseas talent in promoting the COI's internationalization

ZD believed that "*returned overseas talents play a crucial role in driving technological* *innovation and COI internationalization in China.*" China's biopharmaceutical industry has witnessed three development stages: In the first stage, a group of local entrepreneurs and returnee scientists brought the knowledge, technology, and experience obtained through studying and working in developed Western countries back to China. Leveraging the fast-following strategies of "me-too" or "me-better", they rapidly founded a group of domestically competitive biotechnology startups. In the last two decades, China's biopharmaceutical enterprises have made significant progress, witnessing the emergence of a multitude of high-quality biopharmaceutical companies. Regarding innovative drugs, Chinese companies have also shifted their strategies from "me-too" and "me-better" towards achieving "best-in-class" and "first-in-class", transitioning from followers and imitators to pioneers and leaders in some segments. Nonetheless, it could not have been achieved without international exchanges and cooperation, which have brought technologies, projects, and talents to China.

4.2.2.3 The role of multinational pharmaceutical companies in promoting local COIs

CK expressed that "*multinational pharmaceutical companies are increasingly focusing on combining global innovation with localization, with AstraZeneca's I-Campus as a good example*" (see Figure 4.4). "*Through AZ's innovation ecosystem, it actively supports the internalization of local enterprises, showcasing Chinese innovative products to the world. AZ is also committed to sharing the Chinese experience worldwide. China's integrated innovation, with nebulization chambers as a good example, has been successfully implemented in multiple countries, benefiting patients worldwide.*"

Figure 4.4 AstraZeneca I·Campus

Source: Compiled based on the information from AstraZeneca

Chapter 5: Discussion

This chapter will summarize and discuss the findings of the literature research, field research, case study, and focus group discussion, in response to the research questions (RQ): RQ1 "What are the core enablers of clusters of innovation (COIs) in the biotechnology and healthcare industry and what joint actions and impact do they have on COIs?" and RQ2 "Do international exchanges and cooperation have a positive impact on fostering the formation and development of COIs?". We attempt to put forward some innovative ideas "standing on the shoulders of giants".

5.1 Core enablers of COIs in China's biotechnology and healthcare industry

In the literature, the concepts of "component", "organization", and "actor" have been used to describe the factors of COIs. However, in this study, we choose to use the term "core enablers". "Core" indicates that these factors are "essential" in driving the formation of COIs, while "enabler" encodes the meaning of "enabling" and "empowering". According to this concept and definition, the essential criteria for screening the enablers are whether they could empower innovation and promote the development of COIs. For example, classical economics believes that "land is the mother of wealth", but this study does not include "land" in the "core enablers" of COIs, because "land" does not directly empower innovation and is far less important than other core enablers. Sometimes, it may even hinder the development of COIs and limit the growth of the local economy. Moreover, as mentioned above in Chapter 1, the reason why China's science and technology industrial parks cannot be upgraded to COIs happens to be that many of them rely too much on land, which is a "non-renewable resource". Their business models are more or less "real estate" or "industrial real estate" models, and their income mainly depends on "rent" and the price difference between land and property ("land appreciation" and "property appreciation"). The development mode relying on the land factor is a traditional "factor-driven" mode, rather than a "innovation-driven" mode. It tends to form "path dependence" and "low-end lock-in" in the cluster, making it challenging for the cluster to upgrade to a real COI.

Based on the results of the literature research, field research, case study, formal interviews with various organizations within and outside the cluster, and focus group discussions with Chinese and international researchers with expertise on industrial clusters and COIs, and lightened by their ideas, we classified the core enablers that affect the formation and development of COIs into “explicit enablers” and “implicit enablers”. “Explicit enablers” are the innovation components that have been well explored in previous studies and are considered “widely-known and obvious”, including universities, research institutions, innovative enterprises, entrepreneurial governments, professional service providers, knowledge and technology sources, technology capital and professional investors, and innovative and entrepreneurial talents. Besides, we have also identified some “underexplored” enablers that play a key role in leading COIs. They are “hardly noticeable” and may easily be ignored, including “innovation organizers”, “organizations for cluster promotion”, and “innovation institutions, paradigms, and cultures”. In this study, we call them “implicit enablers” of COIs (see Figure 5.1).

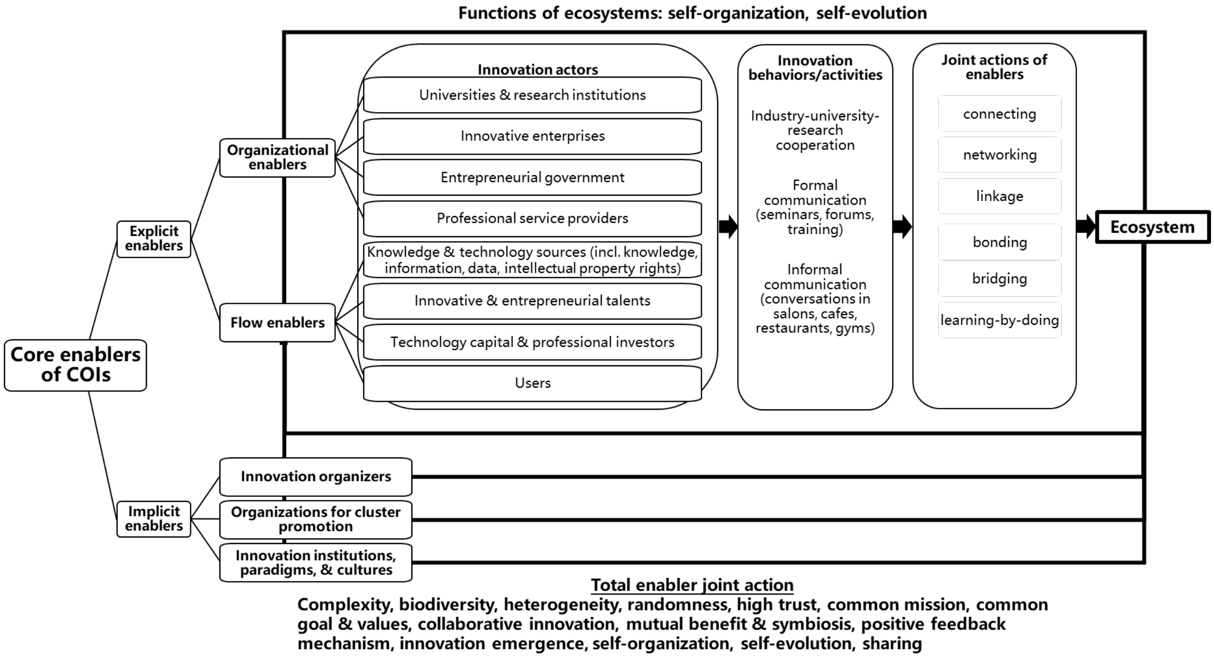

Figure 5.1 Core enablers of the formation and development of COIs

5.1.1 “Explicit enablers” of COIs

We further categorize explicit enablers into “organizational enablers” and “flow enablers”. “Organizational enablers” include universities, research institutions, innovative enterprises, entrepreneurial governments, and professional service providers; while “flow enablers” include knowledge and technology sources (including knowledge, information, data, and intellectual property), innovative and entrepreneurial talents, and technology capital and professional investors. It is particularly worth mentioning that “users” should be added to the category of “flow enablers” as an additional core enabler. This enabler was not mentioned in

Chapter 4 because it was barely mentioned directly in the interviews and focus group discussions. However, through literature research, field research, and the case study of Bio Island, we have found that "users" are becoming more and more important in the new innovation paradigm. Therefore, we included "users" as an explicit core enabler and "flow enabler" of COIs. The following is a summary of the research findings on the core enablers of COIs.

A. Universities and research institutions

The "geographical proximity" to universities and research institutions is a sufficient but not necessary condition for the formation and development of COIs. At present, the number of universities and research institutions has become an important indicator of a cluster's innovation capabilities (C. Wang, 2012). Extensive studies and practices have shown that when knowledge-intensive enterprises (high-tech enterprises) select their locations, the geographical intensity of universities and research institutions is an important factor to consider. There are 226 high-tech parks in China, of which 83.6% were established around universities and research institutions. The geographical proximity brings convenience to enterprises' interaction with these universities and research institutions. With respect to the case of Bio Island, it is only a river away from Guangzhou University Town. However, Bio-Island not only has established cooperation with the universities in this university town but also has formed cooperation networks with prestigious universities and research institutions across China and around the world.

We have found that the "joint action mechanism" is more important than "geographic proximity". Universities and specialized research centers are the driving force of innovation in almost all regions, and the commercialization mechanism is the key to transforming technological innovation into economic success.

We believe that it is more important to focus on the "quality" of the collaborations rather than the "quantity" of universities and research institutions within or near the COI. The transformation rate of innovations will become a more important indicator of COIs' innovation capabilities. The low transformation rate is one of the main reasons for China's insufficient innovation capacity. Research has shown that at present, the 5100 colleges, universities, and research institutes in China produce 30,000 scientific research outputs every year, but only about 20% can be commercialized and mass-produced, and only 5% can be industrialized; however, in developed countries, the transformation rate of scientific research outcomes is as high as 70-80% (G. Zhao, 2017). The *China Patent Investigation Report 2022* showed that the effective industrialization rate of patents was 36.7% in China, 48.1% for enterprises, and 3.9 % for colleges and universities (Strategy Planning Department of China National Intellectual Property Administration & Intellectual Property Development & Research Center, 2022).

There are many factors contributing to the low transformation rate of Chinese universities and research institutions' outputs. Mechanism constraints, such as the lack of an effective incentive mechanism, ambiguous ownership of innovation's intellectual property rights, and unclear interest distribution, are some of the main factors restricting the transformation rate. In addition, the following questions remain to be addressed: Do universities include innovation and entrepreneurship in their guideline for transformation and upgrading? Can the majors set up by universities meet the needs of industries and enterprises for development? Is there a dedicated organization and a corresponding incentive mechanism for outcome transformation? Do the personnel responsible for technology transfer and outcome transformation have relevant successful experiences, or do they act simply based on theoretical knowledge? In addition, although many universities in China have established entrepreneurship schools, they are often not formal organizations, but secondary or tertiary informal organizations under the School of Management. Moreover, the teaching faculty often lacks or even has no experience of successful entrepreneurial practices.

In the following, we will take the universities in Silicon Valley as an example to provide reference and inspiration to Chinese universities.

The development experience of Silicon Valley, a global benchmark of COIs, has verified that universities and research institutes are the most critical drivers of regional innovation and development vitality. Stanford University, as a role model of "entrepreneurial universities", has long proposed the vision of "creating a research-driven university serving the economy and industry". Through three institutional innovations, it has realized the plan of "extending to industry" and building an "entrepreneurial university" (Cohen & Fields, 1998). The three institutional innovations are as follows: a) The Stanford Research Institute (SRI) was initially founded to carry out government-funded research but later devoted to promoting the cooperation among government, the university, organizations, and private high-tech enterprises, helping high-tech enterprises on the west coast to win government contracts. b) Through honorary cooperation projects, the teaching faculty of Stanford University School of Engineering is open to cooperative enterprises, and the enterprises' employees are allowed to participate in the postgraduate programs of the University. c) Incentives such as the establishment of Stanford Research Park have effectively promoted cooperation among public and private organizations, the university, government, and enterprises, thus building an innovation network in Silicon Valley (W. Chen et al., 2020).

At present, the universities in Silicon Valley are also undergoing further transformation. In Engel and Del-Palacio (2011) words, universities are shifting from licensing models to venture models. That is, universities are no longer satisfied with being solely intellectual property providers. They are actively seeking to establish relationships between entrepreneurs and venture capital or other investors; or, as investors, they are actively promoting the commercialization and industrialization of scientific and technological innovations. Many universities have “come out of the box”, striving for more offers from different projects for their students. They attempt to create an entrepreneurial-friendly environment through multiple strategies: a) Entrepreneurship and business management are included as core courses in many disciplines. b) Students are allowed to gain relevant experience by working at start-ups or venture capital firms. c) Through practice and training, they provide students with opportunities to learn fund-raising, the most challenging but most important ability for entrepreneurship. d) Since the successful operation of enterprises requires talents from different backgrounds and with different abilities, universities are offering interdisciplinary courses, attracting students in engineering who want to study law or business to jointly develop a project. In addition, universities also promote the relationship between the university and future entrepreneurs through some special tools, such as business and economic plan competitions or awards, interdisciplinary research projects, and incubators and accelerators, thereby promoting business plans for scientific innovation. At the same time, universities have also launched a number of venture capital fundraising to establish a closer relationship with investment institutions and legal or other service providers, thereby providing more comprehensive services and support for enterprises invested by the university (W. Chen et al., 2020).

Since 2008, the Office of Technology (OTL), as an important organization for technology transfer and licensing in universities in Silicon Valley, has set “the creation of spin-off companies related to the university” and “the transfer of technology to start-ups” as key performance indicators and included them in the annual work report. These measures have greatly promoted the transfer and transformation of universities and research institutions’ outcomes and promoted local innovation and entrepreneurship (W. Chen et al., 2020).

B. Innovative enterprises

From the field research, interviews, and focus group discussions, we found that innovative enterprises were the core enablers for outcome transformation in COIs. Therefore, in this section, we will elaborate a bit more on innovative enterprises. The concept of innovative enterprises was proposed by Lazonick (2002), who believed that innovative enterprises could control technological routes and market conditions by adapting their organizational capabilities, thereby reducing costs, producing high-quality products, and maintaining a continuous increase in profits. Lazonick advocates that the source of an enterprise's competitiveness is continuous technological innovation. Therefore, enterprises can continuously accumulate technological and organizational capabilities by implementing innovation strategies. Enterprises are key actors in the production, adoption, and application of new technologies. They have specific beliefs, expectations, goals, capabilities, and organizations and continuously acquire and accumulate knowledge (Teece & Pisano, 1994). Many interviewees in our study believed that basic research, scientific discovery, and technological invention would tackle the challenge from "0" to "1", while the transformation of outcomes (including commercialization, industrialization, and capitalization) would tackle the challenge from "1" to "100". The former is mostly accomplished by universities and research institutions, while the latter is the responsibility of enterprises.

COIs in the biotechnology and healthcare industry are mainly driven by small and medium-sized innovative enterprises. That is different from the traditional production-driven industrial cluster, which is led by large enterprises. In traditional industrial parks, such as China's economic and technological development zones and high-tech zones in the initial stage, the formation of industrial clusters was mainly driven by industry-leading enterprises, large-scale producers, and multinational corporations, which took the lead and brought in supporting enterprises, suppliers, and distributors. Specifically, that is the formation mode of production-driven industrial clusters. For example, in the automotive industry, a complete vehicle factory may drive 200 or 300 enterprises of spare parts to gather around the factory within a 30-minute drive radius (to meet the requirements of "zero inventory" and a "just-in-time" mechanism). Then, do COIs in the biotechnology and healthcare industry follow the above model and development path? Are they driven by large corporations or small and medium-sized enterprises? From the case study, we have found that when Bio Island was officially opened in July 2011, it was basically dominated by small and medium-sized enterprises. It was not until 2017 that the first Fortune 500 enterprise was settled, marking the preliminary maturity of the industrial cluster and the initial formation of a COI. At present, there are more than 500 enterprises on Bio Island, of which only eight are Fortune 500 enterprises. This is a typical example of an industrial cluster and a COI where small and medium-sized enterprises attract the agglomeration of large and multinational corporations.

COIs must strengthen enterprises' position as the main enablers of innovation, leverage the advantages of science and technology leading enterprises, and cultivate small and medium-sized innovative enterprises. The interviewee ZNS believed that enterprises' scale was not necessarily directly associated with innovation. Evidence has shown that China's national and local large pharmaceutical enterprises attach more importance to production and marketing, with less attention to innovation and insufficient investment in R&D, which is mainly manifested in the lack of willingness to bear innovation risks and to make long-term investments. The interviewee LYD believed that traditional state-owned pharmaceutical enterprises pay more attention to distribution channels and production, such as enterprises of biopharmaceuticals and consumables. In recent years, the Chinese government has paid more attention to innovation and required enterprises to increase the proportion of R&D in revenue. State-owned enterprises are exploring the path of innovation and outcome transformation, but due to the limitations of mechanisms and professional talents, the progress is not satisfactory. The national authorities of science and technology and competent authorities overseeing state-owned enterprises have repeatedly suggested in official documents to "strengthen the dominant position of enterprises in innovation", support leading enterprises in science and technology to integrate competitive forces in the country (enterprises, universities, and research institutes related to the industrial chain), deepen the industry-university-research integration led by enterprises, and cultivate leading scientific and technological enterprises with international influence and small and medium-sized tech enterprises.

C. The entrepreneurial governments

At the beginning of this study, especially in the "literature research" stage, we found that many Chinese researchers believed that the formation of science and technology industrial parks and COIs was driven by "non-governmental forces" and was the result of "free choice by the market". They even believed that globally, there was barely any successful case of a renowned science and technology industrial park or COI led by the government. Because in the past, the traditional government gave people a general impression and perception that it was bureaucratic, inefficient, inactive (it is better to do less), and afraid of taking risks, while private entities were usually dynamic. However, during our field research and interviews on Bio Island, we found that local governments and authorities in China were actively and proactively supporting innovation and efficiently helping enterprises solve their problems encountered in the innovation process. We call them "entrepreneurial governments". For example, the transformation and upgrading cases of company HX and its collaborator WL (as mentioned in Chapter 4) can well illustrate the positive role of the government's industrial planning in guiding enterprises' development and pointing out the direction for their transformation and upgrading. Through regional innovation systems and industrial innovation systems, the government indirectly leads enterprises to establish and improve their innovation systems. In a world full of uncertainty, the Chinese government has vigorously explored to construct an entrepreneurial government and created a positive image in people's minds. It has been actively seeking investment, attracting talents, and promoting technological progress and industrial development, turning itself into an indispensable core enabler for the formation and development of COIs.

The case study of the successful practice of Bio Island has shown that the formation and development of COIs in the biotechnology and healthcare industry in China cannot be achieved without the support of the central and local governments. To a certain extent, the development of many industries, industrial clusters, and COIs is achieved through the government's "top-down" efforts in "pulling resources to do great things". The entrepreneurial government plays a decisive role in the business environment, with multiple facets: it is the industry's planner and guide, the policymaker, the constructor of national, regional, and industrial innovation systems, the investor of knowledge and technology sources, the funder of basic research (e.g., R&D of new drugs), the safeguard of the market, the regulator of industries, the builder of environmental and public infrastructures, and the provider of supporting services for industries and enterprises. Sometimes it also integrates and coordinates other core enablers. In particular, the park's administration committee and the state-owned enterprises responsible for the park's operation and management play the role of COI governors and public service providers.

Is it China-specific that the entrepreneurial government serves as a core enabler of COIs? Does it also apply to other countries? To address this question, after the field research, interviews, and focus group discussions, the researcher further studied relevant international literature.

According to Mazzucato (2013), an economist in the UK, for so many years, one of the important practices of the United States has been the involvement of the government in scientific and technological innovation activities, which is quite different from its claim of "weak government and strong market". Vallas et al. (2011) concluded that the knowledge economy is not a natural phenomenon that occurs bottom-up but is driven top-down by implicit industrial policies; government and industrial leaders strongly support the government's intervention to foster the development of the biotechnology industry, but the advocates sometimes are hypocritical; the government should let the market operate freely. Since policymakers around the world are vigorously promoting their countries' economic development by copying the U.S. model, it is particularly important to present real cases behind the development of innovation and economic growth (Mazzucato, 2013).

The government intervenes in various forms to support the development of biotechnology. The development of the biotechnology and healthcare industry benefits from the vigorous efforts of the government. The huge knowledge infrastructure for the development of biopharmaceutical enterprises relies on government funding rather than commercial investment. As government funding focuses on basic scientific research, the development of the knowledge infrastructure is fostered. Vallas et al. (2011) showed that through 50,000 competitive grants, the National Institutes of Health (NIH) of the United States provided support to more than 325,000 researchers in more than 3,000 universities, medical schools, and other research institutions in various U.S. states and around the world. These grants accounted for 80% of NIH's budget. Another 10% of the budget was used to pay the salaries of the 6,000 scientific researchers in the laboratories affiliated with the research institutions. NIH has 26 research centers in Maryland, which are expanding in scale and have an outstanding position in the biotechnology industry. In addition, the U.S. Food and Drug Administration (FDA) is also located in Maryland, making this region one of the most renowned biotechnology COIs in the U.S. Besides these knowledge-creation projects, government support is also evident in the development of most of the biological drugs in the U.S., the R&D of 75% of the new molecular solid drugs can be traced back to NIH laboratories funded by the government rather than private pharmaceutical enterprises. That is a very important point, as government-funded laboratories usually invest in R&D with higher risk, while large pharmaceutical enterprises tend to invest in innovative generic drugs with less risk (Mazzucato, 2013).

In practice, the U.S. government plays an important role in leading the development of the knowledge infrastructure, directly promoting the overall development of the biotechnology industry and contributing to its great success. The long-term support from the U.S. government has fostered the sustainable development of the knowledge infrastructure, contributed to the prosperity of the biotechnology industry, and attracted a large number of investors. The U.S. government has always been the most important investor in knowledge creation in the medical sector nationally and internationally. Such a knowledge infrastructure is indispensable; once it is missing, venture capital and public funds are unlikely to invest in the biotechnology industry as they tend to follow rather than create the innovation trend (Mazzucato, 2013).

In August 1978, the American Congressional Office of Technology Assessment submitted a report titled *Government Involvement in the Innovation Process* (Congress of the United States, 1978) to the Congress. The report emphasized that the government should promote technological innovation through policy choices and that scientific and technological innovation constitutes a major, if not the most crucial, aspect of innovation management. Government intervention in innovation has two pathways: The first is to address market failures and the second is to select the key sectors for national competitiveness. The government leads the economy to a new “technology-economy paradigm” (this paradigm was proposed by Carlota Perez [2010]). On November 7th, 2010, Carlota Perez pointed out in her speech at the *Pujiang Innovation Forum* in Shanghai, China that the policies of a country determine the country’s development and whether it can succeed economically and socially in the future.

The literature mentioned above shows that the entrepreneurial government plays a significant “top-down” guiding and driving role in the formation and development of COIs not only in China but also in the UK and the U.S. In countries and regions that truly drive growth through innovation, the entrepreneurial government is proactive and active. Besides addressing “market failure” and superintending the existing market, it also needs to foresee the trend of technological change and make (and guide) investments to create (new) markets.

D. Professional service providers

Professional service providers are part of the business environment of COIs. Then, what basic services, business-supporting services, and life-supporting services are needed to attract enterprises to settle in a biotechnology industrial park? What service upgrades are needed for science and technology industrial parks to upgrade to COIs? Who (which entities) will provide these services?

In Chinese science and technology industrial parks, the common basic services include property management, basic life-supporting services (e.g., residences for scientists and schooling services for the children of international high-level talents), and business-supporting services (e.g., human resources, business registration, patent and intellectual property application, high-tech enterprise certification, application for special government support and policy benefits, accounting, legal, investment, and financing). Except that property management is the standard service provided by the park, other services mentioned above are all sourced in the city/region where the COI is located. For cities with a more developed economy and more comprehensive services, it is easier to attract talents, enterprises, and investment.

Upgrading biotechnology and healthcare industrial parks to COIs also requires high-end and highly specialized scientific and technological innovation services, making the "professional service providers" an essential component of the park/cluster's innovation environment. Such providers include the CRO (contract research organization), CMO/CDMO (contract development and manufacturing organization), and CSO (contract sales organization) mentioned in Chapter Four. They also include service providers of clinical research outsourcing, clinical research outcome industrialization, pharmaceutical processes, and medical device design, among others. With the support of local governments and park administration committees, some renowned professional service providers and research institutions have established or participated in the operation of public technology service platforms, public laboratories, and public pilot platforms, providing support and services for the innovation of enterprises within or outside the park (COI). The main purpose of large-scale public key platforms is to solve the problem of insufficient funds and capabilities among innovative enterprises, especially small and medium-sized enterprises. In the biotechnology industrial parks of first-tier cities (e.g., Guangzhou, Shanghai, Beijing, and Shenzhen) and new first-tier cities (e.g., Suzhou, Hangzhou, Chengdu, and Wuhan), groups of "professional service providers" emerged, and a number of public service platforms have been established. However, at present, Chinese biotechnology industrial parks and COIs still lack professional service providers and best practices related to technology transfer and outcome transformation.

E. Knowledge and technology sources

COIs are gathering places of specialized knowledge and technological innovation. However, different opinions were found in the formal interviews and focus group discussions regarding "knowledge and technology sources". Some believed that universities and research institutions were the main sources of knowledge and technology, while others argued that knowledge and technology sources should also include enterprises, investment institutions, and governments as they could generate knowledge and technology through innovative behavior. Some stated that technology could be replaced by "ideas" and "creativity" because ideas and creativity do not necessarily need rigorous technicalization to be innovative. For example, according to interviewee ZMQ, due to the expiration of a drug patent, a multi-national biotechnology enterprise turned the drug into a disposable injection and registered a new patent, thereby turning the drug into a “medical device” and realizing product innovation. However, this innovation is low at the technological level and is basically an “idea” and “creativity”. That discussion is very valuable and inspiring, providing diversity to the research.

F. Technology capital and professional investors

Technology capital and professional investors play an indispensable role in forming COIs and promoting innovation. In this regard, we have the following findings:

1) COIs need technology capital and professional investors who are “knowledgeable about the industry”. It is widely recognized that the biological industry has high entry barriers, high professional requirements, strict regulation, long investment cycles, and fierce competition. It requires high pre-IPO investment and has high risk, which has deterred many investment institutions. As a result, the investment in this industry tends to take place “in earlier stages” (start-ups and early-stage projects), “on a small scale” (investment in small enterprises to help them grow), and “in a specialized manner” (focusing on specific segments). Therefore, technology capital and professional investors need to be “knowledgeable about the industry”, which highlights that investment institutions and private investors must be familiar with the development laws of the science and technology industry and should not solely seek short-term benefits. They should be aware that investment in scientific and technological innovation is a continuous investment that covers the whole process of entrepreneurship, even including the stage before the company’s establishment. “Professional” means they must have sufficient knowledge and understanding of the biotechnology and healthcare industry’s development trends, characteristics, and networks. They should also have extensive relevant practical experiences and sufficient patience. They are not just financial investors but value investors. Generally speaking, for innovation investment, investors must pay sufficient attention as early as when an idea occurs and provide support when the company needs capital (Hwang & Horowitt, 2012).

2) Some interviewed investors who used to be engaged in traditional industries, such as real estate and manufacturing, tend to show a strong desire for control. They ask for companies’ holding during the early investment and sometimes even force the founder out, which could greatly undermine the enthusiasm of technology inventors and entrepreneurial teams, making them less motivated for entrepreneurship and innovation.

3) Some financial investors do not have a sufficient understanding of the long-term cycle of the biotechnology industry. In order to gain a return as soon as possible, they may reduce the continuous investment in innovation (R&D). Such behaviors will seriously hinder

innovation.

4) As several investors stressed in the interview, “30% investments and 70% management” - projects’ post-investment management is crucial. There are sufficient funds in the market; what is lacking is the “talent” and “teams” who know how to use the funds appropriately to empower startups and innovation teams by leveraging their experience, networks, and other resources and who fully understand the needs of entrepreneurs and innovators. Technology capital and professional investors essentially serve for innovation. They must proactively and appropriately engage in the affairs of the invested companies to help the entrepreneurial team overcome their “weaknesses” and integrate into local COIs.

5) From the field research and interviews, we found that in the COI’s early stages, technology capital and professional investors were mainly attracted by policies, such as industrial support policies, investment incentives, and industry-guiding funds initiated by the government. In the middle stages, quality investment projects are the most attractive to investors, who are more likely to identify high-value leading technology projects with strong innovation, great market potential, and high return on investment. Meanwhile, it is easier for enterprises and innovation projects to raise funding in this region than in other regions. In the later stages, investment is attracted by “fund clusters”. That is, at this stage, fund clusters are gradually formed in the region of the COI. Technology capital and professional investors appreciate the innovative atmosphere and the opportunity for mutual learning in this region, where it is easier to obtain industry information and tacit knowledge. The fund clusters are conducive to accumulating industry investment experience and enhancing investment capabilities and, in turn, contribute to the sustainable development of the COI, forming a virtuous cycle.

G. Innovative and entrepreneurial talents

The biotechnology industry, like other high-tech industries, is a “talent-intensive industry”, where “talent” is the core enabler in the formation and sustainable development of COIs.

Western scholars (e.g., Schumpeter) mostly emphasize the role of “entrepreneurs” and “entrepreneurship” in innovation. According to M. Ma (2015), the innovation theory was first put forward in *The Theory of Economic Development* by Schumpeter (1912), where the word “innovation” was mentioned 53 times, “technology” 60 times (including what Schumpeter called financial technology and fintech, besides natural science-based technologies), “new combination” 74 times, “institution” 79 times, and “entrepreneur” 379 times. In terms of frequency, “innovation” was far less frequent than “entrepreneur”, which implies the close relationship between innovation and entrepreneurs. Drucker (1995) was the first to regard the practice of innovation and entrepreneurship as the organized, purposeful, and systematic work of all enterprises and organizations, and the duty and responsibility of managers.

Chinese scholars and policymakers tend to value the contribution of “high-tech talents” and “scientists” to innovation while highlighting the role of “leading figures”.

In this study, we believe that as scientists, entrepreneurs, and capitalists move towards collaborative innovation, their roles begin to have blurred boundaries and may even overlap (the overlap will generate new roles, as shown in Figure 5.2), and their technological knowledge, business knowledge, and financial investment knowledge will flow. The “innovative and entrepreneurial talents”, especially the “leading talents”, play a key role in fostering the formation and development of COIs, which in turn are conducive to the further agglomeration of the above-mentioned core enablers.

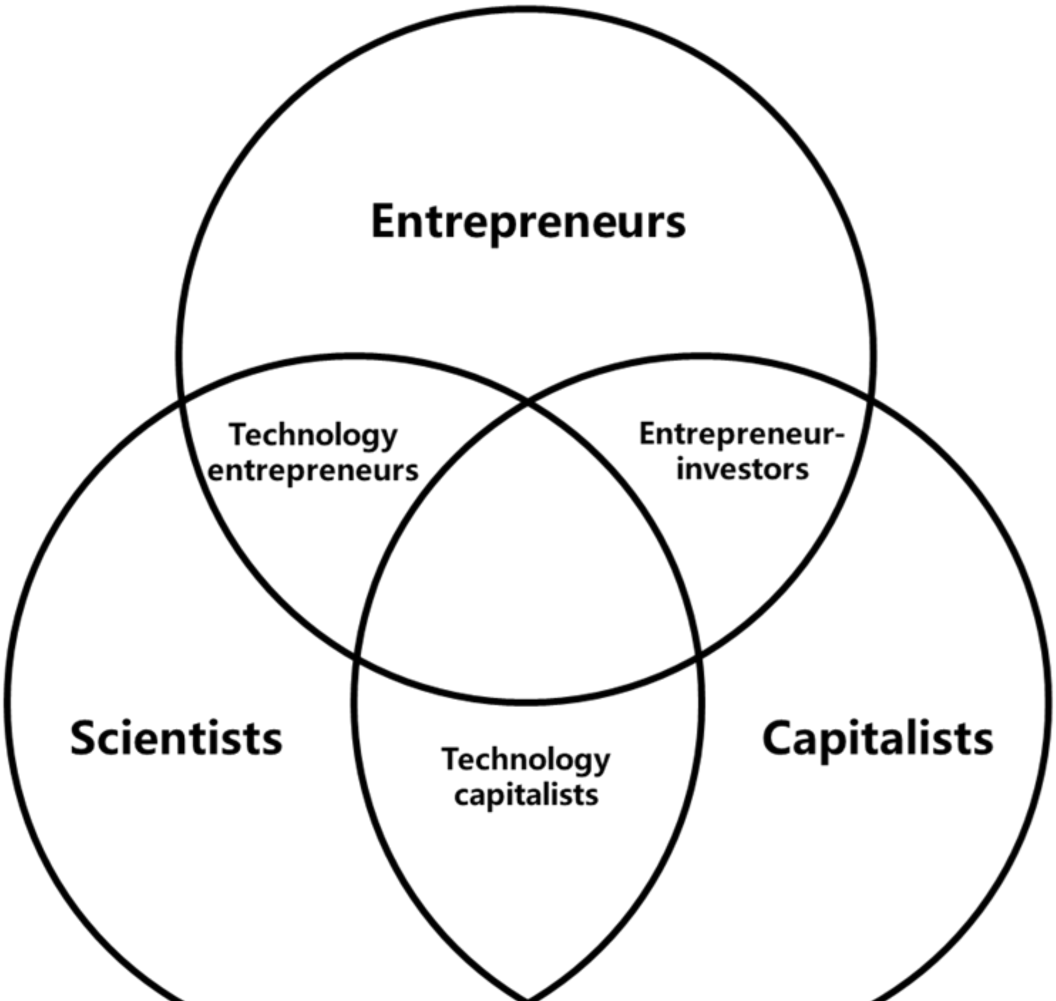

Figure 5.2 Categories of leading innovative and entrepreneurial talents

H. Users

More and more studies have shown that innovation is undergoing a transition from producer-led innovation to user-oriented innovation. For example, in the past few decades, the computer sector has gone through a critical symbiotic evolution, which requires a large system with “user-producer” relationships, puts user information systems in the central position, and needs a large number of sales and service inputs (Malerba, 2009, p. 397). From the case study of Bio Island, we can see that in the biotechnology and healthcare industry, all technologies, including innovative drugs, new vaccines, new medical devices, and innovative medical services, aim to serve humans and involve patient-oriented value-based healthcare, new drug development, and policymaking. In particular, after the outbreak of COVID-19, the vigorous information sharing by mainstream and non-mainstream media, as well as social media, enabled the public to quickly acquire a large amount of knowledge that in the past was only accessible to infectious disease experts, doctors, biological scientists, and other professionals, such as the difference between antigen detection and nucleic acid detection and the classification and characteristics of vaccines, including inactivated vaccines, recombinant protein vaccines, and mRNA vaccines. In this case, users are no longer passively accepting products; they take ownership of their choices. The rise of producer-consumers (hereinafter referred to as “prosumers”) and the new innovation paradigm of “industry-university-research-users” have made “users” one of the “flow enablers” of COIs. Enterprises’ innovation behavior and core competitiveness are more closely connected with “prosumers”, which further drives changes to the producer-led mode (including the infrastructure and supporting facilities). For example, the parks’ conventional supporting infrastructure, such as facilities for R&D, office, pilot test, and production, are transforming into “open communities”, such as “prosumer community”, “stakeholder community”, and “science education community”, which are more public-friendly and can contribute to the upgrading of COIs into an open innovation ecosystem.

During the field research on Bio Island, we observed a preliminary formation of such “open communities” with user/public participation. In 2021, Bio Island’s first smart healthcare leisure station was built. Once you step into the station, you will first get your temperature measured by an infrared camera, and the result will be transmitted to the electronic screen in real-time. The room is equipped with Hengrui’s (a leading pharma in China) new medicine box, with a display of various Chinese major new drugs and innovative products for tumor treatment, arthritis, and anesthesia, among others. In addition, you can find the latest products developed by various enterprises on Bio Island - cutting-edge healthcare detection products and first-aid medical equipment, such as COVID-19 antigen tests, non-invasive colorectal cancer genetic tests, HPV tests for cervical cancer (the user can scan the QR code to get the product and then put it back into the testing box after sampling; upon notification, the staff will collect the sample and send the results and corresponding advice to the user's mobile), urinalysis strips for the auxiliary diagnosis of diseases such as kidney diseases, diabetes, and urinary infection (the results can be obtained within one minute), the medical ultrasonic atomizer with negative ions (it can purify the air while improving human body's natural resilience), and automated external defibrillators (AED, to provide emergency support for patients with heart disease). Many citizens visit Bio Island for the experience on weekends or even daily. Such innovative initiatives are outcomes of "user orientation", enabling users to have access to biomedical products that previously were only accessible when they were sick and products that they would not know otherwise (in the past, only the doctors were knowledgeable about such products).

There are many such examples on Bio Island, and many enterprises have established open spaces for product display and communication. From the case of Bio Island, we can see that the open environment of a COI can create new scenarios and possibilities for face-to-face communication between innovation actors and their users. Through interaction with research institutions and enterprises, users can learn more about the product's technical features and gain information and knowledge that cannot be found in the product description. Meanwhile, users can also share their feedback on the product with the producers, helping the latter to improve their products and services based on users' needs and develop innovative solutions.

5.1.2 "Implicit core enablers" of COIs

Inspired by interviews and focus group discussions, based on the literature and field research, we put forward "implicit enablers", which, along with the above-mentioned "explicit enablers", are core enablers of COIs. Implicit enablers include "innovation organizers", "organizations for cluster promotion", and "innovation institutions, paradigms, and cultures", each of which will be discussed in the following.

A. Innovation organizers - the "keystone figure" of COIs

We hold that the innovation organizer is the "keystone figure" and "keystone species" of a COI or an innovation ecosystem. In an ecosystem, the keystone species generally play the role of a "hub and spoke", having valuable joint actions with other components of the ecosystem.

Their influence on the whole ecosystem is far beyond the proportion of this species. Without the keystone species, the biodiversity of the tropical rainforest will collapse, and many other symbiotic species will disappear. In an innovative tropical rainforest, the keystone figure is the key hub that gathers different types of people to create an environment that can nurture and nourish new beings. The keystone figure is a bridge between people. Such figures break the boundaries of different communities and link different economic systems to create a larger and continuous economic system (Hwang & Horowitt, 2012).

Innovation organizers are the persons who can predict the development trend of the times, the trend of technological transformation, and the future of industrial development in a complex industrial innovation ecosystem and who take the lead in identifying opportunities and taking action. They can integrate the enablers scattered within and outside the COI and tend to build bridges between people and between organizations. Through tangible and intangible "bridges" and "ties", they can build trust, overcome obstacles, resolve conflicts, reduce doubts, promote cooperation, and bring mutual benefits. They are "one in a million" leaders who not only have great ideas but also can gather people with ideas and special capabilities with capital.

Innovation organizers must have the following extraordinary characteristics:

1) Insight. They can identify potential opportunities and perceive the trends of technological transformation, industrial development, and economic growth. They are also the doers whose "knowledge and action go hand in hand".

2) Vision. They have a common vision, which is essential for building an ecosystem and achieving win-win outcomes.

3) Charisma. They have the ability to call on the mission and draw a blueprint and are good at top-level planning and innovation strategy making.

4) Bridging ability. They are the pioneers in COIs to "open a way and build bridges".

5) Integrative ability. They have the ability to link multiple innovation networks and integrate different industrial resources and innovation enablers in spite of organizational, institutional, disciplinary, cultural, and cognitive barriers, turning scientists, entrepreneurs, investors, and other professional service providers into a team with common goals by building trust, eliminating doubts, and encouraging collaborative innovation.

6) Influence. They have the ability to persuade people to do things they would not dare to think about or do, but they never have to use coercion or threats to achieve that. They attract people through long-term interests and non-economic incentives and help them resist the temptation of short-term interests (Hwang & Horowitt, 2012).

7) Execution. They are goal-oriented and persistent. Even in the face of an uncertain future and unpredictable outcomes, they are still very aware of the potential value of their actions and can make things happen. They are often “deal makers” with rich connections.

Innovation organizers play the important role of “innovative weavers and ecological engineers” and can be considered as the “core enabler” of the “core enablers”. They often play the role of “informal leaders”, assisting cluster administrators, calling on other core enablers to set up common visions and goals, and formulating innovation strategies. They link the internal and external enablers of the local COI, enhance the “embeddedness” of the other enablers in the local innovation culture, “bridge” national innovation networks and global innovation networks, and promote international technological exchanges and cooperation. They promote the enablers’ joint actions and make them produce chemical reactions to maintain the balance between all enablers of the ecosystem, eventually achieving “mutualism”, which was initially proposed in biology.

B. Organizations for cluster promotion - the “keystone organization” of COIs

Organizations for cluster promotion are the organizations established by innovation organizers for leading figures and teams with the support of the government. They are bridging organizations and can be enterprises, associations, alliances, or other non-governmental organizations. Organizations for cluster promotion help establish connections and links between internal and external enablers of the cluster. They break the barriers between regions, organizations, mechanisms, disciplines, industries, and clusters, help build mutual trust between people and between organizations, and promote exchanges and cooperation. Having earned the public trust and become the “medium” of trust, they balance the interests of all parties and drive them to jointly build clusters for mutual benefits. They are the “connector”, “transformer”, and “router” between the enablers within and outside of a COI. At the same time, they also function as the “adhesive”, “lubricant”, and “catalysts” among the enablers. MedCity is a good example and benchmark of an “organization for cluster promotion.” As shown in Figure 5.3, London benefits from several life sciences innovation districts, which cement the UK capital as a life sciences supercluster.

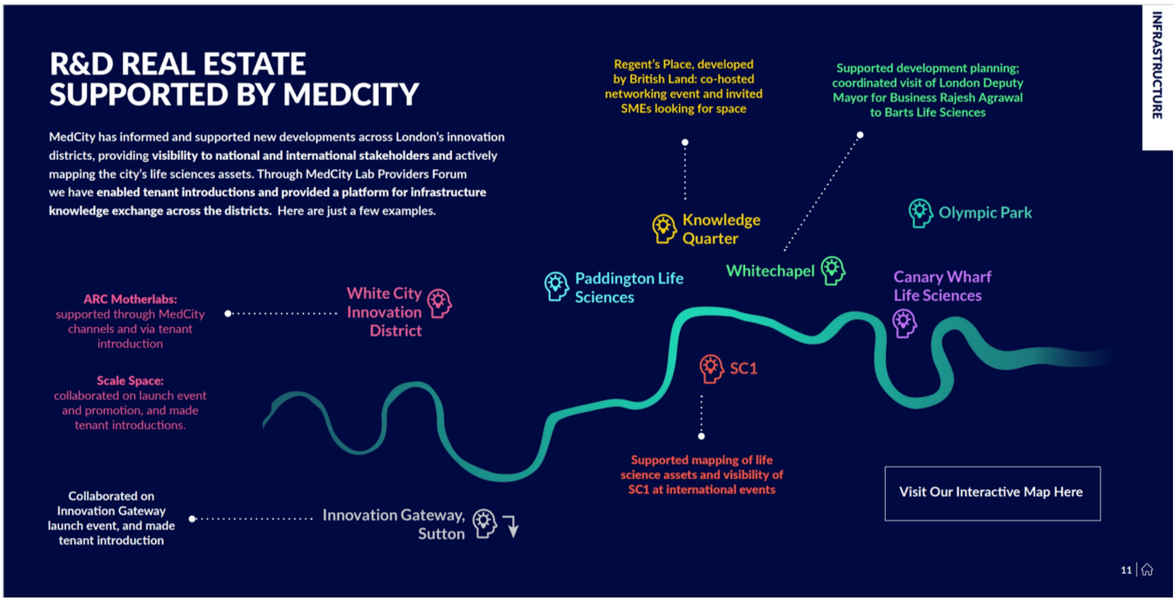

Figure 5.3 London life science innovation districts

Source: MedCity (2023)

Since MedCity is literally understood as a medical city, it may lead to misunderstandings. Therefore, in the interview, the researcher asked the head of MedCity, coded as IP, whether it is like a management agency similar to a science city or a science park. IP answered this question by explaining what MedCity is and why. According to IP, MedCity is not a park or a management agency and does not have any physical facilities. It is an organization for promoting the world-leading health and life sciences cluster in London. It is a non-profit organization jointly initiated by the Mayor of London and the city's Academic Health Science Centers, partially funded by the local government in London (the Greater London Authority), with the aim of fostering international collaborations between biotechnology, MedTech, and pharma companies and London's world-leading life sciences ecosystem to supercharge innovation, drive inward investment, and develop skills and talent across the sector in the UK. MedCity is committed to supporting enterprises, academics, researchers, public entities, and regulators across the ecosystem, and its mission is to drive life science innovation and investment in London, securing the UK's position as a global science superpower.

When the researcher asked what MedCity does and how it operates to achieve its mission and goals, IP responded that MedCity builds collaborations to accelerate the uptake of medical innovation across the UK and helps policymakers understand what is required for life sciences to thrive in a competitive international landscape, mainly through: a) connecting partners, b) amplifying strengths, c) providing opportunities, and d) driving sector growth.

Besides a formal interview with the person in charge of MedCity through a video conference, we also made a site visit to the Francis Crick Institute in London on September 13, 2023, and conducted face-to-face communication with its former Principal Group Leader and International Activities Ambassador, JS (Fellow of Royal Society) and IP, the head of MedCity, as well as other personnel. Neelam, the former CEO of MedCity, stated that MedCity and London and Partners officially integrated on April 1, 2023, bringing together MedCity's expertise in life sciences with London and Partners' business leadership, global reach, and scale, to enhance the impact of life sciences and the industry's development. The integration of the two organizations represents their long-term investment in health and life sciences in London, enabling MedCity and London and Partners to go further in developing London as a world-leading life sciences cluster (London & Partners, 2023). Professor David Lomas, Vice Provost of Health at University College London and a founding member of MedCity, expressed that they had witnessed first-hand the impact of MedCity in maintaining London's position as a global powerhouse in life sciences. It is an early advocate of digital health entrepreneurialism and cross-sector collaboration on advanced therapies such as gene therapies and, since COVID-19, on accelerating the pathway of new diagnostics from laboratories to patients and healthcare settings (London & Partners, 2023). It can be seen that MedCity is a typical and world-leading regional "organization for COI promotion" focusing on the biotechnology and healthcare industry, having reference value and practical significance.

Through interviews and focus group discussions, we have learned that in recent years, China's central and local governments have paid more attention to the role of organizations for cluster promotion and have successively issued relevant policies to support the development of such organizations. Since 2019, the Ministry of Industry and Information Technology of China has initiated the cultivation of advanced manufacturing clusters, selected a number of advanced manufacturing clusters through competitions, and supported the construction and development of organizations for cluster promotion (Ministry of Industry and Information Technology of China, 2020). The Ministry is "exploring the construction of specialized and market-oriented organizations for cluster promotion, guiding and supporting clusters to establish organizations for cluster promotion by joining forces of leading enterprises, associations, and research institutions, striving to build a number of market-oriented third-party professional organizations that can provide long-term services for clusters. It will support organizations for cluster promotion to continuously enhance their 'soft power' (public services) and 'hard power' (innovation platform construction) to empower enterprises' development in the cluster. In the future, the Ministry will further improve the working mechanism for cluster cultivation and development, formulate targeted policies and measures, guide high-quality enabling resources to gather efficiently in clusters, and support organizations for cluster promotion to enhance their service capabilities.

The *Blue Book of Guangdong's Development - Annual Report on Development of Guangdong*, prepared by the Development Research Center of Guangdong Provincial People's Government (2022), suggested: "We should strengthen (cluster) promotion organizations and join forces of 'government + promotion organizations + leading enterprises', explore the new mechanism of cluster governance. First, it is needed to speed up the construction of the cluster promotion organization system. Second, it is necessary to promote the balanced development of the organizations, with mature organizers helping the developing ones, form an inter-city industry promotion alliance, and improve the cooperation mechanism of co-cultivation and benefit sharing in the industry. Third, it is needed to give full play to the leading role of leading enterprises, encouraging them to take the lead in establishing organizations for cluster promotion, such as industrial associations, public service platforms, and novel R&D institutions, and drive cluster members to create network synergies in technology, products, and business innovation by involving all parties, so as to avoid problems such as improper resource allocation and excessive competition, thereby shaping the cluster into a cooperative and win-win organism."

From the above-mentioned interview and official document, we can see the government's support and practical measures for "organizations for cluster promotion" and the value and role of such organizations. They should play a crucial role in the governance of biotechnology COIs. In the case of Bio Island, the Bio Island Company, to some extent, plays the role of an organization for cluster promotion.

At present, "organizations for cluster promotion", as an institutional innovation, are playing an important role in China's COIs.

C. Innovation institutions, innovation paradigms, and regional innovation cultures

1) Innovation institutions. From the literature research, we have learned that the COI is essentially an innovation system, where "organizations" and "institutions" are often considered the main components". Institutions are sets of common habits, norms, routines, established practices, rules, or laws that regulate the relationships and interactions between individuals, groups, and organizations - they are the game rules (Edquist, 1997). Each COI needs appropriate innovation institutions (which are different from traditional institutions and are conducive to innovation), growth paradigms, and regional cultures to foster the formation, development, and evolution of the ecosystem. These intangible and invisible "innovation

institutions, paradigms, and cultures" are essential "implicit enablers" that maintain the "orderly" development of COIs and prevent chaos.

At the initial stage (the formation stage) of COIs and innovation ecosystems, innovation institutions are mainly formed in two ways. One is "occasional" and "natural" formation by pioneer enablers (e.g., the enterprises, universities, and research institutions that were the first to enter the COI). The "habitual behaviors" of these early innovation actors naturally affect the formation of the COI's institutions, which can be understood as a "bottom-up" formation. The second is "top-down" and "man-made" formation, mainly through the top-level design and industrial planning of the park (or COI) by the local government and the park's administration committee or the state-owned enterprise entrusted by the government to be responsible for the park's development, operation, and management. That is the case of Bio Island and most other science and technology parks in China.

However, in the second stage, that is, the development stage of COIs, the two formation ways mentioned above will intersect. Whether it is "bottom-up" or "top-down", the government needs to cooperate with the market and society to jointly establish the innovation ecosystem (Shanghai Institute for Science of Science, 2015). The number of innovation actors in the COI is increasing, and the "biodiversity", "heterogeneity", and "uniqueness" of the innovation ecosystem are gradually enhancing, creating conditions for the COI's next stage of evolution.

The third stage of COIs is the evolution stage. Darwin's theory of evolution defined the evolution mechanism as heredity, variation, and natural selection. A species' individuals must have variation; otherwise, evolution is impossible. However, there is a genetic mechanism that retains the individuals' original traits while forming differences. Natural selection, through its effect on the heredity and variation of species, leads to the rise of new species and the extinction of pre-existing species (Shanghai Institute for Science of Science, 2015). Similarly, in the COI, institutions are hereditary. They are inherited from some "conventional practices" that have been formed for a long time and are deeply rooted in the behavior of the innovation actors. They also affect the new entrants, which will gradually learn, adapt, and follow these "institutions". As innovation starts and continues, when the existing "conventional practices" cannot keep up with the speed of innovation, and the existing "common sense" cannot solve the problems in the innovation process, the innovation actors will go through learning and constant trial and error, which means breaking the existing "conventional practices", resulting in changes in institutions. Through recording and comparing the advantages and disadvantages of different practices, the COI's innovation system will "naturally select" the successful practices. At this point, the "conventional practices" have completed the "variation", resulting in the rise of new best practices. For example, the "technology-economy paradigm" is a best-practice model and is composed of a set of general and similar technology and organizational principles. These principles represent the most effective way for a specific technological revolution to be exploited and leveraged to revitalize and modernize the entire economy. According to Perez (2002), the new "technology-economy paradigm" has a direct impact on innovation and investment behaviors and is comparable to a gold rush or the discovery of a new continent.

2) Innovation paradigms. This study has found an essential trend of COIs - the transformation of the innovation paradigm in accordance with the application of new technologies. In Chapter Two, it was mentioned that the innovation paradigm transformed from the "triple helix" (government-industry-academia) to the "quadruple helix" (government-industry-academia-users) with the enabler of "users" added (see Chapter Four for details), At the same time, the innovation paradigm evolved from "Open Innovation 2.0" to "Open Innovation 3.0" (i.e., embedded/symbiotic innovation), which also impacted the evolution of COIs. Therefore, the "innovation paradigm" is also one of the "implicit enablers" of COIs. If scientific and technological innovation is the primary productive force, the innovation paradigm will be the "relationship of production". Productive forces determine the relationship of production, whereas the relationship of production reacts on productive forces. Paradigm innovation and transformation are not static; they are dynamic and must keep pace with and adapt to the speed of technological innovation and transformation. When the existing organizational mode and institutions cannot cope with or make full use of the potential of new technologies, the COI and the enablers within the cluster must undertake a profound change in the mode of industrial organization and innovation behavior in accordance with the new era, new opportunities, new technologies, and new industries. The innovation pioneers point out the direction through their actions, bring about an increase of economic externalities and corresponding conditions, and help others "keep pace with the times" through training and exchanges. Their successful experience and practices make them a "benchmark case" and a "role model", and the publicity by enterprises and the government enables more people to see the "profitable" opportunities. According to Perez (2002), this new innovation paradigm will eventually become a new universal "common sense", which is gradually embedded in the constituents of social practice, legislation, and other institutional frameworks, promoting the mass innovation that is suitable and hindering the inappropriate innovation. This inclusion-exclusion mechanism is rooted in the technological evolution driven by revolution.

3) Innovation culture. Through literature research, the case study, interviews, and focus groups, we have identified the innovation cultures that are conducive to COIs: entrepreneurial culture (entrepreneurship), innovation culture, team culture, and learning culture.

Entrepreneurial competence and innovation ability can be enhanced in a short time through education and training, while the entrepreneurial culture and innovation culture requires years of cultivation, just like “Rome was not built in a day”. These “invisible” “implicit enablers” constitute the “soft power” of COIs.

5.2 Joint actions of core enablers of COIs

Based on the literature review, Engel and Del-Palacio (2009) believed that an industrial cluster is not only a professional agglomeration within the same industry but also an innovation system that takes into account the development stages and innovation activities of the actors in the cluster. The innovation system approach highlights the relationships or joint actions between enablers. The Organization for Economic Co-operation and Development (OECD, 1997) pointed out in *The National Innovation Systems* that innovation is the result of a complex set of relationships among actors and organizations.

At present, we are in the overlapping stage from the innovation system to the innovation ecosystem (W. Li et al., 2014). Most studies take the perspective of regional innovation ecosystems (rather than a theory). More theoretical and empirical research is still needed to explore how to accurately expand the concept of the innovation ecosystem to the regional level and identify the components of the regional innovation ecosystem, their joint actions, and related classifications (X. Liu et al., 2020).

5.2.1 The innovation vitality of COIs is determined by core enablers’ “willingness” and “ability” of joint actions within the same space

Core enablers’ stronger willingness and higher ability to have joint actions is more conducive to fostering innovation. Then, what are the key factors that may affect enablers’ willingness and ability to jointly act?

1) On the surface, the purpose determines the motivation and the demand determines the will. For example, the upgrading needs at different evolutionary stages of COIs lead to different types of joint actions. For example, the key to upgrading from “enterprises flocking together” to “industrial agglomeration” lies in enterprises’ efficient joint actions, including not only the joint actions of upstream and downstream enterprises, but also those between R&D

and production enterprises and between producers, distributors, suppliers, and service providers. They are often enterprises' spontaneous actions according to their needs and are considered enterprise behavior and market-oriented behavior. The key to upgrading from "industrial agglomeration" to "industrial clusters" lies in "industrial joint actions", which not only encompasses joint actions within the same industry but also those across industries. For example, during the field research and formal interviews, we observed companies specializing in gene diagnostic technology having joint actions with the instrumentation industry, those working on sleep respiratory devices having joint action with the electronics and computer industries, infrared diagnostic technology companies having joint actions with artificial intelligence companies, and companies developing proteomics having joint actions with biotechnology and information technology industries. Interdisciplinary joint actions and collaborations contribute to "cross-sector integration" and "cross-sector innovation", which are arguably even more important than joint actions within the same industry. The key to the transition from an "industrial cluster" to a "COI" is the formation of a cross-cluster and cross-regional innovation network that links different innovative actors and enablers.

The Bio Island Company has held various formal and informal activities on Bio Island. These activities facilitate joint actions between innovation actors and enablers and among enablers within and outside the COI. The activities that impressed the interviewees include the China Bioindustry Convention, the UK-China Open Innovation Workshop, face-to-face roundtable discussions between government officials, hospital directors, and enterprise executives, policy briefing sessions, company visits, academic seminars, workshops, and training sessions. Apart from government-driven activities, other innovation actors within the COI have also initiated and organized various external activities aligned with their needs. For example, industry associations, universities, research institutions, enterprises on Bio Island, and third-party service providers regularly host exchange events, aiding in knowledge spillover and innovation diffusion.

2) From the perspective of innovation's nature and process, "matching" and "trust" determine COI enablers' willingness to act jointly, while the ability to "integrate resources (enablers)" and "establish mutual trust" affects the enablers' ability to act jointly.

According to Mowery and Rosenberg (1979), the innovation process includes the exploration and exploitation of the opportunities for new and improved products, processes, or services, based either on the advance in technical practice ("know-how") or the change in market demand, or a combination of both. Therefore, innovation is essentially a matching process. By "matching", we not only mean technological innovation and technology's practical application must match market demand; it also includes the matching between different enablers, a process in which enablers regard each other as resources and integrate with each other. Therefore, “matching” is also an ability, more specifically, an ability to “integrate resources (enablers)” and “optimize resource allocation” to maximize productivity, or in other words, to create maximum value with limited resources (as “maximum” is difficult to quantify, the “maximum” here refers to a goal).

The level of “trust” determines the enablers’ willingness to cooperate with each other and the depth and range of cooperation. The ability to build mutual trust among enablers is a key factor affecting the matching and joint actions. People cooperate and trade because of trust. Kenneth Arrow, the Nobel Laureate in economics, said, “Now trust has a very important pragmatic value, if nothing else. Trust is an important lubricant of a social system. It is extremely efficient; it saves a lot of trouble to have a fair degree of reliance on other people’s words. Unfortunately, this is not a commodity which can be bought very easily” (Arrow, 1974, p. 23). From this perspective, “trust cost” is the largest cost of “innovation”, “transformation of innovations”, and innovative product transactions. Due to geographical proximity, it is easier for enterprises and other innovation actors in the same park (cluster) to establish mutual trust, thus reducing the “transaction cost”.

5.2.2 COI enablers’ joint actions are a process of “interactive learning”, “cognitive improvement”, and “tacit knowledge” exchange, which is crucial to fostering innovation

Among the joint actions between the core enablers of COIs, interactive learning is crucial to innovation. In a broad sense, an economy’s “innovation system”, from basic research to applied research, sometimes makes progress in the fundamental theory and at other times improves and further develops the “existing technology”. Theories need to be disseminated and put into practice: the improvement of production efficiency mostly comes from mutual learning among enterprises or technology improvement through production practice. We should pay more attention to how this learning is generated (Stiglitz & Greenwald, 2014).

The innovation process may be accidental, but two processes are constant: coordinating and integrating specialized knowledge and learning under uncertainty. “Innovation is internally uncertain, given the impossibility of predicting accurately the cost and the performance of the new artifact, and recreation of users to it. It therefore inevitably involved processes of learning through either experimentation (trial and error) or improved understanding (theory) (Pavitt, 2009, p. 88)”. The so-called cognition refers to the process in which individuals establish mental models, belief systems, and knowledge structures and use these tools to understand and construct their world, give it meanings, and decide what action to take (Lam, 2009). From the above definition, we can see that “cognition” itself is a kind of “ability”. The decoding, filtering, and recoding (reconstruction) of external information during core enablers’ joint actions in the COI may become the basis of innovative ideas and the source of innovative technology inspiration (promoting innovation), but it can also lead to cognitive biases, which may become barriers to the enablers’ joint actions.

The biotechnology innovation involves a great deal of tacit knowledge, including all kinds of “wisdom”, “experience”, and even “lessons” from failure, involving a lot of analysis, judgment, and creativity. Such non-coded “tacit knowledge” is the key determinant of innovation activities in a particular geographical space. As it can hardly be clarified and coded, it is difficult to exchange such knowledge over a long distance. Therefore, its spillovers first and most likely to take place in local scientist networks, especially among “star scientists”, leading figures, and key opinion leaders, who tend to spread knowledge through “informal communication” such as conversations in cafes, restaurants, and gyms. Such communication takes place far earlier than formal presentation or publication. Some valuable knowledge may be spread only within the local COI, such as the lessons learned from the failure of scientific trials or clinical studies during the R&D of new drugs. These “informal communication” and exchanges will help other research institutions and enterprises to avoid detours, thus saving time and cost (Fagerberg et al., 2013).

Innovation is increasingly relying on the joint action and knowledge flow among core enablers such as the government, enterprises, universities, research institutions, users, investors, professional service providers, and organizations for cluster promotion. Therefore, “interactive learning” and the exchange of “tacit knowledge” are directly related to and impact the innovation process.

During the case study and interviews of Bio Island, we found that for enterprises that had established long-term cooperation with star scientists and national scientific research institutions and had more interaction with the government, technology capital, and professional service providers, their number of innovative products (the number of technology patent applications), financing amount (or whether it is listed), and performance were better than the enterprises that had less interaction with other enablers.

5.2.3 Evolution of the forms of COI core enablers' joint actions

A. From "small-group interaction" to "total enabler joint action"

From the literature research, we acknowledged that COIs are complex systems comprised of enablers with joint actions and that the process of developing from an innovation system to an ecosystem is a process of joint actions among enablers within the COI and between the internal and external enablers of the COI. The form of joint actions can impact holistic behaviors, and when the form of joint actions is altered, new holistic behaviors are usually generated.

According to the report released by OECD (1997), the core of innovation systems is the flow of knowledge among the actors within the region. The main indicators for measuring and evaluating the performance of innovation systems should include:

a) Joint industry activities, referring to R&D collaborations and other technical collaborations;

b) Linkage between the public and private research sectors, mainly referring to the joint actions between enterprises, universities, and public research institutions;

c) Technology diffusion, including the adoption rate of new technologies and the delivery of innovation through means such as machinery and equipment ("The Evaluation of the Innovation Ecosystem for Chinese Cities" Research Group, 2016).

From the OECD report, we can see that in the past, joint actions in COIs tended to occur only between two or three enablers. During the field research and interviews, we also observed such a phenomenon. For example, joint actions might take place between government and enterprises, between universities/research institutions and enterprises, between different enterprises, between enterprises and professional service providers, between enterprises and capital, between talents and enterprises, and between knowledge/technology and universities/research institutions.

The transformation of biotechnology innovations is a very complex process, involving all industrial resources and enablers within and outside the COI. Therefore, it is necessary to further explore how to give full play to the enablers' joint actions and enhance efficiency, through what measures and institutions, and who can drive all these to happen.

Zhou Qiren, a professor at the National School of Development of Peking University, pointed out, "The optimal carrier of innovation is neither a super large company nor an individual, but a 'cluster' of entities that share the same spirit, learn from each other, and encourage each other. Frequent interaction between universities, research institutions, capital, and entrepreneurs and effective integration of resources will be an increasingly important principle of innovation genesis" (Z. H. ISLAND, 2018).

Based on the concept and viewpoints of "total factor productivity" (see its definition below), this study proposes the "total enabler joint action" in COIs, an important means to measure resource utilization efficiency and realize innovation.

In the 1950s, Solow (1957) proposed the total factor productivity (TFP) for measuring technology progress. Measuring the growth rate of TFP is to assess technological progress's contribution to economic growth and the quality of the economic growth. Based on the neoclassical growth model, Hayashi and Prescott (2002) put forward a new explanation for the "lost decade" in Japan, pointing out that the decline of TFP and the reduction of workweek length led to the continuous recession of the economy.

As the Chinese economy is moving towards a high-quality development path, enhancing innovation capacity and increasing the contribution of the TFP growth rate to economic growth is one of the imperatives for the Chinese economy. The report of the 19th National Congress of the Communist Party of China (J. Xi, 2016b) first proposed "improving total factor productivity". Specifically, it stated, "Enhance the quality, efficiency, and momentum of economic development, improve total factor productivity, and focus on accelerating the construction of an industrial system with coordinated development of the real economy, scientific and technological innovation, modern finance, and human resources". In the report of the 20th National Congress of the Communist Party of China (J. Xi, 2022), the word "vigorously" was further added. Regarding how to vigorously improve TFP, many interviewed experts expressed that the key lies in the "two ends", namely, the investment in basic scientific research and the transformation of research outcomes. According to J. Su (2019), TFP actually reflects the contribution of those factors that cannot be measured quantitatively in the production process, including factors such as technology, institutions, entrepreneurial competence, human capital, returns to scale, industrial structure, and openness. Improving TFP, in fact, implies increasing the investment in such factors and, through technology progress, human capital improvement, structural reform, and opening up, improving the utilization efficiency of resources that can be measured quantitatively.

However, we posit that innovation efficiency cannot be improved by increasing investment alone. It is necessary to identify the form and law of enablers' joint actions.

According to the literature, many Western scholars posit that enterprises are the most important organizations in COIs (innovation systems) and that entrepreneurs are the most critical resource integrators. However, in China, the government plays a significant role, as most science and technology industrial parks are developed and managed by the government. According to the field research and case study, we claim that enterprises and entrepreneurs can foster enablers' joint actions in COIs by integrating and utilizing resources, but lack a holistic and public-oriented vision. The activities are mostly on the enterprise level (the micro level); only a few multinational companies and industry-leading enterprises may carry out activities on the mid-level, promoting the joint actions between the enablers in a certain industry segment, for example, by holding forums on gene diagnosis, stem cells, and vaccines. It can be regarded as a "bottom-up" process. In comparison, the government's behavior is more on the macro level and sometimes on the mid-level. It promotes the interaction between enablers in a "top-down" manner, such as holding face-to-face communication between drug approval and administration authorities, health authorities, and enterprises, meetings between hospitals and biotechnology enterprises, and high-level industry forums, which are public activities on a more macro-level. Moreover, some government officials may conduct in-depth research on enterprises and endeavor to solve their problems encountered in operations and development. However, as the government needs to pay attention to "fairness" and balance of interests, it mainly focuses on solving "public problems". In addition, due to the constraints of the system and mechanism, it should not and cannot do everything. For example, to solve problems related to the commercialization and marketization of innovations, it is not appropriate for the government to get excessively engaged. In this case, it is necessary to involve a third-party organization (other than the enterprise or the government) to promote the joint actions of all enablers despite the constraints of the mechanism and take better care of and balance the needs and interests of different innovation actors, core enablers, and stakeholders.

After analyzing enterprises and the government, now we look at other enablers of COIs. In China, universities and research institutions are mostly public organizations (i.e., within the system) and are thus constrained by the mechanism. Capital is not the optimal enabler to foster the "total enabler joint action" either because it has a strong "profit-seeking" nature, whereas enablers' joint actions do not always directly yield profit or create economic benefits. With respect to professional service providers, they often play the role of "Party B" and lack the power to influence or call upon "Party A".

Therefore, we believe that what fosters and drives the "total enabler joint action" in COIs is neither "Party A" (usually the government or state-owned entities) nor "Party B" (private entities such as enterprises, intermediaries, and professional service providers), but "Party C" (non-governmental organizations and non-profit organizations, such as organizations for cluster promotions). The implicit enablers in COIs are the key to achieving "total enabler joint action". Through linkage, connecting, bridging, networking, and a set of institutions for open innovation, innovation organizers and organizations for cluster promotion integrate and optimize resources to prevent resource mismatch and enhance resource utilization efficiency, promoting the joint actions of all the enablers within and outside COIs to realize "total enabler joint action" and "total enabler innovation", thereby fostering the high-quality development, transformation, and upgrading of the COI, improving the transformation rate of innovations, and enhancing innovation efficiency. Moreover, risks can also be reduced to a certain extent thanks to experience sharing (see Figure 5.4).

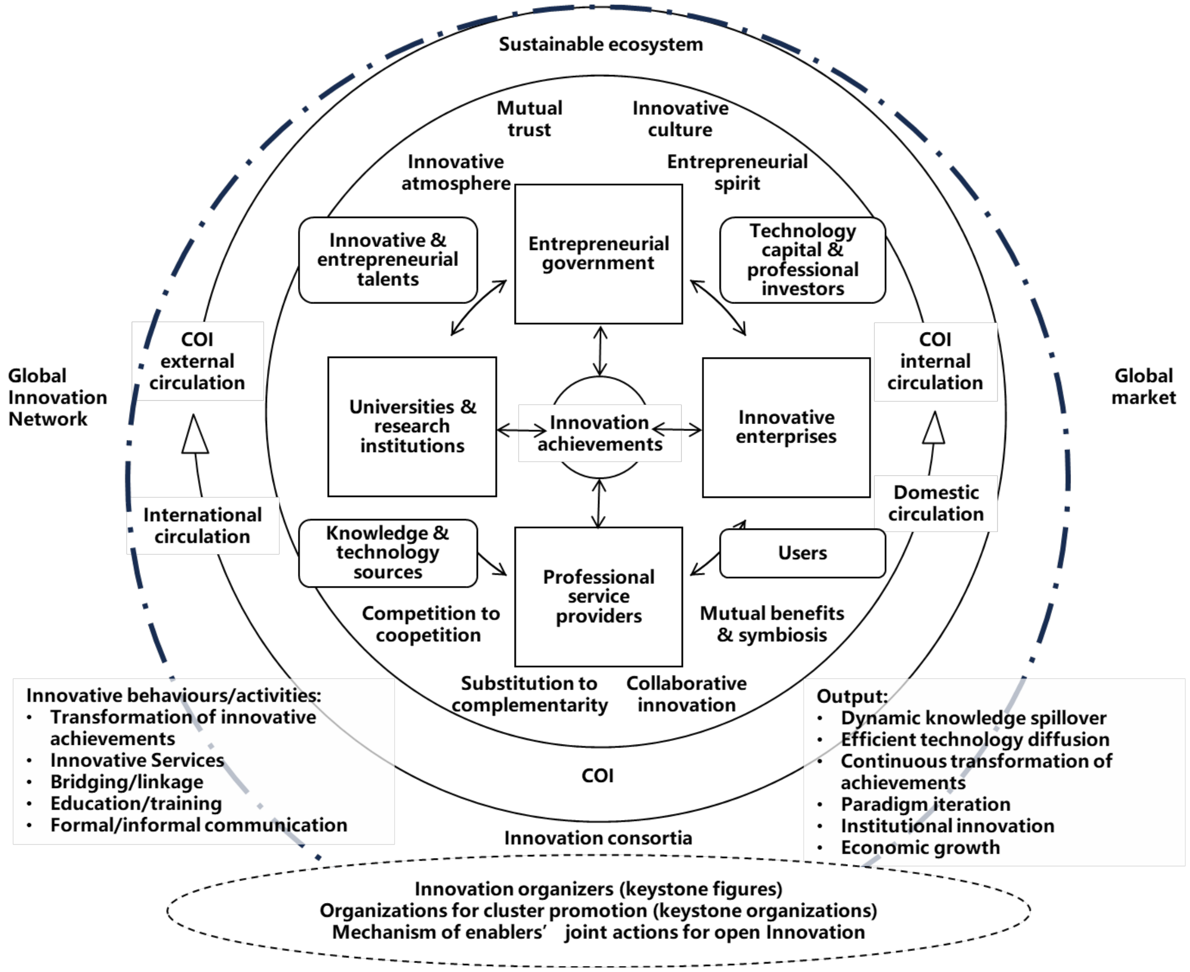

Figure 5.4 Theoretical model of core enablers and "total enabler joint action" of China's COIs in the biotechnology and healthcare industry

B. "Total enabler joint action" requires breaking through institutional constraints and establishing an "innovation consortium"

The purpose of "total enabler joint action" is to promote innovation, whereas the transformation rate of outcomes is an important indicator of innovation performance. In recent years, Chinese central and local governments have paid increasing attention to the transformation of scientific and technological outcomes. The transformation rate has become a performance indicator not only for universities and research institutions but also for high-tech parks and COIs. However, the difficulty of transformation and the low transformation rate of scientific and technological innovations have become bottlenecks and pain points that restrict scientific and technological innovation and industrial development. We hold that mechanism constraints are currently the core issue restricting the transformation of outcomes.

Therefore, it is necessary to overcome the mechanism constraints, break the barriers between organizations, and carry out institutional innovation. The responsibility of identifying and solving problems, evaluating achievements, and contribution awarding should be jointly taken by scientists and enterprises (instead of scientists alone as in the past). For instance, "technological innovation is an innovation aimed at creating new technologies or based on scientific and technological knowledge and the resources it creates" (X. Lu, 2013). From the field research of Bio Island, we learned that when product innovation shifts to service innovation, it is no longer a pure technological innovation. The former (e.g., the creation of a new drug or vaccine) and the latter (e.g., the development of a new product or service based on the existing technology) often go hand in hand. For example, the development of inhaled mRNA COVID-19 vaccines enabled a shift from innovative intramuscular vaccines that require professional medical staff to inhaled vaccines that even non-professionals can operate. It relieved the problem of medical staff shortage during the pandemic, improved the safety of vaccination, and reduced the cost of vaccine use. That is an excellent case of innovation. However, universities and research institutions alone would not be able to successfully commercialize such an innovation and make innovative products and services popularized and applied. They would need the capital operation ability of "bold" venture capital and professional investors, the commercialization, industrialization, and marketization ability of enterprises, and the support, approval, and promotion of the government. Therefore, it is imperative to break out of the institutional constraints and establish an "innovation consortium".

For the first time, the "innovation consortium" was mentioned in the *Law on Science and Technology Progress* (Standing Committee of the National People's Congress, 2021). As a newly proposed joint research organization in China, the innovation consortium is a task-based and systematic innovation organization that gives full play to enterprises' dominant position and leading role in technological innovation and the government's guiding and driving role as the innovation organizer, with research on key core technologies being its major tasks. Leveraging complementary resources in the innovation ecosystem, it fosters collaborative innovation and value co-creation.

As the transformation of innovation outcomes is becoming a major indicator of COIs' performance, COIs will become an experimental site of reform, shifting from "a cluster of multiple individual organizations bound by mechanisms" to an "innovation consortium with collaborative and institutional innovation", where the various enablers will jointly act to promote the transformation of outcomes.

C. "Total enabler joint action" needs to shift from "centralized" to "decentralized" and "distributed."

During literature research and the case study of Bio Island, we found that the evolution of COIs was a dynamic process, transitioning from "single centralized" to "polycentralized" and finally to "decentralized" (see Figure 5.5).

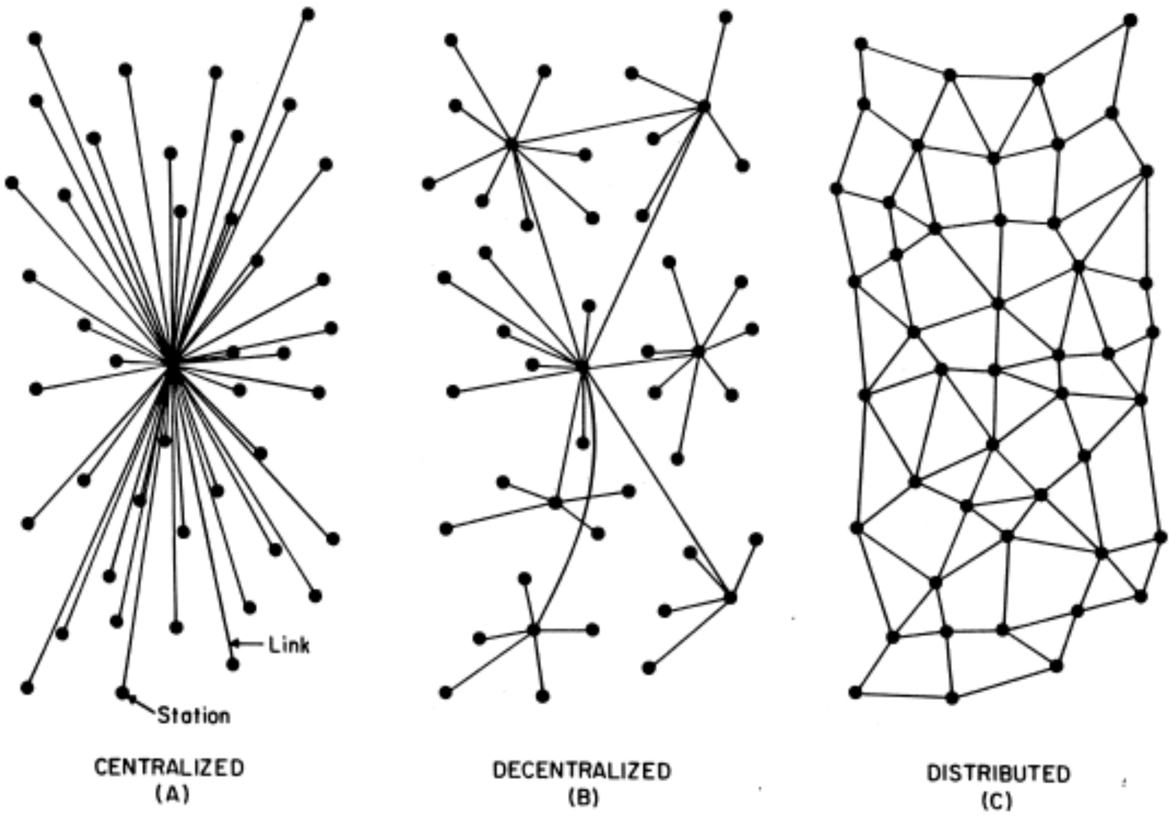

Figure 5.5 Centralized, decentralized, and distributed networks

Source: Baran (1964)

Guangzhou International Bio Island Co., Ltd. (referred to as the "Bio Island Company") was the first enterprise to settle in Bio Island (before its official opening). As a state-owned enterprise administering Bio Island on behalf of the local government, the Bio Island Company undertook the responsibilities of Bio Island's development & construction, investment promotion, and operation & management. At that time, the Bio Island Company was the single center of Bio Island, attracting enablers to gather through "investment promotion (behaviors and activities)".

At the initial stage of Bio Island (the opening stage), the condition for transitioning from "enterprises flocking together" to "industrial agglomeration" was "enterprise interaction", which was driven by the Bio Island Company through planning and organizing forums and workshops on open innovation.

In the mid-stage (the development stage), the condition for upgrading from "industrial agglomeration" to "industrial cluster" was "industrial interaction", which was promoted by the Bio Island Company through planning and organizing industry-related training, forums, and other activities (each dedicated to a specific segment), such as the China Bioindustry Convention. Such "industrial interactions" attracted more enterprises, research institutions, capital, and talents to gather and settle in Bio Island, and noticeable biotechnology industrial clusters began to emerge, including industrial segment clusters such as the diagnostic technology cluster and the medical device cluster. Meanwhile, Bio Island started to be "polycentralized", that is, enterprises, research institutions, and other innovation actors took themselves as the center to carry out industrial interaction and innovation activities, promoting the exchanges and cooperation among the enablers.

When Bio Island developed to the advanced stage, the condition for upgrading from an industrial cluster to a COI was the formation of a "collaborative innovation network with high connectivity within the ecosystem and with the world". At this stage, the Bio Island Company had grown into a "Group". While still functioning as a "bridge" connecting the innovation enablers, its role shifted from a "bridge builder" to a maker and maintainer of the innovation network. From the perspective of COI as a whole, the cluster was becoming "decentralized".

If Bio Island enters a mature stage in the future, it should be fully "decentralized". At that time, the COI must have high self-motivation and self-government ability and have formed an innovation ecosystem with a virtuous circle and sustainability (see Figure 5.4 and Figure 5.5 above).

In terms of the nature of its behaviors, the Bio Island Company (Group) functions as an "organization for cluster promotion", playing a key role in the formation and development of COIs.

According to the literature, a system of innovation is defined as the network of public and private organizations whose activities and interactions initiate, import, modify, and diffuse new technologies through (Freeman, 1987) or influence the production, diffusion, and use of economically useful new knowledge elements (Lundvall, 1992). An enterprise is regarded as a relationship of cooperation and competition with a wider network and is a part of this network. The innovation system can be inter-enterprise, interregional, statal, or global. From a meso perspective, a network is an analysis unit rather than a company. The network consists of customers, subcontractors, infrastructure, suppliers, and various functions, as well as the connections (or relationships) between them. In the network, key innovation capability is a part of the collective activities generated through actor networks and their connections (or relationships) (Freeman, 1987). Network effects (especially those related to innovation knowledge and experience) have been considered essential factors affecting the diffusion of innovation (Hall, 2009, p. 471). Therefore, the competition between different COIs in the future is the competition between "innovation networks".

Based on the discussion above, this study concludes that COIs and innovation ecosystems are composed of multiple sub-COIs and sub-innovation ecosystems. They are not formed linearly with a simple combination of "linkages", but a complex of points, lines, and surfaces with a multi-dimensional network structure, more specifically, a "nebula-like" structure (see Figure 5.6).

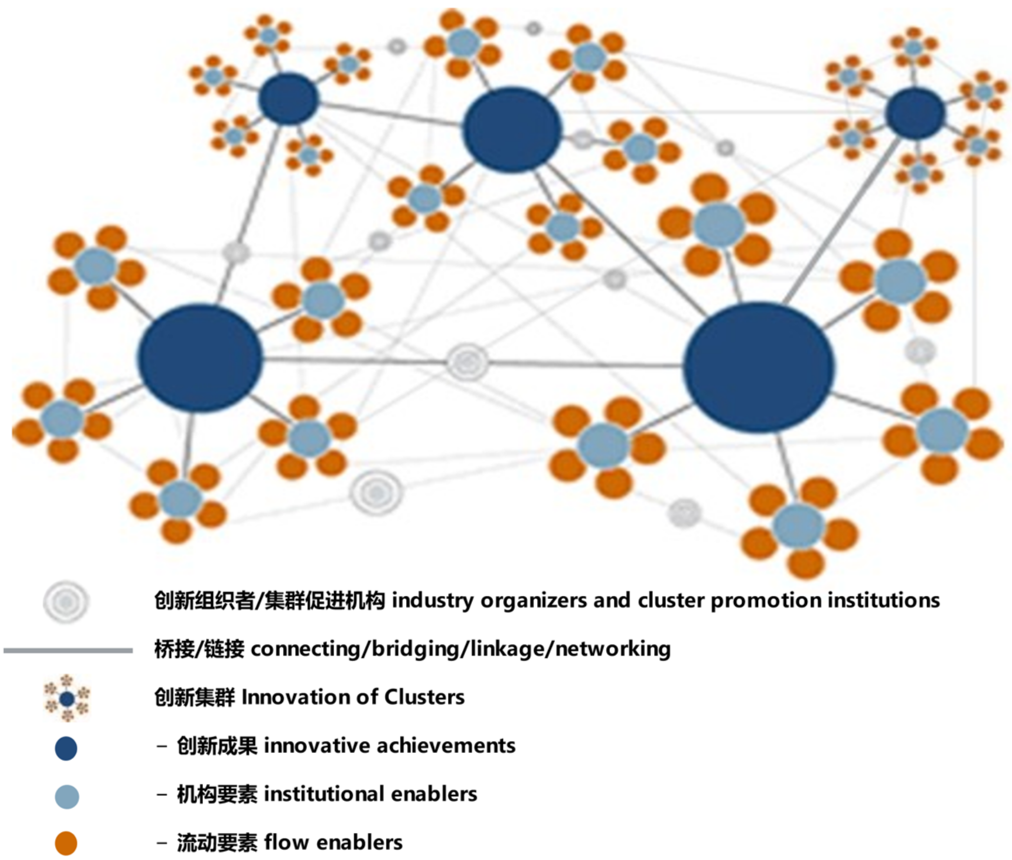

Figure 5.6 Core enablers of the development of COIs in the biotechnology and healthcare industry and their joint actions

5.2.4 Mechanism of COI core enablers' joint actions

During the focus group discussion, several experts mentioned the importance of a joint action mechanism and cultural factors for COIs. One of them quoted the following: when a COI develops to a certain stage, it will gradually form "a set of attitudes, values, norms, and expectations, also called distinctive 'regional culture', which further strengthens the systematic nature of regional innovation systems, impacting the behavior and practice of enterprises in the region" (Asheim & Gertler, 2009, p. 300). It is exactly this common regional culture (the commonly experienced institutional power) that shapes the way in which enterprises in the region interact with each other. COI enablers do not only include enterprises, which makes the enablers' joint actions more complex. It requires the engagement of multiple innovation actors. The enablers of COIs have joint actions through a set of "effective" innovation mechanisms that have been verified by practice. COIs in different regions and industries may have different practical experiences, either successful or failed, and different "innovation mechanisms" may be created "according to local conditions".

Based on the literature and focus group discussions, this study concludes that the regional innovation culture and institutional environment of COIs determine how enablers jointly act, forming a set of "dynamic mechanisms of positive feedback", that is, the "increasing marginal returns" in economics, so as to reduce costs and increase profits. Driven by the innovation mechanism, the enablers in the COI begin to have joint actions, forming the flow of innovation resources, resulting in various relationships with the features of mutual benefits, interdependence, consensus, symbiosis, co-creation, sharing, and win-win. It brings trust and order to the innovation ecosystem, enables innovation actors to shift from "competition" to "cooperation" and from "substitution" to "complementarity", and turns "closed innovation" to "open innovation" and "collaborative innovation".

To sum up, from the perspective of the integrity of COIs, the core enablers of COIs in the biotechnology and healthcare industry have become a "community with a shared future in health" with "common visions and goals" (e.g., "human health"), developed common "game rules", and formed an innovation ecosystem with open innovation, mutual trust, rapid learning, collaborative competition and cooperation, resource sharing, diverse symbiosis, cluster co-governance, and self-evolution. The enablers' joint actions foster resource integration and resource allocation optimization, improve productivity through innovation, accelerate the transformation of innovation outcomes, and create market value and social value, thereby promoting high-quality development of the industry and realizing regional economic growth.

5.3 International exchanges and cooperation's positive impact on the formation and development of COIs

According to the interview, in recent years, transnational technology transactions have become more and more frequent among Chinese biomedical enterprises, with a rapid upward trend. Through a search on INSIGHT - China Pharma Data, we have found that cross-border license-out transactions of Chinese innovative drugs have increased rapidly since 2018, and ushered in an outbreak in 2020. In 2020, there were 41 cases of cross-border license-out of Chinese innovative drugs, and the total amount of transactions disclosed was $6.794 billion US dollars, nearly 10 times that of the previous year. In 2022, there were 37 cross-border license-out transactions of Chinese innovative drugs, and the disclosed transaction amount reached $23.682 billion US dollars, achieving the $20 billion milestone for the first time. According to incomplete statistics from Caixin, in the first half of 2023, among the nearly 30 cross-border transactions of product rights between Chinese and overseas pharmaceutical enterprises, Chinese innovative drugs' license-out accounted for more than two-thirds. More than 20 Chinese biopharmaceutical enterprises have made product license-out, including at least five large transactions (more than 1 billion US dollars), with a total amount of about $12 billion US dollars. In the industry review of the first half of 2023, the healthcare team of Stifel (US) stated that 2023 would be the first year for China to become a net exporter of pharmaceutical innovations (A. Hua, 2023).

There is no boundary between technology and innovation. In today's world, the trend of technological exchanges and cooperation is inevitable. China is an integral part of the world. We have learned the lesson from history that "isolation from the world" stagnates technology and hinders innovation. Moreover, closed space and organization will inevitably lead to "entropy" and "chaos". We can find some different cases in the world. For example, countries that recognize multi-nationality, such as the United States and Switzerland, are often innovation powers with globally recognized innovation capacity. The experience of such countries shows that innovation tends to occur in places where people of different nationalities, backgrounds, races, cultures, beliefs, and expertise jointly live, work, communicate, and cooperate.

From the development history of China's industrial parks, we can find that many development zones have introduced professional equipment, production processes, advanced technology, and international standards, as well as advanced business management and business models by bringing in foreign-funded enterprises and multinational companies. That is basically exchanging the market for technology. For example, we can find such cases in the automotive industry and mobile phone industry, but they mostly have not been successful, often ending up losing the market without obtaining technology.

In the case study, we have found that Bio Island has taken an “innovation route” different from that of traditional science and technology industrial parks and has fostered COIs through international exchanges and cooperation: a) It has successfully initiated “UK-China bridge” and other “international bridges” open innovation projects and developed corresponding innovation policies and institutions; b) It has attached great importance to incentivizing returned talents from abroad for entrepreneurship and innovation; c) Through precise industry segmentation positioning, the increasingly developed industrial cluster has attracted a number of multinational pharmaceutical enterprises and local industry-leading enterprises to settle in Bio Island. With the innovation strategy for multinational pharmaceutical enterprises’ “localization” and for local industry-leading enterprises’ internationalization, it has further strengthened international exchanges and cooperation, promoted the transnational flow of technology, capital, talent, and other flow enablers, and further driven the upgrading from industrial clusters to COIs.

To sum up, due to the mobility of technology, the locality of tacit knowledge dissemination, the heterogeneity of clusters, and the externality of networks, COIs in the biotechnology and healthcare industry must adhere to “open innovation”, actively integrate into the global innovation network, integrate global technology and industrial resources through “bridging”, pay attention to the introduction of returned talents from abroad and high-level overseas talents, and stay highly connected with the world through “local buzzers and global channels”. With the assistance of organizations for cluster promotion, the local government and the park’s operation and management agencies can leverage the global innovation network and global technology to foster innovation and development in China for the global market, jointly fostering the joint actions of COI enablers, and driving the transformation of outcomes, thereby realizing the emergence of innovation, high-quality development of the economy, and sustainable development of the ecosystem.

Chapter 6: Conclusions

6.1 Main findings

This study is based on the case of Bio Island and was completed through five years of literature research, field research, formal interviews, and focus group discussions. The findings of this study are summarized as follows.

With the advent of the bioeconomy, biotechnology is developing rapidly, knowledge is continuously iterating, and cognitive boundaries are frequently interrupted. With the integration of biotechnology with new technologies such as information technology, computing science (cloud computing), big data, digitization, automation, the internet of things, blockchain, nanotechnology, 3D printing, robotics, and artificial intelligence, discipline boundaries are broken and industrial boundaries are diluted. Moreover, biotechnology is increasingly used in sectors such as medicine, big health, agriculture, materials, energy, and environmental protection, forming new cross-industrial development models such as “+biology” and “biology+”. Cross-disciplinary, cross-regional, cross-organizational, and cross-institutional exchanges and cooperation are more conducive to promoting innovation through “knowledge flow”, resulting in the generation or even constant emergence of new knowledge and technology at the intersection and cutting-edge.

Furthermore, the outcomes of knowledge and technological innovation must be applied, and their value should be realized through commercialization, industrialization, capitalization, and internationalization. That is, it is imperative to realize the “transformation of innovation outcomes” to drive the growth of the local economy and serve human health. Only in this way can COIs’ “knowledge and technology sources” be continuously supplemented (instead of being exhausted or becoming “pseudo-knowledge and technology sources”), eventually forming a virtuous cycle.

We hold that the formation, development, and evolution of COIs is an open process with continuous cycles from agglomeration to diffusion. Through a set of “feedback mechanisms”, it selects and evolves to a higher-level and diversified organizational form to meet the needs of the continuous development of the innovation ecosystem. The pursuit of profit maximization by enterprises in the COI is mainly driven by market factors, but governments, universities, research institutions, and some non-profit organizations should pursue beyond that, such as social values, public interests, and national interests. Therefore, driven by organizational mission and objectives and influenced by the internal and external environment, the COI enablers are dynamically balanced with characteristics of self-organization, self-adaptation, self-repair, self-evolution, and emergence, promoting the gradual prosperity of the innovation ecosystem. At this tipping point, the emergence of innovation “triggers” will upgrade the cluster’s quantitative changes into qualitative changes.

The Chinese government attaches great importance to and supports the development of the bioindustry and bioeconomy and encourages driving the high-quality development of bioindustry (bioeconomy) and regional economy through scientific and technological innovation. At the same time, with people’s increased consumption power, there is a higher demand for biotechnology and health products and services. All these factors are forcing accelerated transformation and upgrading of biotechnology and healthcare industrial parks to COIs. Against the above background, governments at all levels and park administrators and operators must tackle the problems during the parks’ transformation and upgrading, mainly including the shift a) from the model relying on income from “land” and “property” rental, sale, and management to the model focusing on scientific and technological services and innovation services, b) from the traditional “project-based” investment promotion approach to “cluster-based” approach, c) from low-end and “labor-intensive” industrial clusters based on “production system” to high-end and “talent- and capital-intensive” COIs based on “knowledge system”, d) from “linear industry chain mindset” to “composite cluster mindset”, e) from “closed innovation system” to “open innovation system”, and eventually f) towards an embedded “innovation ecosystem” characterized by mutual benefit and symbiosis.

This study categorized the core enablers of COIs into “explicit enablers” and “implicit enablers”. Explicit enablers include “organizational enablers” (“universities and research institutions”, “innovative enterprises”, “entrepreneurial government”, and “professional service providers”) and “flow factors” (“technology capital and professional investors”, “knowledge and technology sources”, “innovative and entrepreneurial talents”, and “users”). “Implicit enablers” include “innovation organizers”, “organizations of cluster promotion”, and “innovation institutions, paradigms, and cultures”. The “implicit enablers” of COIs are of particular interest as they are “hardly noticeable” and may easily be ignored. Innovation organizers are usually leaders with strong comprehensive capabilities and mediators trusted by internal and external COI enablers. They play the important roles of “innovation organizers” and “ecological engineers” indispensable to innovation ecosystems. Organizations for cluster promotion are often founded by such leading figures as innovation organizers (however, they are not governmental organizations or organizations led by industry-leading enterprises, but third-party organizations with credibility). This is the only way to overcome bureaucracy, prevent conflicts of position and interest, and break out institutional constraints and limitations.

Entrepreneurship is a critical internal driving force of COIs that enables the integration of all resources and the pursuit of business opportunities. Entrepreneurial culture and innovation culture are the “catalyst”, trust is the “lubricant”, team culture is the “adhesive”, and learning culture is the “fuel” and “fertilizer” that fosters COIs’ sustainable development and self-evolution.

Looking forward, we can see such a vision of biotechnology and healthcare industry COIs: Encouraged and supported by entrepreneurial governments and assisted by innovation organizers and organizations for cluster promotion in top-level design, COIs will establish a common vision of “a community with shared future in health” and “high-quality development”, link up core enablers to promote “total enabler joint action”, increase the transformation rate of outcomes to drive the regional economy, form innovation institutions and regional innovation culture through best practices, and proactively integrate into the global innovation network to achieve high connectivity with the world, ultimately becoming a self-evolving and sustainable innovation ecosystem.

6.2 Theoretical contributions

This study focuses on addressing two research questions: “the core enablers and their joint actions for the formation and development of COIs in the biotechnology and healthcare industry” and “the impact of international exchanges and cooperation on COIs”.

We put forward the theoretical concept of “enablers” and highlighted their value and role in “enabling” and “empowering” the formation and development of COIs. In addition, we categorized the enablers into four “organizational enablers” and four “flow enablers”. Moreover, referring to the development trend of the innovation paradigm, we included “users” as an additional enabler in the COI enabler theory.

The above-mentioned enablers are “explicit enablers”, most of which have been explored in the literature to a certain extent. They are “obvious” and easy to recognize. However, this study also identified “implicit enablers” and pointed out that the reason why some “pseudo-COIs” failed to transform, upgrade, or sustainably develop is due to the lack of these implicit enablers. This study highlighted that the two implicit enablers, namely, “innovation organizers” and “organizations for cluster promotion”, are COIs’ “new” species - keystone species (keystone figures and keystone organizations). We used the word “new” because in the literature, the term “species” often refers to entrepreneurs and enterprises, who are usually considered the keystone species. Without the “keystone species” in the ecosystem of COIs, biodiversity will collapse. Besides, “innovation institutions, innovation paradigms, and regional innovation cultures” are also considered implicit enablers. At the same time, we also emphasized the importance of “total enabler joint action” in the transformation and upgrading of COIs.

Lastly, the successful practice of the “international bridges” of Bio Island (a model innovation) shows the importance of international exchanges and cooperation in fostering the integration of COIs into the global innovation network and COIs’ high-quality development.

6.3 Limitations and prospects for future research

The COVID-19 has changed the way people work and live. For example, home office and online communication have become the “new normal”. More and more enterprises and freelancers have adopted such a working mode, and many presential training, forums, and seminars have turned online. It has led to certain changes in the flow of resources, such as knowledge, technology, and talent. How much do these changes affect COIs’ development, internationalization, innovation, and outcome transformation? Would large-scale outbreaks of infectious diseases and online communication reduce COIs’ dependence on geographical proximity? Due to time constraints, these aspects have not been thoroughly studied.

Moreover, through what kind of innovation mechanism can COIs’ core enablers improve the transformation rate of outcomes and drive economic growth? How can international exchanges and cooperation foster the transformation of outcomes? How can government policies incentivize the development of innovation organizers and organizations for cluster promotion, thereby driving the development of COIs? These could be interesting topics for future research.

Bibliography

Amin, A., & Robins, K. (1990). The re-emergence of regional economies? The mythical geography of flexible accumulation. *Environment and Planning. D, Society & Space*, *8*(1), 7-34.

Amin, A., & Thrift, N. (1992). Neo-Marshallian nodes in global networks. *International Journal of Urban and Regional Research*, *16*(4), 571-587.

Arrow, K. J. (1962). The economic implications of learning by doing. *The Review of Economic Studies*, *3*(29), 155-173.

Arrow, K. J. (1974). *The limits of organization*. W.W. Norton.

Asheim, B. T., & Gertler, M. S. (2009). The geography of innovation: regional innovation systems. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford handbook of innovation* (pp. 291-317). Oxford University Press.

Asheim, B. T., & Isaksen, A. (2002). Regional innovation systems: the integration of local ‘sticky’ and global ‘ubiquitous’ knowledge. *The Journal of Technology Transfer*, *27*(1), 77-86.

Bai, X., & Du, C. (2021). *产业经济学* [Industrial Economics]. Economic Science Press.

Baran, P. (1964). *On distributed communications: I. introduction to distributed communications networks*. RAND Corporation.

Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, *28*(1), 31-56.

Becattini, G. (1978). The development of light industry in Tuscany: an interpretation. *Economic Notes: Economic Review of Banca Monte Dei Paschi di Siena*, *7*(3), 107-123.

Becattini, G. (1986). *Small firms and industrial districts: the experience of Italy*. Economia Internazionale.

Becattini, G. (1989). Sectors and/or districts: some remarks on the conceptual foundations of industrial economics. In E. Goodman, J. Bamford, & P. Saynor (Eds.), *Small firms and industrial districts in Italy* (pp. 123-135). Routledge.

Becattini, G. (2017). The Marshallian industrial district as a socio-economic notion. *Revue D'économie Industrielle*, *157*(1), 13-32.

Becattini, G., Bellandi, M., & De Propris, L. (Eds.). (2009). *A handbook of industrial districts*. Edward Elgar Publishing.

Bergek, A., & Jacobsson, S. (2003). The emergence of a growth industry: a comparative analysis of the German, Dutch and Swedish wind turbine industries. In J. S. Metcalfe & U. Cantner (Eds.), *Change, transformation and development* (pp. 197-227). Physica.

Braczyk, H., Cooke, P., & Heidenreich, M. (Eds.). (1998). *Regional innovation systems: the role of governances in a globalized world*. Routledge.

Breschi, S., & Malerba, F. (1997). Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. In C. Edquist (Ed.), *Systems of innovation: technologies, institutions and organisations* (pp. 130-156). Pinter.

Bryman, A., & Bell, E. (2012). *Social research methods*. Oxford University Press.

Burton-Jones, A. (1999). *Knowledge capitalism: business, work, and learning in the new economy*. Oxford University Press.

Calzada, I. (2016). (Un) plugging smart cities with urban transformations: towards multi-stakeholder city-regional complex urbanity? *Urbs. Revista De Estudios Urbanos Y*

Ciencias Sociales, *6*(2), 25-45.
Carayannis, E. G., & Campbell, D. F. J. (2009). 'Mode 3' and 'quadruple helix': toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management*, *46*(3/4), 201-234.
Carayannis, E. G., & Campbell, D. F. J. (2010). Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology. International Journal of Social Ecology and Sustainable Development, 1(1), 41–69.
Castells, M., & Hall, P. (1994). *Technopoles of the world: the making of 21st century industrial complexes*. Routledge.
Chen, J., & Tang, Z. (2002). 国外产业集群研究综述 [A review of foreign industrial clusters]. *Foreign Economics & Management*, (08), 22-27.
Chen, W., Ren, H., & Sun, L. (2020). *适应性创新——不确定性下产业园区生存之道* [Adaptive innovation -- the way for industrial parks to survive under uncertainty]. Citic Press.
Chesbrough, H. W. (2003a). *Open innovation: the new imperative for creating and profiting from technology*. Harvard Business School Press.
Chesbrough, H. W. (2003b). The era of open innovation. *Massachusetts Institute of Technology Sloan Management Review*, *44*(3), 35-41.
Chesbrough, H. W. (2006). *Open business models: how to thrive in the new innovation landscape*. Harvard Business School Press.
Chesbrough, H. W. (2007). The market for innovation: implications for corporate strategy. *California Management Review*, *49*(3), 45-66.
Chesbrough, H. W. (2011). *Open services innovation*. Jossey-Bass.
Chesbrough, H. W., & Brunswicker, S. (2014). A fad or a phenomenon? The adoption of open innovation practices in large firms. *Research-Technology Management*, *57*(2), 16-25.
Chyi, Y., Lai, Y., & Liu, W. (2012). Knowledge spillovers and firm performance in the high-technology industrial cluster. *Research Policy*, *41*(3), 556-564.
Cohen, S., & Fields, G. (1998). *Social capital and capital gains, or virtual bowling in Silicon Valley* [Doctoral dissertation]. University of California, Berkeley.
Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change*, *10*(4), 945-974.
Cooke, P., Uranga, M. G., & Etxebarria, G. (1997). Regional innovation systems: institutional and organisational dimensions. *Research Policy*, *26*(4-5), 475-491.
Cortright, J., & Mayer, H. (2002). *Signs of life: the growth of biotechnology centers in the US*. Brooking Institution.
Cunningham, N. J. (1960). Industrial innovation. *Business History*, *2*(2), 97-100.
Davis, S., & Meyer, C. (2000). What will replace the tech economy. *Time*, *155*(21), 76-77.
Deng, X., & Gao, L. (2006). 经济时代的发展阶段及其划分标志 [The Developmental Phases and Marking Events of Economy Eras]. *Forum on Science and Technology in China*, (2), 111-114, 70.
Denzin, N. K., & Lincoln, Y. S. (Eds.). (1994). *Handbook of qualitative research*. Sage Publications, Inc.
Development Research Center of Guangdong Provincial People's Government. (2022). 第5期：培育广东“双十”产业集群的建议 [Issue 5: Suggestions for cultivating Guangdong's "Double Ten" industrial clusters]. In X. Zhong (Ed.), *广东发展蓝皮书：广东发展报告（2022）* [Blue Book of Guangdong's Development - Annual Report on Development of Guangdong (2022)] (pp. 64-74). Social Sciences Academic Press.

Drucker, P. F. (1995). *Innovation and entrepreneurship*. Butterworth Heinemann.
Dubina, I. N., Carayannis, E. G., & Campbell, D. F. J. (2012). Creativity economy and a crisis of the economy? Coevolution of knowledge, innovation, and creativity, and of the knowledge economy and knowledge society. Journal of the Knowledge Economy, 3(1), 1–24.
Edquist, C. (1997). *Systems of innovation: technologies, institutions and organizations*. Routledge.
Edquist, C. (2009). Systems of innovation: perspectives and challenges. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The oxford handbook of innovation* (pp. 181-208). Oxford University Press.
Edquist, C., & Johnson, B. H. (1997). Institutions and organizations in systems of innovation. In C. Edquist (Ed.), *Systems of innovation: technologies, organizations and institutions* (pp. 41-63). Pinter Publishers.
Engel, J. S. (Ed.). (2014). *Global clusters of innovation: entrepreneurial engines of economic growth around the world*. Edward Elgar Publishing Limited.
Engel, J. S. (2015). Global clusters of innovation: lessons from Silicon Valley. *California Management Review*, *57*(2), 36-65.
Engel, J. S. (Ed.). (2022). *Clusters of innovation in the age of disruption*. Edward Elgar Publishing Limited.
Engel, J. S., & Del-Palacio, I. (2009). Global networks of clusters of innovation: accelerating the innovation process. *Business Horizons*, *52*, 493-503.
Engel, J. S., & Del-Palacio, I. (2011). Global clusters of innovation: the case of Israel and Silicon Valley. *California Management Review*, *53*(2), 27-49.
Enos, J. L. (1962). *Petroleum progress and profits: a history of process innovation*. The Massachusetts Institute of Technology Press.
Etzkowitz, H., & Leydesdorff, L. (1995). The triple helix: university-industry-government relations: a laboratory for knowledge-based economic development. *European Association for the Study of Science and Technology Review*, *14*(1), 11-19.
Fagerberg, J. (2009). Innovation: a guide to the literature. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The oxford handbook of innovation* (pp. 1-26). Oxford University Press.
Fagerberg, J., Martin, B. R., & Andersen, E. S. (Eds.). (2013). *Innovation studies: evolution and future challenges*. Oxford University Press.
Fornahl, D., & Hassink, R. (2017). *The life cycle of clusters: a policy perspective*. Edwar Elgar.
Freeman, C. (1973). A study of success and failure in industrial innovation. In B. R. Williams (Ed.), *Science and technology in economic growth* (pp. 227-255). Palgrave Macmillan.
Freeman, C. (1982). *The Economics of Industrial Innovation*. Printer.
Freeman, C. (1987). *Technology policy and economic performance：lessons from Japan*. Pinter.
Freeman, C. (1988). Japan: a new national system of innovation? In G. Dosi, C. R. Freeman, R. R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical change and economic theory* (pp. 331-334). Printer.
Freeman, C., & Soete, L. (1974). *The economics of industrial innovation*. Routledge.
Glaeser, E., Kallal, H. D., Scheinkman, J., & Shleifer, A. (1992). Growth in cities. *Journal of Political Economy*, *100*(6), 1126-1152.
Globalization Think Tank & Bank of China. (2022). *中国留学发展报告（2022）* [China study abroad development report (2022)]. Social Science Academic Press.
Grabher, G. (1993). The weakness of strong ties: the lock-in of regional development in the Ruhr area. In G. Grabher (Ed.), *The embedded firm: on the socioeconomics of industrial networks* (pp. 255-277). Routledge.

Granstrand, O., & Holgersson, M. (2020). Innovation ecosystems: a conceptual review and a new definition. *Technovation*, *90-91*(102098), 1-12.

Hall, B. H. (2009). Innovation and diffusion. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The oxford handbook of innovation* (pp. 459-484). Oxford University Press.

Hannan, M. H., & Freeman, J. (1984). Structural inertia and organizational change. *American Sociological Review*, *2*(49), 149-164.

Hanusch, H., & Pyka, A. (2007). Introduction. In H. Hanusch & A. Pyka (Eds.), *Elgar companion to neo-Schumpeterian economics* (pp. 1-16). Edward Elgar Publishing.

Hayashi, F., & Prescott, E. C. (2002). The 1990s in Japan: a lost decade. *Review of Economic Dynamics*, *5*(1), 206-235.

Hewitt-Dundas, N. (2013). The role of proximity in university-business cooperation for innovation. *The Journal of Technology Transfer*, *38*(2), 1-23.

Hirst, P., & Zeitlin, J. (1997). *Flexible specialization: theory and evidence in the analysis of industrial change*. Contemporary Capitalism.

Huang, L. (2003). 区域技术创新生态系统的特征 [Characteristics of regional technological innovation ecosystems]. *Forum on Science and Technology in China*, (001), 23-26.

Huberman, A. M., & Miles, M. B. (1994). *Qualitative data analysis* (2nd ed.). Sage Publications, Inc.

Hwang, V. W., & Horowitt, G. (2012). *The rainforest: the secret to building the next Silicon Valley*. Regenwald.

Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic Management Journal*, *39*(8), 2255-2276.

Jacobs, J. (1961). *The death and life of great American cities*. Random House.

Kline, S. J., & Rosenberg, N. (1986). An overview of innovation. In R. Landau & N. Rosenberg (Eds.), *The positive sum strategy: harnessing technology for economic growth* (pp. 275-306). National Academy of Sciences.

Lam, A. (2009). Organizational innovation. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The oxford handbook of innovation* (pp. 115-147). Oxford University Press.

Laursen, K., & Salter, A. (2006). Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal*, *27*(2), 131-150.

Lazonick, W. (2002). Innovative enterprise and historical transformation. *Enterprise & Society*, *1*(3), 3-47.

Li, B., Dong, W., & Fu, J. (2012). 中国情境下创新集群建设模式探析 [Analysis of innovation cluster construction mode in China]. *China Soft Science*, (11), 161-169.

Li, B. (2022). *生物经济：一个革命性时代的到来* [Bioeconomy: The arrival of a revolutionary era]. China Democratic and Legal Publishing House.

Li, H. (2004). *管理研究方法论* [Management research methodology]. Xi’an Jiaotong University Press.

Li, W., Chang, J., Wang, M., Zhu, X., & Jin, A. (2014). 创新3.0与创新生态系统 [Innovation 3.0 and innovation ecosystem]. *Studies in Science of Science*, *32*(12), 1761-1770.

Lin, Q., Wang, X., He, W., & Yang, X. (2020). 全球生物技术产业集群建设情况综述 [A summary of global biotechnology industry cluster]. *Global Science, Technology and Economy Outlook*, *35*(2), 26-31.

Liu, X. (2022). *创新生态系统：理论、战略与实践* [Innovation Ecosystem: Theory, strategy, and Practice]. Intellectual Property Publishing House.

Liu, X., Dong, C., & Ding, X. (2020). 数字创新时代：中国的机遇与挑战 [Digital innovation era: Opportunities and challenges for China]. *Science of Science and Management of S.& T.*, *41*(6), 3-15.

Liu, X., & White, S. (2001). Comparing innovation systems: a framework and application to China's transitional context. *Research Policy*, *30*(7), 1091-1114.

Liu, Z. (2015). “互联网+”与产业集群互联网化升级研究 [Study on the "Internet+" and the Internet-Based Upgrading of Industry Clusters]. *Science of Science and Management of Science & Technology*, (8), 73-82.

Lorenz, E. (1992). Trust, community and cooperation: toward a theory of industrial districts. *Post-Print*, (1), 11-13.

Lu, G. (2003). 产业创新：超越传统创新理论的新范式 [Industrial Innovation: New Model beyond the Traditional Innovation Theory]. *Jianghan Tribune*, (2), 10-13.

Lu, X. (2013). *管理学大辞典* [Dictionary of management]. Shanghai Lexicographical Publishing House.

Lundvall, B. (1988). Innovation as an interactive process: from user - producer interaction to the national systems of innovation. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical change and economic theory* (pp. 349-369). Pinter Publishers.

Lundvall, B. (Ed.). (1992). *National systems of innovation. Towards a theory of innovation and interactive learning*. Pinter Publishers.

Lundvall, B. (2013). Innovation studies: a personal interpretation of 'the state of the art'. In J. Fagerberg, B. R. Martin, & E. S. Andersen (Eds.), *Innovation studies: evolution and future challenges* (pp. 20-70). Oxford University Press.

Ma, Z. (2010). 基于DMI模型的我国产业集群升级——以WAPI为例 [Upgrading of China’s industrial clusters based on DMI model - A case study of WAPI]. *Economic Management*, *32*(6), 54-60.

MacKinnon, D. F., Cumbers, A., & Chapman, K. (2002). Learning, innovation and regional development: a critical appraisal of recent debates. *Progress in Human Geography*, *26*(3), 293-311.

Malerba, F. (2009). Sectoral systems: how and why innovation differs across sectors. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The oxford handbook of innovation* (pp. 380-406). Oxford University Press.

Mansfield, E. (1988). The speed and cost of industrial innovation in Japan and the United States: external vs. Internal technology. *Management Science*, *34*(10), 1157-1279.

Marshall, A. (1890). *Principles of economics* (1920ed.). Macmillan.

Marshall, A. (1919). *Industry and trade: a study of industrial technique and business organization and of their influences on the conditions of various classes and nations*. MacMillian and Co. Limited.

Martin, M. J. C. (1994). *Managing innovation and entrepreneurship in technology-based firms*. Wiley.

Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography*, *6*(4), 395-437.

Mazzucato, M. (2013). *The entrepreneurial state: debunking private vs. public sector myths*. Anthem Press.

Menzel, M. P., & Fornahl, D. (2007). Cluster life cycles - dimensions and rationales of cluster development. *Jena Economic Research Papers*, *19*(1), 205-238.

Moore, J. F. (1993). *Predators and prey: a new ecology of competition*. Harvard Business Review.

Morgan, K., & Cooke, P. (1998). *The associational economy: firms, regions, and innovation*. Oxford University Press.

Mowery, D. C., & Rosenberg, N. (1979). The influence of market demand upon innovation: a critical review of some recent empirical studies. *Research Policy*, *8*(2), 102-153.

Nelson, R. R. (1993). *National innovation systems: a comparative analysis*. Oxford University Press.

OECD. (2005). Oslo manual: guidelines for collecting and interpreting innovation data (third edition). Organisation for Economic Co-operation and Development Publishing.

Pang, Y. (2006). 中国集群经济的没落疑题 [The decline of China's cluster economy]. *China Quality and Brand*, (2), 64-69.

Pavitt, K. (2009). Innovation processes. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The oxford handbook of innovation* (pp. 86-114). Oxford University Press.

Perez, C. (2002). *Technological revolutions and financial capital: the dynamics of bubbles and golden ages*. Edward Elgar Publishing.

Perez, C. (2010). Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics*, *34*(1), 185-202.

Piore, M. J., & Sabel, C. F. (1984). *The second industrial divide*. Basic Books.

Polanyi, M. (1966). *The tacit dimension*. University of Chicago Press.

Porter, M. E. (1990). *The competitive advantage of nations*. The Free Press.

Porter, M. E. (1998). *Clusters and the new economics of competition*. Harvard Business Review.

Porter, M. E., & Ketels, C. (2009). Clusters and industrial districts: common roots, different perspectives. In G. Becattini, M. Bellandi, & L. De Propis (Eds.), *A handbook of industrial districts* (pp. 172-185). Edward Elgar Publishing.

Pouder, R., & St. John, C. H. (1996). Hot spots and blind spots: geographical clusters of firms and innovation. *Academy of Management Review*, *21*(4), 1192-1225.

Pyke, F., Becattini, G., & Sengenberger, W. (Eds.). (1990). *Industrial districts and inter-firm co-operation in Italy*. International Institute for Labour Studies.

Pyke, F., & Sengenberger, W. (Eds.). (1992). *Industrial districts and local economic regeneration*. International Labour Organisation.

Rickne, A. (2000). *New technology-based firms and industrial dynamics: Evidence from the technological system of biomaterials in Sweden, Ohio and Massachusetts* [Doctoral dissertation]. Chalmers University of Technology.

Rogers, E. (1962). *Diffusion of innovations*. Free Press of Gleneoe.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*(5), 1002-1037.

Schmookler, J. (1966). *Invention and economic growth*. Harvard University Press.

Schumpeter, J. A. (1912). *The theory of economic development* (tenth printing 2004ed.). Transaction Publishers.

Schumpeter, J. A. (1934). *The theory of economic development: an inquiry into profits, capital, credit, interest and the business cycle* (Vol. 46ed.). Harvard Economic Studies.

Schumpeter, J. A. (1939). *Business cycles: a theoretical, historical and statistical analysis of the capitalist process*. McGraw-Hill Book Company.

Schumpeter, J. A. (1942). *Capitalism, socialism and democracy* (3rd editioned.). George Allen and Unwin.

Sekaran, U., & Bougie, R. (2013). *Research methods for business: a skill-building approach*. Wiley.

Shanghai Institute for Science of Science. (2015). *促进上海创新生态系统发展的研究* [Promoting the Innovation Ecosystems of Shanghai]. Shanghai Science and Technology Press.

Simanis, E., & Hart, S. (2009). Innovation from the inside out. *Massachusetts Institute of Technology Sloan Management Review*, *50*(4), 77-86.

Solow, R. M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, *39*(3), 312-320.

Stiglitz, J. E., & Greenwald, B. C. (2014). *Creating a learning society: a new approach to growth, development, and social progress*. Columbia University Press.

Tansley, A. G. (1935). The use and abuse of vegetational concepts and terms. *Ecology*, *16*(3), 284-307.

Teece, D., & Pisano, G. (1994). The dynamic capabilities of firms: an introduction. *Industrial and Corporate Change*, *3*(3), 537-556.

"The Evaluation of the Innovation Ecosystem for Chinese Cities" Research Group. (2016). *中国城市创新生态系统评价* [Evaluation of urban innovation ecosystem in China]. Social Science Academic Press.

Tian, Y. (2011). 产业集群升级路径选择研究 [Research on Upgrading Path Selection of industrial clusters]. *Science & Technology Progress and Policy*, *28*(12), 53-57.

Toffler, A. (1980). *The third wave*. Morrow.

Tonković, A. M., Veckie, E., & Veckie, V. W. (2015). Applications of penta helix model in economic development. *Economy of Eastern Croatia – Yesterday, Today, Tomorrow*, *4*, 385-393.

Torch High Technology Industry Development Center & Institute for Strategic Consulting of Science and Technology. (2021). 国家高新区创新能力评价报告2020 [Evaluation report on innovation capability of national high-tech zones 2020]. *Journal of Henan Science and Technology*, *40*(17), 3.

Vallas, S. P., Kleinman, D. L., & Biscotti, D. (2011). Political structures and the making of US biotechnology. In F. L. Block & M. R. Keller (Eds.), *State of innovation: the US government's role in technology development* (pp. 57-76). Boulder, CO: Paradigm.

Vanhaverbeke, W. (2017). *Managing open innovation in SMEs*. Cambridge University Press.

Von Hippel, E. (1988). *The sources of innovation*. Oxford University Press.

Wang, C. (2012). *中国高新区战略转型研究——基于产业集群视角* [Study on the Strategic Transformation of China National High-Tech Industrial Development Zones from the Perspective of Industrial Clusters]. People's Publishing House.

Wang, J. (2004). 关于发展创新型产业集群的政策建议 [Developing Innovation-Based industrial Clusters Policy Recommendations]. *Journal of Economic Geography*, *24*(4), 433-436.

Wang, J. (2023). *园区和集群：创新驱动区域发展之思* [Industrial Parks & Clusters: Reflections on Innovation-driven Regional Development]. Publishing House of Electronics Industry.

Wang, J., He, C., Tong, X., Wang, J., Li, P., Pan, F., Chen, P., Ma, M., Mei, L., Lin, T., Zhang, Y., Tan, W., Chen, Q., Liu, X., Song, J., Ren, B., Li, P., Jiang, J., & Zhu, L. (2010). *超越集群——中国产业集群的理论探索* [Beyond Clusters: Theoretical Exploration on China's Industrial Clusters]. Science Press.

Wang, J., Tong, X., Zhu, H., Liu, J., Zhou, W., Gai, W., Ge, Y., Yuan, Y., Zhang, H., & Wang, K. (2019). *创新的空间——产业集群与区域发展* [Industrial Clusters and Regional Development]. Science Press.

Wang, L. (2014). *基于创新驱动的产业集群升级研究* [Research on Industrial Cluster Upgrading Based on innovation driven]. [Doctoral dissertation]. Party School of the CPC Central Committee.

Wang, X. (2018). *中美产业创新能力比较分析——以生物医药产业为例* [Comparative Analysis Industrial Innovation Capability Between China and The United States - Biopharmaceuticals as an example]. China Economic Publishing House.

Wang, X. (2006). 企业人力资本与技术创新的相互作用研究 [Research on the interaction between human capital and technological innovation in Enterprises]. *Productivity Research*, (3), 214-215.

Wei, H. (2008). *中国产业集聚与集群发展战略* [Industrial agglomeration and cluster development strategies in China]. Economic Management Press.

Wei, J. (2010). 国外产业集群理论:基于经典和多视角研究的一个综述 [Theory of foreign industrial clusters based on classic and multi perspective]. *R&D Management*, (03), 13-22.

Weber, A. (1909). *Über den standort der industrie* [Theory of the location of industries] (C. J. Friedrich, Trans.; 1929 ed.). University of Chicago Press.

Whitford, J. (2001). The decline of a model? Challenge and response in the Italian industrial districts. *Economy and Society*, *30*(1), 38-65.

Xing, S. (2016). *科技企业家* [Tech entrepreneur]. Southwestern University of Finance and Economics Press.

Yu, R., & Li, Y. (2003). 论技术创新与产业融合 [On technological innovation and industrial integration]. *Productivity Research*, (006), 175-177.

Yue, F. (2009). 产业集群升级机制及政府的作用 [Upgrading mechanism of industrial clusters and the role of government]. *Journal of Guangdong University of Business Studies*, (1), 11-16.

Zhang, F., Xu, L., & Hou, T. (2010). 关于技术创新概念界定的探讨 [Discussion on the definition of technological innovation]. *Productivity Research*, (3), 26-27.

Zhang, X., & Huang, X. (2013). 三螺旋理论，传统“产学研”理论的创新范式 [Triple helix theory: Innovation paradigm of traditional theory of industry-university-research]. *Journal of Dalian University of Technology (social sciences)*, *34*(4), 1-6.

Zhao, C., Chen, J., Li, J., & Mei, L. (2018). 企业创新系统：概念内涵与研究演进 [Enterprise innovation system: Concept connotation and research evolution]. In J. Chen & J. Gao (Eds.), *创新与创业管理（第18辑）* [Innovation and Entrepreneurship Management (Volume 18)] (pp. 124-142). Science Press.

Zhao, G. (2017). *国家创新战略与企业家精神* [National Innovation Strategy and Entrepreneurship]. Citic Press Corporation.

Zhou, L., & Zhang, H. (2017). *产业裂变新格局与产业创新方向研究——基于珠三角国家级高新区的实证* [Research on the new pattern of industrial fission and the direction of Industrial Innovation – An empirical study based on the national high-tech zones in the Pearl River Delta]. Economic Science Press.

Zhou, Y., & Wang, W. (2003). 我国高新区阶段发展的理论框架，兼论高新区“二次创业”的能力评价 [The theoretical framework of the stage development of China's high-tech zones and the ability evaluation of the "second venture" of high-tech zones]. *Journal of Economic Geography*, (7), 452-455.

Z. H. ISLAND. (2018). *本质* [Nature]. China Machine Press.

Webliography

China Center for Information Industry Development. (2019, September 30). *To build an advanced manufacturing cluster, we must first cultivate the whole industrial chain*. The Paper. Retrieved August 29, 2023, from https://www.thepaper.cn/newsDetail_forward_4507894

Curley, M., & Salmelin, B. (2013, December 30). *Open innovation 2.0: a new paradigm*. Open Innovation Strategy and Policy Group, European Union. Retrieved April 29, 2023, from https://ec.europa.eu/futurium/en/system/files/ged/24-oispgopeninnovation20anewparadigm-whitepaper.pdf

Du, J. (2022, December 26). *Summary and interpretation of China's bioeconomy industry policies in 2023 - the industry has entered a period of rapid growth*. Qianzhan Industrial Research Institute. Retrieved April 29, 2023, from https://www.qianzhan.com/analyst/detail/220/221226-6d81a375.html

Guangzhou International Bio Island. (2015, December 30). *Guangzhou International Biological Island is located in the "heart of Guangzhou"*. Bio Island Company. Retrieved December 6, 2023, from http://www.bio-island.com/advantages.aspx

Hua, A. (2023, July 29). *The Second Journey of Innovative Drugs to open up overseas markets*. Caixin Weekly. Retrieved September 7, 2023, from https://weekly.caixin.com/2023-07-29/102087528.html

Jiang, J. (2022, January 7). *The era of bioeconomy is accelerating*. Economic Daily. Retrieved December 5, 2023, from http://www.china-cer.com.cn/guwen/2022010716392.html

Jin, Z. (2022, February 20). *China's residents' health literacy has increased by about 15% in the past decade*. Guangming Daily. Retrieved December 5, 2023, from https://epaper.gmw.cn/gmrb/html/2022-02/20/nw.D110000gmrb_20220220_5-01.htm

London & Partners. (2023, February 10). *MedCity To Join Forces with London & Partners* Retrieved October 5, 2023, from https://media.londonandpartners.com/news/medcity-to-join-forces-with-london-partners

Ma, M. (2015, September 11). *What is Schumpeter innovation*. China Economic Times. Retrieved September 6, 2023, from https://xuewen.cnki.net/CCND-JJSB201509110050.html

MedCity. (2023, June 30). *MedCity Impact Report 2023*. London & Partners. Retrieved October 5, 2023, from https://www.medcityhq.com/wp-content/uploads/2023/06/MedCity_Annual-Review-2023_dp_27th.pdf

National Economic Council, & Office of Science and Technology Policy. (2015, October 31). *A Strategy for American Innovation*. The White House. Retrieved November 30, 2023, from https://obamawhitehouse.archives.gov/sites/default/files/strategy_for_american_innovation_october_2015.pdf

OECD. (1997). *The National Innovation System*. Organisation for Economic Co-operation and Development. Retrieved May 22, 2023, from https://www.oecd.org/science/inno/2101733.pdf

OECD. (2001). *Innovative clusters: drivers of national innovation systems*. Organisation for Economic Co-operation and Development. Retrieved May 28, 2022, from https://read.oecd-ilibrary.org/science-and-technology/innovative-clusters_9789264193383-en

Panori, A. (2016, March 24). *Cluster of Innovation: understanding life cycle*. The Economist Intelligence Unit. Retrieved May 30, 2022, from https://urenio.org/2016/03/24/innovation-clusters-understanding-life-cycles/

PCAST. (2004a). *Sustaining the nation's innovation ecosystem: report on maintaining the strength of our science & engineering capabilities*. The President's Council of Advisors on Science and Technology. Retrieved October 1, 2023, from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-04-sciengcapabilities.pdf

PCAST. (2004b). *Sustaining the nation's innovation ecosystem: report on information technology manufacturing and competitiveness*. President's Council of Advisors on Science and Technology. Retrieved October 1, 2023, from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-04-itreport.pdf

Porter, M. E., & Stern, S. (1999). *The New Challenge to America's Prosperity: Findings from the Innovation Index*. Council on Competitiveness. Retrieved September 30, 2023, from https://www.hbs.edu/ris/Publication%20Files/Downloads_Porter_index1_el_be68d54c-4990-45da-88c0-ee754c99ffdb.pdf

PwC. (2021, August 1). *Review and prospect of M&A activities in China's big health industry from 2013 to the first half of 2021*. Pricewaterhouse Coopers. Retrieved April 29, 2023, from https://pdf.dfcfw.com/pdf/H3_AP202109021513766480_1.pdf?1630676229000.pdf

Qianzhan Industrial Research Institute. (2020, July 8). *Distribution status and scale analysis of biomedical industrial parks in China*. Qianzhan Industrial Research Institute. Retrieved May 24, 2022, from https://f.qianzhan.com/yuanqu/detail/200708-8a6c30dd.html

Qu, R., & Yang, X. (2019, May 16). *Gather the spirit of the world to strengthen international scientific and technological innovation cooperation in an all-round way through the efforts of all parties*. China Daily. Retrieved December 5, 2023, from http://finance.people.com.cn/n1/2019/0516/c1004-31087941.html

Strategy Planning Department of China National Intellectual Property Administration & Intellectual Property Development & Research Center, 2022. (2022, December 28). *China Patent Investigation Report 2022*. China National Intellectual Property Administration. Retrieved December 1, 2023, from https://www.cnipa.gov.cn/module/download/downfile.jsp?classid=0&showname=2022%E5%B9%B4%E4%B8%AD%E5%9B%BD%E4%B8%93%E5%88%A9%E8%B0%83%E6%9F%A5%E6%8A%A5%E5%91%8A.pdf&filename=5485425747ed467397ebabdbc317293a.pdf

Su, J. (2019, March 15). *High quality development from the perspective of total factor productivity*. Guangming Daily. Retrieved September 6, 2023, from https://news.gmw.cn/2019-03/15/content_32641511.htm

Wang, J. (2021, October 15). *Wang Jici: I have something to say about the "chain leader system"*. The Paper. Retrieved May 29, 2023, from https://www.thepaper.cn/newsDetail_forward_14915814

WIPO. (2023). *Global innovation index 2023*. The World Intellectual Property Organization. Retrieved September 26, 2023, from https://www.wipo.int/global_innovation_index/en/2023/science-technology-clusters.html

Wu, Z. (2019, October 10). *Analysis on the operation mode of biomedical industrial park in China*. Equal Ocean. Retrieved December 6, 2023, from https://www.iyiou.com/news/20191010114948

Xi, J. (2016a, May 31). *Xi Jinping: Strive to build a world power in science and technology - Speech at the National Science and Technology Innovation Conference, the Academician*

Conference of the Chinese Academy of Sciences and the Chinese Academy of Sciences, and the Ninth National Congress of the China Association for Science and Technology. Xinhua News Agency. Retrieved December 5, 2023, from http://www.xinhuanet.com/politics/2016-05/31/c_1118965169.htm

Xi, J. (2016b, October 27). *Report of the 19th National Congress of the Communist Party of China*. Xinhua News Agency. Retrieved July 7, 2023, from https://news.cnr.cn/native/gd/20171027/t20171027_524003098.shtml

Xi, J. (2022, October 16). *Report of the 20th National Congress of the Communist Party of China*. Xinhua News Agency. Retrieved July 7, 2023, from https://news.cri.cn/20221016/59193a49-fe7b-7354-4381-14dc14541e89.html

Xinhua News Agency. (2017, August 14). *National Health and Family Planning Commission: The total scale of China's health service industry will reach 16trillion yuan by 2030*. Xinhua News Agency. Retrieved April 29, 2023, from http://m.xinhuanet.com/2017-08/14/c_1121481192.htm

Xinhua News Agency. (2023, September 10). *Xi Jinping sent a congratulatory letter to the 2023 Pujiang Innovation Forum*. China Youth News. Retrieved September 21, 2023, from https://zqb1.cyol.com/images/2023-09/11/01/ZQB01B20230911C_l.pdf

Ministry of Industry and Information Technology of China. (2020, October 23). *Letter on reply to proposal No. 1440 (economic development category No. 106) of the third session of the 13th National Committee of the Chinese people's Political Consultative Conference*. Department of Development Planning. Retrieved August 29, 2023, from https://www.miit.gov.cn/zwgk/jytafwgk/art/2020/art_4d2cb291bd0a417eae9ef4df19d9f192.html

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Other References

Clinton, W. J., & Jr. Gore, A. (1994). *Science in the National Interest* (Report No. ED373994).

Congress of the United States. (1978). *Government involvement in the innovation process: a contractor's report to the office of technology assessment* (Report No. NTIS order #PB-286545).

OECD. (1996). *The Knowledge-based Economy* (Report No. OCDE/GD (96)102).

Standing Committee of the National People’s Congress. (2021). *Law on Science and Technology Progress* (Report No. Decree No. 103 of the President of the People's Republic of China).

National Development and Reform Commission of China. (2016). *Notice on printing and distributing the 13th five-year plan for the development of biological industry* (Report No. FGGJ [2016]2665).

National Development and Reform Commission of China. (2019). *Notice on accelerating the construction of strategic emerging industry clusters* (Report No. FGGJ [2019]1473).

National Development and Reform Commission of China, State Health Commission of China, State Administration of Traditional Chinese Medicine, & State Bureau of Disease Control and Prevention of China. (2021). *Notice on printing and distributing the implementation plan for the construction of high quality and efficient medical and health service system during the 14th five-year plan* (Report No. FGSH [2021]893).

The State Council of the People's Republic of China. (2023). *Report on the Work of the Chinese Government (2023)* (Report No. State Council Gazette Issue 2023 No. 8).

Ministry of Science and Technology of China. (2017). *Notice on printing and distributing the 13th five-year plan for Biotechnology Innovation* (Report No. GKFS [2017]103).