INSTITUTO
UNIVERSITÁRIO
DE LISBOA

Medical Device Contract Research Organization (CRO) as Knowledge-Intensive Business Services (KIBS): Exploring China's Innovative Medical Device Sector

CHEN Zhenlang

Doctor of Management

Supervisor:
PhD Sandro Mendonça, Assistant Professor,
ISCTE University Institute of Lisbon

April, 2021

BUSINESS
SCHOOL

Marketing, Operations and General Management Department

Medical Device Contract Research Organization (CRO) as Knowledge-Intensive Business Services (KIBS): Exploring China's Innovative Medical Device Sector

CHEN Zhenlang

Doctor of Management

Supervisor:
PhD Sandro Mendonça, Assistant Professor,
ISCTE University Institute of Lisbon

April, 2021

BUSINESS
SCHOOL

Marketing, Operations and General Management Department

Medical Device Contract Research Organization (CRO) as Knowledge-Intensive Business Services (KIBS): Exploring China's Innovative Medical Device Sector

CHEN Zhenlang

Doctor of Management

Jury:

PhD Fatima Salgueiro, Associate Professor with Habitation,
ISCTE University Institute of Lisbon
PhD António Bob Santos, Executive Director,
National Innovation Agency
PhD Virginia Trigo, Emeritus Professor,
ISCTE University Institute of Lisbon
PhD Sandro Mendonça, Assistant Professor,
ISCTE University Institute of Lisbon
PhD Zhang Chichen, Full Professor
Southern Medical University

April, 2021

INSTITUTO UNIVERSITÁRIO DE LISBOA

Medical Device Contract Research Organization (CRO) as Knowledge-Intensive Business Services (KIBS): Exploring China's Innovative Medical Device Sector

CHEN Zhenlang

Declaration

I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed: Chen Zhenlang Date: 23rd March, 2021

Name: Chen Zhenlang

作者申明

本人郑重申明：除了论文致谢中明确说明并致以谢意的部分外，所呈交的论文不包含任何他人或作者本人已用于获得任何教育机构的学位和证书而使用过的材料。同时尽我所知，除了文中特别加以标注引用的内容外，本论文不包含任何其他个人或集体已经发表或撰写的成果作品。

作者签名：陈振浪 日期：2021.3.23

姓名(拼音)：Chen Zhenlang

[This page is deliberately left blank.]

Abstract

China has witnessed rapid economic growth in the past 40 years of economic reform and opening up. In this context, healthcare development and innovation dynamics is of great significance in China's modern economy. In particular, sectors like medical equipment and devices are one of the pillars of Chinese healthcare system. Due to the soaring costs of medical devices technical change and strict government supervision, R&D outsourcing of the medical device sector to specialized service entities known as CROs (contract research organizations) has attracted more and more attention. In this Thesis, CROs are seen as knowledge-intensive business services (KIBS) in the evolving national innovation system of China since they act as innovation intermediaries to promote the effective use of knowledge in society.

To explore the development of KIBS innovative performance of Chinese medical device CROs, qualitative methodological approach is adopted. Semi-structured interviews were conducted with 20 experts from four different groups of key stakeholders of medical device CROs. Six findings are drawn from the key points expressed by the interviewees, forming a guidance for the further innovation of medical device CROs: (1) CROs can be extended by vertical integration, providing inclusive services; (2) CROs can be transformed by information technologies and digitalization; (3) CROs need to develop quick response capabilities through fast delivery; (4) CROs can be optimized by better resource allocation; (5) CROs need to provide an incentive scheme; and (6) CROs need to focus on reputational capital.

The results show that Chinese medical device CROs perform innovation activities in a way compatible with the KIBS concept, and thus directly affect the economic competitiveness of the medical device sector in China.

Keywords: contract research organization (CRO); medical device innovation; stakeholders; knowledge-intensive business services (KIBS)

JEL: I11; L24; L84

[This page is deliberately left blank.]

Resumo

A China testemunhou um rápido crescimento económico nos últimos quarenta anos com as políticas de Reforma e abertura. A inovação nos cuidados de saúde é de grande importância na economia moderna e na China. O sector de dispositivos farmacêuticos e médicos é um pilar do sistema de saúde chinês. Devido aos custos crescentes dos dispositivos médicos e à supervisão estrita do governo, a terceirização de I&D do setor de dispositivos médicos para CROs (organizações de investigação por contrato) atraiu cada vez mais atenção. Os CRO são aqui vistos como serviços profissionais intensivos em conhecimento (KIBS) no sistema nacional de inovação, uma vez que actuam como intermediários de inovação para promover o uso efectivo do conhecimento na sociedade.

Para explorar o desenvolvimento do desempenho inovador do CRO de dispositivos médicos chineses é adoptada neste estudo uma metodologia baseada em entrevistas qualitativas semi-estruturadas. Entrevistas semi-estruturadas foram conduzidas com vinte especialistas de quatro grupos diferentes das principais partes interessadas na área dos dispositivos médicos. Seis proposições-chave são retiradas da evidência expressa pelos entrevistados, formando uma orientação para a futura inovação nos CROs: (1) os CROs podem ser alargados pela integração vertical, fornecendo serviços inclusivos; (2) os CRO podem ser transformados pela digitalização; (3) os CRO precisam de dar respostas rápidas; (4) Os CROs podem ser optimizados por uma melhor alocação de recursos; (5) Os CROs podem beneficiar de esquemas de incentivos; e (6) Os CROs precisam de um foco no capital reputacional.

Os resultados mostram que OS CRO de dispositivos médicos chineses exercem actividades de inovação de UMA forma compatível com o conceito de KIBS, afectando assim directamente a competitividade económica do sector dos dispositivos médicos na China. Por outro lado, a CROs de dispositivos médicos, enquanto KIBS, são um factor crucial para facilitar o processo de I&D nos produtos farmacêuticos e no sector da biotecnologia.

Palavras-chave: Organizações de investigação por contrato; Inovação de dispositivos médicos; Intervenientes; Serviços empresariais de conhecimento intensivo

JEL: I11; L24; L84

[This page is deliberately left blank.]

摘　要

改革开放40年来，中国经济快速发展。在此背景下，医疗发展与创新动态在中国现代经济中具有重要意义。特别是医疗器械等行业，是中国医疗体系的支柱之一。由于医疗器械技术变革成本的飙升和政府监管的严格，医疗器械行业的研发外包给被称为合同研究机构(CRO)的专业服务实体越来越受到关注。本文将CRO视为中国国家创新体系中的知识密集型业务服务(KIBS)，因为它们作为创新中介促进知识在社会中的有效利用。

采用定性研究方法，探讨中国医疗器械创新系统KIBS创新绩效的发展。采用半结构化访谈的方式，采访了20位来自医疗器械CRO关键利益相关者四个不同群体的专家。根据受访者所表达的重点，得出六项研究结果，对医疗器械CRO的进一步创新形成了指导意见:(1) CRO可以通过纵向整合进行延伸，提供包容性服务;(2) CRO可以通过信息技术和数字化进行转化;(3) CRO需要通过快速交付发展快速响应能力;(4)通过更好的资源配置，可以实现CRO的优化;(5) CRO需要提供激励方案;(6) CRO需要关注声誉资本。

结果表明，中国医疗器械CRO，作为KIBS的创新活动，直接影响中国医疗器械的经济竞争力；另一方面，作为KIBS的医疗器械CRO是促进医药或生物技术领域研发过程的关键因素。

关键词：合同研究组织；医疗器械创新；利益相关者；知识密集型商业服务业

JEL: I11; L24; L84

[This page is deliberately left blank.]

Acknowledgements

How time flies! My doctoral life is approaching the finishing line almost before I know it. Looking back on the long journey of six years, my meaningful doctoral life is full of unforgettable moments from Guangzhou (the "school district apartment" of the Southern Medical University), to Shanghai, to Lisbon, and then back to Shanghai. It would have been impossible for me to complete my study without the great care, sustained support and generous help from my supervisors, professors, families and friends. The journey of invaluable memories and experience will accompany me in the rest of my life. Here I want to thank all those who have helped me along the way.

First of all, I wish to acknowledge Prof. Sandro Mendonça. Words failed me when thinking of his painstaking efforts and meticulous care. Prof. Mendonça also holds an important position in the Portuguese government with a very tight schedule. As my supervisor, he offered me meticulous and systematic guidance on the topic selection, literature review, interview design, research methodology, thesis writing, etc. In particular, Prof. Mendonça patiently guided and strictly controlled the process of CRO stakeholder identification and interview results extraction, which deeply impressed me with his rigorous attitude towards research, profound academic attainments and broad international vision. Under the guidance of Prof. Mendonça, I have mastered some basic theories and research methods of management and lifted myself from a management practitioner to a researcher. In terms of corporation governance, Prof. Mendonça also gave a lot of sharp insights which inspired me in the various attempts in the service innovation of our company. This is also a good example of the emphasis on application and practice in the ISCTE DBA program. During my stay in Lisbon, Portugal, Prof. Catia Miriam Costa gave me on-site guidance for my thesis, which enriched my basic theoretical framework of management.

I wish to thank Prof. Virginia Trigo and Prof. Nelson for enlightening me with their professional knowledge and helping me develop an international vision. I am also grateful to Prof. Wang Dong, Ms Vian Ou and Ms Eva Xu at the Southern Medical University for their help. I have also truly enjoyed the heated discussions and exchanges with my 2015 doctoral classmates and wish to express my thanks for their generous help. Dr Yang Minghui, Dr Jin Shuiqing and Dr Ye Bin have unselfishly shared their thesis writing experience. Especially Dr

Yang Minghui shared with me thesis writing skills and encouraged me in those hard times even in his busy schedule as a senior international magazine reviewer. My thanks also go to the CRO stakeholders for participating in the interviews of this study.

I am very grateful to my wife, children, parents and other family members for their understanding, tolerance and continuous encouragement of my study in the past six years. Finally, I would like to express my sincere thanks again to my supervisor, Prof. Mendonça, who kept me from giving up my thesis writing and finally helped complete my study. Hereby, I would like to express my highest respect and heartfelt thanks to Prof. Mendonça for his great help, rigorous academic style and profound academic attainments.

致　谢

回首博士六年学习的充实时光，期间从中国广州（南方医科大学的“学区房”）、上海、里斯本再到上海，期间凝聚着导师、老师、家人们大量的关心、支持和帮助，这些将成为我人生中重要的回忆及宝贵人生经历；在此一一进行致谢。

首先要感谢的是我的超级导师Sandro Mendonça教授。Sandro教授在我的论文指导中倾注了大量的心血（我无法直接用言语来形容其中点滴心血和无微不至，Sandro教授同时身兼葡萄牙政府重要岗位平日工作非常繁忙），从选题、文献综述、访谈设计、研究方法、论文写作等方面给予我全面系统的指导，尤其在器械CRO利益相关者识别和访谈结果提炼的环节进行耐心的指导及严格把关，使我深深感受到Sandro教授科学严谨的治学态度、渊博的学术造诣、广阔的国际视野。在Sandro教授的教导下，我掌握了一些管理学基本理论及研究方法，完成从管理实践者向研究者的蜕变。在公司治理上，Sandro教授也给了很多锐利的意见，在我企业服务创新方面多方尝试；这也充分展现了我们这门管理学博士课程重应用和实践。Cátia Miriam Costa教授在我葡萄牙期间对我论文给与现场指导，丰富了我管理学基本理论框架。

在博士学习期间，得到了 Prof. Virginia Trigo, Prof. Nelson等诸多授课老师的帮助，给我传授了专业知识及拓展了国际视野，在此一并表示感谢！同时也非常感谢南方医科大学的卫生管理学院的王冬教授、欧玮艳(Vian Ou) 和许睿敏(Eva Xu)等各位领导、老师给予的帮助！也感谢一起攻读博士的 2015 级同学们的课堂课外热烈讨论和交流，早期毕业的叶斌、金水庆博士等博士论文心经分享，尤其是杨明晖博士作为资深国际杂志审稿人在百忙中在论文写作技巧上倾囊相授，在艰难时刻坚定我论文写作的信心！非常感谢CRO行业相关领军人物接受本课题的访谈。

十分感谢的我妻儿（女）、父母等家人过去六年对我学业的理解、包容和持续的鼓励。最终，特别感谢我的超级导师Sandro教授，使我未放弃论文写作最终完成学业。在此，再次对Sandro教授的大力帮助、严谨的治学风格、深厚的学术造诣表示崇高的敬意和衷心的感谢！

[This page is deliberately left blank]

Contents

[This page is deliberately left blank.]

List of Tables

[This page is deliberately left blank.]

List of Figures

[This page is deliberately left blank.]

List of Abbreviations

KIBS	Knowledge Intensive Business Services
GDP	Gross Domestic Product
SOE	State-Owned Enterprises
CPC	Communist Party of China
FMSD	Four Modernizations Synchronous Development
R&D	Research & Development
DALYs	Disability Adjusted Life Years
CRO	Contract Research Organization
FMD	Fountain Medical Development Ltd.
CROs	Contract Research Organizations
RMB	RenMinBi
NMPA	National Medical Products Administration
SMOs	Site Management Organizations
RP	Research Problem
RQ	Research Questions
EDP	Electronic Data Processing
GCP	Good Clinical Practice
ICH	International Conference on Harmonization
FDA	Food and Drug Administration
LLC	Limited Liability Company
INC	Incorporated
CAGR	Compound Annual Growth Rate
M&A	Mergers and Acquisitions
eCRO	electronic Contract Research Organization
PD	Product designer
PPD	Pharmaceutical Product Development
GLP	Good Laboratory Practice
GMP	Good Manufacturing Practice
GSP	Good Supply Practice
CFDA	China Food and Drug Administration

SATCM	State Administration of Traditional Chinese Medicine
SMO	Senior Medical Officer
CMDE	Center for Medical Device Evaluation of the National Medical Products Administration
CTO	Chief Technology Officer
CRC	Clinical Coordinator
CEO	Chief Executive Officer
VP	Vice President
IPO	Initial Public Offerings
IRT	IRTON
EDC	Educationcity
Q&A	Question & Answer
ICT	Integrated Capability Team
ISO	International Standardization Organization
BSI	British Standards Institute
EU	The European Union
US	The United States

Chapter 1: Introduction

This chapter is the starting point of this thesis, which outlines the scope of the research with an introduction of the background, research problem and research questions, followed by a description of the methodology and a brief discussion about the structure of the thesis. The chapter concludes with a figure outlining the structural framework. Medical Device CRO as KIBS: Exploring in the China innovative health technology systems

1.1 Research background

As competition intensifies in the international landscape, the world economy is undergoing deeper integration which complex product manufacturing processes are becoming more distributed among different regions. Meanwhile, the major shift in global industries and the major adjustment in the global industrial structure have resulted in greater uncertainties in the economic development. Against this backdrop, innovation has become one of the key factors to the overall competitiveness of a country, an important basis for the deep division of labor in international industries and the foundation of regional development amid economic globalization (Dakhli & Clercq, 2004). The creation and transfer of knowledge and information are better realized in specific contexts, this institutional and interactive set-up is referred to f the national innovation system which serves as an anchor and a catalyst for innovation and technical change (Freeman, 1987; Castellaci et al., 2005). Today, since modern economies are very much service-based economies a key component of innovation systems is those services that creatively serve and leverage all other sectors. These services are Knowledge Intensive Business Services (KIBS). KIBS are becoming increasingly important to the generation, communication and dissemination of productive knowledge (Castellaci et al., 2005; Miles, 2008). A discussion over the innovation development process of a changing economy like China therefore entails a deeper analysis of KIBS (Muller, 2001).

Since the start of the reforms in 1978, China has experienced an unprecedented rate of economic growth, becoming the second largest economy in the world after the United States. In 1978, the People's Republic of China announced the "Reform and Opening-up" economic policy aimed at attracting world markets by attracting foreign investment and decentralizing its large and expanding agricultural sector (where most of the population live and work) (Kerr,

2013).

It must be recognized that export-oriented growth is also part of the "Reform and Opening-up" vision (Oxley, 2014). The high GDP growth rates of China observed have happened simultaneously to a rapid integration into the world trade system (Godinhoa & Ferreira, 2012). In this way, China opened up the market and put itself in the process of global innovation. The process of adopting and contacting foreign technology is called imitative innovation, i.e. acquiring technology by observing its working principle, and then adjusting it according to local conditions (Zhou, 2006).

In the early stage of Reform and Opening-up, although some moderate support had been given to the development of small enterprises, China's manufacturing industry was still dominated by state-owned enterprises responsible for producing durable and infrastructure goods and services. Foreign direct investment was obtained to help modernize the country's physical infrastructure, including ground transportation, electricity production, water supply, sewage treatment, telecommunications, airports and ports. China's leadership sees SOE reform measures as a potential source of innovation in China (Kerr, 2013).

Since 2000, with the growth of China's economy, DEMPTOS trademark registration has grown rapidly, indicating that Chinese companies are paying more and more attention to R&D investment (Figure 1.1) (Godinhoa & Ferreira, 2012).

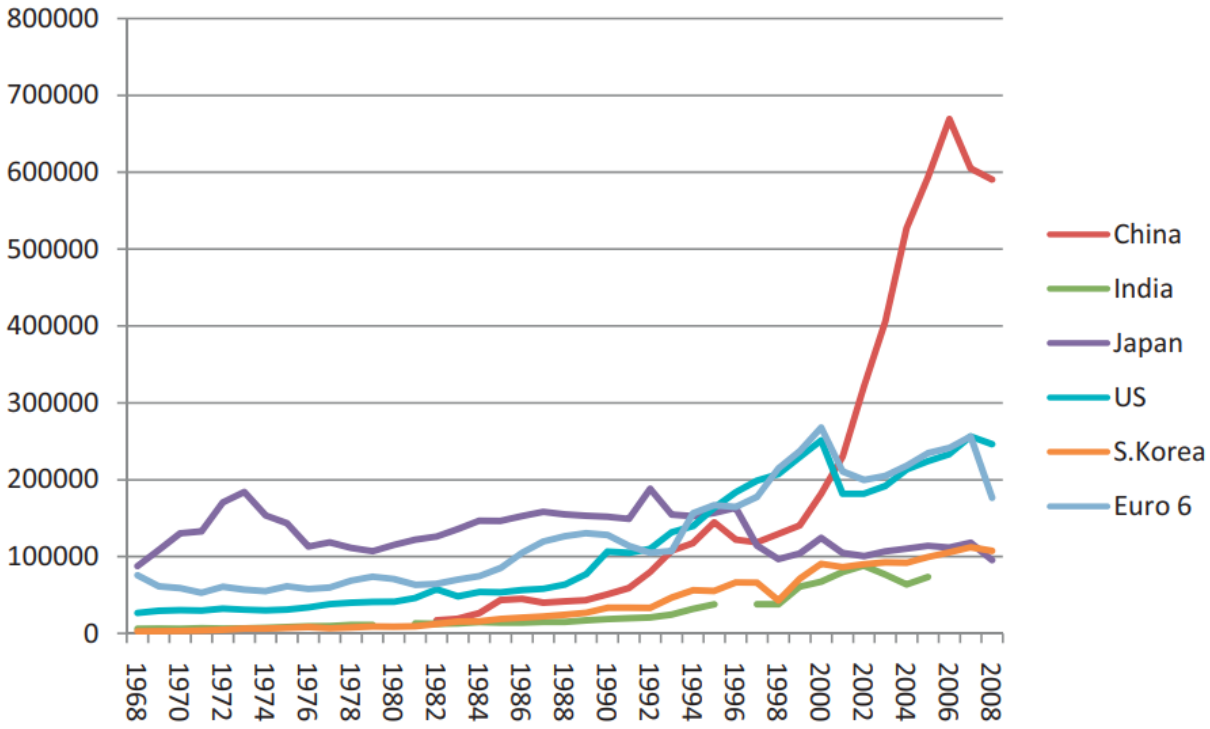

Figure 1.1 Trademark applications in the largest PTOs, 1968-2008

Source: Godinhoa and Ferreira (2012)

Since Deng Xiaoping led the giant China to economic modernization, China has experienced 30 years of rapid economic growth. Now it has not only become an economic superpower, but also a technological superpower (Huang & Sharif, 2015). For China's present and future, the central government has proposed a specific goal of "economic and social development". In October 2010, the 5th Plenary Session of the 17th Central Committee of the Communist Party of China (CPC) outlined China's 12th five-year plan and proposed the Three Modernizations, targeting agricultural modernization synchronized with industrialization and urbanization. Two years later, in November 2012, the Report of the 18th CPC National Congress explicitly announced a new, grand policy orientation of Four Modernizations Synchronous Development (FMSD), which is aimed at synchronously developing industrialization, information, urbanization and agricultural modernization–all with Chinese characteristics. China continues to strengthen its innovation system: the rate of spending on R&D in China outpaces overall economic growth. In terms of R&D intensity, in 2013 China spent US$191 billion (current prices) or 2.08% of its rapidly increasing GDP on R&D, placing it second only to the U.S. (in terms of absolute amount of annual expenditure on R&D) (Coccia, 2014). China's rapidly growing domestic market – now the second largest in the world – will continue to grow and is likely to surpass the US market by 2018. As market size is an important determinant of innovation activities, the burgeoning demand will drive Chinese companies to continuously advance their technological capabilities to profit from successful innovation, providing a global advantage that no other economy enjoys.

Since the implementation of the Reform and Opening-up, the introduction of advanced technologies from overseas has been one of the major contributors to China's technological advances. However, internationally, as China rises as a major economic power, developed countries who own advanced technologies have adopted a more cautious attitude towards the transfer of technology. Domestically, labor costs have been on the rise. In light of the two factors, China must develop new competitive edges based on better quality of labor forces and hi-tech and promote the development of innovative economy, while building upon its existing comparative advantages, so as to maintain stable and rapid economic growth. To achieve this goal, the Chinese government has issued a series of policies during recent years, including the National Outline for Medium and Long-Term Science and Technology Development Planning (2006, 2020) in 2005 by the 5th Plenary Session of the 16th CPC Central Committee, the National Science Conference and the Two Sessions in 2006 and the Innovation-driven Development Strategy proposed at the 18th National Congress. "Improving independent innovation capabilities and building an innovative country" has been prioritized as a national

strategy and become a strategic goal and a strong indicator in various sectors of economy and society (Fan, 2014).

As an important pillar in economic growth, health services can help alleviate poverty which is a major constraint on economic development. Eradication of poverty and the improvement of health conditions of low-income families or impoverished areas and populations are the goal of and the fundamental approach for economic growth (Macinko, Starfield, & Shi, 2003).

With a large population and a vast land, China is a major developing country with extreme imbalances among regions and a large proportion of rural population (Hung, 2008). Due to this basic national condition, health remains a prominent issue in the process of accelerating economic development. This is mainly manifested as follows.

The challenge of an aging population. As aging rises as a global concern, China now has the largest number of elderly people in the world. There is a robust demand in the healthcare, nursing, rehabilitation and life care of the elderly, which brings about tremendous challenges to resources and service provision in healthcare.

The challenge of new-type urbanization. With a large migrant population, China is experiencing a train of changes in health-influencing factors brought about by new-type urbanization. This poses even higher requirements to the shared governance of society and optimized allocation of health resources (Laiyun, 2012) .

The challenge of changes in the spectrum of diseases. On the one hand, the prevention and control of typical diseases in developing countries such as hepatitis, tuberculosis and other conventional infectious diseases remain a daunting task. On the other hand, while people's living environment and lifestyle change swiftly in economic and social transformation, chronic diseases have become a major health concern. There are over 260 million chronic disease patients in China. Deaths due to chronic diseases account for 86.6% of total mortality and over 70% of disability-adjusted life years (DALYs) in China.

The challenge of globalization. Globalization has brought about more threats of new and sudden infectious diseases, posing a new challenge to the national public health.

R&D outsourcing, i.e. "R&D agreements", means that enterprises outsource R&D to other organizations in the form of contracts, and seek external forces to innovate, so as to rationally allocate resources and enhance the competitiveness of enterprises. The entrusted institution, organization or individual is called a CRO (Contract Research Organization). CROs are a knowledge-intensive industry with high technical requirements. Although China's pharmaceutical industry adopted R&D outsourcing strategy later than other industries and its

international counterparts, it has registered rapid growth. Through this "network collaboration" mode, a professional outsourcing market system will be built, which effectively solves the problem of the current sluggish innovation in the pharmaceutical industry and is on the way of becoming a global trend. However, drug quality and market prospects are confronted with difficulties. International pharmaceutical companies are also facing increasingly fierce competition and challenges. Therefore, outsourcing may be the best choice for pharmaceutical companies. Pharmaceutical outsourcing has become a major trend in the global pharmaceutical industry. According to the statistics of Frost & Sullivan, in 2017 the total market size reached US $104.1 billion, of which the CRO market size was US $44.6 billion, and the C(D)MO market size was US $59.5 billion. For the Chinese market, compared with international pharmaceutical giants, the technology of small and medium-sized enterprises in China is relatively backward, and the R&D personnel are lacking in both quality and quantity. This has exerted tremendous pressure on the huge R&D cost of new drugs. A turn to providing R&D outsourcing services for larger companies has helped these enterprises dedicated to new drug R&D to strike a balance between short-term benefits and long-term growth. In recent years, outsourcing services in China's emerging pharmaceutical market have grown by leaps and bounds, becoming one of the tops in the world. It is reported that there are nearly 1,000 bio-medical outsourcing service enterprises in China, represented by WuXi AppTech, Chem Partner and FMD. The outsourcing service scale now stands at four billion dollars, with an average growth rate of 25% every year. These enterprises have opened a bigger market by pursuing appropriate growth models.

Outsourcing the non-core links of drug R&D to small and medium-sized enterprises can effectively reduce R&D costs. Resources of enterprises are better pooled to boost the sound development of core links, thus improving work efficiency and professionalism. At the same time, CRO operation, as the main mode of asset-light model for pharmaceutical enterprises, can adjust the allocation of human and material resources to effectively address the waste or shortage of resources, and optimize the process of new drug application and registration. This is conducive to the early approval of patents for new drugs, shortening the R&D cycle and enabling products to be marketed at an earlier time. Therefore, drug R&D outsourcing has become a popular development mode in the innovative pharmaceutical industry.

1.2 Research questions

CROs are private corporations that perform a wide variety of clinical research-related duties and functions on behalf of biotechnology, pharmaceutical and medical device companies sponsoring studies in human subjects.

The vast majority of China's CROs are for pharmaceutical companies, engaging in drug clinical trials, and/or upstream or downstream R&D outsourcing services. Since CROs engaging in medical device clinical trial services only account for an extremely small proportion, these companies are more commonly known as pharmaceutical CROs. In recent years, with the rapid development of the medical device industry, CROs focusing on clinical trials of medical devices and service outsourcing appeared and are called the medical device CRO. Medical device CROs in China share some common problems.

The requirements for CROs are very high. However, with limited clinical resources and weak expertise, most medical device CROs could only find and solve quality problems in the monitoring process. They are unable to meet the requirements of the sponsor in a systematic and all-round way. There is a mismatch between the high requirements or demands of innovative medical device enterprises and the capabilities of device CROs. As a result, reliability in the entire medical device CRO industry may gradually decline.

How can medical device CROs be redefined and reconstituted to live up to the expectations of the market by the development of innovative medical devices?

With the further improvement of drug and medical device regulations in China, the R&D process for pharmaceuticals and medical devices has been increasingly complicated by high R&D investment, time-consuming R&D cycles as well as low success rate. This has led to the outsourcing of clinical trials of pharmaceuticals and medical devices. The clinical trial R&D outsourcing services are also known as the Contract Research Organization (CRO). From 2016 to 2017, the CRO market size was approximately RMB 8 billion to RMB 10 billion, of which the medical device clinical trial outsourcing sector took up a low proportion because of the low ratio of medical devices to medicine and the late start of the medical device CROs.

Both global and domestic large-scale pharmaceutical CROs have been merging and acquiring medical device CRO business in the past few years. For example, Quintiles acquired Novela in 2013 (Pharmaceutical Processing World, 2013) and ICON (Cision Pr Web, 2014) acquired APTI (Pharmarnet, 2016) in 2014. Domestic Tiger acquired JT CRO in 2016 and Beiyirenzhi CRO in 2015. The CRO business of medical devices will blow out in the next five years and continue growing. However, the medical device is significantly different from the

medicine. For example, the coronary stent, the X-ray machine and the different types of dressings are very different, and therefore the corresponding R&D and clinical research are also very different. If we can select CRO clinical services for certain device features such as innovative devices, it will be representative. For one reason: in line with the general trend of national policies, the National Medical Products Administration encourages innovative medical devices; secondly, in the innovative device clinical research process, there will be new problems. Therefore, solving these new problems, it is also important to related clinical service innovation.

With a series of policies, including special approval procedures for innovative medical devices, selection of domestic medical equipment items, and priority approval procedures for medical devices, the development of national brands and domestic equipment has earned great support. The shift to domestically produced medical devices has been accelerated. The medical device industry in China has taken a stand.

At the same time, medical devices are diversified, lacking clinical normalization. With the accelerated reforms in the standardized clinical trials of devices, the demand, in terms of approval and registration of medical devices, has risen rapidly. The favorable policy and prosperous market will hopefully bring about the rapid development of the device CRO industry (Oriental Wealth Network, 2019).

Due to the diversity of medical devices and the specificity of clinical trials, their clinical trial programs, evaluation indicators and examination methods are different from those of drug clinical trials. Therefore, the potential entrants and substitute products of the medical device CRO industry are small, and the business is very large. To a certain extent, it depends on the demanding upstream medical device industry.

We can identify people (groups) who are closely related to the interests of CROs and the key stakeholders through communication and interviews with upstream and downstream customers and partners of CROs. Why are they closely related to CRO innovation? CROs' stakeholders may include mainstream customers, suppliers, employees, partners and considering the particularity of pharmaceutical industry, regulatory agencies such as the NMPA.

Domestic CRO business services mainly focus on pharmaceutical research instead of medical device research. Therefore, a key concern in the innovative medical device industry chain is how the device CRO plays its role in the industrial system. How to find a strategy or method to promote business performance and productivity with the innovation of the device CROs' own services?

This thesis takes KIBS as the theoretical basis for clinical outsourcing services for innovative medical devices in China. It proposes a service innovation path and hopes to improve

the competitiveness of medical CROs.

Taken together, this leads to the research problem of this study, which is:

RP: The development of the innovative performance of China's medical CRO knowledge-intensive business services

To analytically probe into this intellectual and management challenge, we further put forward two research questions. These provide the research focus and the driving force of this study, and are:

RQ1: Which are the key stakeholder dynamics affecting knowledge-based evolution in medical device CROs?

RQ2: How are innovation-driven strategies more appropriate to medical device CRO KIBS to catch up with China's economic growth?

1.3 Research method

The theoretical basis of pharmaceutical R&D outsourcing service industry is established through qualitative research, to identify the potential and competition landscape of the industry. Corresponding development strategies and paths are put forward by discussing and investigating the existing problems in the industry, which are conducive to the sustainable development of China's medical device CRO KIBS industry.

The two research questions outlined in Section 1.2 are further explained by developing a conceptual framework based on literature review.

"Qualitative research" refers to the in-depth and long-term study of social phenomena by means of field experience, open-ended interviews, participatory and non-participatory observation, literature analysis and case investigation in the natural setting. This kind of research usually takes induction as the main approach of analysis, collecting first-hand data locally and instantly, understanding the significance of their behaviors and the perspectives on things of the parties involved, and then establishing hypotheses and theories on this basis, and verifying the research results through various channels (Li, 2009).

In order to analyze the second question and understand the innovative development strategy of medical device CRO industry, it is necessary to know stakeholders' thoughts and opinions on innovation. We conducted semi-structured interviews with clinical customers, regulators, partners and employees of device CROs. There is a total of 20 interviewees including founders and general managers of innovative medical device companies, those from the regulatory departments of NMPA (National Medical Products Administration) or special experts in device

review, those from large SMOs (Site Management Organizations) in the same industry, and key employees of the company. They are based all over the country, and each interview lasted for 15-60 minutes. The details of the semi-structured interviews are described in Section 4.3 and Section 4.4 of this thesis.

Figure 1.2 shows the research design of this thesis, i.e., it highlights how the several steps (both theoretically and analytically) fit together to address the challenge of the thesis (the research problem) and yield a robust answer to our key interrogations (the research questions).

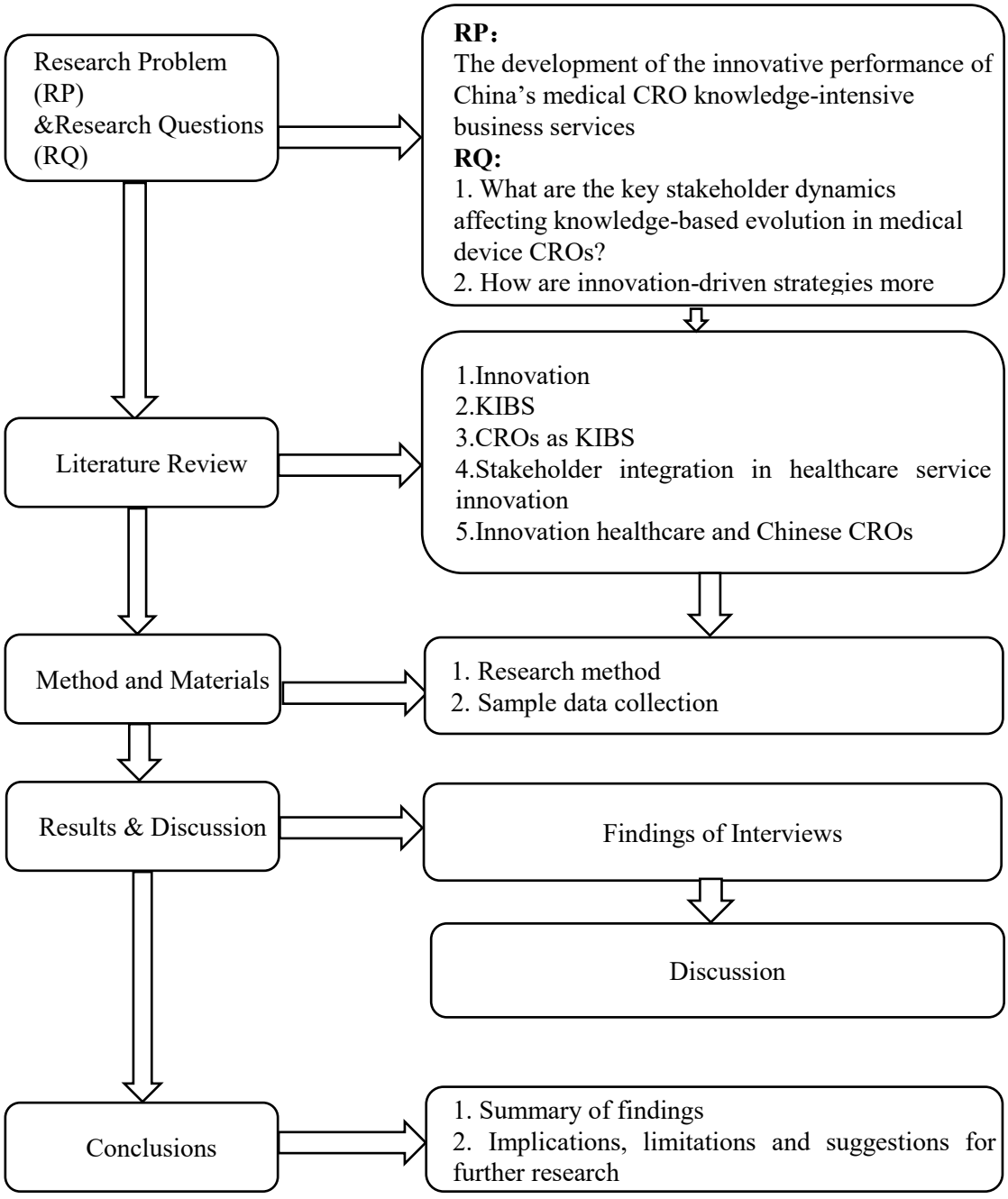

Figure 1.2 Research design.

1.4 Outline of the thesis

This study consists of six chapters and is structured as follows:

The first chapter is an introduction of the study, including the research background, research problems, research questions, research methods and the structural framework.

The second chapter discusses the literature review. It first defines the concept of KIBS and CRO and gives an introduction of the development of innovation in modern economies and innovation in KIBS. It then goes on to discuss the role of KIBS in innovation systems, and that of medical device CROs as KIBS, followed by a discussion of the theoretical framework of stakeholder theory and stakeholder integration theory applied in the healthcare service innovation.

The third chapter elaborates upon innovation in the Chinese context. It introduces the development course of innovation and then looks at innovation in the context of the Chinese economy. Furthermore, healthcare system innovation in China is introduced and explained. After that, CRO innovation in China is discussed including its history and development.

The fourth chapter introduces the research method. It first defines the research paradigm and the research method. The size of the sample, the source of data collection and the measurement of variables are also elaborated.

The fifth chapter presents the empirical analysis. It first discusses the descriptive statistics, identifying key stakeholders strongly connected to CROs, which helps to answer the first research question of the thesis. After that, findings of the interviews are summarized in combination with the theoretical framework of innovation in KIBS. The last part of the chapter discusses the theoretical framework of innovation indicators (Tether, 2005) and the opinions of stakeholders are further categorized into "organization innovation", "social innovation" and "technological innovation" which are consistent with the interview questions.

The sixth chapter is a conclusion. It first summarizes the findings of the research, the answers to the research questions, the solution to the research problem, followed by recommendations, contributions, limitations and suggestions for further research.

1.5 Summary

This chapter presents the scope of the study. The research background is described, and the gaps to be addressed in the literature are also identified. To fill in the gaps, the research problem and research questions are presented. The research method and the structure of the study are

also outlined in Section 1.4. This chapter provides brief outline of the thesis, along with figuring out research problem and research questions for this study. The next chapter moves forward to literature review, which provides a theoretical foundation for the study.

[This page is deliberately left blank.]

Chapter 2: Literature Review

2.1 Introduction

The purpose of this chapter is to provide the theoretical framework to understand the role of CRO in an innovation environment. Starting with a definition of the concept of knowledge-intensive business services (KIBS), it reviews the significance of innovation in the modern economic development. Indicators of innovation are then introduced, followed by a further discussion of stakeholders' integration in the innovation process.

Chapter 2 is structured as follows: Section 2.2, presents an overview of innovation; Section 2.3 presents the defining characteristics of KIBS; Section 2.4 describes the innovation contributions of KIBS; Section 2.5, introduces stakeholder theory; Section 2.6, describes the redefinition of contract research organizations (CROs) by describing knowledge-based intermediaries in innovative health care (CROs) redefined as KIBS; Section 2.7, argues for stakeholders integration in healthcare innovation; and the final section concludes the chapter.

2.2 Innovation in general

2.2.1 The meaning of innovation

Innovation has been widely considered as the driving factor of sustained economic growth (Fagerberg, 2010) and the actors of competitive advantage for enterprises (Dodgson, 2014). Both micro- and macro-economic policies aim to enhance the innovation capacity of enterprises and regions in order to promote development, that is, as a way to develop the economy, increase employment, social welfare, and protect the environment and natural resources (Bullinger, Auernhammer, & Gomeringer, 2004).

Innovation refers to the first attempt to put into practice the concept of new products or new processes in the market and other selected environments. There are significant differences between innovation and invention. The latter is the birth of a new product or new process concept. Innovation mostly occurs in companies. In order to transfer invention into innovation, a company usually needs to combine different types of knowledge, capabilities, skills and resources. For example, an enterprise may need production knowledge, market insights, a well-

functioning distribution system, and sufficient financial resources (Fagerberg, 2010).

2.2.2 Key characteristics of innovation

The long lag between invention and innovation may be related to the fact that in many cases some or all of the conditions for commercialization may be lacking (Costa & Mendonça, 2019). Therefore, although it is reported that Da Vinci had some advanced ideas in the field of aircraft, due to the lack of sufficient materials and production skills, especially that of power source, these ideas could not be realized in practice. These ideas might become feasible with future inventions and the commercialization and improvement of the internal combustion engine. Therefore, many inventions may need supplementary invention and innovation to succeed in the innovation stage.

Another complex factor is that invention and innovation constitute a continuous process. For example, the car as we know it today is a fundamental improvement over the original commercial models through the combination of a large number of different inventions and innovations. In fact, the first versions of almost all major innovations, from steam engines to airplanes, are crude, unreliable versions of equipment that eventually spread widely.

Therefore, what we think of as a single innovation is often the result of a long process involving many interrelated innovations. It is natural to apply a systematic perspective instead of focusing on a single invention or innovation. Innovation can also be classified by "type". Muller (2001) distinguished five different types: new products, new production methods, new sources of supply, new market development and new ways of business organization (Muller, 2001). He suggests that process innovation be divided into "technological process innovation" and "organizational process innovation". The former is related to new machinery, and the latter is related to new ways of work organization. However, organizational innovation is not limited to the new method of organizing production process in a given time. Organizational innovation, in the view of Muller (2001), also includes the arrangement across the primary industry, such as the reorganization of the whole industry.

Another method is also based on Muller's work. He pays special attention to continuous improvement, which is characterized by "incremental" or "marginal" innovation, which is of greater significance to his point of view.

2.2.3 How innovation differs in sectors, space and time

A remarkable fact of innovation is its variability in time and space. As Schumpeter (1934) pointed out, "clusters" seem to exist not only in certain fields, but also in time periods. As an explanation of this dynamic, Schumpeter (1934) continues Marx's early view that technological competition (competition through innovation) is the driving force of economic development. If a company in a certain industry or department successfully introduces an important innovation, it can obtain a higher profit margin. This is a signal to other companies (imitators). If entry conditions permit, these companies will "swarm" the industry or sector, hoping to share the benefits. As a result, the first mover advantage of the original innovator may soon be weakened. The "swarm" of imitators may lead to the robust growth of the innovation sector or industry over a certain period of time. Sooner or later, however, the impact on the growth from innovation will diminish, hence, slower growth.

Schumpeter (1934) believes that if imitators improve on the basis of the original innovation, i.e., they become innovators themselves, they are more likely to achieve their goals. It is usually equivalent to high, medium and low R&D intensity in production (or added value), or R&D directly (in the industry itself) or embodied in machinery and other inputs. Based on this, industries such as aerospace, computers, semiconductors, telecommunications and pharmaceutical and medical devices are generally classified as "high technology", while "medium technology" usually includes electrical and non-electrical machinery, transportation equipment and parts of chemical industry. The remaining "low technology" and low R&D categories include textile, clothing, leather products, furniture, paper products, food and other industries (Fagerberg, 2004).

In just two decades, we have witnessed great economic changes in the United States and Western Europe. Today, based on manufacturing, these countries are undoubtedly service-oriented economies. Through the study of service innovation, innovation scholars have the opportunity to develop a comprehensive innovation account which is suitable for both service industry and manufacturing industry, covering all aspects of the innovation process.

According to Gallouj and Windrum (2009), service industry is a laggard in innovation. In addition, it is believed that where change occurs, usually the result of diffusion of innovation, will be developed and first applied in manufacturing. These are obtained through new capital investment or through suppliers (mainly through the pressure exerted by manufacturers upstream and downstream of the supply chain). Although he later acknowledges that computer services, telecommunications and science-based services are innovators (Pavitt, 1989), he

insists that they are noteworthy because they are exceptions to the rules. They also emphasize the importance of organizational innovation, which seems to go hand in hand with product and process innovation in the service sector, and the role of KIBS providers and ICT in the broader innovation process (Gallouj & Windrum, 2009).

Outsourcing produces service and service innovation as a key issue for companies that outsource production activities, design and manufacturing operations. Gallouj and Windrum (2009) discussed service innovation in the network. Consoli and Mina (2008) provide an example of a very exciting and promising field of service research: Health.

2.2.4 Actors of innovation

Organization and institution are usually considered as the main components of innovation system. An organization is a formal structure established consciously with a clear purpose (Edquist & Johnson, 1997). They are actors. Some important organizations in system innovations are enterprises, universities, venture capital organizations and public institutions responsible for innovation policy, competition policy or drug regulation. The important systems in system innovations include patent law, rules and regulations that affect the relationship between universities and enterprises. Obviously, these definitions are a word "North" (Bonaccorsi, 2015), which distinguishes "rules of the game" from "players".

Rickne (2000) lists 11 functions that are important for new technology companies (i.e. not innovation in a direct sense): (1) create human capital; (2) create and disseminate technology opportunities; (3) create and disseminate products; (4) incubate (provide facilities, equipment and administrative support); (5) promote regulation that may expand markets and facilitate market access; (6) legitimize technologies and companies; (7) create markets and disseminate market knowledge; (8) strengthen networks; (9) guide technology, markets and partner search; (10) promote financing; and (11) create new markets. A new technology-based company can take advantage of the labor market.

2.2.5 Measurement of innovation

In the practical evaluation of innovation, the importance of measuring innovation is increasingly valued by managers and consulting agencies. The performance management surveys conducted by Boston Consulting Group (Janusz, 2012), McKinsey Innovation Index Survey (Fagerberg, 2004) and Business Application Research Center (Costa & Mendonça, 2019) are examples of consulting surveys for innovation measurement. Existing surveys show that it

is important to rethink the enterprise's innovation measurement system (Chapman, Soosay, & Kandampully, 2002). Practitioners also emphasize this finding. According to the Boston Consulting Group survey, 74% of managers believe that innovation tracking should be included in core business processes, but only 43% of companies actually measure innovation. In addition, 59% of the companies pointed out that their innovation performance measurement system was not effective (Janusz, 2012).

The academic research has not yet given a general framework for measuring overall innovation. Moreover, it is unclear whether the metrics from academic research results are applicable to the organization. For example, Chapman, Soosay, and Kandampully (2002) claims that the innovation measurement method recommended in the research literature seems to be too theoretical. These theoretical indicators are not directly applicable to enterprises (Miles, 2008). Even a common understanding of the innovation process is missing, because the innovation process is quite complex and contains many influencing factors (Sau, 2003). In addition, there is a lack of measurement strategies to evaluate innovation (Dodgson, 2014). Therefore, the problem faced by enterprises is that the measured data are too little or unimportant, or that they do not carry out any innovation measurement at all (Consoli & Mina, 2008). What's more, organizations are divided on what should be measured.

In terms of service company metrics, many service companies have already launched specific products (e.g. retail banks, airlines, insurance companies, etc.), and a "step-by-step" innovation model is appropriate. However, the service industry is more likely to adopt a continuous change innovation model rather than a "step-by-step" innovation model, which means using the European innovation mode tools such as the Community Innovation Survey (conceived around the stepped change model) may greatly underestimate the number of innovation activities in the service industry.

The second problem with service innovation is that the form of innovation is often vague, while conceptualization in the Oslo manual (Koschatzky, 2006) and the community innovation survey involves a clear distinction between product (technology) innovation and process innovation. Some people think that it is often difficult for services to classify their innovation into these categories since services are usually processes. It may be difficult to know whether innovation is described as "product innovation", "process innovation" or both. A related difficulty is to distinguish between organizational innovation and process innovation in services. "Process" can be narrowly understood as the definition and repetitive activities related to the production of specific service products. In contrast, organizational change is often more widely understood as a change in the mode of supply organization within an enterprise (such as

"stratification", introduction of new departments, introduction of team work, or change of division of labor within a team, etc.) and a change in the relationship between a company and its customers, other enterprises and/or organizations such as universities (e.g. reaching cooperative arrangements or signing "open book" agreements), and possible organizational changes in other organizations. However, one of the difficulties in organizational innovation is that they are often difficult to identify, define and score.

More specifically, Tether (2005) points out some characteristics of innovation indicators in service firms which include four points:

- Service firms will have greater difficulty in determining the orientation of their innovation activities between products, processes and organizational changes.
- Service firms will be more likely to claim an organizational orientation to innovation than will the manufacturers, and, concomitantly, will be less likely to claim a product and/or process orientation to innovation.
- Service firms, and especially those with an organizational orientation to their innovation activities, will be less likely to acquire knowledge and technology through "hard" sources such as R&D and the acquisition of advanced equipment, and will be more likely to source knowledge and technology through "soft" sources, such as cooperation with suppliers and customers.
- Also reflecting their more organic nature, service firms, and especially those with an organizational orientation to their innovation activities, will be less likely to claim that their strengths at innovation lie in ''hard'' advantages in R&D knowledge or efficiency of production, but will be more likely to claim that their advantages lie in "soft" attributes including the skills of their work force and their cooperation practices with customers and suppliers.

2.3 The concept of knowledge-intensive business services (KIBS)

With the rapid development of the service industry, the meaning of KIBS has been continuously extended. Services today are considered productive parts of the working economy, and are understood to actively contribute to the structural evolution of other sectors (Costa & Mendonça, 2019). A subset of the services industry has been deemed of special note; not only these outfits are productive, they are innovators of a particular kind: they are enablers of the productivity of other operators in other industries. They are known as Knowledge Intensive Business Services (KIBS) (Miles, 2008). This type of service innovation is essential for corporate competitiveness

and national innovation at large.

The concept of KIBS is produced in this context. From the perspective of policy research and management practice, many countries and international economic organizations have defined the knowledge intensive business service industry according to their own situation. The Organization for Economic Cooperation and Development (OECD) believes that knowledge-intensive business service industries are those with high technology and human capital investment density and high added value. The U.S. Department of Commerce defines them as service industries that can integrate science and engineering technology or be promoted by science and engineering technology in the process of providing services. According to the Chinese Development Research Center of the State Council (2001), KIBS refer to information-driven service activities in the digital era, i.e. services that rely on the Internet, e-commerce, intellectual property rights and other intangible assets, as well as information processing and validation services like R&D testing, business development and management consulting.

Miles (2008) originally introduced KIBS in the literature by emphasizing a perspective from input characteristics and output characteristics. They consider that companies and organizations that significantly rely on the professional knowledge of specialized fields and provide knowledge-based intermediate products or services to society and users play an active and key role in knowledge-based economy. That is to say, as intermediate actors, KIBS activate knowledge in related firms, either as sources of innovation, facilitators of innovative processes, or spreaders of their clients' innovative outputs to other corners of the economy.

Hipp and Tether (2002) thinks that a KIBS are organizations with important knowledge asset to serve either manufacturing or service customers, as well as non-commercial entities such as universities and other R&D institutions. Muller (2001) put forward that KIBS are an industry that provides high-knowledge value-added services for other enterprises, i.e. they are "consulting" companies. In other words, KIBS have an essentially "relational" function and serve a variety of other actors in a national system of innovation (Simmie & Strambach, 2006).

KIBS are not only different from the manufacturing industry which provides core products, but also different from the general service industry by providing highly differentiated knowledge-intensive products:

- The core asset of KIBS is knowledge (Schreyögg & Geiger, 2016);
- The main function of KIBS is to transfer knowledge and skills to customer organizations (Leiponen, 2006);
- KIBS contain a wide range of highly specialized knowledge base, including explicit and implicit knowledge, which can be used to develop new tailor-made solutions to

specific, idiosyncratic problems (Muller, 2001; Bullen, Fahey, & Kenway, 2006; Miles, 2008);

- KIBS require frequent interaction and close cooperation with their customers (Bullen, Fahey, & Kenway, 2006) and with other knowledge-based organizations (Janusz, 2012);
- KIBS are used as the customer knowledge base, especially the tacit knowledge base and explicit knowledge base, so as to increase the communication between other unconnected knowledge bases (Windrum & Tomlinson, 1999);
- KIBS transform information and knowledge into customized solutions that customers want to buy but also acquire through a process of knowledge exchange (Windrum & Tomlinson, 1999; Hipp & Tether, 2002).

Although there is no standard definition or unified concept of KIBS, there is some consensus on the industrial branches and enterprises that constitute KIBS. In Europe, the nomenclature of economic activities (a classification of economic activities in Europe) is becoming increasingly popular. KIBS include computer and related activities, research and development activities and other business services. There are sub categories under each major category. For instance, there are six sub categories of computer and related activities (hardware consulting; software consulting and supply; data processing; database services; maintenance and repair of office, accounting and computing equipment; other computer related activities). Table 2.1 shows the contents of KIBS in NACE in detail.

Table 2.1 Classification of KIBS according to NACE Europe (Sectors and Subsectors)

NACE	Description
72	Computers and related activities
72.1	Consulting in hardware
72.2	Consulting and supply of hardware
72.3	Data processing
72.5	Activities of databases
72.6	Maintenance and repair of office and computer equipment
73	Other computer activities
73.1	Research & Development
73.2	Research and experimental development in physical and natural sciences

74	Other activities of the firm
74.1	Legal, accounting, accounting and audit; tax consulting: market research and opinion polls: business and management consulting: holdings
74.11	Legal activities
74.12	Accounting, accounting and audit activities; tax consulting
74.13	Market research and opinion polls
74.14	Commercial and management of consulting activities
74.2	Architecture and Engineering activities and related techniques
74.3	Tests and analyses' techniques
74.4	Advertising
74.84	Other activities of the firm (not specified)

Source: Muller (2001)

In the Chinese context, Zhou (2007) conducted a detailed and in-depth discussion on KIBS classification, with a statistical summary of various KIBS classifications proposed by scholars, and the clarification of the extension of KIBS involved in the literature. On this basis, he points out that it is a simple and feasible method to classify KIBS from the perspective of service production mode. In order to make use of the existing statistical data, this thesis adopts the classification method of Zhou in combination with China's national economic industry classification (National standard, GB/T4754-2002) and international standard industry classification (ISIC Rev. 3), and based on the main KIBS industries involved in the relevant literature, divides KIBS into four categories and fourteen sub-classes.

The development of KIBS is the result of the rapid growth of KIBS demand in economy. The growing demand for different types of technical knowledge, especially ICT knowledge, is the most fundamental reason for the growth of KIBS demand (Mendonca, Crespo, & Simoes, 2015). Service outsourcing is the main driving force for KIBS development. With the division of labor being increasingly segmented, the service functions initially provided by one department to other departments within the enterprise are now "externalized" to provide services to a larger market. This is very common in technology, especially in IT services and some design and engineering services. In early 2005, the European Change Monitoring Center published a report on service outsourcing, stating that the most important reason for service outsourcing is that customers should focus on developing core competitiveness. There is a growing trend of global transfer of service industry to emerging markets. KIBS are the main force of the international transfer of service industry since they must meet the needs of global

customers for local knowledge.

2.4 Encapsulating the role and place of KIBS in innovation systems

KIBS are carriers of information and knowledge, and their contribution to creating a competitive advantage and development has drawn increasing attention in the literature (Simmie & Strambach, 2006; Doloreux, Freel, & Shearmur, 2010). KIBS have developed three types of innovative features (Tether, 2005). First, they are themselves innovation activities (new services and new technology applications). Second, KIBS are a source of innovation for other sectors. Third, when it comes to knowledge transfer, KIBS are carriers of innovation and provide input (intermediate services) for other firms as a knowledge-based solution.

Analytically, the contribution of KIBS to the innovation system can be divided into two interdependent parts (Figure 2.1). On the one hand, the innovation activities of KIBS firms have a direct impact on the competitiveness of national and regional economies. On the other hand, KIBS also exert indirect effects on and give positive feedback to the demand side, which can be generated by customers' using the services of KIBS companies, successfully transferring knowledge to customers, or solving innovation problems for them. This can improve their competitiveness.

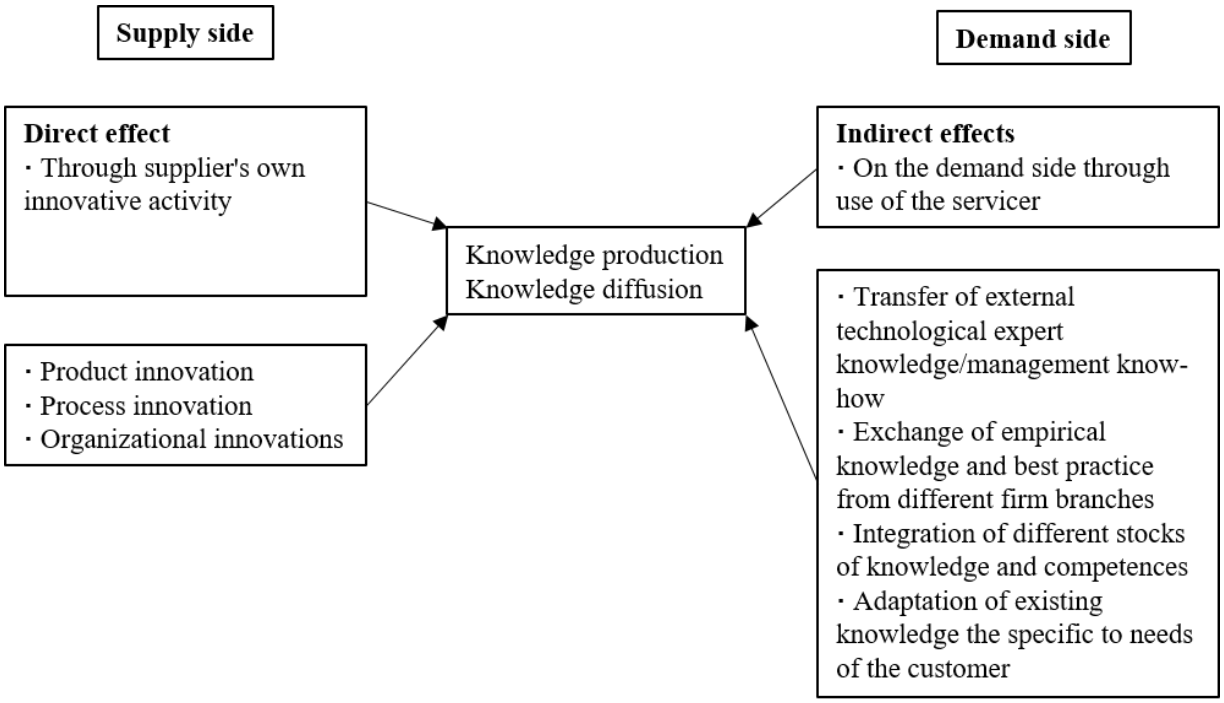

Figure 2.1 Contribution of KIBS firms to innovation in innovation systems

Source: Strambach (2001)

The innovation activities of KIBS are related to process, product or organizational

innovation, and manufacturing. The increasing tradability of knowledge-intensive business services over the past decade, together with the technical possibility of long-distance dissemination of knowledge-intensive business services, has fostered the internationalization not only of large KIBS firms, but also of KIBS traditionally targeted to national and regional markets (O'Farrell, Wood, & Zheng, 1998). Thus, in the process of globalization, managing knowledge products such as innovative or computer-based consulting products is also becoming increasingly important for value creation and competitiveness in national and regional economies. Empirical investigations show that the contribution of innovation in different service sectors needs to be looked at individually. The EDP (Electronic Data Processing) branch is characterized by a high degree of product innovation, and customer implementation can bring about process innovation again. Software branches and technical consultations not only are users of technology but also play a key role in the transfer and dissemination of technological innovations.

It is difficult to make a quantitative statement on the productivity and innovativeness of KIBS. Indicators and traditional tools used to assess productivity and innovativeness in production systems can only be used to a very limited extent in services. The reasons are as follows:

- Traditional R&D concepts are influenced by technological innovations in the manufacturing industry.
- Internal innovation and knowledge organizations are often only a weak formalization of the service firm.
- In contrast to manufacturing firms, most KIBS firms do not distinguish R&D activities from organizational aspects: a quantitative measure of innovation input such as investment in the R&D field and employment cannot therefore be used.
- Patent applications are of limited use as indicators of output for service firms. The reason is that the innovation cycle of KIBS products is extremely short. In addition, KIBS companies' advances in patented technology are difficult to be protected because they are mainly personnel and background.
- Investment in intangible capital assets has not been shown in statistics.

The strategic significance of KIBS in innovation systems mainly stems from indirect effects and positive feedback, which, in the long-run, can increase the ability to adjust on demand sides and thus contribute to increased competitiveness.

These effects are the result of a successful interaction and learning process between KIBS vendors and KIBS users, influenced by the institutional background. The role of KIBS in

national and regional innovation is closely related to the "products" these services supply to the market. Specialist expertise, research and development capabilities, and problem-solving expertise are the true products of KIBS.

In innovation systems, KIBS play an important role in knowledge circulation in the form of expert technical knowledge and managerial knowledge (Castellaci et al., 2005). Due to the differentiation and acceleration of knowledge and information growth and the vertical disorganization of firm functions, the more complex coordination of changes in firms' functions and production and sales requires not only technological innovation, but also expertise in organizational change. The growing division of domestic and international labor, increasing knowledge, and the resulting concern about a firm's core capabilities mean that any given firm's capabilities are narrowed. As half-life knowledge becomes shorter and shorter, it will become increasingly difficult for businesses to provide a wealth of intra-organizational expertise in all relevant areas and keep up with the latest developments.

On the other hand, independent KIBS firms, which must establish themselves and ensure the survival of new products in both national and international markets, face competition in innovation, time and quality which forces them to continuously build new capabilities in their fields of knowledge. It should be emphasized that as a result of this development, the integration of external and internal knowledge and the integration and use of abilities are becoming increasingly important for innovative change and problem solving. The KIBS company, as a source of external knowledge, by virtue of its skills and capabilities, is more widely involved in modernization and rationalization of production than before, the management and sales of the company. They also disseminate knowledge among companies in different branches with what they have obtained from experience and their "best practices".

2.5 Knowledge-based intermediaries in innovative healthcare: redefining CRO as a KIBS

ICH-GCP defines CRO as follows: a person or an organization (commercial, academic, or other) contracted by the sponsor to perform one or more of a sponsor's trial-related duties and functions (Shi, 2014). China GCP defines CRO as follows: contract research organization (CRO) refers to the organization authorized by the sponsor to sign a contract and perform certain responsibilities and tasks of the sponsor in clinical trials (Michael, 2017). All in all, CROs are private corporations that perform a wide variety of clinical research-related duties and functions on behalf of biotechnology, pharmaceutical, and medical device companies sponsoring studies

in human subjects.

According to the stage of research, CRO enterprises are divided into two main categories: preclinical CRO and clinical trial CRO. Preclinical CROs are mainly engaged in compound research services and preclinical research services, in which compound research services include survey and research, synthesis and process development of lead compounds and active drug intermediates, and preclinical research services include pharmacokinetics, pharmacology, toxicology, and animal models. Clinical trial CROs mainly offer clinical research services, including technical services for phase I to IV clinical trials, clinical trial data management and statistical analysis, registration declarations, and post-marketing drug safety monitoring (Figure 2.2).

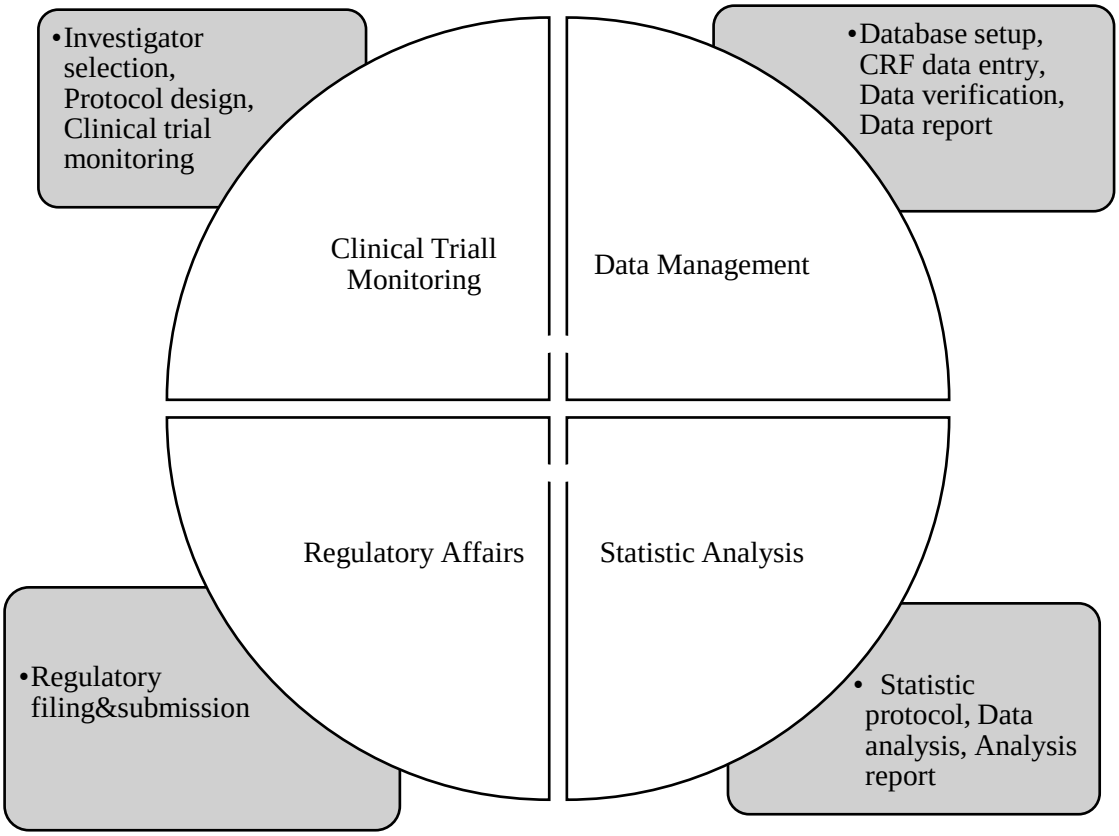

Figure 2.2 CRO service scope

Source: Xia and Gautam (2015)

First, the sponsor, i.e., a pharmaceutical, medical device, or biological enterprise, contracts with a CRO to execute one or multiple segments of the clinical trials. The contents include clinical trials of the period, drug registration, policy and regulation consultancies, drug promotion, pharmaco-economic research, including the clinical study centers selection.

Second, an appropriate clinical trial organization (and signing a contract to complete the phase I clinical trial) needs to be selected. During this process, the study protocol is confirmed

on behalf of the sponsor in conjunction with the principal investigator (the investigator organizes and conducts the clinical trial in strict accordance with the study protocol), and the CRO's clinical trial monitor, as required by the GCP, regularly monitors the full course of the clinical trial and ensures the quality of the clinical trial: similarly, the CRO's quality assurance and quality control staff. In addition, government authorities such as the China FDA (Now named as National Medical Products Administration, NMPA) will carry out regular inspection on some clinical trials to ensure the quality of clinical trials.

Third, CROs may also undertake work such as data management, statistical analysis, or writing up of research reports during the course of a clinical trial.

Because of economic and regulatory factors, CROs are playing an increasingly visible role in clinical research and the management of clinical trials, such that interactions with CRO personnel and CRO-originated queries regarding study participants have become a ubiquitous presence in the professional lives of clinical investigators.

Quintiles, the biggest CRO in the world, was founded by a biostatistician from the University of North Carolina to provide fee-for-service consultative data support for clinical trials, and a newly formed company, Theradex Oncology Experts, received the clinical trials monitoring service contract from the National Cancer Institute.

In the 1980s, both the National Cancer Institute and large pharmaceutical companies were searching for ways to address rising research and development costs, including increasingly detailed requirements for New Drug Application submission to regulatory agencies such as the U.S. Food and Drug Administration (FDA) and the various national precursors of the European Medicines Agency, at a time when available capital for research was perceived as increasingly limited. CROs were envisioned as a form of outsourcing, a broader corporate trend of subcontracting that originated during the same period (the term "outsourcing", a contraction of "outside resourcing", dates to 1981). CRO outsourcing provided "spillover capacity" for data management and bio-statistical analysis during peak activity periods, when the pharmaceutical companies' own employees had insufficient capacity to complete all necessary tasks. By the 1990s, the scope of CRO activities had expanded to services in all aspects of phase II to IV trials, including interfacing with investigators, collecting samples for laboratory analysis and conducting analyses, and assisting with dealer management systems and the preparation of regulatory submissions. By 2020, over 70% of clinical trials will be conducted by CROs, with the largest four CROs, Quintiles, Parexel, Pharmaceutical Product Development LLC, and INC Research, currently associated with the lion's share of trials.

Fortune Business Insight reported that the CRO market will grow from an estimated $38.9

billion in 2018 to $90.9 billion in 2026. The increasingly prominent role of CROs in clinical research is also evidenced by the shift of sponsors from using "preferred providers", longitudinal relationships with a single CRO, to choosing "strategic partnerships" with CROs on a rotating basis, with contract terms of up to three to five years (Figure 2.3). Several major forces are driving the continuously increased market share of CROs, including the globalization of clinical trials, the growth in narrowly used and costly specialty drugs, and the increasing challenge and cost to pharmaceutical companies of hiring skilled benefits-eligible permanent workers.

Figure 2.3 Global CRO market

Source: Global CRO Market Service Research Report (2019)

In 2004, approximately 60% of CRO revenue came from the United States, whereas approximately 40% was international; in 2013, these numbers were nearly reversed at 43% and 57%, with a growing role of CROs noted in emerging clinical trial markets such as India, China and Central and Eastern Europe. "Specialty drugs" requiring expertise in delivery routes, rare diseases, or genomic and other biomarkers are projected to account for 42% of drug costs in 2016, up from 23% in 2011, and CROs are offering more extended services related to approved specialty drugs. These post-approval commitments represent an important source of ongoing growth for the CRO industry. The explosive growth of CROs in the last 20 year rests primarily on economic grounds. Conversely, increasing product development safety and improving clinical trial scientific methodology have not yet been key drivers of trends in CRO use. The lengthy time to new drug approval and the high cost of conducting all phases of clinical trials are major challenges for sponsors. According to a review by the Tufts Center for the Study of Drug Development, drug development cycles are shorter with "high CRO usage" sponsors.

However, despite the growth of CROs, the cost of drug development still substantially increased between 2003 to 2014, from a reported median of $802 million to $2.6 billion per new approval, although these figures have been widely challenged.

The total sales volume of global medical device market increased rapidly from US $308 billion in 2009 to US $437.8 billion in 2018, and the total sales volume of global medical device market in 2019 was about US $451.9 billion. The global medical device industry is growing at a compound annual growth rate (CAGR) of 5.6% (Evaluate Med Tec 2018). In 2018, the sales scale of medical devices in China was US $ 82.2 billion RMB, with a growth rate of about 20%, far higher than the global average. (China Report Hall, 2017; Oriental Wealth Network, 2019)

2.6 Stakeholder theory

The stakeholder approach began in the mid-1980s (Carmeli, Gilat, & Weisberg, 2006). The traditional group of related parties only includes shareholders, employees and other stakeholders within the company, which are not considered to be comprehensive by Freeman and Liedtka (1997). He then provides a new form of stakeholder by considering external groups such as local communities, society and the environment. As a result, the stakeholder theory provides a new perspective for organizations to think about corporate responsibility. This proposition requires the company not only to pursue the maximization of shareholders' interests, but also to meet the needs of other stakeholders. Miles and Kastrinos (1998) adds that the most important point of stakeholder theory is to find out who the organization's stakeholders are and how the organization performs its responsibilities to them. These stakeholders are crucial to the company as their potential investment depends on how the company manages and maintains its relationship with them.

Stakeholder theory is a view of capitalism that stresses the interconnected relationships between a business and its customers, suppliers, employees, investors, communities and others who have a stake in the organization. As for the theory, the theory argues that a firm should create value for all stakeholders, not just shareholders. Stakeholders include shareholders, workers, customers, suppliers, communities, legislators, representatives of labor organizations, human rights groups, governments, and non-governmental organizations.

Cannon, Daryl, and David (1994) lists the groups and individuals of stakeholders, and put forward the primary and secondary expectations of stakeholders. The primary and secondary expectations of stakeholders are illustrated in Table 2.2.

Table 2.2 Stakeholders' primary and secondary expectations

Stakeholder	Primary Expectations	Secondary Expectations
Shareholders	Economic	Added value
Employees	Remuneration	Training, satisfaction
Customers	Goods and services provided	Quality
Creditors	Reliability	Security
Suppliers	Payment	Long-term relationship
Community	Safety and security	Development of community
Government	Compliance of regulation	Improved competitiveness

Source: Cannon, Daryl, and David (1994)

Lusch and Vargo (2016) proposes that it is possible to develop different methods to explain stakeholder theory. They use descriptive, instrumental and normative methods to divide stakeholders into three categories. The following sections discuss the concepts and characteristics of each type of stakeholder theory.

The purpose of descriptive stakeholder theory is to understand how companies manage the relationship with stakeholders and how managers represent the interests of stakeholders. It focuses on how companies respond to different stakeholders by achieving different types of corporate goals. Lusch and Vargo (2016) points out that the theory of descriptive stakeholders can be used to describe the nature of a company, the management mode considered by managers, how board members believe in the interests of company policies, and the actual management mode of a company.

Instrumental stakeholder theory studies the organizational consequences of considering stakeholders in management by exploring the relationship between stakeholder management practice and the realization of different corporate goals (such as profitability and sustainable growth). The study also shows that stakeholder theory can participate in a part of enterprise strategy, and the value of stakeholders can be maximized when the enterprise pays attention to the relationship between key stakeholders (Donaldson & Preston, 1995).

Donaldson and Preston (1995) believe that normative approach is the core of stakeholder theory, because it determines the theoretical procedures related to corporate activities. The normative approach focuses on moral and philosophical aspects, and attempts to answer questions such as "what is the company's responsibility from the perspective of stakeholders"

and "why does the company not only care about the interests of shareholders, but also take care of the interests of other stakeholders".

Donaldson and Preston (1995) suggest that it is possible to develop different ways to explain stakeholder theory (Figure 2.4). They identify three types of stakeholders, with descriptive, instrumental, and normative approaches. The following parts discuss the concept and feature of each type of stakeholder theory.

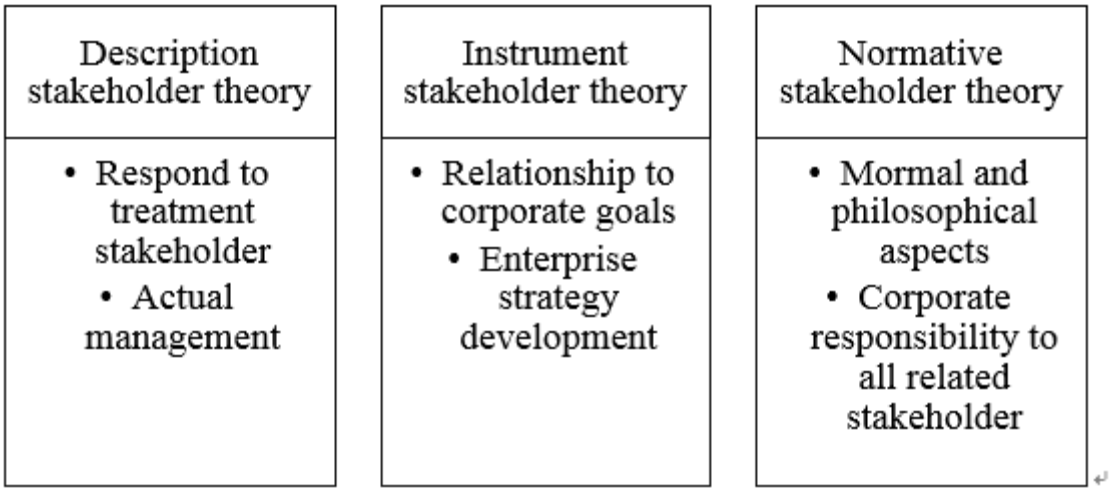

Figure 2.4 Stakeholder theory

Source: Donaldson and Preston (1995)

Before the 1960s, American companies emphasized the importance of shareholders' interests and prioritized the maximization of their responsibilities to shareholders. In the early 1960s, organizations began to consider customer activities and environmental protection. This aroused people's increasing concern about standardizing enterprise activities, which can be seen as an enlightenment period of stakeholder management. From then on, people began to pay attention to product quality, human rights and labor relations. Freeman and Liedtka (1997) suggest that decision makers in organizations should consider both shareholders and stakeholders. In addition, Clarkson (1995) claims that stakeholder groups can be divided into primary and secondary groups. He points out that the main stakeholders are the internal parties of the company, including employees, customers and shareholders. The secondary stakeholders are external groups, such as social, religious and other non-governmental organizations. Eesley and Lenox (2006) further clarifies the secondary stakeholders. In their view, stakeholders should not be ignored, as their actions are closely related to resources and competitiveness. Wood and Mellahi (2003) also proposes that companies need to realize their responsibilities by fulfilling the expectations of stakeholders and contributing to the mission of social

responsibility. Wood also put forward a view that appropriate social control measures must be developed to encourage a wide range of positive effects from the stakeholder theory.

2.7 Stakeholders integration in healthcare service innovation

Scholars suggest that service innovation teams should also integrate internal and external stakeholders to carry out service innovation (Kindström et al., 2012; Edvardsson et al., 2013). In SDL, co-creation of service innovation is defined as "participation in the creation of core products by customers and other partners" (Miles, 2008). In terms of value creation, an organization must manage the co-creation of service innovation with multiple internal and external stakeholders (Kuzu, Gökbel, & Güles, 2013). This stakeholder integration is traditionally regarded as a management task; it is defined as the mapping between stakeholders and decision-making, which stakeholders will be integrated, and to what extent (Wood & Mellahi, 2003).

Comprehensive tacit knowledge about services and their outcomes is not only discussed in the context of customers. In addition, internal stakeholders, such as front-line employees and experts from other units, possess explicit and implicit knowledge (Backes et al., 2014). Therefore, employees are the number one source of ideas (Schulteß & Satzger, 2010). Their personal and collective knowledge should be integrated and promoted in service innovation (Leiponen, 2006). However, the core innovation team is usually only discussed implicitly in the literature. According to Johne and Storey (1998), in most cases, the core innovation team is newly established for a new project. Schilling and Werr (2009) and Leiponen (2006) emphasize that the overall success of service innovation projects depends on the core innovation team, i.e. a collection of employees from different functional departments with the required and useful knowledge and skills. The integration of internal stakeholders is driven by the integration of specific functions or skills, because they can introduce "different knowledge and capabilities into the innovation process, thus promoting innovation creativity, learning and knowledge development" (Schilling & Werr, 2009). In addition, as pointed out by Power (2005), top management integration is crucial to the success of service innovation projects. The integration of top management affects the strategic importance and legitimacy of the project, and creates opportunities for contact with other internal stakeholders. As an integrated decision maker, the core innovation team should master a series of different skills and abilities on the one hand, and provide an internal interactive platform within the organization on the other hand (Power, 2005; Schilling & Werr, 2009; Edvardsson et al., 2013). Service innovation promotes the integration,

participation and mobilization of stakeholders in different departments within the organization. This is because innovation directly affects organizational structure, communication network, workflow and the daily work of internal stakeholders (Brem et al., 2011). This may be true, especially for front-line employees. Through daily contact with customers, they can have an in-depth understanding of customers' needs (Power, 2005). Although these benefits have been demonstrated, current studies only show isolated cases of front-line staff integration at the conception stage (Gustafsson et al., 2012). Their integration is more likely to occur at later stages of the innovation process, such as testing or training (Melton & Hartline, 2010). One explanation for the lack of implementation in practice may be that it is difficult for managers to set aside time and resources for front-line employees to participate in the service innovation process (Schilling & Werr, 2009), especially in customer service.

Service innovation research emphasizes that customers are the stakeholders of service innovation. Customer demand and its role in service are regarded as the key issues of service innovation (Tucci et al., 2007). Only by integrating their willingness and potential needs or tacit knowledge, including meeting customers' unmet needs, can it be achieved (Ramaswamy & Gouillart, 2010). In order to obtain especially potential demand, we need to work with customers as active partners to create service innovation (Gustafsson et al., 2012). First of all, it means that customers become part of the service innovation process through personal participation, sharing their service experience and introducing their ideas or evaluation concepts (Miozzo et al., 2016). The co-creation of this service innovation is characterized by the exchange and high communication between the two sides (Melton & Hartline, 2010). However, while the benefits of customer integration can be identified, such as competitive advantages, higher market fit, faster time to market, and more successful innovation (Schulteß & Satzger, 2010), it is not clear which customer integration approaches lead to the best results at different stages of the innovation process (Johnson, Gustafsson, & Witell, 2014).

2.8 Conclusions

This chapter offers the logic behind innovation in KIBS and KIBS in healthcare, stakeholders integration in healthcare service innovation. Section 2.2 introduces what innovation is and how to innovate, the actors and measurement of innovation. Section 2.3 defines KIBS. Section 2.4 encapsulates the role and place of KIBS in innovation systems. Section 2.5, 2.6 and 2.7 show CRO as a KIBS in healthcare system, stakeholder theory and its implication in healthcare service innovation.

The next chapter would further introduce how innovation and innovation of the healthcare and CRO industry differ in the Chinese context.

[This page is deliberately left blank.]

Chapter 3: Innovation in the Chinese Context

3.1 Introduction

In Chapter 2, the definition of innovation and the actors and measurement of innovation are firstly described. Then the definition of knowledge-intensive business services (KIBS) and how innovation plays in KIBS are elaborated, followed by further discussion of the stakeholder theory in order to identify possible key stakeholders in the context of specialized and technical, business-to-business service innovation and how innovation specifically performs in the CRO entity (a particular KIBS in healthcare sector).

Chapter 2 provides a general theoretical basis related to innovation, KIBS and the stakeholder theory for analysis. In this chapter, the elaboration will particularly move to how innovation and innovation of the healthcare and CRO industry differ in the Chinese context. The sections of Chapter 3 are organized in the following ways. Section 3.2 presents the rapid economic development since 1979. Section 3.3 shows the innovation in China, which consists of two parts: the development of innovation in China and China's innovation in the context of Chinese economy. Section 3.4 discusses the structure, the challenges and the evolution of the healthcare system in China, elaborating from three perspectives: medical device R&D innovation, drug R&D innovation and medical service R&D innovation. Section 3.5 introduces the development of China's CRO with a more detailed introduction of medical device CRO, and CRO industry innovation. The last section is a summary of this chapter.

3.2 Economic development in China

3.2.1 1979-1992: Rapid development after opening-up policy

(1) Adjustment of the structure of national economy

In the face of such major problems as disproportional indicators in national economy, unreasonable and unclear management system, and low efficiency, we must adjust, reform, rectify and improve the national economy. In the process of adjustment, reform, rectification and improvement, we should explore new ways of economic development and transformation of economic development mode. Through the continuous adjustment from 1979 to 1980, the

structure of the national economy and the proportions of indicators became more reasonable. The proportion of agriculture in the total output value of industry and agriculture increased to 30.8%, and that of light industry climbed to 47.7%. The accumulation rate decreased by 31.6%. From 1979 to 1984, the average annual growth rates of GDP, social output value, industrial output value and national income were 8.8%, 9.1%, 9.1% and 8.3% respectively. Especially from 1934 to 1984, the growth rate increased year by year, showing a trend of sustained and steady growth and signaling a sound momentum of rapid economic and social development (Yang & Zheng, 1988).

(2) Speeding up of agricultural development

From 1979 to 1984, the output of grain and cotton increased by 75.19 million tons and 4.051 million tons respectively, faster than the previous 20 years. The output of oil crops, jute, tea, fruit and other economic crops also increased significantly. From 1985 to 1989, there were some unfavorable factors constraining the development of crop cultivation industry. The output of oil crops, jute, sugar crops, fruit and other crops has been reduced or hovering, especially that of oil crops and jute has been slashed: from 15.784 million tons and 4.119 million tons in 1985 to 12.952 million tons and 660 million tons in 1989. In 1990, the Ministry of Agriculture invested 6.671 billion yuan in agricultural capital construction, an increase of 31.73% over the 5.064 billion yuan in 1989, in accordance with the Decision on Developing Farmland and Water Conservancy Capital Construction. In November 1989, the State Council decided to designate 1990 as the year of agricultural science and technology popularization, which achieved good results. It increased grain production by 6 billion kg, cotton by 110 million kg, oil crops by 400 million kg, and sugar crops by 1.22 billion kg. The total agricultural output value increased by 112.7 billion yuan, with a growth rate of 17.25%, and the input-output ratio reached 1:6.

(3) Accelerated industrial development and infrastructure investment

In 1979, special measures were taken for light industry, such as increasing loans, ensuring the supply of raw materials and fuel, and opening up more production channels. In 1980, the government implemented the "six priorities" measures for light industry, vigorously supported collective enterprises and the development of small commodity production, and made heavy industrial production oriented to agriculture, light industry and market supply. 1985-1989 was the high growth stage of China's industrial economy (Zhao & Zhao, 2002). In 1989, China's total industrial output value reached 2201.7 billion yuan, an increase of 1.266 times over the 971.6 billion yuan in 1985, and an average annual growth of 25.3% for five years. The policy of "rectifying" the national economy put forward at the Third Plenary Session of the Eleventh Central Committee of the Communist Party of China achieved initial results, and the

development of industrial economy entered a new stage. However, from 1990 to 1992, due to the influence of the "rectification" policy and the macroeconomic situation, the growth rate of industrial economy slowed down obviously. Outputs of raw coal, crude oil and natural gas were only 36 million tons, 37.9 billion tons and 490 million cubic meters, respectively, increased by 3.3%, 2.74% and 3.20%, and the growth rate of power generation, pig iron and crude steel was relatively large. The total industrial output value was 2392.4 billion yuan, 2662.5 billion yuan and 3459.9 billion yuan respectively, showing an overall upward trend.

(4) Guaranteeing the living needs of the people

In rural areas, a number of measures were implemented such as the distribution policy, raising the purchase price of agricultural and sideline products, and reducing the agricultural tax and unified purchase task of some areas and commune teams, so as to increase farmers' income. In cities, the livelihood of residents was improved by increased employment, raising wage levels and providing non-staple food subsidies. In enterprises, a bonus system was implemented to expand the proportion of non-productive investment in housing, science, education, culture, health and urban construction, increase the income of workers and improve their treatment.

3.2.2 1993-2012: High-quality economic development under transition period

In the spring of 1992, Deng Xiaoping's "Southern tour speech" clearly pointed out that socialism can also develop market economy, which pointed out the direction for further deepening the reform of economic system and provided the basis for economic development and transformation of economic development mode. In 1992, the 14th National Congress of the Communist Party of China explicitly put forward the establishment of a socialist market economic system, so that the market plays a fundamental role in the allocation of resources under socialist macro-control. China's reform and opening up and economic development entered a new stage.

In 1993, the CPC Central Committee established the basic framework and program of action for the socialist economic system. At the end of the 20th century, the socialist market economic system was initially established, which greatly promoted the economic development. However, in the process of rapid economic development, there are also some problems: (1) There is a strange phenomenon of maintaining GDP growth and excessive currency, resulting in financial disorder; (2) Inflation is threatening the healthy operation of the economy; and (3) Residents' living standards are slowly improving.

In 1997, the 15th National Congress of the Communist Party of China reiterated the policy of actively promoting the reform of the economic system and changing the mode of economic development. It is necessary to realize "two fundamental changes", and prioritize improving the distribution structure and mode, adjusting and optimizing the industrial structure, and constantly improving people's life. In the first half of 1998, the growth of China's foreign trade and export dropped sharply, the driving force of domestic demand on the economy declined, and the speed of economic development showed an obvious slowing trend. At that time, in terms of macro-control policy, China mainly adopted proactive fiscal policy and prudent monetary policy, basically realizing the "soft landing" of the economy. From 1997 to 2001, through proactive fiscal policy and prudent monetary policy, China's economy was effectively improved; the consumption level of Chinese residents was increasing year by year, and the quality of people's life was significantly improved.

Since the 16th National Congress of the Communist Party of China in 2002, China has made great progress in exploring and grasping the law of economic development. China's comprehensive national strength has been continuously strengthened and people's living standards have been greatly improved. From 2003 to 2007, first, in terms of its contribution to GDP, investment has become the core driver of China's economic development; second, from the development of the structure of the three industries, the overall structure is reasonable. Third, from the perspective of import and export, in 2001, China's accession to WTO gradually expanded the international market, accelerated the development of China's import and export processing trade, and expedited its economic development again. The export increased from 266.1 billion US dollars in 2001 to 1217.78 billion US dollars in 2007, an increase of 951.68 billion US dollars. The large-scale export has made China's dependence on foreign trade increase year by year since its accession to WTO. The dependence on foreign trade has jumped from about 40% to 65%. China's economy has been over-dependent on the foreign demand market with foreign trade taking up 27.34% of GDP, which is far higher than that of the United States, a world economic and trade power. 2002-2007 is the period with the largest number of construction projects, the largest amount of foreign capital utilization and the fastest growth. The foreign direct investment is 34171.4 billion US dollars, 41081.0 billion US dollars, 4366.4 billion US dollars, 4400.1 billion US dollars, 4147.3 billion US dollars and 3787.1 billion US dollars respectively, which is the best period of foreign direct investment since 1978's reform and opening up (National Bureau of Statistics, 2010). Fifth, in terms of the consumption of resources, China's energy consumption intensity dropped from 170,200 tons of standard coal / 100 million yuan in 1979 to 51,700 tons of standard coal / 100 million yuan in 2007. The

consumption intensity of water resources decreased from 0.26 m^3/yuan in 1999 to 0.13 m^3/yuan in 2007. This transformation of economic development mode with sustainability as the core has promoted the rapid and healthy growth of China's economy and pointed out the direction for China's economic development (National Bureau of Statistics, 2010).

In October 2007, the report of the 17th National Congress of the Communist Party of China proposed that we should focus on the realization of the scientific outlook on development, further promote the construction of the micro foundation and macro-control system of the market economy, eliminate the institutional obstacles hindering scientific development, adopt the new concept that the economic system reform should be closely combined with economic development and the transformation of development mode, and make it a major strategy. This is an urgent and important strategic task related to the overall situation of national economic development. The transformation of the mode of economic development then encountered new problems. In 2008, as the worst economic crisis since 1992 broke out in the world, China's economy was severely damaged with more prominent problems: blocked exports, difficulties in the operation of businesses, fiscal revenue reduction, unemployment risk, and delayed pace of mode transformation.

In December 2008, the Central Economic Work Conference made a judgment on the economic situation: the fundamentals and long-term trend of economic development remained unchanged; and economic development is still in an important period of strategic opportunities. In 2009, maintaining steady and rapid economic development was the primary task of economic work. The Party Central Committee and the State Council continued to intensify policy efforts to enrich, improve and implement the "package" plan (also known as the "four trillion investment plans"). First, implement the industrial revitalization plan. Through the adjustment and revitalization planning of ten key industries, such as automobile, electronic information and logistics, the statistical data show that, in addition to the logistics industry, the industrial added value of the other nine industries is nearly 80%, accounting for 1/3 of the GDP. The State Council promulgated the Outline of the Reform and Development Plan for the Pearl River Delta Region (2008-2020) and approved the revitalization plans for Chongqing, Shanghai, Fujian and other regions. Third, vigorously expand consumer demand. Fourth, promote independent innovation. From 2009 to 2010, we invested 100 billion yuan to guide the independent innovation of various factors and promote the formation of new economic growth points around the expansion of domestic demand and industrial revitalization. Through these measures, the growth rate of GDP in 2009 reached 9.2% (American Psychological Association, 2011), which was higher than the "guarantee 8%" target set at the beginning of the year. In 2010, we

continued to improve the level of macro-control, and introduced measures to expand domestic demand, stabilize growth, adjust structure, promote transformation, tighten monetary policy, and control inflation. In 2011, the central bank continued to tighten monetary policy and raised the deposit reserve ratio four times. In order to promote the healthy and stable development of real estate, we strengthened the regulation and control of real estate, continued to curb speculative investment in house purchase, and introduced eight new policies for macro-control of the real estate market, involving eight aspects such as tax, credit, affordable housing, purchase restriction order and government accountability. Statistics show that in 2012, China's GDP reached 51.93 trillion yuan, 142 times higher than that in 1978. In terms of scale and speed, China's economic development speed is unprecedented, and the living standards of the people in China have improved significantly (National Bureau of Statistics, 2012, 2013).

China has constantly changed its economic development mode. In the process of incremental reform, the market economy system gradually has replaced the planned economic system. The decisive role of the market in resource allocation is constantly optimized. The economic development mode, which is mainly based on extensive and introverted growth, has gradually shifted to the intensive and open economic development mode, gradually forming the intensive economic development mode featuring the export-oriented, external demand-driven, continuous adjustment of industrial structure, pursuit of high speed, high accumulation, high input, high consumption and low consumption, but the percentage of extensive growth is still very high.

3.2.3 China's green economy

In 2014, China's total economic volume reached 63646.3 billion yuan, breaking through ten trillion US dollars for the first time, providing important guarantee and support for the development of green economy. As the economic volume increases, the quality is also improving. The industrial structure is becoming more optimized. In 2014, the proportion of the added value of the tertiary industry to GDP in China was 48.2%, 5.6% higher than that of the secondary industry. Green industries such as clean energy developed rapidly. The driving effect of the industry increased steadily. Meanwhile, the resource efficiency has been continuously improved. New progress has been made in the social security system. The quality of economic development has been improved. In general, the achievements of green economy development in China can be summarized as follows:

(1) The rapid development of green industries and steady increase of driving effect:

In recent years, China’s green industry has a strong momentum of development. With regard to the proportion of new energy, many indicators in China have been among the tops in the world, with its hydropower installation ranking the first in the world for, wind power installation the first in the world, the scale of nuclear power under construction the first in the world, and the utilization scale of solar water heater the first in the world. With the implementation of the 12th Five-Year Plan and 13th Five-Year Plan, China's total investment in the new energy sector will exceed 3 trillion yuan. It not only provides material basis and technical support for ecological civilization construction, but also makes positive contribution to economy. The increase of smart cities also confirms the impact of driving innovation on the development of China's green economy (Figure 3.1).

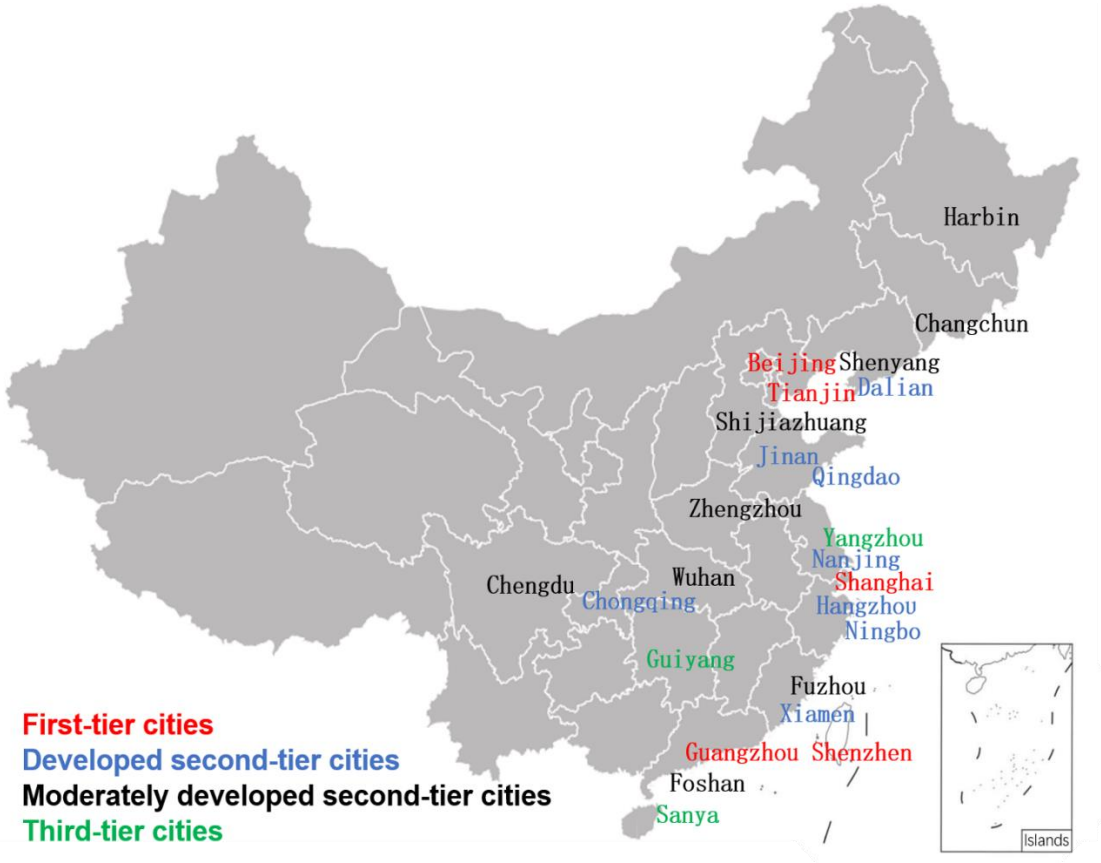

Figure 3.1 Distribution of smart city sample

Source: Cao, Zhang, and Qian (2019)

(2) Energy structure is continuously optimized, and resource efficiency is continuously improved:

Since the implementation of the 11th Five Year Plan, China has vigorously promoted the energy supply revolution and established a diversified energy supply system, which includes conventional energy such as coal, oil and natural gas, and renewable energy such as nuclear power and hydropower. BP’s research predicts that by 2035, China will surpass the United

States as the largest nuclear power producer, accounting for 30% of the world’s total nuclear energy production over the previous 4%; marked achievements have been made in energy conservation and environmental protection, with continuous enhancement of resource efficiency. Since the implementation of the 11th Five Year Plan, the energy consumption per 10,000 yuan of GDP has declined from 47.5% in 2006 to 63% in 2014. This indicates that the energy utilization efficiency of China has been continuously improved, which lays a solid foundation for the development of green economy.

(3) New progress has been made in social security construction. The quality of development has been improved:

Social security construction occupies a part of China's strategy for future development (Figure 3.2). A large number of people are enrolled in five social insurance programs to further increase the level of social benefits for the population.

Figure 3.2 China's strategic goals

Source: American Institute of Physics (2018)

3.2.4 The Belt and Road Initiative

The Belt and Road Initiative is a grand and panoramic strategic vision put forward by President Xi Jinping in 2013, including the "Silk Road Economic Belt" and "the Maritime Silk Road in the 21st Century". The Belt and Road strategy has been powering China's economic growth:

(1) The B&R will provide China with an important opportunity to resolve excess capital and capacity, and provide an important strategic opportunity for many other industries such as real estate, steel, cement, building materials and so on. China's economic development mainly relies on the market of developed countries to vigorously develop labor-intensive manufacturing industries, such as the United States, Europe and Japan. With the increase of labor costs, China is gradually losing its comparative advantage in low-end manufacturing industry. Some industries that have accumulated excess capacity in China are far from reaching saturation in many underdeveloped countries along the belt and road, hence tremendous potential demand. The B&R is boosting international cooperation in production capacity. Its core is not simply commodity trade and products, but the export of industries and capacity (Guangming Daily, 2015). For example, China's equipment manufacturing volume is huge. The output of machine tools, ships, high-speed rail and power generation equipment is among the tops in the world. We shall give full play to China's capabilities in equipment manufacturing and operation management, so as to cultivate new and broader market.

(2) The B&R is a long-term and ambitious strategy to boost GDP growth and domestic employment from a macro level. It can provide sustained driving power for China's economic growth. China's investment in the 48 countries along the Belt and Road stood at 12.03 billion US dollars in 2015, an increase of 66.2% (First Essay Network, 2015). Outbound investment has obvious driving effect on China's economy. China's investment in water and electricity supply, transportation, post and telecommunications, metal smelting, electrical manufacturing, transport equipment and other industries will be a strong catalyst for the Chinese economy and for domestic employment (Wang, Chen, & Long, 2016). It provides a good opportunity for China's economic transformation and industrial restructuring and upgrading. From the micro level, raw material manufacturers, construction parties, management parties, financial institutions and other micro entities are fully revitalized. Chinese enterprises are not only involved in the construction of projects, but also more engaged in the future operation. Large central enterprises, state-owned enterprises and small and medium-sized private enterprises can participate in it. Micro entities will accumulate valuable experience in international production and operation, industrial upgrading and structural adjustment, and enterprise governance.

(3) A global value chain around China is being built. The B&R will greatly improve the local investment environment of countries along the line, drive the development of related industries, and improve the living standard of the residents. As an important part of the campaign, the China-Pakistani Economic Corridor with a total investment of 46 billion US dollars will benefit the people of Pakistan, especially those in the impoverished and volatile Baluchistan province. As a result, many of Pakistan's domestic problems such as poverty, terrorism and employment will be greatly mitigated. The B&R not only brings prosperity to the countries along the line, but also is of greater significance to building a global value chain led by China. China "dares to be the first in the world" in many aspects. For example, multilateral financial institutions such as the Asian Infrastructure Investment Bank have broken through the restrictions in the project rating and credit granting by traditional international financial institutions for developing countries. Chinese enterprises export and constantly optimize their technological, commercial and institutional advantages. The B&R is a platform for the development of soft power in terms of technological innovation, financial innovation, human capital and management experience. It provides opportunities for China to take part in and lead regional economic integration through policy communication, facilities interconnection, trade liberalization, financial integration and people's hearts. Meanwhile, the initiative has been used to hedge against the U.S.' "Asia Pacific rebalancing" strategy and the Trans-Pacific Partnership agreement targeting China, so as to enhance China's image and voice in global affairs.

The B&R Initiative will link the potential 3 billion middle class in the world, strengthen interconnection and interflow through trade and infrastructure construction, create more employment opportunities, encourage private sector participation, and make the world more connected and open. It will help China relieve the downturn pressure on the economy, effectively divert excess capacity, promote economic growth, and create a global value chain with China's leading role. In this process, we should pay attention to stimulating the vitality of private capital, gradually reducing the industry concentration, strengthening the ability construction of enterprises, and coordinating the development of different regions in China. The B&R is a grand project. It cannot be measured simply by the return on investment of every infrastructure project, but should be placed in the context of global economic downturn and slow recovery. We will see the great social benefits it will generate. It will not only improve the well-being of more than 60 countries along the line, but also provide inexhaustible impetus for the growth of China's economy, and accelerate the recovery process of the world economy.

At the beginning of 2020, a sudden outbreak of Covid-19 raged across the world, and then evolved into a once-in-century global public health crisis. The novel coronavirus pneumonia

epidemic is a typical black swan event. Its biggest impact on the economy is uncertainty and unpredictability. As long as the global epidemic is not effectively controlled, it is difficult to make a definite prediction of the depth, breadth and duration of the world economic recession. Therefore, it is difficult to accurately assess the impact of the epidemic on China's economy. In 2020, flexible and moderate monetary policy and positive and promising fiscal policy will work together to support the economic operation. Taking monetary and financial policies as an example, since the end of January 2020, the People's Bank of China has strengthened the guidance of expectations through various monetary policy tools such as open market operation, standing loan facilities, refinancing, rediscount, and reducing the legal reserve ratio, and set up a financial system to provide sufficient liquidity, maintain reasonable and sufficient liquidity in the financial market, and maintain the quality of goods. The interest rate of the currency market should run smoothly, and financial institutions should be guided to increase credit supply to support the real economy. China is the first in the world to control the epidemic, to resume work and production, and to turn the economic growth from negative to positive. For example, according to the data of the National Bureau of Statistics, China's GDP will grow by 2.3% in the future standing at 101.5986 trillion yuan, reaching the threshold of one million trillion yuan. The GDP per capita will also exceed 11,000 US dollars, approaching the level of moderately developed countries.

The Belt and Road Initiative is a comprehensive development strategy of "promoting reform by opening up, promoting development by reform, and promoting transformation by development". We should combine the trends of inclusive development, economic globalization and regional economic integration, combine knowledge accumulation, technology innovation, market rules and system construction with the international economic relations of the rules of the appropriate, participation, leading into the depth of participation in the whole process of international economy. Through the "reverse investment" to the developed countries. we can shorten the time of knowledge accumulation and technological innovation via the international industrial transfer and regional economic integration of mutual integration. The Belt and Road Initiative" is just such a strategic choice based on reality, which provides a feasible path for Chinese enterprises to deeply participate in international economic operation. Actively promoting the development of the Belt and Road Initiative will not only activate the development potential of the central and western regions, but also further unleash the vitality of development, opening up, innovation and creativity. Moreover, it can optimize the regional layout of the domestic open economy, realize the coordinated development of all regions, and create important strategic opportunities for improving the overall level of the open economy.

3.3 Innovation in China

3.3.1 The development of innovation in China

In 1978, the People's Republic of China kicked off the “Reform and Opening-up” economic policy aimed at attracting world markets by introducing foreign investment and decentralizing its large and expanding agricultural sector (where most of the population live and work) (Kerr, 2013). Back then, China was unable to grow enough food to support its population, with widespread poverty, inaccessible education, especially higher education, and limited foreign participation and presence. This policy allowed entrepreneurs to set up their own companies, in an effort to stimulate the rise of the entrepreneurial class. Therefore, the “Reform and Opening-up” is a major economic and social reform policy aimed at improving the economy and the life of citizens.

It must be recognized that import to export-oriented growth is also part of the “ Reform and Opening-up” vision (Chen & Han, 2014). In this way, China opened the market up and put itself in the process of global innovation. Imitative manufacturing is realized by introducing and learning from other countries. By adopting and incrementally transforming the innovation, China was able to build a huge manufacturing-driven economy that served not only the Chinese market but also the overseas market. As a result, the opening up of China's economy has generated new foreign dominated or funded manufacturing industries which depend on foreign manufacturing technology. This process of introducing and adopting foreign technology is called imitative innovation, that is, acquiring technology by observing its working principle, and then adjusting it according to local conditions. However, China has always envisioned an economic system based on its ability to innovate on its own (Que & Li, 2003). However, the reality is that China remains a manufacturing economy relying on imitating others' innovations.

In the first 20 years after the implementation of “Reform and Opening-up”, although some moderate support had been given to help entrepreneurs and small enterprises, China's manufacturing industry remained dominated by state-owned enterprises responsible for producing durable and infrastructure goods and services (Coase & Ning, 2013). However, the SOE-led manufacturing industry has made slow progress in improving efficiency and output quality (Kerr, 2013). While many observers see SOEs as an obstacle to innovation, China's leadership sees SOE reform measures as a potential source of innovation in China (Kerr, 2013). As state-owned enterprises are closely controlled and supervised by the central government, the latter can promote and has promoted the innovation of state-owned enterprises. Although many

external observers view SOEs as barriers to innovation from China's perspective, SOE reform may trigger innovation not only in market-driven enterprise development, but also in these more strictly state-controlled organizations. The results of the reform and its impact on the innovation of state-owned enterprises are a hot topic, which will be further discussed below.

Since 1990, in order to support the further development of infrastructure, the attraction of foreign direct investment has been increasing. China has separated from the affiliated factories of state-owned enterprises and foreign companies to achieve higher output efficiency and quality. The quality and quantity of manufacturing output expanded rapidly, and China became the world’s largest supplier of manufacturing products in 2010, with manufacturing as a source of GDP and manufacturing employment (Woetzel, 2015). How did China achieve this? Foreign investment may constitute an important factor. Other driving factors may include: (1) funding the modernization of physical infrastructure and enhancing productivity by improving supply and demand logistics and general liquidity; (2) injecting external risks and competition into the production system mainly run by state-owned enterprises and farmers; and (3) the existence of huge and accessible pools of low-cost labor where in some cases marginal cost was nearly “0”.

Innovation in the first two decades of “Reform and Opening-up” is mainly imitation, and the existing production technology is obtained through foreign direct investment and other methods, which enables Chinese enterprises to adopt or “imitate” technological know-how. Therefore, this form of innovation is called imitation (Zhou, 2006). With the emergence of best or near best practice technology, China can gradually increase the known know-how on the basis of trial-and-error learning. Although this approach has led to the development of some large companies with global competitiveness, these are exceptions to the general law of economic growth that relies on imitation technology. Imitation is not a kind of innovation that can usually transform the economy or even industry, because it mainly helps to fine tune the known methods and gradually increase productivity and growth. As long as the cost of production factors is reasonable, imitation is a feasible economic growth strategy. Until recently, due to such a large difference in labor costs, there is still a huge cost gap between China and other global producers. Consequently, China's dependence on imitation is relatively small in the short term. Table 3.1 shows the ranking of 35 major countries in the world based on *the Innovation Nation Building Index in the Innovation Nation Building Report (2009)*.

Table 3.1 Innovative Nation Building Index Rankings and Scores

Country	Score	Ranking	Country	Score	Ranking
United States	85.27	1	Belgium	76.05	19
Japan	83.50	2	Spain	75.67	20
Sweden	81.43	3	Italy	75.27	21
Finland	80.77	4	China	74.73	22
Korea	80.63	5	Portugal	74.62	23
Denmark	80.20	6	Slovenia	74.38	24
Austria	80.16	7	Czech Republic	74.01	25
Germany	80.12	8	Romania	73.94	26
Switzerland	79.87	9	Hungary	73.38	27
France	79.54	10	Lithuania	73.25	28
Norway	78.88	11	Slovakia	72.87	29
United Kingdom	78.61	12	Latvia	72.65	30
Netherlands	78.27	13	Greece	72.49	31
Ireland	77.67	14	Poland	72.02	32
Australia	77.30	15	Mexico	71.08	33
New Zealand	77.26	16	Bulgaria	70.27	34
Canada	76.91	17	Turkey	69.99	35
Estonia	76.53	18			

In the second decade of the 21st century, China's manufacturing-based economy has achieved great success, followed by the adoption of new and emerging technologies, and the demand for highly skilled labor is increasing. Although the number of technical and engineering graduates entering the labor market has increased due to greater investment in higher education and the increase in university graduates in technology fields such as engineering, science and management, this trend in turn has started to push up the labor cost, hence the growth of the labor market, the increase in the total cost of manufacturing products and the environmental impact. The rising cost of pollution management, coupled with the global economic recession that began in 2008 (Harding, 2016), has accelerated China's independent innovation capability and faced new pressure (Woetzel, 2015).

3.3.2 China's innovation in the context of the Chinese economy

At present, China plays an important role in technology-intensive industries such as wind turbines, high-speed rail, aircraft engines and aerospace-related equipment. Most of these products are developed by state-owned enterprises. The high-speed railway is an example to illustrate that some state-owned enterprises export new enhanced and developed products through independent innovation on the basis of imitation and innovation. The high-speed rail was originally imported from Germany. After independent innovation, China has exported it to Russia and Indonesia (Yeoh, Hua, & Yepes, 2019). In terms of private and/or joint-venture business development, China has made significant progress in technology-intensive industries such as telecommunications and information technology, Internet and social media. China has four of the top ten Internet technology companies in the world, Alibaba, Baidu, Tencent and Xiaomi, three of which have entered the top ten. Since 2013 other companies have made great progress. China has already become an important player in global markets, with major companies such as Haier (consumer durables) and Huawei (mobile hardware and network). As a result, the government, state-owned enterprises and private sector organizations have some very innovative examples of major technology business development.

Many of these enterprises started investing in higher education as a major move to drive innovation, while China has recently been investing more and more high-level resources to lift the skill level of its labor force. For example, in 1978, the number of university students enrolled was less than 1 million. In 1998, it was 3.4 million. In 2019, there were 30.3 million college students in China versus 19.7 million, the total number of students in public and private American universities (academic research think-tanks). China cultivates more PhD (30,000 in science and engineering) than any other area in the United States (Wertime, 2014). According to the Global Innovation Index, China ranks 29th among innovative economies. In this regard, it is ahead of other middle-income countries. At the same time, its performance in human capital promotion and R&D funds is comparable to that of developed countries (De, 2015).

In 2006, China's Ministry of Education established the Chinese Academy of Sciences, mainly following the model of the National Science Foundation of the United States, which allocates research funds through peer review. Recently, China has become a global patent leader. In 2014, China had nearly 1 million patents, more than the 578,800 patents of the United States. In 2010, 16% of Chinese patents came from universities, up from 10% in 2010 (De, 2015). China's research and development expenditures reached a new high in 2017, hitting 2.1% of gross domestic product, as the country continues its drive to become a technology powerhouse.

China spent 1.76 trillion yuan ($254 billion) on research and development in 2017, a year-on-year increase of 12.3%, according to the National Bureau of Statistics (link in Chinese). China's R&D spending has increased rapidly over the last decade or so as the country has tried to gain a competitive edge in emerging industries (Figure 3.3).

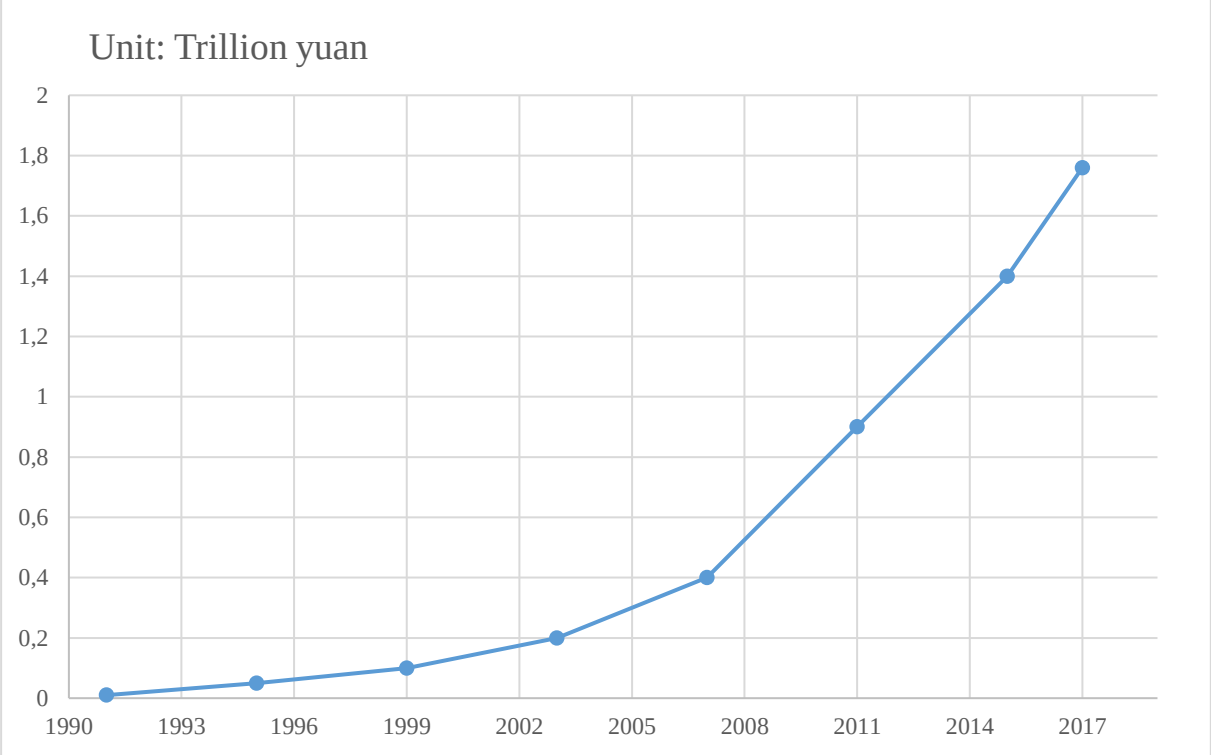

Figure 3.3 China's R&D expenditure, 1991-2017

Source: Cai (2018)

After gradually acquiring knowledge from a few more successful centers and foreign countries, these technology or innovation experiments began to drive the development of innovative companies and new technologies which requires more investment in addition to space, public utilities and engineering talents. These centers need to provide training, networks or connections for novel knowledge, markets, professionals, capital and research, not only for technology development, but also for legal, marketing, management and sales services. However, even at the beginning of the 21st century, many innovation centers could only provide mixed useful service support and lacked complex network capabilities.

Today's evidence suggests that China's innovation centers are more complex than recently observed (Stough, Aberman, & Baycan, 2013). For example, Guangdong Province has several fully integrated innovation centers, including Guangzhou, Shenzhen, Dongguan, Foshan and Zhongshan, and new innovation centers in plan in Zhuhai and Zhaoqing. A wider range of services are now available to support startups, as well as existing companies that are ready to grow. These also include the by-products of existing companies that have subcontracted these

new businesses to these centers, knowing that there is a wide range of services needed to optimize their development potential. These services go far beyond providing space and utilities, managed and led by a person with rich experience. Not only in China, but also in the most recognized innovation fields in the world, such as Silicon Valley, Cambridge (UK), Austen, Dyksas, etc., there are “perfume shops”. In addition, at the most basic level, each of them provides a “makers space” for young entrepreneurs to explore ideas. When ideas begin to merge, they can help with prototyping, customer/market development, and financing (mainly through early crowdfunding, but in a more robust form). At the highest level, these centers now help connect emerging growth companies to develop global market plans, network with potential local and international partners and their supply chains, and even help where mergers or acquisitions may be needed. In short, today's innovation centers have learned from early experiments in China as well as global experiences, and have integrated these experiences into the design, management, and operation of best practice facilities (Jain, Triandis, & Weick, 2010).

As shown in Figure 3.4, China's R&D investment has been increasing rapidly year by year since 2008. According to statistics, China's R&D investment intensity began to show a steady increase. By 2013, the intensity of R&D investment entered the “2” era for the first time, reaching 2.00%; since then, it has continued to maintain a rising trend year by year, rising to 2.41% in 2018. In 2011, China's patent applications for inventions surpassed those of the United States for the first time and became the first in the world, accounting for a quarter of the global total, and in 2013, China's PCT international patent applications jumped to the third place in the world. The World Intellectual Property Office (WIPO) released the data of the international filings for patents, trademarks and industrial designs in 2020. China filed 68,720 PCT applications in 2020, up 16.1%, continuing to lead the world in this field. The gap between China's technological innovation capability and that of developed countries in Europe and the United States is narrowing in some areas, and has changed significantly from “out of reach” in the past to “on the back” today.

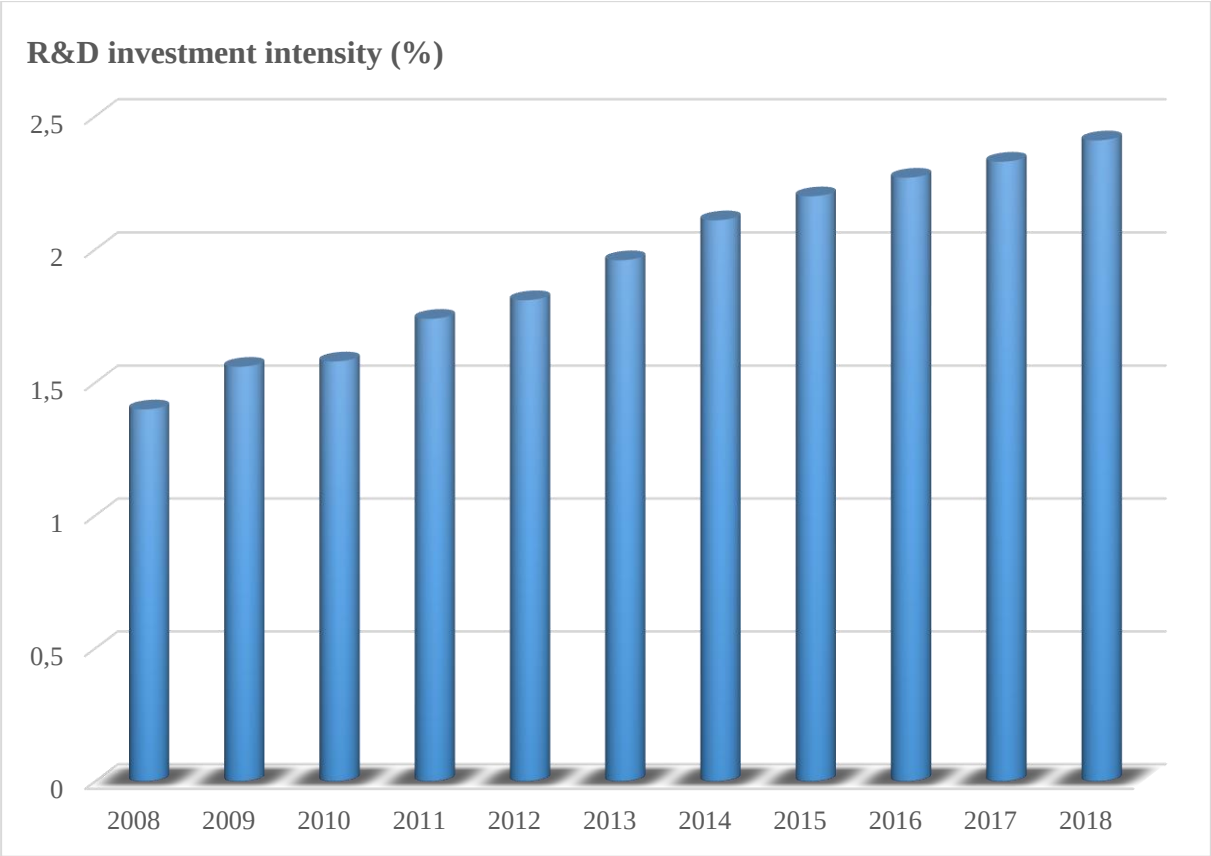

Figure 3.4 R&D expenditure in China, 2008-2018

3.4 Healthcare innovation in China

The construction of “Health China” has become a national strategy, giving priority to the people’s health in the strategic position of development.

First, we will accelerate the development of a hierarchical medical system. Second, we will comprehensively deepen the comprehensive reform of public hospitals. In 2017, comprehensive reforms were carried out in all public hospitals at all levels and of all types. Third, we will improve the mechanism for ensuring the supply of drug and medical device. Fourth, we will promote the development of health services.

To advance the development of a healthy China, we need to concentrate on tackling key and core technologies, solve the problem of "stranglehold" in drugs, medical devices, vaccines and other fields, and attach great importance to the application of new-generation information technology (Giving Priority to People's Health in the Strategic Position of Development - On the Study and Implementation of General Secretary Xi Jinping's Important Speech at the Symposium of Experts and Representatives in the Field of Education, Culture, Health, Sports).

3.4.1 Healthcare system in China

China is carrying out a new round of healthcare reforms. An introduction of the development of the Chinese health system from the founding of the People's Republic of China in 1949 to the reform of market economy in the early 1980s might be helpful to the better comprehension of this method. The market-oriented reform has led to soaring medical costs, unaffordability of medical services, the pursuit of profits (or even profits-driven) by public hospitals and the poor doctor-patient relationship, forcing the Chinese government to launch a new round of reforms.

In 2009, China celebrated the 60th anniversary of the founding of the People's Republic of China. From 1949 to 1978, in the first 30 years since the founding of the People's Republic of China, China has made many proud achievements in the field of health (Coase & Ning, 2013). Although China's per capita income was low at that time, it had a universal healthcare system with a low-cost, wide-coverage primary healthcare model. In urban areas, in addition to preventive measures, public hospitals also provided free or inexpensive healthcare services for citizens. In rural areas, barefoot doctors provided medical care for farmers at the lowest cost. They are regarded as one of the great achievements of China in the Mao Zedong era. China's health level was greatly improved with some indicators reaching the level of developed countries at that time. Life expectancy increased from about 35 years in 1949 to 68 years in 1978, higher than that in some countries richer than China. During the same period, the infant mortality rate decreased from 250 per 1,000 live births per year to less than 50 per 1,000 live births per year.

When China began its economic reform in the early 1980s, the old healthcare system came to an end as China tried to shift to a market-oriented healthcare system. After 30 years of economic reform, China has created an economic miracle. While the GDP is growing at an annual rate of 9.8%, China's healthcare system has not improved as much as the economy does. On the contrary, it has deteriorated in many ways, both in rural and urban areas. In terms of medical quality, efficiency and fairness, China's medical system is far behind the current level of economic development and people's needs. Especially compared with Australia, Hong Kong, Japan, Malaysia, Sri Lanka and other countries, medical expenses (but not health outcomes) increased rapidly, and the doctor-patient relationship deteriorated. After years of reform and exploration, China's medical insurance system and its contents have basically established a framework of medical insurance system with special features (Figure 3.5).

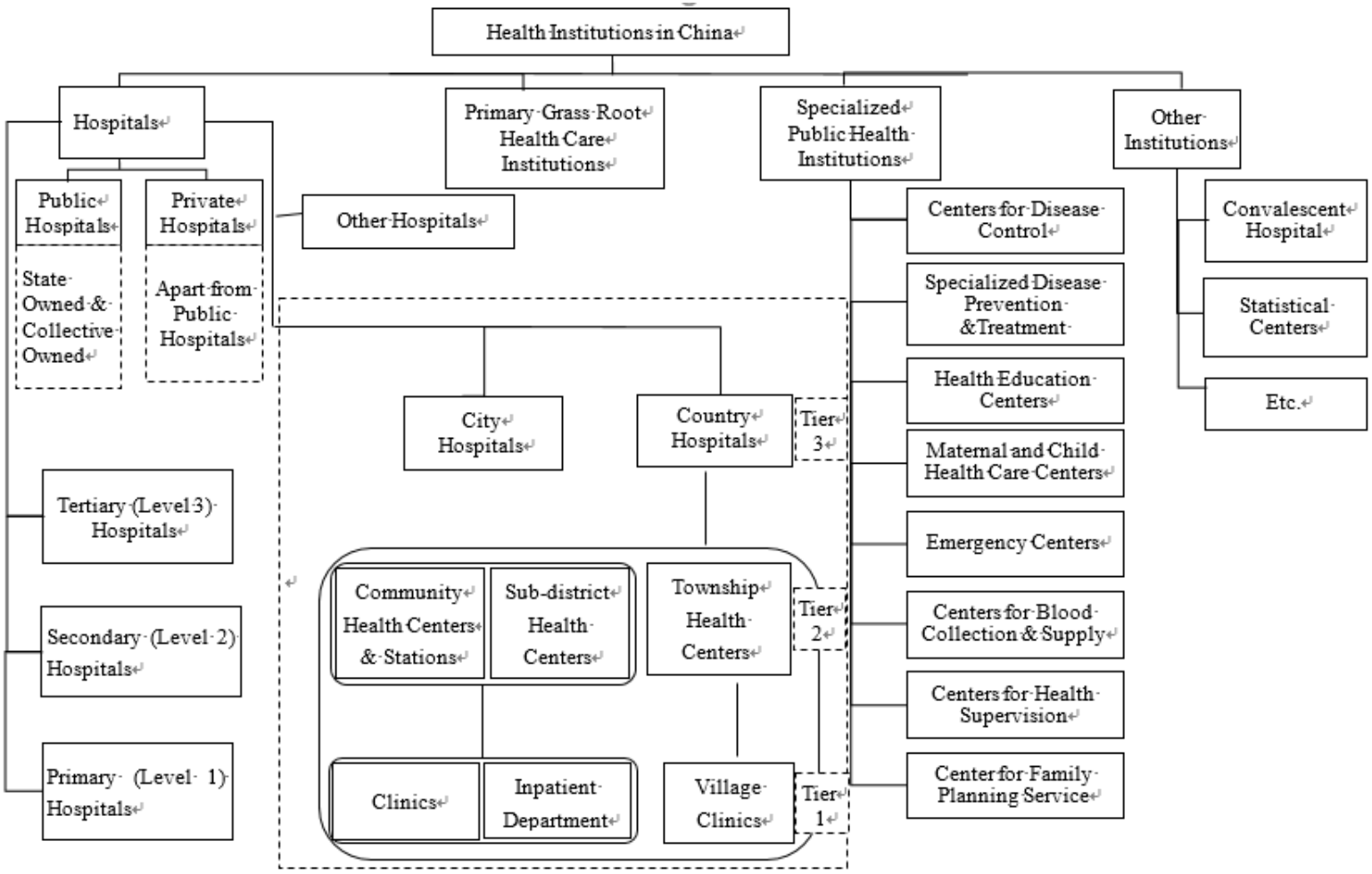

Figure 3.5 Health Care System in China

Source: Wang et al. (2018)

Note: The thin dashed line explains the distinction between public/social hospital. The thick dashed line indicated the Three Tier Health Care Delivery System in urban and rural area in China.

The main reasons for the above-mentioned problems are government failure and market failure. The government failed to meet people's basic medical needs, resulting in the collapse of the public health service system. The lack of government supervision exacerbated the market failure. Some hospitals and doctors offered unnecessary medical services, which not only increased the economic burden on patients, but also might damage their health. The government cuts the budget according to the market principle, and people pay higher medical expenses out of their own pocket. In the past three decades, the total expenditure on health has increased nearly 90 times, far exceeding the growth of GDP. It now accounts for 5% of GDP and is largely self-paying. By 2000, about 60% of medical costs were paid by patients themselves (Coase & Ning, 2013). Moreover, even the wealthier people who can afford the medical care cannot receive satisfactory medical services due to the large number of patients. A tertiary hospital receives an average of over 10,000 outpatients per day. The shortage of medical staff, especially pediatricians, anesthesiologists and general practitioners (GP) is also acute (Figure 3.6). Among all positions in the Chinese healthcare system, pediatrics is notoriously poorly remunerated but comes with high pressure.

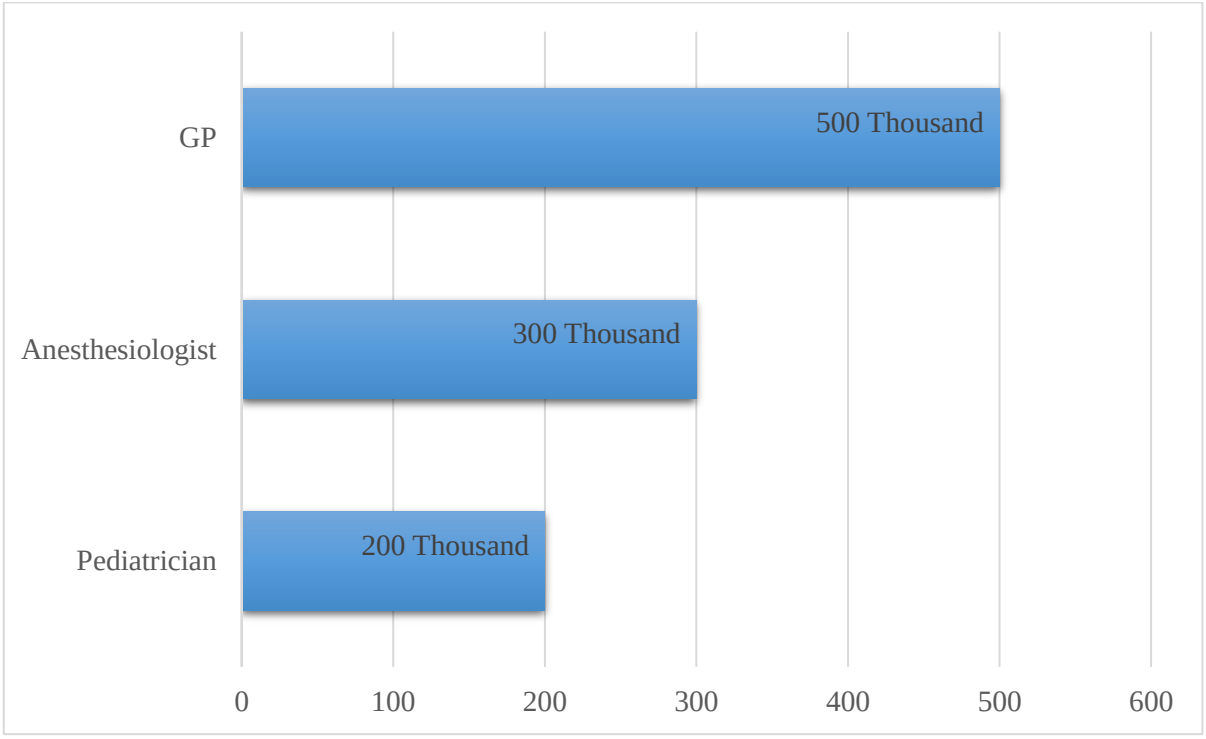

Figure 3.6 Shortage of doctors in China

Source: National Bureau of Statistics (2019)

Since then, the government has made medical reform one of the top priorities, and kicked off relevant programs (Coase & Ning, 2013). The Chinese government launched an open international tender for various reform proposals, soliciting the participation of groups around the world such as the World Bank and WHO. Healthcare reforms have been subject to heated

debate and attention from the media. On April 6, 2009, the State Council issued the document "Guiding Opinions on Deepening the Reform of the Medical System", promising that by 2011, RMB 850 billion (US$123 billion) will be invested in addition to recurrent expenditures to provide universal primary care to its 1.3 billion population. The general framework and long-term goal of the reform were to establish a universal health security system, not just one health care system, acknowledging the health impact of the environment, lifestyle and socioeconomic environment. Under this framework, the current guideline for medical modification is a comprehensive reform program that aims to harmonize all relevant systems, including health financing systems, public health systems, medical service systems, management and regulatory systems, drug and equipment supply systems, medical staff training systems, and other supporting strategies, to ensure that people can receive optimal care (Carmen, Beatriz, & Erezuela, 2021).

3.4.2 Innovation in the Chinese healthcare system

The 12th Five-Year Plan of 2011~2015 in China emphasized health system improvement and innovation support (2011 National People's Congress). Under the five-year plan, a recent report by McKinsey described the Chinese health sector as "infrastructure improvement, further medical reform, and major innovation support" (Le Deu et al., 2012). Their analysis shows that support for healthcare innovation focuses specifically on biopharmaceutical research and development rather than innovation in healthcare delivery and services. However, healthcare delivery innovation needs to adapt to the increased demand resulting from national health reforms. Although reforms reduce medical costs by increasing government subsidies, the implementation relies on expansion of the existing structure of medical services (Ilavarasan & Parthasarathy, 2012). Hospitals currently face greater revenue pressure from the primary care delivery mechanisms in China due to policy changes aimed at eliminating important sources of revenue for physicians, including patient prompts ("red envelopes") and drug rebates (Richard & Chen, 2012). New models of efficient medical services, including less costly outpatient options, are needed in China to address the greater demand that arises as access expands.

In other countries, the driving force for change and innovation in healthcare delivery models has been a response to the pressures of rising costs, access to significant barriers and inadequate numbers of trained workers. Providers and entrepreneurs around the globe are finding new ways of care. Many of these innovations are notable for business models that increase cost efficiency while maintaining or improving quality, all of which make healthcare

more readily available and affordable for low-income populations. Together, these innovations bring positive impact on the healthcare system and have helped to promote well-received reforms in healthcare in India, Kenya, and elsewhere. Superficially, China's challenges are in many ways similar to those facing other emerging economies, albeit on a larger scale. China is working to provide more medical services and affordable services to the 1.3 billion population. In the context of rising economic performance, this driving force for achieving accessibility and affordability has been driven, and health investments have increased dramatically, now at 5% of total GDP (Le Deu et al., 2012). With the advent of new financial resources, health has been prioritized as an area of government and private sector investment. The medical reforms in 2007 and 2009 expanded social insurance coverage, thereby increasing the demand for healthcare.

The healthcare innovation promotion environment is that of health and business agencies, capacities, capital markets, legal systems, and labor markets, allowing health-related businesses and organizations to form and develop (private sector working group, Global Alliance for health manpower 2012). Favorable environments have also been described as innovative ecosystems (Adner, 2012) with important consequences for the generation and development of innovations and how innovations act on the environments in which they operate.

According to Breznitz and Murphree (2011), loosely structured policies at different jurisdictional levels create policy uncertainties that provinces and municipalities can use to interpret policies differently to achieve their own local objectives. The central government may even encourage provincial or municipal competition in a permissive or unstructured policy environment where central policies recommend conservative practices, but at the local level, allow for a more gradual approach. Powerful individuals with jurisdiction must be placed so as not to intervene and restore a more conservative interpretation of the policy. It is in this context of ambiguity or structural uncertainty that innovation can flourish (Breznitz & Murphree, 2011). Although structural uncertainty takes risks, it can also foster innovation when with regulations open to interpretation, private investment can work with government investment to drive rapid growth and diffusion of innovation. The analysis presented by the authors shows that structural uncertainty is a strong factor at play in China's domination in IT production and is happening "against the declared public wishes of China's central government" (Breznitz & Murphree, 2011). It is unclear and beyond the scope of this study to determine whether structural uncertainty in the health sector limits or enhances innovation in health services. Perhaps, structural uncertainty is directing innovation toward specific gaps identified by the government or unexpected gaps brought about by policy implementation.

3.4.3 Medical device R&D innovation

According to the *Medical Device Blue Book: China's Medical Device Industry Development Report (2019)*, the compound growth rate of China's medical device industry continues to maintain at about 15%. In 2018, the main revenue of China's medical device manufacturers was about 638 billion yuan. During 2021 and 2022, the main revenue of medical device manufacturers is expected to exceed one trillion yuan. The market is huge (Shen et al., 2019). According to the 2019-2024 China's Medical Device Industry Market Prospects and Investment and Financing Report, affected by the national medical device industry policy support, the domestic medical device industry as a whole has entered a stage of rapid growth. It is estimated that the scale of China's medical device market will exceed 700 billion yuan in 2020. At the growth stage, the development space is relatively large. In 2020, the sudden outbreak of covid-19 swept the world. In the process of fighting against the epidemic, medical devices played a key role. Meanwhile, the medical device industry also received the attention of the whole world. China has been constantly exporting masks, ventilators and other anti-epidemic materials to support countries. In February 2020, China produced over 100 million masks a day, which greatly alleviates the contradiction between supply and demand of masks in the early stage of anti-epidemic. At the same time, China is also capable of producing 2,200 invasive ventilators per week. Since the outbreak of the epidemic, domestic medical device enterprises have supplied more than 29,000 ventilators to China and 18,000 ventilators to foreign countries. During the epidemic, there was a shortage of about 1 million ventilators worldwide. In addition to masks and ventilators, the medical devices urgently needed in the global fight against the epidemic also include common medical devices such as forehead temperature guns, disinfection equipment and extracorporeal membrane oxygenator, membrane oxygenation (ECMO), virus detection kit, disinfection and distribution robot, nursing and rehabilitation equipment, etc. In 2019, China's National Medical Products Administration received a total of 3,511 category III medical device registrations, a significant increase of 47.4% compared with 2018, indicating the strong development momentum of China's medical device market. At the same time, domestic medical device enterprises started import substitution in the domestic market (Liao, 2019), gradually increase the international market share and go to the overseas market. The conditions for China's medical manufacturing industry to enhance its position in the global market are mature.

During the 13th Five-Year Plan period, the State Council of China issued two major policies, including supporting domestic medical devices and innovative medical device industry, science

and technology policies, and supporting innovation platforms, intellectual property rights, standards and policies in key areas. From 2013 to 2018, China's medical device market size grew at a more rapid rate compared to the global medical device market size (Figure 3.7).

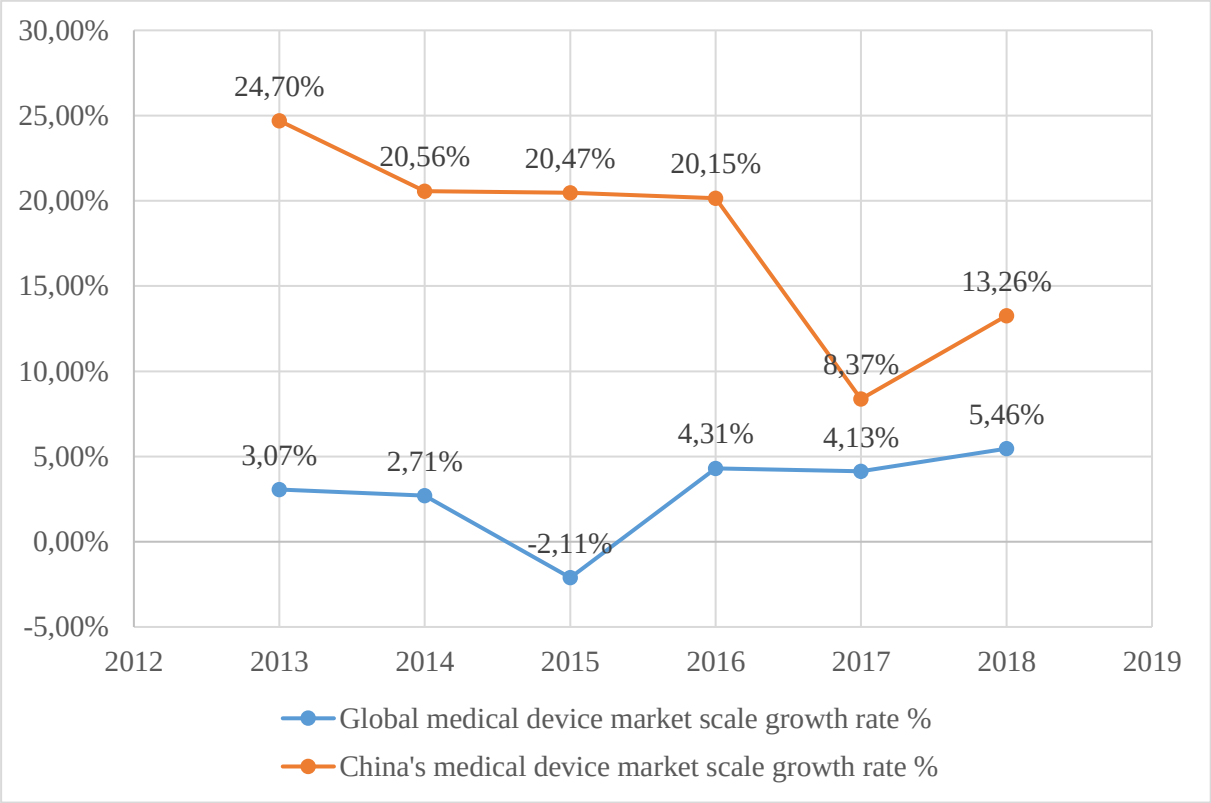

Figure 3.7 Comparison of the growth rate of China's medical device market size and that of the global medical device market size during 2013-2018 (Unit: %)

On October 8, 2017, the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council jointly issued the *Opinions on Deepening the Reform of the Review and Approval System to Encourage Innovation in Pharmaceuticals and Medical Device*s, covering medical device clinical trials, encouraging innovation and meeting the demand of clinical aspects of innovation requirements, which marks that the review and approval system of medical equipment of our country has entered a substantive stage. At this point, the clinical evaluation of medical devices in China has expanded from the original single way to four ways, and entered the stage of high quality and high efficiency under the guidance of the corresponding principles.

Subsequently, in 2018, China issued the *Technical Guidelines for Accepting Data from Overseas Clinical Trials of Medical Devices*, highlighting ethical, legal and scientific principles to provide guidance for overseas trials of medical devices. In December 2019, in order to cater to the treatment needs of severe life-threatening diseases, China issued the *Guiding Principles of Conditional Approval for Listing of Medical Devices*, which accelerated the approval

procedures by combining the relevant requirements of the registration management of medical devices in China and the examination and approval practice. In 2020, China also issued the *Regulations on the Management of Expanded Clinical Trials for Medical Devices*, which provides convenience for patients with life-threatening diseases requiring early intervention due to no effective treatment, and ensures the safety, effectiveness and accessibility of expanded medical devices. The introduction of a series of guiding principles makes the innovation and development of medical devices in China step forward to the stage of standardization and high-speed. The Ministry of Industry and Information Technology approved the establishment of the national high-performance medical device innovation center on May 6, 2020. It will focus on the demand for high-performance medical devices in the fields of prevention, diagnosis, treatment and rehabilitation, focusing on high-end innovative medical devices including interventional devices, and strive to get through the principles and technologies, key materials and key technologies. The R&D and industrialization chain of devices, systems and products should be established. The construction of innovation system in the field of medical devices should be solidly promoted, so as to improve the production and manufacturing of high-end medical equipment and the overall industrial level in China.

We have continuously deepened the reform of the medical apparatus and instruments for examination and approval system. Since the official implementation of the "Special Approval Procedures for Innovative Medical Devices (Trial)" in 2014 and "Priority Approval Procedures for Medical Devices" in 2017, a green approval channel has been opened for specific medical device products, accelerating the listing of medical devices with strong innovation, high technical content and urgent clinical needs, while accelerating the pace of import substitution of high-end medical devices.

Compared with the general three types of medical devices, the average time is 83 days less, and the inspection cycle of all innovative devices is shortened by more than one third. Compared with drugs, innovative medical devices are dominated by domestic enterprises (Figure 3.8). In 2019, a total of 1,335 category III medical devices with high technical content were approved for registration, of which 1,055 were registered in China, accounting for 79.0%. Since the start of the special examination procedure for innovative medical devices in 2014, as of December 31, 2019, a total of 238 products had entered the special examination and approval procedure for innovative medical devices in China, including 78 cardiovascular related products (except imaging equipment, endoscope, etc.) and four AI products.

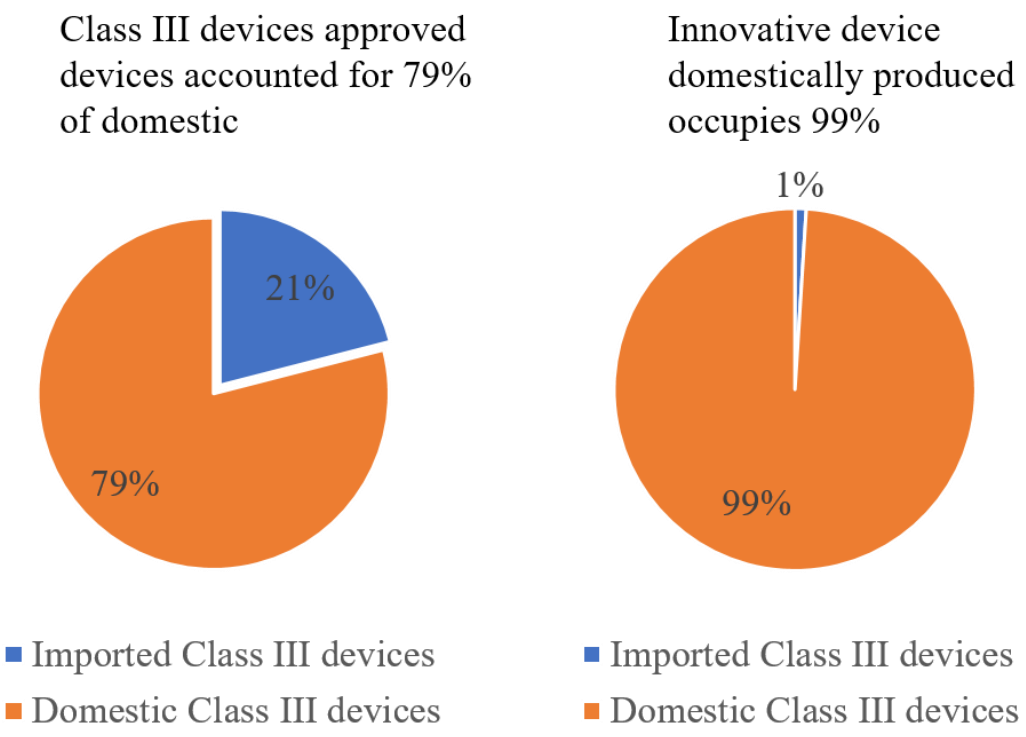

Figure 3.8 Domestic enterprises of innovative medical devices (category III medical devices) are dominant.

Source: NMPA (2018)

We have strengthened the support of clinical trial stage. We have continued to deepen the reform of medical device review and approval system, optimized clinical trial and approval resources, invested precious resources into clinical urgent need and innovative devices, and promoted safe, effective and risk-controllable products to market as soon as possible. We have actively promoted the archival work of medical device clinical trial institutions to improve the conditions for the implementation of medical device clinical trials. By the end of 2020, more than 1,000 medical device clinical trial institutions had been registered, providing more choices for clinical trial institutions and accelerating the overall clinical trial progress.

In recent years, cardiovascular interventional therapy instruments have become the most concentrated field of research and development in the world. Cardiovascular interventional therapy has become one of the three major modern medical treatment methods, which are parallel with traditional medical drug treatment and surgical treatment (Sohu, 2020). Cardiovascular innovation in China is becoming more original. Although these technical principles are not revolutionary, the structural design and working principles of the device are original, not a simple imitation of foreign devices. Zhongshan Hospital, Fudan, for example, carried out research and development of the world's first mitral valve sandwich Valve Clamp and achieved success in FIM. Changhai Hospital of Shanghai carried out the research and

development of tricuspid involved in instrument LuX-Valve. Professor Liu Liwen at Xijing Hospital created the original Liwen surgery. Professor Zhang Zhiwei participated in the research and development of absorbable interatrial septum Closure. The Prince of Wales Hospital in Hong Kong participated in the research and development of left LAmbre Closure and bring up the left auricle seal "Minimalist type" heart ear plug (Minimalist Appendage Closure, MAC). It is an original instrument or technology in the world.

In order to promote the transformation of innovative results (innovative medical devices) made by doctors, Academician Ge Junbo initiated the establishment of Chinese Cardiovascular Physicians Innovation Club (CCPI) in 2015, which was later upgraded to China Medical Innovation Alliance (CMIA) in 2018. The organization offers innovation training, design communication, research support, industrial cooperation, in hope of facilitating clinical doctors, meeting the needs of clinical subject innovation guiding its active participation in medical technology and related equipment research, and further providing preclinical and clinical research platform. As a result, it can help improve the domestic medical technology and equipment product market, break the bottlenecks in Chinese cardiovascular sector, rely on innovation, and go to the world. CCPI has formed a mature operation mode of "five-in-one", including innovation college and innovation competition.

3.4.4 Drug R&D innovation

In recent years, the pharmaceutical industry in China has maintained a rapid growth trend with a growth rate higher than that of the national economy. The pharmaceutical industry will rapidly expand its share in the gross national product in the future. At the same time, the State Council officially approved the biomedical industry as an emerging strategic industry to be supported as a national pillar industry. China's per capita drug consumption level is also growing steadily. At present, the annual sales of drugs in China's hospital drug market is close to 100 million yuan, with an annual growth of more than 100 million yuan. The average annual growth of drug retail market is more than 100 million yuan, with an annual sales scale of 100 million yuan. And it is expected that the average annual growth of drug sales will reach more than 100%, making it the third largest drug market in the world. China's modern pharmaceutical industry will become one of the pillar industries and new economic growth points in the 21st century. The "three high and one long" (high risk, high investment, high technology, long cycle) accurately summarizes the most prominent characteristics of innovative drug research and development projects.

The total amount of innovative R&D investment is low, but the growth is significant. The proportion of investment in basic research stage is too low. China's innovative drug R&D investment has increased significantly in recent years, compared to less than 400 million yuan before 2006, an increase of nearly 26 times in 2015. However, compared with developed countries, there is still a significant gap in the total amount, with the highest investment of 11 billion yuan in history which is only about 2% of the United States and 4% of the European Union in the same period. In recent years, the proportion of funds invested in the basic research stage of innovative drugs in China is too low, accounting for only about 15% of the total investment in pharmaceutical R&D. Most of the investment is dissipated in applied research and experimental development, which not only curbs the initial power of original innovation and the development of pharmaceutical enterprises, but also makes it difficult to improve the innovation ability in R&D activities (Ding, 2012). The proportion of R&D investment in the basic research stage of innovative drugs in the United States, Japan and the European Union is about 60%.

The total number of innovative R&D personnel has been gradually increased. Innovative drug R&D is a knowledge-intensive human capital activity, which requires the cooperation of multi-disciplinary and high-level scientific research personnel (Tian, 2017). The level of R&D personnel largely determines the innovation ability of the pharmaceutical industry. After years of development, the number of pharmaceutical R&D personnel in China has formed a large scale. In 2011, the number of pharmaceutical R&D personnel exceeded 100,000 for the first time, with an annual growth rate of 68%. However, compared with developed countries with a large base of scientific and technological innovation personnel, there is still a big gap. In 2011, the number of pharmaceutical R&D full-time personnel in the United States reached 620,000 and that of the European Union exceeded 500,000 in 2006. In addition, the proportion of scientific research personnel in the pharmaceutical industry is too low. The reserve of innovative talents is insufficient.

The R&D output of innovative drugs is poor: first, the number of new molecular entities and new biological products is very small; second, the sales growth of innovative drugs in China is slow, and the profitability is poor. Good market returns can help pharmaceutical enterprises to recover the high cost of innovative drug R&D, which is the source and guarantee of sustainable innovation ability.

General Secretary Xi Jinping pointed out that we should reform and improve the system of examination and approval, speed up the evaluation of the consistency of quality and efficacy of generic drugs, encourage enterprises to improve their innovation and R&D capabilities, and

achieve the advanced level of medical equipment at an early date (Xinhua News Agency, 2017). Premier Li Keqiang also stressed the need to strengthen the R&D and innovation of original drugs, first imitated drugs, traditional Chinese medicine, new preparations and high-end medical devices, and accelerate the industrialization of major drugs for frequently occurring and rare diseases such as cancer, diabetes, cardiovascular and cerebrovascular diseases (Beijing Youth Daily, 2016). To this end, China has issued the *Opinions on the Review and Approval System Reform for Pharmaceuticals and Medical Devices*, and the *Opinions on Deepening the Reform of the Review and Approval System* to Encourage Innovation in Pharmaceuticals and Medical Devices, in an effort to promote the overall reform and upgrading of drug safety system, guarantee the safety and efficacy of drugs and enhance international competitiveness.

We have released the vitality of R&D innovation through the implementation of MAH system. MAH system refers to a system in which drug research institutions, drug manufacturers and other entities with drug technology apply for and obtain drug registration certificates, bring the drugs to the market in their own name, and take responsibility for the whole life cycle of drugs (Shanghai Securities News, 2019). Compared with the traditional drug registration management system, MAH system has three advantages: first, to encourage R&D innovation, drug research institutions can obtain profits through product marketization, which can effectively stimulate innovation vitality; second, to optimize the allocation of resources, research institutions and production enterprises can forge strong alliance. With complementary advantages, drugs can be put into production and go to market by using qualified production lines, which effectively intensifies resources and speeds up the marketization; third, to optimize the allocation of resources and strengthen the management of the whole life cycle of drugs, with the holder taking the main responsibility for the whole life cycle of drugs, and the entrusted production, sales or pharmacovigilance units taking the relevant legal responsibilities and the responsibilities agreed with the holder, it is more clear and reasonable than the segmented responsibility of each link.

We can improve clinical research capability through the reform of drug clinical trial management. An important goal of the reform of drug review and approval system is to take clinical value as the guidance. Whether it is to create "globally new" or improved new drugs, or to develop generic drugs with the same quality and efficacy as the original drugs, it requires high-quality, high-level and international clinical practice.

The ability of clinical research should be supported, which puts forward higher requirements for drug clinical research. In the whole life cycle of drug research and development, drug clinical trials are the critical stage for confirming the efficacy and safety of

drugs (Shi, Liu, & Zhu, 2019), it is the key link from laboratory to hospital. In the process of promoting the reform of drug review and approval system, China has raised the reform of clinical trial management to an unprecedented height. We should expand the supply side of clinical resources by changing the management mode of clinical trial institutions from qualification to registration; shorten the waiting time of applicants by promoting the application of drug clinical trial from explicit permission to default permission; improve the utilization rate of clinical data by accepting overseas clinical trial data to support domestic marketization and registration; establish and improve the mutual recognition mechanism of ethics committees to further improve the efficiency of the review. The effective implementation of the above-mentioned series of reform measures has effectively promoted the research and development of new drugs and accelerated the speed of marketing.

In recent years, cardiovascular interventional instruments have become the most concentrated area of research and development in the world. Cardiovascular interventions have become one of the three major modern medical treatments alongside traditional drug therapy and surgical treatment (Sou, 2020). Cardiovascular innovations in China are increasingly ingenious. Although the principles of these technologies are not revolutionary, the structural design and working principles of the devices are original and are not simply imitations of foreign devices. Fudan Zhongshan Hospital, for example, carried out the development and success of the world's first mitral valve clamping device, and Shanghai Changhai Hospital carried out the development of the LuX valve, a tricuspid valve interventional device. Professor Liu Li-Wen of Xijing Hospital created the original Li-Wen procedure. Prof. Zhiwei Zhang was involved in the development of the absorbable atrial septal closure device. Prof. Yat-Hsien Lam at the Prince of Wales Hospital in Hong Kong was involved in the research and development of the left ear closure and proposed the "minimalist" ear plug (Minimal Accessory Closure, MAC) for left ear closure, which is the most original device or technique in the world.

To promote the transformation of physician innovations (innovative medical devices), Academician Ge Junbo initiated the China Cardiovascular Physicians Innovation Club (CCPI) in 2015, which was later upgraded to the China Medical Innovation Alliance (CMIA) in 2018. The organization provides innovation training, design exchange, research support, and industrial cooperation in the hope of facilitating clinicians, meeting the needs of clinical discipline innovation, guiding them to actively participate in medical technology and related equipment research, and further providing preclinical and clinical research platforms. This will help improve the domestic market for medical technology and equipment products, break through the bottleneck in China's cardiovascular field, rely on innovation, and go global. China

has developed a mature "five-in-one" model of operation, including innovation academies and innovation competitions.

3.4.5 Medical service innovation

Medical service is a concept widely used from daily life to policies, regulations and national development strategy. A clear concept of medical service is to standardize the service content of medical institutions, define the scope of application of medical services and all kinds of life and health insurance, deal with the relationship between doctors and patients, and develop social health undertakings. While strengthening hospital medical services, modern medical services pay attention to social medical services outside the hospital, including follow-up after discharge, family beds, public health education, disease census, social medical assistance and counterpart support, medical services to the countryside, etc. (Zeng & Liu, 2016).

China's medical service market has a huge scale, and is expanding rapidly driven by the aging population, urbanization, wealth growth and basic medical security system. In 2016, China's total health consumption was 4.6 trillion yuan, maintaining a compound growth rate of about 15% in the past ten years. However, compared with the level of 7.7% in high-income countries, China's medical and health expenditure only accounts for 5.6% of GDP. Considering the huge base of population and consumption, it is not difficult to see that there is still a lot of room for growth in China's medical service market in the future. At the same time, the medical reform policy is developing in depth. The government continues to increase investment to ensure that all people have access to basic medical and health services. It also encourages social capital investment to improve service quality and meet the multi-level and diversified needs of the people. The deepening of the new medical reform not only has brought opportunities for social capital to enter the medical service industry, but also has a profound impact on the market structure. Compared with public hospitals, private hospitals are still in a weak position. But with the strong support of policy, they are stepping into a stage of rapid development. Institutional investors and industrial capital have poured in. With the help of capital, private hospitals will realize resource integration faster, accelerate market expansion, and upgrade management, medical technology, service quality and large-scale operation. However, the rapid expansion of the market is often accompanied by higher risks. Therefore, prudent decision-making is essential. We believe that the strategic positioning of private hospitals should comprehensively consider the local economic development level, supply and demand situation, health care reform and tax policies, and combine with their own strength to determine the

appropriate medical service sector and entry mode. In terms of growth point, four medical service sectors are optimistic. One is high-end medical care. The high-end medical service will sink in the service area. At the same time, the popular specialties in the past will also shift from the general public to the rich people. In addition, the combination of medical and tourism services is also expected to grow. The second is specialized chain. It is expected that there will be investment hotspots in the service and replicable specialized areas. At the same time, with the advancement of medical system reform, especially with the enhancement of the mobility of medical talents, private hospitals are expected to enter the specialized fields with higher technical barriers. Third, in terms of general hospitals, capital, talent and management all mean higher barriers to entry, but on the other hand, it also means that the status of hospitals with public recognition will not be shaken. Thus, the advantage of first mover is obvious. Therefore, all kinds of capital for the layout of the general hospital will be put on the agenda. In addition, the emphasis on the quality of life and the enhancement of health care awareness will also promote the rapid development of health services. The enthusiasm of the capital market and traditional medical institutions for telemedicine, mobile medicine and wearable devices is the best evidence.

Public hospitals still occupy a dominant position in China's medical service system, not only providing about 90% of the service volume, but also gathering high-quality medical resources and medical talents. However, on the one hand, the reform of the national medical and health system will force public hospitals to reshape the revenue mechanism, improve efficiency and cut costs. It will also push them to the market, which may result in the outflow of patients and talents. In the face of the new market structure, it is suggested that public hospitals should start to change and innovate from the following five aspects: changing the performance management system, improving the patient experience, introducing marketing management to develop a solid relationship of mutual trust with patients, establishing standardized medical services and clinical processes, and improving the hospital information system.

3.5 CRO innovation in China

3.5.1 CRO in China

China’s domestic medical devices before the market investment in CRO expenses accounted for about 3% of its market sales. Based on the calculation of China's medical device market size

of US $ 96 billion in 2019, the medical device CRO market size is about US $ 2.8 billion, and the annual compound growth rate will exceed 20% in the future, which is entering the prime of development. Medical device companies are turning to clinical trials to differentiate their Class III/II products from competitors to improve the adoption and value proposition in the market. This has resulted in global medical device companies outsourcing their clinical trial services to CROs with a current adoption rate of 20% to 25%. Despite the deep market penetration and continued growth, in-depth insights into the activities of medical device CROs and their dynamic influence on the medical device sector are quite limited to date.

It has been more than 20 years since MDS Pharma service investment set up China's first CRO to pursue its clinical research business in pharmaceuticals in 1996. With the rapid growth of the medical industry in China, the R&D market demand has been increasing. In recent years our clinical trial CRO also entered a high-speed development stage. The market of clinical trials in our country has been tremendous in nearly five to ten years, and multiple Mergers and Acquisitions (M&A) CRO factors are conducive to the development of CRO in China. Nevertheless, with changing domestic and foreign environments, CRO companies face greater opportunities and challenges:

First, clinical research quality management standards have gradually converged toward Europe and the United States with the development of industry, the regulatory level of pharmaceutical policies and higher clinical research requirements for innovative medicines. Only CRO companies capable of independent innovation can build their own competitive advantage and lead the industry. In the context of big data and Internet Plus, the CRO industry itself will also explore new development and service models, such as the emerging eCRO model, in the aspects of big data integration and informatics (Bo, 2016).

Second, the CRO industry tends to be global. With China joining the International Conference Harmonization (ICH), foreign-owned pharmaceutical companies have increased their business with foreign CROs in the country. State-owned pharmaceutical companies have increased their cooperation with foreign CROs. Domestic CROs can learn advanced operation and management experience by enhancing cooperation with foreign CROs (Table 3.2). Foreign CROs can also provide more talents for the development of domestic CROs, while they must build strong competitive edges against domestic CROs.

Table 3.2 Major Chinese CRO companies

Companies	Company Summary
Wuxi AppTec	Established in 2000; businesses cover small molecule drug R&D and related production services
Joinn Medicine	Established in 1995; focus on preclinical researches to understand drug's efficacy and toxicity, along with selling study animals and reagents
ChemPartner	Established in 2002; primarily provide preclinical research. In June 2017, it is acquired by Guantum Hi-tech
Sundia	Established in 2004; provide new drug R&D and production services
PharmaRon	Established in 2003, provide early stage chemistry studies and preclinical researches
Mediciloan	Established in 2004; provide comprehensive medicine R&D services
Hangzhou	Established in 2004; focus on clinical studies, data management, andTigermedbiostatistics, registration, etc.
Guangzhou Boji Medical	Established in 2002; focus on clinical trial outsourcing service
Shanghai Xin Gao Feng	Established in 2007; provide comprehensive services to new drug R&D; acquired by Zhejiang Yatai Pharmaceutical Company in 2015
Huawei Medical Company	Provide new drug R&D, registration, etc. In 2016, it is acquired by Baihuacun with $2.77 billion.

Source: The Fierce Consultant (2020)

Third, throughout the global pharmaceutical CRO corporate trajectory, companies experience a common process of growing from small to large in size, shifting from decentralized to centralized in operations, and requiring more skilled practitioners. The integration of the CRO industry has become an inevitable trend, making it strong and comprehensive through Mergers and Acquisitions (M&A).

Compared with other giant enterprises in the same industry in the world, the specifications of Chinese CRO enterprises today are relatively small (Figure 3.9). In China, WuXi AppTec is far more than other CRO companies in terms of specifications, and is the CRO giant, It's business popularity and business level are the first in the country with a CRO market share of 9.7% in 2016, while the aggregate market shared of the top ten CRO companies in China only

reached 23.3%.

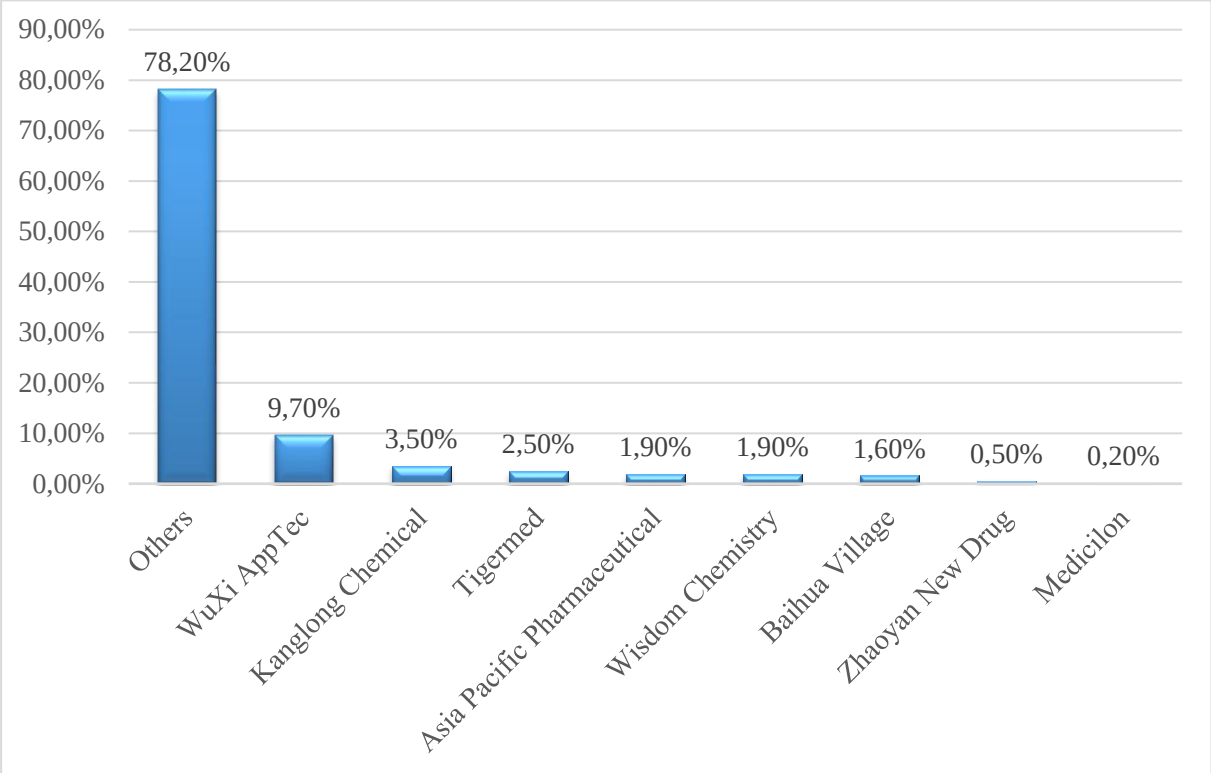

Figure 3.9 Market Share of China's CRO Industry, 2016

Source: China Report Hall (2017)

Competitiveness is an important means by which CRO giants develop. CRO giants such as ICON, Paraxel, PRA, Quintiles, PD and others have been actively expanding the original business scope and the business coverage through M&A in recent years, and then improving the comprehensive competitiveness of the company. In the development wave, the CRO company should play its own professional characteristics, create its own brand, achieve the growth and expansion of the company itself and strive to rise to the ranks of international CRO enterprises (Lei et al., 2018).

According to relevant data, by the end of May 2020, there were more than 140 medical device CRO institutions in China. Other drivers include cost-containment pressures, increasing product pipeline, increasing regulatory demands, IP related issues and etc. Similar to big pharmacy, device companies are moving towards outsourcing as a way to efficiently utilize operational resources, penetrate new markets and satisfy compliance needs. Traditionally, the supply base for medical device trials has been those players who offer device trials as a standalone service.

Currently, many medium and global CROs are entering this market, either through acquisition or collaboration, as a result of increased outsourcing of support services by device companies. Biometrics services involving data management, statistical analysis and data

analysis have the highest outsourcing rate among device companies at 65% to 70% followed by clinical trial monitoring and site management.

To compete with global giant CROs such as Quintiles, Covance, PPD (Pharmaceutical Product Development), Icon and Parexel, Chinese CROs must create their unique business model. CROs in China have innovated their business model in three aspects: value proposition, value chain, and value network. By doing so, they have been successfully developed to facilitate the integration of R&D capabilities in countries to meet global challenges.

Most of China's pharmaceutical CRO companies are concentrated in the North, Shanghai, Guangzhou and the Yangtze River Delta region, where the pharmaceutical industrial parks are more systematic and have a high degree of aggregation (Figure 3.10). According to the “China CRO Industry Map”, the current country is estimated to have 500 pharmaceutical companies, with Beijing occupying the largest number, estimated at 167, followed by Shanghai with about 100, Jiangsu with 90, and Guangdong with 51, and other provinces with less than 20.

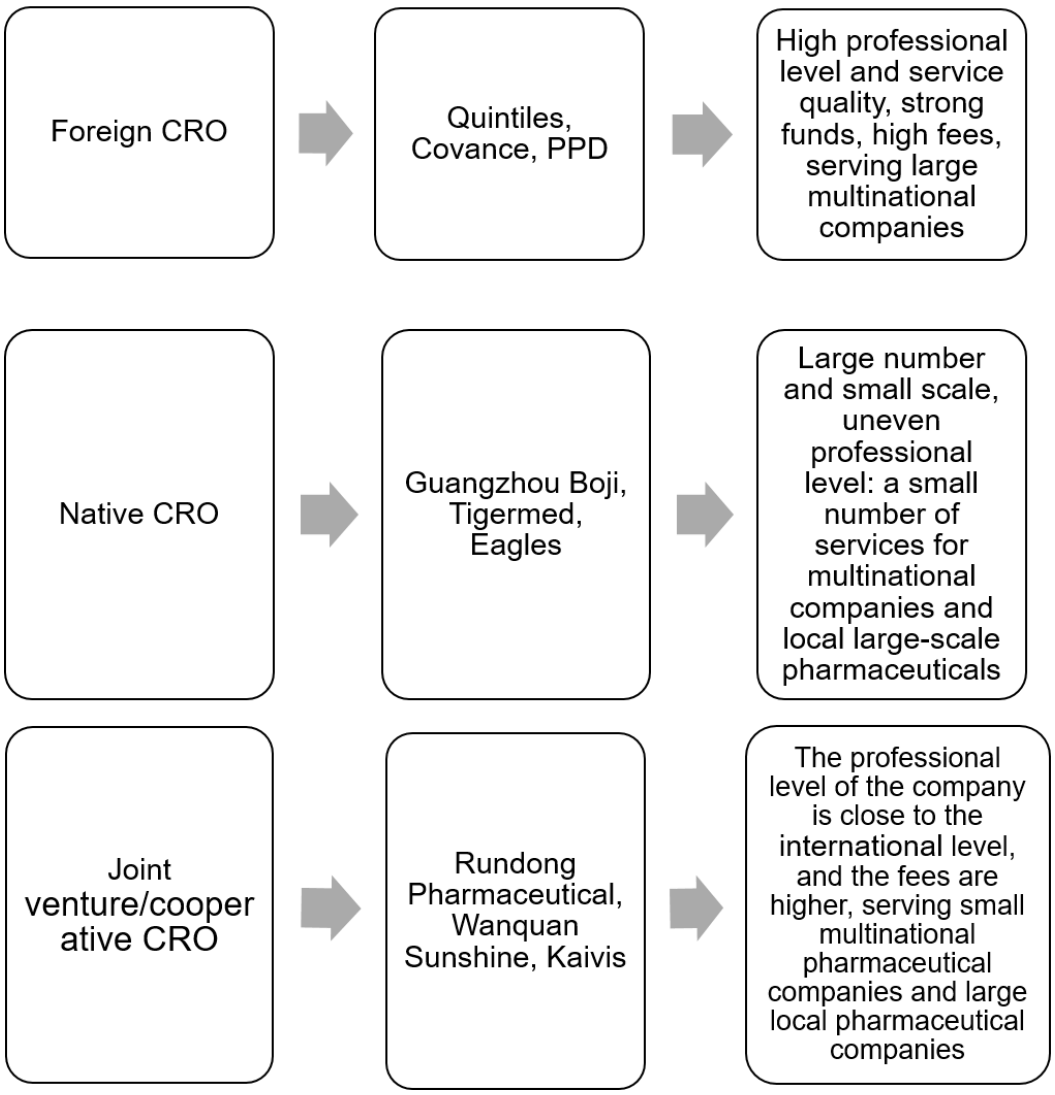

Figure 3.10 Classification of existing contract research organizations in China

The Chinese CRO has changed its value proposition from merely cost saving to customer value-added. When Chinese CROs began their operations in the early 2000s, most of them (Table 3.3) struggled to survive by attracting customers to the advantage of low human and material costs without overemphasizing service quality. However, the relentless "red ocean" competition of high-end customers for price and demanding requirements eventually forces the less capable R&D and management CROs out of the market. The surviving CROs in China then seek out new value propositions through three main dimensions:

- They invest in technological improvements and apply state-of-the-art biotechnology to R&D services;
- They invest in R&D capacity building, install state-of-the-art laboratory instrumentation and advanced laboratory facilities to ensure economies of scale and high efficiency;
- They adopt global R&D standards and guidelines in practice to meet international

requirements, including good laboratory practice (GLP), good manufacturing practice (GMP), and good supply practice (GSP).

Table 3.3 Top 10 CRO companies clustered in China

Region	Number of companies	Corporate Representatives
Beijing	167	Beijian Renji, Zhaoyan New Drug, Kanglong Chemical
Shanghai	100	Quintiles, WuXi AppTec, Jing Ding
Jiangsu	90	Warwick Pharmaceuticals, Kingsway, Yixin Group
Guangdong	51	Boji Pharmaceutical, Zhongshan Pharma, Guangzhou Yushi
Tianjin	19	Kailaiying, Fangen Pharmaceutical, Tianjin Weifan
Shandong	15	Shandong Xinbo, Maibury
Zhejiang	14	Tiger, Sairun
Sichuang	14	Chengdu Hyzaar, Xiansai
Hubei	11	Lihe Chemical, Punosel
Shanxi	10	Xi'an Mingchen, Semico

Source: Yan and Chen (2019)

All these efforts have enabled Chinese CROs to adopt a new system of value proposition, which is considered an increasingly important quality to be pursued by customers.

There are many examples to demonstrate the important shift in the Chinese CRO from a "cost saving" mindset to a value-added claim. Pharmaron, a preclinical CRO founded in 2003 by returnee corporation, who are researchers experienced in pharmaceutical MNC. Initially, this CRO was named according to a mission statement "to provide the highest quality R&D services while helping our customers to advance the project in a timely, cost-effective manner". In addition to its strong medicinal chemistry capabilities, Pharmaron has rapidly increased its investments in state-of-the-art biotechnology to expand its business, from a single chemical services business in drug R&D to a range of preclinical services in multiple disciplines such as chemistry, biology, DMPK, pharmacology, toxicology, and chemical development. Pharmaron is currently able to conduct leading preclinical studies that meet global standards. In addition, Pharmaron has developed an advanced information system to provide customers with accurate and timely project traceability. Its central capability in R&D capacity and information management has gone up to the seventh of the top ten pharmaceutical MNCs as its long-term customers.

Considering China's policy resolve to fully support TCM's sustainable development, some CROs such as Bionovo chose to mainly focus on TCM related contractual services. Based on

its accumulation ability in TCM clinical trial research, this CRO is aimed at its market share in TCM phase I-IV clinical trial research. To this end, Bionovo has created a series of clinical research practices and guidelines to guide the practice and ensure the quality of clinical research on TCM. In addition, it provides additional value to its customers by promoting the pharmaceutical economics of traditional Chinese medicine, which is also strongly encouraged by the NMPA and the national administration of traditional Chinese medicine (SATCM) in recent years. Currently, it is capable of providing over 300 clinical research services covering 20 therapeutic areas and is now expanding its reach to consulting services. An increasing number of local and global customers value and select contract services provided by CROs in China, and no longer rely solely on local academic organizations. Both global and local customers are keen to offer more technology-intensive and knowledge-based contracts to Chinese CROs, thereby contributing to the development of R&D capabilities and profitability of Chinese CROs.

3.5.2 Medical device CRO

(1) The medical device CRO industry overview

Medical device CRO is a third-party organization that accepts the commission from medical device R&D manufacturing enterprises or organizations, and is responsible for implementing all or part of the R&D and medical trials in the process of medical device marketing on behalf of the commissioning party in order to obtain commercial remuneration.

CRO organizations are usually composed of professional talents familiar with the R&D process and registration laws and regulations of medical devices, with a standardized service process and a cooperation network in a certain region, which can help medical device manufacturers reduce R&D investment, shorten R&D cycle, improve R&D efficiency, reduce the risk of R&D failure and speed up the approval process for marketization.

From R&D to marketing of medical devices, it is a complex systematic project with high technology, high risk, high investment and long cycle.

For example, from R&D to marketing, medical devices that are not exempted from clinical trials have to go through production line preparation, system establishment, process development and verification, raw material selection, sample production, performance verification, registration inspection, clinical trials, training, system assessment, registration declaration, product registration and production license application, etc. CROs play an important role in the whole life cycle of medical device development (Figure 3.11).

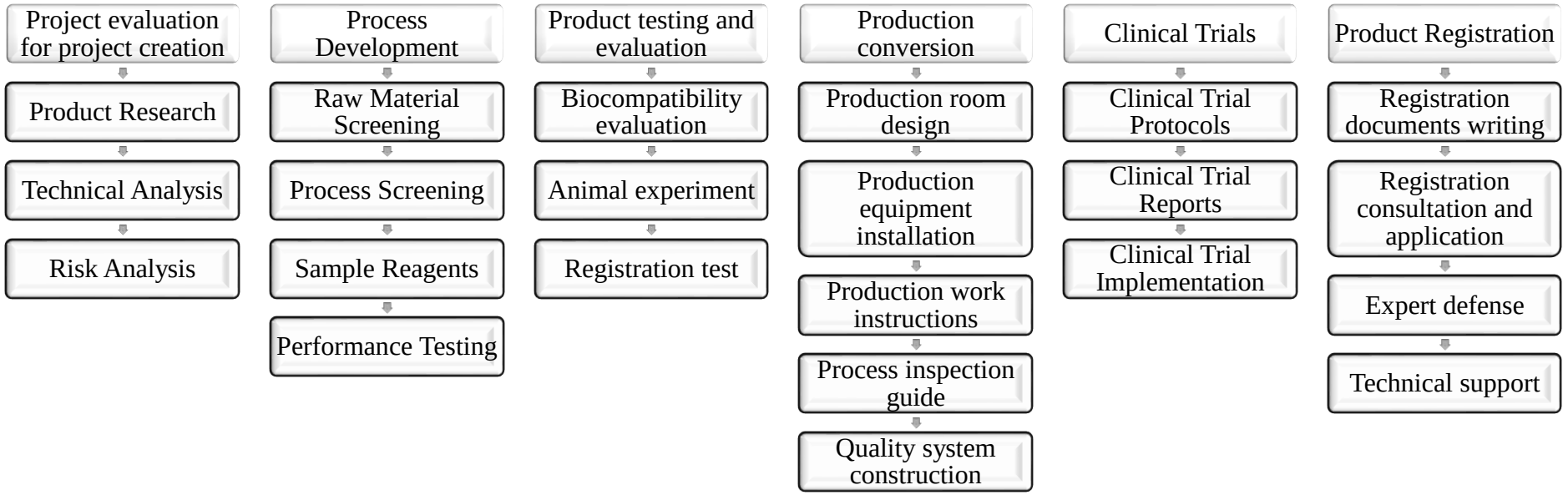

Figure 3.11 Medical device CRO development process and module content

Source: Zhang (2015)

Macro regulatory environment is becoming more and more perfect: China's relevant medical reform policies will promote the development of primary medical institutions and the replacement of existing medical and health institutions equipment, placing China on the way to become a huge consumer market for medical devices.

At the same time, the country has also launched a series of favorable policies for the medical device industry in recent years to promote the innovation-driven development of enterprises and the domestic substitution of high-end products.

In addition, the implementation of quantity-based procurement, two-ticket system and priority approval of innovation will significantly enhance the concentration of the medical device industry, which is conducive to promoting the high-quality development of the industry. With the in-depth implementation of policy reform, the macro policy environment of domestic medical device industry is being constantly improved.

The registration system unties R&D and production: the implementation of the listing license holder system (medical device registration system) is a medical device management system commonly adopted by the international community. The implementation of the system realizes the unbundling of production and R&D, which is conducive to promoting the cooperation between medical device enterprises, R&D units and CRO organizations. The medical device CRO industry will usher in significant development opportunities.

In 2017, the State Council issued the Opinions on Deepening the Reform of the Review and Approval System to Encourage Innovation in Pharmaceuticals and Medical Devices, marking the official commencement of the medical device listing license system in China.

In August 2019, the NMPA issued the Notice on Expanding the Pilot Work of the Medical Device Registrant System to expand the pilot scope to 21 provinces and cities. As of the end of December 2019, all 21 provinces and municipalities had released their medical device registrations system implementation plans for the pilot.

Encourage recognition of the value of professional services: the new Quality Management Standards for Medical Device Clinical Trials and the practice of medical device clinical trial site verification are centered on "truthfulness and standardization", taking into account the characteristics of medical device clinical trials, while keeping the general technology of clinical trials in line with the requirements of new drug clinical trials.

This has overturned the understanding of traditional medical device clinical trials. It is difficult for manufacturers to retain such a large and professional team within the enterprise to engage in medical device clinical trials, which will greatly increase the manpower burden on manufacturers, resulting in a rapid rise in the demand for device CROs in the approval and

registration of medical devices.

(2) Domestic medical device CRO market size

As a hot spot for medical device outsourcing in the world, the domestic medical device CRO industry is developing rapidly. However, at present, the business of domestic medical device CROs mainly focuses on clinical trial services, registration technical services and quality management system technical services. Most of them are clinical trial CROs.

Moreover, compared with the pharmaceutical clinical trial CRO, the unit price of medical device clinical trial CRO is lower. Zhongcheng Medical Research Institute expects that the domestic medical device CRO market size will be around 10 billion in 2020.

(3) Focuses on high-value device, AI, surgical robots are the future direction

The acceptance of medical device R&D outsourcing service is different in different segments of medical devices. Enterprises that develop and produce high value medical devices and consumables have higher acceptance of medical device R&D outsourcing service, while enterprises that develop and produce low value medical devices and consumables have lower acceptance. Enterprises that develop and produce high-value medical devices and consumables have high investment costs, high requirements for technology and scientific research talents, and high risks of independent R&D and clinical trials. Medical device R&D outsourcing service enterprises just have strong professional advantages in these aspects. Therefore, the enterprises that develop and produce high-value medical devices and consumables have higher acceptance of outsourcing services and stronger willingness to pay.

In the fields of cardiovascular intervention, orthopedic intervention, neural intervention, IVD and large-scale imaging diagnosis, there are many kinds of high-value medical devices and consumables, such as drug balloon, vascular stent, cardiac intervention valve, PCR analyzer, MRI equipment, etc. Relevant enterprises will actively research and develop outsourcing services, and the demand is strong. Most medical device R&D outsourcing service enterprises are involved in these fields. The number of R&D outsourcing enterprises in emerging fields such as artificial intelligence, surgical robot and 3D printing is also increasing. This is mainly because the clinical application of products in these fields is growing rapidly, and the technical threshold is high. In order to speed up the pace of product marketization, relevant R&D enterprises tend to take the form of R&D outsourcing. In ophthalmology, dentistry, plastic surgery and other fields, the requirements for technology and talents are low, the risks of R&D, production and clinical trials are low, and the demand for R&D outsourcing of related enterprises is weak. Therefore, there are less enterprises involved in R&D outsourcing services.

(4) Domestic medical device CRO competition landscape

Regional distribution patterns: In 2020, there are a large number of CRO companies in China (Figure 3.12), but the business is more fragmented and smaller in scale. As the CRO industry develops, it continues to move toward a vertically integrated platform to provide one-stop whole-process services for users. According to the statistics of Zhongcheng Medical Machinery Research Big Data Platform, as of the end of May 2020, there were more than 140 domestic medical device CROs. In terms of the distribution by province, the number of medical device CROs in Beijing reached 50, ranking first in China (Figure 3.13).

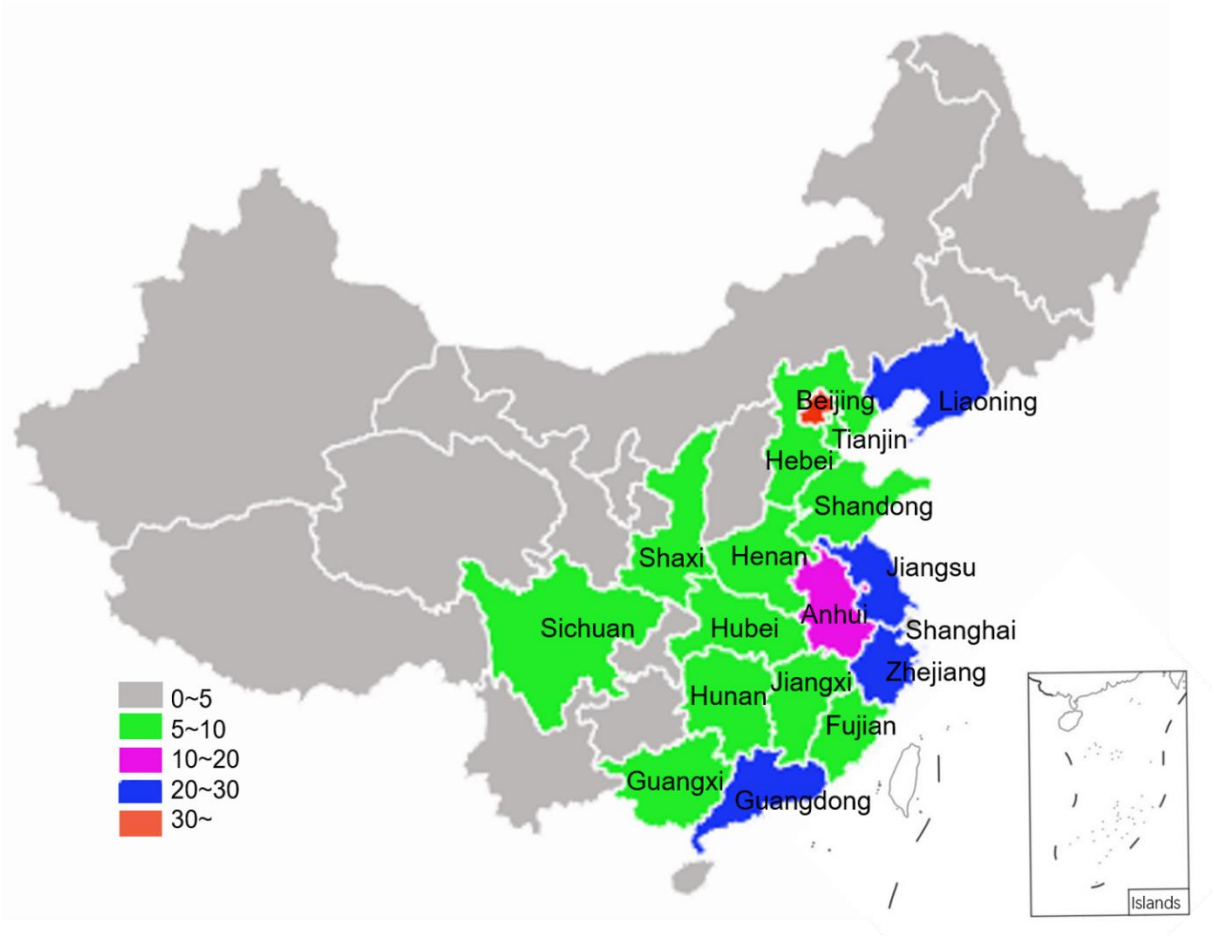

Figure 3.12 Distribution of the number of domestic medical device CROs in 2020

Source: Yun (2021)

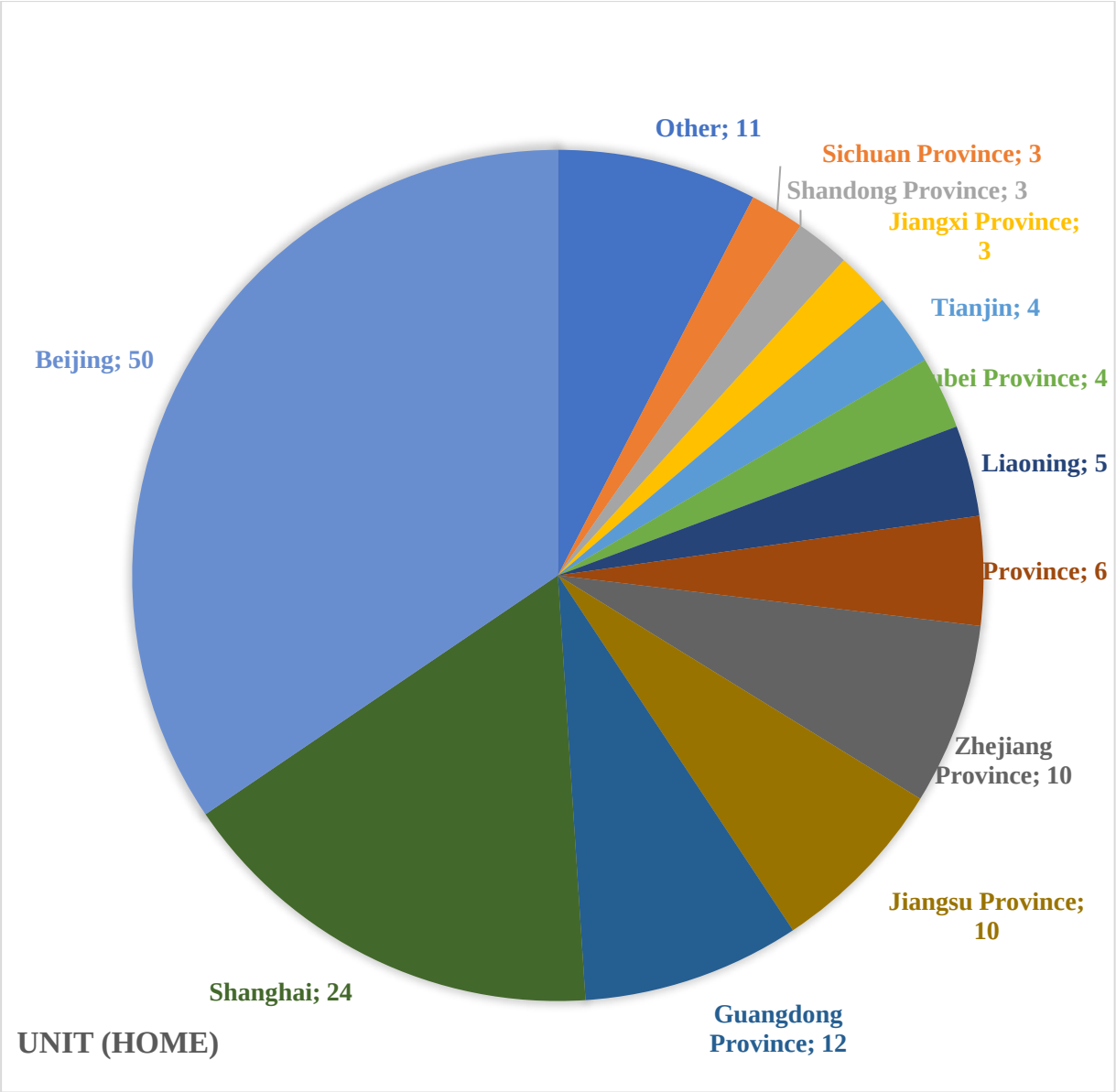

Figure 3.13 Number of medical device CRO institutions by province in 2020

Source: Yun (2021)

Shanghai ranked second with a number of 24 and accounted for more than 50% of the total together with Beijing; that of Guangdong, Jiangsu and Zhejiang was 12, 10 and 10 respectively. The above five regions as a whole accounted for more than 70% of the total, mainly due to the mature development of biomedical industry, abundant R&D resources, and sufficient educational resources and high-end talents and other factors such as innovation power in these regions.

Market competition landscape: At present, there are many small enterprises in the domestic medical device CRO industry, with generally low revenue and profitability and relatively fragmented market share. Customer acquisition channel is the focus of medical device R&D outsourcing service enterprises. According to the survey of enterprises, it is found that the

differentiation of customer acquisition channels is strong. Some enterprises have a single channel to get customers, with only one channel to introduce old customers; others have rich channels to get customers, including introduction of old customers, training activities, network promotion, introduction of associations and parks, introduction of investment institutions, medical conferences and exhibitions, etc. Among them, the introduction of old customers and network promotion are the main channels for medical device R&D outsourcing service enterprises to obtain customers. According to the feedback of the research enterprises, the proportion of customers obtained through the two channels is 30% and 25% respectively. The introduction of old customers has even become the only channel for some enterprises to obtain customers, which reflects that the services provided by medical device R&D outsourcing service enterprises are recognized by more and more medical device enterprises. However, as a channel to get customers, the proportion of old customer introduction is relatively high, which has a negative impact on the future customers of enterprises, while the proportion of training activities, park and association introduction is relatively low, which is the direction that enterprises should expand in the future.

Domestic medical device CROs are mainly represented by Tigermed, Links CRO (Shanghai), AoZenda, Medisys, Yongming Medical, Jiutai Pharmacy, ZhiZhong Technology, Huitong Medical and Juyi Technology.

3.5.3 Innovations in the CRO industry in China

China's CRO industry achieves innovation through consulting full-service chains. The CRO in China is able to conduct contractual services covering the entire value chain of drug development, from early drug discovery to post marketing re-evaluation. The service provided by CRO in China covers almost the entire outsourced market. At the same time, these CROs each had their own unique specialty and were determined to reinvent their internal key business processes to stand out as prominent local and outstanding overseas CROs.

There are many preclinical CROs in China that face small-scale competition for fierce competition. To survive, they need to have the appropriate R&D capabilities to provide highly specialized services in the service chain that cannot be matched by other CROs. For example, Tigermed (Tigermed, 2021), who specializes in clinical trials, data management, biostatistics, regulatory affairs, and medical translation. For reasons of cost reduction, some global CROs also relocated clinical research operations and established multicenter clinical trial laboratories in China. In this context, Tigermed established an internal regulatory affairs department to provide customized regulatory services for drugs, biological products, and medical devices.

Tigermed is committed to accelerating medical product development with cost effectiveness and quality. While clinical trial planning, management and implementation generated the largest profits for Tigermed, accounting for 58.6% of total sales in 2012, high profits were obtained through data management (66.61%) and Regulatory Affairs (61.39%). Tigermed was ready to expand and occupy the global market share. It has recently participated in an international multicenter clinical research program on antidiabetic drugs conducted by Eli Lilly. With the booming growth of the entire Chinese CRO market, some large CROs have taken a further step to gain an expanded value chain. Wuxi AppTec, one of the largest CROs in China and operating exclusively in preclinical experimental operations in the past, has begun to provide a "one-stop service" covering a full spectrum of coverage from drug discovery to the clinical and regulation (Wuxi AppTec, 2020). To this end, Wuxi AppTec acquired AppTec (a famous medical device company in the U.S.) in 2008 and established an integrated service. Instead, VenturePharm, which began as a clinical CRO, has been successfully developed to deliver preclinical research services to large pharmaceutical companies.

The Chinese CRO industry has also been innovative through bridge networks, and enjoys the great advantage of a unique comprehensive network of local universities/academic institutions, hospitals, and domestic pharmaceutical companies. In any mature pharmaceutical industry in the world, pharmaceutical companies (particularly multinational companies) tend to be the major platforms for drug R&D. However, in China, universities and research institutions are the main R&D forces, and local pharmaceutical companies are still far from having enough innovation capacity. They receive a large financial investment from the government and are never devoid of expert resources. The complex connection of CROs with these universities or research institutions is a great advantage for foreign and local pharmaceutical companies. Most CROs are actually spin-offs from universities and academic institutions, or have been established from a Chinese Returnee who is studying at the corresponding University and remains in good relationships with academic staff. Therefore, they have easy access to well-equipped university laboratories and other advanced facilities. This is also the reason why the CRO in China is able to participate in many academic projects initiated by universities or researchers. Similarly, Chinese CROs are also able to invite prestigious and influential local researchers for professional assistance to enhance their internal R&D capabilities. For example, Rundo employs the executive chair of the Chinese Over-the-Counter Pharmaceutical Association and Academia Sinica as academic advisors (Rundo, 2021).

In 2020, there are 1059 clinical trial centers which were GCP certified and the source of patients was rich enough to conduct multiple clinical R&D studies. However, foreign

pharmaceutical companies always have difficulty accessing these hospitals and conducting clinical studies simultaneously at different sites (Zhou et al., 2013). On the contrary, the Chinese CRO has always maintained a good relationship with the local hospital. Tigermed, for example, developed a collaborative network covering most high-end hospitals while conducting clinical research in China. Through a similar network with hospitals, many other Chinese CROs are also able to participate in innovative medical and pharmaceutical research projects. Giant, a clinical CRO in Beijing, was invited to participate in a large, large-scale data project to record and analyze medical records from the leading hospitals in China, initiated by the Chinese Academy of Medical Sciences. Some local pharmaceutical companies have also tried to develop their own R&D capabilities, supported by the government's industrial policies and funding. In doing so, they may need to turn to CROs for professional help or even invite CROs to join their innovative R&D programs run or supported by the government. For example, CRO Medicilon, founded by returnee entrepreneurs of China, has participated in several innovative drug projects run by local pharmaceutical companies and funded by the Chinese government.

In addition, the integrator status of the Chinese CRO industry is innovative. The Chinese CRO has been trying to develop its own business model to surpass itself at the international level. They have successfully established their unique position as promoters of integrating local R&D capabilities in China through collective and individual efforts in three major areas:

- the development of internal R&D capabilities;
- the specialization of technical roles and the expansion of the entire value chain;
- the establishment of competence networks involving local research units (universities, academic institutions, and hospitals) and pharmaceutical companies.

With ever-growing R&D capabilities and a unique network with major players in the pharmaceutical industry in China, CROs are able to provide a feasible and effective means for global participants to enter the Chinese market while integrating Chinese pharmaceutical R&D capability into the global pharmaceutical industry.

To optimize the productivity and efficiency of research projects, global pharmaceutical companies may need to carefully design their strategies when acquiring local R&D capabilities (Zimmer, 2014). Considering the increased pharmaceutical R&D capabilities in China, global companies tend to seek the help of Chinese CROs, which often bring more benefits and less risks than joint ventures or collaborations. CRO involvement in business can produce more gains in technology acquisition, experimental efficiency, and cost savings as CROs are generally less constrained by complex operating procedures and financial technology exchange negotiations. Joint ventures can provide a high level of technology.

In addition, joint venture cooperative agreements may also be stymied by concerns about possible disclosure of intellectual property rights, government regulation, and coordination costs. CROs can provide legal and commercial mechanisms to protect foreign pharmaceutical companies from these agency threats (Zhang & Deng, 2008). As part of the development of the CRO industry, this additional function of the CRO is strongly encouraged and supported by the Chinese government, unlike joint venture cooperative agreements, which in many cases may have to undergo rigorous government review for approval. As commercial contracts between CROs and foreign organizations are often clear and specific, the risks of intellectual property leakage and possible conflicts of coordination are relatively low.

3.6 Conclusion

This chapter is a continuation of the innovation topic of Chapter 2. Innovation in China is further discussed with a closer look at the development of innovation and in the context of Chinese dynamic economy. The organization of and innovation in China's healthcare system are introduced subsequently, which serves as the ground of Chinese CRO and innovation.

This chapter, together with Chapter 2, frames the theoretical basis and specific industrial background of the research on medical device CRO as KIBS in the Chinese context.

[This page is deliberately left blank.]

Chapter 4: Methods and Materials

4.1 Introduction

This thesis attempts to understand the role of device CROs in China's innovative medical device R&D outsourcing sector. In order to obtain the expected research results and meet the practical needs of the research, the research process mainly adopts qualitative research methods, including data collection methods such as semi-structured interviews and case study analysis, leveraging appropriate data-processing techniques and reviewed in the light of a suitable theoretical framework. The conclusion is derived from this integrated approach.

After an overview of the methodology in Section 4.2, the specific method of data collection is described in Section 4.3, with collected samples and data shown in Section 4.4, followed by conclusions in Sections 4.5

4.2 Methodology overview

4.2.1 The nature of qualitative research

Qualitative research is a comprehensive set of empirical methodologies widely used in contemporary social sciences. It includes a wide range of methods such as interviews, direct-observation fieldwork, narrative inquiry, case studies, etc. As it yields deep insights into the working of reality in organized societies and in actual business organizations, it has become an indispensable part of the research toolkit of modern management research (Makarenko et al., 2017). The purpose of qualitative research is to understand the phenomena by taking into account the perspective of the participants and to interpret the reasons behind their behaviors, opinions, attitudes and experiences.

As it integrates a variety of specific methods and techniques, qualitative research can make research more compelling, rigorous and robust by providing evidence extracted from a variety of different sources and treated through a multi-method design. Admittedly, qualitative research has certain limitations (Elfenbein & Schwarze, 2020). For example, it is difficult for qualitative research to generate research results with universal significance. This issue of generalizability of conclusions remains a severe shortcoming, thus opening room for using quantitative

approaches in research as a supplement in many such works (Costa & Mendonça, 2019).

Quantitative research has relatively fixed forms and processes while qualitative research has more flexible and heterogeneous ones. Qualitative traditions adopt different research methods and processes for different issues and objects with an emphasis on pertinence, flexibility and suitability (Rapport, 2010). This is a comparative strength of qualitative approaches and is why qualitative research can effectively adapt to, study and explain diverse and complex research issues. Considering the complexity and novelty of the topic of this study, it is reasonable and pertinent to apply qualitative research methods.

When conducting a qualitative research, the researcher must adhere to some fundamental procedures no matter which methods are adopted for specific data collection and analysis. Qualitative research can be carried out through some of the most common qualitative methods such as observation, interviews, focus groups, survey and secondary research (Creswell, 2008). In general, observation is a way of recording what researchers have seen, heard, or encountered with detailed filed notes. Interviews involve one-on-one conversations in which interviewees are asked to answer certain questions. Focus groups bring together a selected group of people for questions and open discussion. Survey is another common way to collect data, where questionnaires are distributed with open-ended questions. Secondary research is used to collect existing data including texts, images, audio or video recordings.

4.2.2 Key standards for a sound quality research design

It is crucial that qualitative research be designed under a set of criteria. The relevant standards include the following points:

- Uninterrupted and direct communication. In qualitative research, it is essential to have such communication with research participants who hold key positions of R&D outsourcing in China's innovative medical device industry. Communication unaffected by irrelevant internal and external factors can help ensure the authenticity of the first-hand data, thus enabling a reliable understanding of the characteristics of the participants;
- Openness. In the research process, the researchers should maintain a relatively neutral position and a more open mind to minimize the impact of their own occupation, role, personality, etc. They need to record, describe and analyze the content of the qualitative research truthfully with a relatively open attitude;
- Induction. Instead of making assumptions as what is usually done in quantitative

research, qualitative research follows an inductive approach which ensures that the research is unaffected by presumptions and existing research results. Methods of analysis used in qualitative research should help to recognize and understand research issues, and unveil the inherent characteristics of the correlations between the participants and the research issue;

- The bigger picture. Qualitative research often starts by taking into account the overall background of participants. They are not simply split into groups or superimposed, but are understood in the system and environment they are in. This study takes into consideration not only the specific situations of the people in key positions of R&D outsourcing, but also the macro and micro environments in which they work, including the business environment where the state, the government and the industry encourage innovation, the phase of development their companies are at, etc.

Qualitative research method is commonly employed in CRO-related studies. For instance, Sariola et al., (2015) investigated how CRO enables outsourcing of randomized control trials in India by using 25 semi-structured interviews with CRO workers. Lamberti et al., (2018) surveyed 400 CRO firms with analysis of the start-up practices, performance and perceptions among sponsors and CROs.

4.3 Methods of data collection

Qualitative research method, and to be more specific, semi-structured interviews are used in this study because of the following two reasons. First, some key stakeholders (Annex A Figure a.1) are invited to participate in the interview, where the number of participants (only twenty people) is far less than the threshold of using survey methods. Second, this study intends to explore stakeholders' thoughts, feelings and beliefs about the innovation of CRO. Semi-structured interviews can collect open-ended data which are personal and even sensitive since the data might be related to certain interests.

4.3.1 Semi-structured interviews

Semi-structured interviews are the common qualitative data source in healthcare research (Dejonckheere &Vaughn, 2019). This method tries to understand the world from a subjective point of view, discover the informants' personal experience in a specific matter, and uncover their lived world. Steps in proceeding semi-structured interviews include determining the purpose of the study, identifying participants, taking ethical issues into account, planning

logistical domain, developing interview guide, and carrying out the interview (David, 1997).

In view of the topic of this study, we define the semi-structured interview procedure as follows:

1) Determining the interviewees, i.e. who are the key participants in innovative medical device clinical research outsourcing services;

   (1) Stakeholders of clinical trials of innovative medical devices;

   (2) For regulators, experts and scholars, select national or regional academic leaders of a certain discipline to be responsible for or participate in a number of clinical trials of innovative medical devices;

   (3) For R&D enterprises, select the relevant medical devices developed by them to win the third prize or above in China Innovative Medical Devices National Competition. Generally, they are the CEO of the enterprise or the CTO chief technical officer, or the clinical registration director of the listed company;

   (4) For CRO or related third-party service companies, select CEOs or senior project managers who are well-known in the industry and provide clinical trial services for innovative medical devices, and have more than 10 years of clinical research experience.

2) Developing an interview plan. The plan includes confirmation of interviewees, selection of interview locations, selection of interview questions, preparation of small gifts, etc. In the process of formulating the interview plan, it is necessary to determine the interview outline and key questions.

- What factors will affect medical device CRO innovation?
- How can CRO of medical devices innovate?
- What are the future perspectives of medical device CRO in China?

The preliminary outline of the semi-structured interview includes the following procedures:

1) Conducting certain background investigation and screening of the interviewees before making appointments with them. We need to choose the appropriate time and location for the interview. The grouping of interviewees by industry, job title, and seniority needs to be balanced;
2) Conducting formal interviews. The interviewer has one-on-one on-site interview with the interviewees and makes sure there are handwritten notes and audio recordings of the whole process;
3) Organizing the recordings and notes after the interview. The organized documents need to be archived;

4) Preparing for the next interview.

4.4 Sample and data collection

A total of twenty interviewees participated in the semi-structured interviews. During the interview, interviewers and interviewees had one-on-one talks on a specific topic for 15 minutes to 60 minutes. The interviewees are based across the country: Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou, etc., and most of them are in charge of the enterprise or institution. They have a very busy and full schedule. Therefore, some of the semi-structured interviews were conducted fact to face, while others were by telephone or WeChat.

In this study, the author selected key representatives of CRO stakeholders of innovative medical devices under the supervision of the National Medical Products Administration:

The interviewees include the general manager, CTO, CTO & co-founder, clinical director, registration and regulation director from the company, statistics expert or review expert of the National Medical Products Administration, medical device inspection center expert or review expert of the National Medical Products Administration, clinical director and clinical coordinator (CRC) from the enterprise. They are all senior practitioners in the clinical outsourcing service system of the medical device industry. Their commonality as interviewees is that they are pioneers or outstanding representatives of innovative medical device industry. Please see the following summaries of the interviewees' background.

Customer:

Mr. Zhan G is the CEO of Broncus Medical and the leader of precise interventional therapy technology for lung diseases. Broncus Medical is a multinational enterprise with R&D bases in China and the United States. It targets the markets in dozens of countries and regions around the world. The company plans to launch a $300 million Hong Kong IPO in 2021. Mr. Zhan G has worked as a management in the field of medical devices for more than 20 years: ten years in Johnson & Johnson, one of the Fortune Global 500, and successively served as the youngest national manager of the Cardiovascular Business Department of Johnson & Johnson in China. Later, he served as VP of a listed cardiovascular interventional device company in Hong Kong for about six years, and was responsible for the marketing in China.

Mr. Zhang T, the CEO and CTO of Dejin medical company with an estimated value of over one billion dollars, is one of the leaders in the cardiac interventional valve sector. Mr. Zhang T has more than 15 years of experience in medical device research and development. He once served as the R&D director of a Hong Kong listed cardiovascular interventional device

company. His research and development of transcatheter mitral valve repair system won the Second Prize of China Innovative Medical Device Competition in 2019.

Prof. Dr. Lu. F is the deputy director and professor of cardiac surgery in the Shanghai Changhai hospital. He owns many invention patents and is responsible for many multi-center clinical studies of heart valves. His "Lu-X valve" won the Second Prize of the National Science and Technology Progress Award. This technology fills the gap of interventional therapy of artificial tricuspid valve in China as implantation of artificial tricuspid valve without extracorporeal circulation support and beating heart can greatly shorten the operation time and relieve the pain of patients, which gives hope to many heart disease patients who are previously not eligible for the procedure.

Ms. Xia Y is the clinical director of Lifetech Group. Lifetech is one of the three major manufacturers of innovative cardiovascular devices in China. Its R&D of more than ten products has been rated as innovative medical devices by the National Medical Products Administration. More than half of the company's medical device clinical trial business is outsourced to CRO. Mr. Mei Q, founder and CTO of Shanghai Heartech, has about 20 years of experience in medical device R&D management, and is responsible for R&D.

Prof. Dr. Yang J is the chief physician and associate professor of vascular surgery at Zhongshan Hospital Affiliated to Fudan University. He is an experienced clinical trial investigator and is responsible for the management of more than 30 clinical studies of medical devices in vascular surgery with more than 15 years of trial management experience.

Ms. He H used to work as the regulatory registration director of a listed medical device company in China. She was responsible for the registration and declaration of a number of innovative medical devices by the National Medical Products Administration. She has more than 15 years of working experience and rich experience in cooperation with CRO.

Regulator/Authority:

Prof. Yao C is an external expert of medical device review of the National Medical Products Administration, Chairman of the Evidence-based Medicine Professional Committee of China Medical Association, and Deputy Director of the Clinical Research Institute of Peking University. Prof. Yao has led nearly 100 clinical trial designs of innovative medical devices, and has rich expertise in medical device review of the National Medical Products Administration. He has worked for more than 30 years as director of the clinical trial organization office of the hospital and the clinical trial verification expert of Jiangsu Food and Drug Administration.

Ms. Fan Bo is an external expert of medical device review of the National Medical Products

Administration, who has worked as the director of Tianjin Medical Device Quality Supervision and Inspection Center for more than 30 years, and has rich experience in medical device review of the National Medical Products Administration.

Ms. Liu Zhen is an expert of Beijing Food and Drug Administration with over 20 years of experience. She worked as Director of medical device regulatory registry of China Medical Device Regulatory Administration, and Secretary General of the Clinical Trial branch of China Medical Device Association, with rich experience in on-site verification of clinical trials of medical devices for more than 20 years.

Prof. Liu Y is an external expert of medical device review of the National Medical Products Administration, and Chairman of the Medical Ethics Committee of China Eastern War Zone General Hospital. He has rich experience in clinical trial medical ethics review of innovative medical devices, and has worked for more than 30 years.

Ms. Xia Y is the clinical director of Lifetech Group. Lifetech is one of the three major manufacturers of innovative cardiovascular devices in China. Its R&D of more than ten products has been rated as innovative medical devices by the National Medical Products Administration. More than half of the company's medical device clinical trial business is outsourced to CRO. Mr. Mei Q, founder and CTO of Shanghai Heartech, has about 20 years of experience in medical device R&D management, and is responsible for R&D.

Dr. Yang J is the chief physician and associate professor of vascular surgery at Zhongshan Hospital Affiliated to Fudan University. He is an experienced clinical trial researcher and investigator and is responsible for the management of more than 30 clinical studies of medical devices in vascular surgery with more than 15 years of management experience.

Ms. He H used to work as the regulatory registration director of a listed medical device company in China. She was responsible for the registration and declaration of a number of innovative medical devices by the National Medical Products Administration. She has more than 15 years of working experience and rich experience in cooperation with CRO.

Supplier：

Mr. Wang Z is the General Manger of Excellence SMO, which has about 600 employees of CRCs (clinical research coordinators). He has about 15 years of work experience.

Mr. Huo Y is the General Manger, and Chief Statistician of Blue Balloon Biometrics. Mr. Huo Y used to work as a senior statistician in the clinical research institute of Peking university. Blue Balloon Biometrics is an important player and supplier of medical device clinical trial. Mr. Huo Y has over 15 years of working experience.

Mr. Xie Y is the Co-founder and CEO of Yaoyanshe, one of the leading and eye-catch

SMO company with Internet Plus and more than 500 employees.

Mr. Sun J is the Co-Founder of IRT, a new provider of EDC system and randomization system. Mr. Sun J used to work in Roche, one of the best pharmaceuticals in the world, as a clinical research manager for over ten years before he started his business, IRT.

Employee：

Mr. Robert Pang, chief medical officer in Links CRO and focuses on medical affairs such as medical writing. Robert has about ten years of work experience.

Mr. Somnous Liang, business development director, responsible for sales and marketing. Somnous has about ten years of work experience.

Ms. Cannon Yang, senior project manager and the head of project management dept., is responsible for project management. Cannon has over 10 years of work experience.

In the interview, the author first introduced the interviewers and the purpose of the research. Then, the author asked questions and communicated with the interviewees according to the semi-structure interview outline. The Q&A process is open, so that interviewees can think and express their views on the issue, and that the two sides can have in-depth communication. Follow-up questions were raised when necessary to clarify the purpose of the study. In some cases, researchers might ask more specific questions in order to get more information about the answers. The author selected a total of 20 senior practitioners engaged in clinical trials of medical devices in China. These senior practitioners have witnessed the booming decade of China's innovative medical device industry. They are also the most innovative explorers and practitioners in the R&D system of China's innovative medical device industry. They are influential and highly representative in the medical device industry. The interviews lasted for 15 to 60 minutes. Among the interviewees, 14 out of 20 were male and six out of 20 were female. The majority of these interviewees had worked in the medical device industry for more than ten years, the longest for more than 30 years, and two for less than ten years.

4.5 Detailed information of the interviewees

Table 4.1 List of the interviewees

No.	Name	Gender	Company or Institution	Title	Interview time (Min)	Interview place	Working experience (years)	Groups of key stakeholders
1	Zhan G W	M	Deno Group	CEO	60	Hangzhou	20+	Customer
2	Zhang T	M	Dejin	CEO and CTO	50	Shenzhen	15+	Customer
3	Xia Y	F	Lifetech Group	Clinical Director	45	Shenzhen	10+	Customer
4	Mei Q	M	Xin Rui	Founder and CTO	40	Shanghai	20+	Customer
5	Yang J	M	Zhongshan Hospital	Professor	35	Shanghai	20+	Customer
6	He H	F	Guanhao Group	Regulatory affairs	30	Guangzhou	15+	Customer
7	Wang V	M	Hangzhou Weiqiang	CEO & CTO	30	Shenzhen	30+	Customer
8	Liu Y	M	Nanjing Military Hospital	Authoritative Statistical Expert/ Review Expert of China's National Medical Products Administration	30	Nanjing	30+	Authority
9	Fan Bo	F	Testing institute	Director/Review Expert of China's National Medical Products Administration	30	Beijing	30+	Authority
10	Yao C	M	1st affiliated hospital of Peking university	Authoritative Statistical Expert/ Review Expert of China's National Medical Products Administration	45	Beijing	30+	Authority
11	Yan X	F	Peking university	Authoritative Statistical Expert/ Review Expert of China's National Medical Products Administration	30	Beijing	15+	Authority

12	Liu Z	F	Beijing FDA	Director, Secretary General of clinical trial branch of China medical device association	30	Beijing	20+	Authority
13	Li T	F	Jiangsu Provincial People's Hospital	Director of GCP Office	30	Nanjing	30+	Authority
14	Wang Z	M	Excellence SMO	General Manager	30	Beijing	10+	Supplier (SMO)
15	Huo Y L	M	Blue Balloon Biometrics	General Manager	30	Beijing	10+	Supplier (Biometrics)
16	Sun J L	M	IRT	Co-Founder	45	Guangzhou	20	Supplier (EDC system)
17	Xie Y	M	LinkTrial CRO	Co-Founder	30	Shanghai	10+	Other CRO (executive)
18	Pang R	M	Links CRO	Project Manager/Medical affair	30	Shanghai	10	Links CRO (management)
19	Canon Y	F	Links CRO	PM/ Management	30	Guangzhou	5	Links CRO (employee)
20	Liang S	M	Links CRO	Management	30	Guangzhou	10	Links CRO (executive)

4.6 Preliminary conclusion

This chapter elaborates upon the research method used in the thesis. It firstly gives an overview of the adopted methodology of qualitative research, followed by a discussion of the collection of data by using semi-structured interviews. Details of the 20 interviewees from a variety of stakeholders' groups are then presented. This chapter provides the rationale and methodological details of the current thesis. The next chapter will illustrate the findings of interviews and analysis of innovation for CRO sector in China.

[This page is deliberately left blank.]

Chapter 5: Results and Discussion

5.1 Introduction

This thesis assesses the CRO actor as an emerging innovation facilitator especially in a highly complex and heavily regulated healthcare ecosystem. Approaching the actual (and potential) role of this knowledge-intensive player from a sectoral system perspective makes it necessary to address its functions and challenges from a variety of angles. In this chapter we go through visits, interviews, and other novel empirical materials such as Wechat communication records, to uncover the factors shaping CROs' contribution to the development of highly sophisticated niche markets in China.

Our diverse array of interviewees allows us to take a stakeholder view of our research problem. The rich variety of experts and decision-makers we sample enables us to examine the similarities and contrasts among the different perspectives and requirements at stake. Indeed, we survey the views of players coming from organizations operating around the CRO as well as from institutions providing the legitimacy requirements for the whole industry. The goal is to understand the capabilities and services that combine to encourage the success of the CRO in its distributed and multi-dimensional environment. We derive stylizations from this empirical research in a way that is aligned with the theoretical literature in innovation studies.

Section 5.2 shows the findings from interviews, from the perspective of customers, regulators, suppliers, employees. Section 5.3 discusses what we get from the findings and elaborates on six structuring lessons or propositions. Section 5.4 provides a review of the results.

5.2 Findings from interviews

Based on the three major interview questions presented in Section 4.3, four different groups of stakeholders, namely, clinical customers, regulators, suppliers, employees are interviewed. Although individual interviewees have different views on the innovation of Chinese CROs, we can extract some common themes from them and conclude that the innovation of Chinese CROs is robust and has a systemic value. The following sections provide details of interviewees' thought and opinions.

5.2.1 Clinical customers

When asking clinical customers about the factors affecting medical device CRO innovation, they pointed out that CRO is knowledge-intensive, and therefore appropriate strategic positioning which concentrates more on R&D is important. They also suggested that professionalism of personnel is another key factor for innovation.

> "*Medical device CRO is a talent-intensive and knowledge-based intensive service, especially when the target of CRO service is high-end medical device head R&D manufacturers, it requires CRO to provide very strong professional ability, efficient organization and operation efficiency…*" (Zhan, Broncus Medical)
>
> "*…there are great differences between interventional heart valves and ultrasound imaging equipment……great differences in professional requirements in the process of clinical research……the device CRO practitioners to study deeply in the corresponding specialty and master the latest knowledge of the specialty*…" (Wang, Weiqiang Medical)

When asking clinical customers about their perception of how to innovate regarding medical device CROs, they replied that CROs need to quickly respond to customers' needs, where effective communication between CROs and customers becomes crucial. They added that the use of Internet and communication technology is vital for CROs to boost innovation. Management team can grasp awesome important information in real time (Figure 5.1). Important information uploads timely and accurately. Important support is given to force, in place, to ensure the agility of an organization.

The left picture in Figure 5.1 shows that at 3:13 AM clinical trial monitor reported a case of a patient treated in the emergency treated after randomization. Something unexpected happened; the middle picture shows that clinical trial monitor reported the patient was enrolled even during Chinese New Year Holiday at 11:11 PM. The right picture shows that at 1:49 AM clinical trial monitor reported the 1st patient was enrolled in a new clinical center after a long-term effort.

Figure 5.1 The innovative organizational use of the Tencent social media app WeChat to wire up live vivid scene

"…medical device CRO can also use professional information platforms such as clinical trial project management system, document management system, data verification software system, etc., as well as real-time communication tools such as Wechat and Dingding to organize study teams and manage the clinical research." (Xia, Life tech Group)

Customers also pointed out that CROs need to effectively assign their resources into R&D development, and center more on innovation projects. For instance, assist in promoting patient enrollment, KOL maintenance.

"CROs of medical devices often attach great importance to the planning of clinical trials and the quality management of clinical research, such as the supervision and audit of clinical quality, but they often lack investment in the progress of projects." (Zhang, Dejin Medical)

"The effective advance of the clinical study is also a major challenge of the CRO's execution. Assuming that the customer's assessment and incentive of the device CRO in the project are also linked with the progress goal, the device CRO will have stronger motivation and pressure to help customers complete the progress goal together …"

(Zhan, Broncus Medical)

The last point they proposed is to provide one-stop service and inclusive services which may lead to more effectiveness and efficiency. For instance, in some cases CRO is required to provide SMO services, that is to say, to appoint qualified clinical coordinators to help physicians carry out their work and meet the requirements of GCP regulations; for those who do not have SMO team, to help customers jointly select qualified SMO suppliers and manage them well.

"…provide personalized services or comprehensive services according to the needs of customers such as SMO…" (Prof. Dr. Lu, Shanghai Changhai Hospital)

When asking customers their opinions about their future perspectives on the medical device CRO, they stated that though CRO is a new market sector in China, but it is highly competitive already. It is important for CROs to have dynamic capabilities, namely a strong innovative capacity and ICT abilities. A set of these factors would help the CRO industry make the transition from "Made in China" to "Innovate in China".

"Only by completing the clinical trial quality system, having deep experience in the target device track, establishing professional technical barriers, having core competitiveness and independent innovation ability, such as building a CRO company in information technology, and growing together with customers, can we be in an invincible position in the industry." (Zhan, Broncus Medical)

"In the trend of domestic substitution of medical devices, we have the ability to develop and run international multi-center clinical research studies, and help China's intelligent manufacturing and domestic innovation go overseas." (Prof. Lu Shanghai Changhai Hospital)

Based on the above-mentioned thoughts of customer interviewees, key points of their opinions with respect to how Chinese CROs can further innovate can be summarized as:

- Greater efficiency and effectiveness of the organization are needed so as to promptly respond to changes in the environment;
- Digital skills are needed to secure interactive communications in a timely manner;
- Robust culture of professionalism is needed for the integration with upstream and downstream actors, and the provision of inclusive services.

5.2.2 Regulators

When asking regulators about the factors affecting medical device CRO innovation, they suggested that the difficulty hindering Chinese CROs from moving forward is the absence of law and regulations in terms of CRO supervision. The CRO industry also lacks the environment for innovation.

> *"Although the legal system of medical devices has been initially formed, it is far from perfect. The fundamental problems that constrain the innovation and development of the medical device industry have not yet been broken through at the regulatory level. At the legal level, some regulations will be issued to solve the mechanism problems that constrain the innovation and development of the industry…" (Liu, Beijing FDA)*

When asking regulators their perception about how to innovate CRO of medical devices, they suggested that an effective interactive environment among regulation, CROs and customers is fundamental as better communications can facilitate the creation of knowledge and knowledge transfer that trigger innovation. The clinical research information including research status and safety events should be reported in time. They added that some digital platform and ICT techniques can be applied in the near future, and that co-construction and sharing with the national drug and device regulatory authority in information co-ordination, planning and management is also necessary. Regulations will play an increasingly important role in encouraging CROs' innovation and piloting the development of the industry.

> *"Severe and unexpected adverse events found in the process of clinical research should be reported to the adverse reaction report database in time, with detailed data content and timely updates" (Prof. Yao, 1st Hospital of Peking University)*

CRO can be the bridge of sponsor and NMPA so as to make the safe and effective medical device products meet the approval conditions as soon as possible.

> *"The State Council requires the NMPA to deepen the reform of the review and approval system and promote the development of public health. For example, we should encourage technological innovation, strengthen the implementation of "Special Approval Procedures for Innovative Medical Devices (Trial)", and give priority to the evaluation and approval of "innovative medical devices with product core technology invention patents and significant clinical application value". NMPA should intervene in advance and assign a special person to take charge, strengthen the communication with the application unit or the third party CRO entrusted by the application unit, scientifically and reasonably reduce the approval time…" (Fan, Testing Lab of CFDA)*

"CRO, as a professional third-party organization, has accumulated a lot of experience in dealing with the registration and application of innovative devices and the operation of clinical trials. It can bridge the applying unit (the sponsor) and NMPA, timely transmit signals and accurately translate the 'information' of both sides, so that the two sides of the bridge can accurately understand each other's 'language'; it can improve the communication efficiency of both sides, encourage the evaluation of innovative devices and deepen the approval's significance…" (Prof. Liu, Nanjing military hospital)

When asking regulators their opinions about the future perspective of medical device CRO, they pointed out the CRO industry needs to establish a set of standards, and at least CROs need to adopt internationally recognized management system standards. Digitalization efforts such as E-platforms and ICT skills are also strongly encouraged among CROs and regulators for better communications.

"The improvement of the regulatory level of medical device administration and the requirements for clinical research of innovative drugs, the quality management standard of clinical research is getting closer to that of Europe and the United States. Only with a complete clinical trial quality system, a high level of insight into policies and regulations, and a certain degree of independent innovation ability, such as exploring digitalization and ICT, can CRO companies build their own competitive advantages and lead the development of the industry" (Prof. Yao, 1st Hospital of Peking University)

Based on the above-mentioned thoughts of regulator interviewees, key points of their opinions with respect to how Chinese CRO can further innovate are summarized as:

- A digital information system for CRO supervision and regulation is needed;
- Practitioners in CRO need to be more professional because they act as a bridge between customers and regulators, and play important roles in official medical device evaluation.

5.2.3 Suppliers

When asking suppliers about the factors affecting medical device CRO innovation, they suggested that the risks of innovative failure should be taken into account, and this is more particular for small and medium-sized CROs. Human capital, financial resources and even reputational capital are also crucial for CRO to sustainably innovate.

"There are certain risks in the innovation investment of medical device CRO. There

may be challenges in terms of whether there is a return in the future and the timeliness of income..." (Huo, Blueballon)

"The device CRO industry is highly dependent on people and talents. How to attract and retain innovative talents determines the success or failure of innovation…" (Sun, IRTON)

"Stable sources of funds, be it the stable and growing business income or external investment…" (Xie, Yaoyanshe SMO)

When asking suppliers their perception about how to innovate CRO of medical devices, they replied that vertical integration may significantly impact the innovation and development of the industry. More specifically, CROs should collaborate with upstream and downstream actors in exchanging and diffusing knowledge residing within the network of these actors. CROs also need to emphasize the importance of resource allocation that could lower transaction costs and improve the efficiency of knowledge transfer by optimizing communication, improving action efficiency, and transforming it into the operation collaboration between CRO and SMO companies, who have long-term and high-frequency cooperation, reduce the market launch cost and unit price cost of suppliers, thus reducing transaction costs.

"CRO is mainly engaged in clinical monitoring business, integrating and purchasing SMO clinical coordinator business, providing integrated operation for customers' clinical research projects…" (Sun, IRTON)

"Device CRO is engaged in professional clinical trial design and medical writing services, accumulating professionally, and providing professional collaboration with data statistical analysis team/company…" (Huo, Blueballon)

When asking suppliers their opinions about the future perspective of medical device CRO, they stated that an interactive business environment among all related stakeholders could trigger CRO innovation. CROs also need to attach importance to the use of ICT in clinical research.

"Develop large-scale CRO, do a good job in cost control and improve professionalism; provide more cost-effective services according to customer needs…" (Huo, BlueBallon)

"Deepen the cooperation among CROs, SMOs and data analysis enterprises, and jointly create a high-level device ecosystem with healthy competition …." (Sun, IRTON Scientific)

Based on the above-mentioned thoughts of supplier interviewees, key points of their opinions with respect to how Chinese CRO can further innovate are summarized as:

- Talented, experienced, and creative personnel are needed because CRO is highly dependent on creative human capital;

- Vertical integration of CRO is necessary to provide inclusive services for customer, and synergize with suppliers in order to reduce transaction costs.

5.2.4 Employees

When asking employees about the factors affecting medical device CRO innovation, they suggested that it is vital for CROs to have more talented, experienced, and skilled employees. Especially, insufficient innovative human capital may hinder Chinese CROs in their efforts to develop further.

"… The outsourcing service of medical device clinical research is a talent-intensive and knowledge-intensive industry. The innovation of CROs of medical device is closely related to the high-end talent density of CROs. And the reality: more than 30% of enterprises are facing the problem of lack of qualified professionals, and the lack of innovative talents is one of the main obstacles to the rapid development of medical device CRO industry…" (Yang, Links CRO)

When asking employees their perception about how to innovate CRO of medical devices, they pointed out that the degree of digitalization is an important factor of CROs' innovation. The construction of "electronic system" is often neglected, resulting in the waste of too many resources in management.

"The strength of electronic system makes people strong, and the weakness of electronic system makes people weak. At the same time, the degree of electronization determines the innovation and development of CRO of medical devices…" (Pang., Links CRO)

Managements and employees in CROs need to promptly respond to customers and regulators (Figure 5.2), understanding their demands, solving critical problems and working together with them in a timely manner. Picture1 and picture 2 (1st left and 2nd left) show that the CRO linked the top statisticians, regulators with sponsors and organized a meeting; Picture 4 and picture 3 (1st right and 2nd right) show that the CRO strongly linked the sponsor and investigators of all clinical study centers, keeping all parties in the same channel.

"To communicate with customers, in addition to email, teleconference and traditional communication, we can also use Wechat, Dingding and other real-time communication tools to organize the project group (see Figure 5.2). Managers can grasp the important information on the front line in real time, understand the needs of doctors/researchers and the front line, and customer support departments and personnel can give timely help and support…" (Yang, Links CRO).

Figure 5.2 The innovative organizational use of the Tencent social media app WeChat to wire up its external customers and employees

Providing necessary trainings is another important factor in facilitating internal knowledge creation and transfer such as GCP, device related knowledge, therapy of specific treatment, etc. Another vital factor is the learning and motivational work environment. If CROs could provide a competitive medium and long-term incentive scheme, it would decrease turnover rate and retain key personnel.

"In addition to GCP related clinical regulations training, knowledge training should also include communication skills and other soft skills. A mistake-tolerant work environment for young employees should also be encouraged…" (Liang, Links CRO)

"According to the characteristics of the project specialty, clinical experts are organized to carry out training on the disease field, clinical anatomy and the latest treatment progress, and statistical experts are invited to train statistical knowledge…" (Pang, Links CRO)

"Device CRO incorporates reform and innovation into the employee incentive scheme, so that employees and enterprises can share project risks and project incentives; improve employee compensation income, attract external high-end talents and stabilize

the company's professional and sophisticated talents…" (Pang, Links CRO)

When asking employees their opinions about the future perspective of medical device CRO, they stated that CRO would develop towards specialization and refinement, and become more efficient and cost effective by linkage of upstream and downstream.

"China's medical device CRO will also usher in rapid growth, and the industry will develop towards specialization and refinement. With the application of digital tools and the popularization of big data, the future services of medical device CRO will be more efficient, and the operation cost can be further reduced…" (Pang, Links CRO)

"…… medical device CRO needs to change its development mode, change its own operation structure and organizational structure according to the latest environment, adopt new technology and new management mode, bring in more compound talents, link up the upstream and downstream of the industry, ……" (Pang, Links CRO)

Based on the above-mentioned thoughts of employee interviewees, key points of their opinions with respect to how Chinese CRO can further innovate are summarized as:

- Employees need to be well trained because CRO is a knowledge-intensive organization which relies on personnel;
- It is crucial to motivate employees using mid long-term incentive plan for a win-win benefit.

5.3 Discussion

According to stakeholder theory in service innovation context, four groups of stakeholders of medical device CROs are identified, including customers, regulators, regulators and employees. As shown in Figure 5.1, these stakeholders of medical device CROs are categorized into two aspects, supply side and demand side, on the basis of Strambach's (2001) framework of KIBS firms to innovation.

With respect to the results of the interviews with the above-mentioned stakeholder groups, their thoughts and opinions in relation to innovation in Chinese medical device CROs are preliminarily sorted out, presented in Figure 5.1. For instance, on the supply side, suppliers may consider that key points of medical device CROs' innovation include creative capital and greater vertical integration, while regulators may suggest that the sector needs digital and technological platform, and more professionalism of practitioners that trigger further innovation. On the demand side, customers may believe the organization's prompt response to changing environment, the use of digital ICT tools, and offering inclusive services are critical factors of

innovation, form whilst employees may hold the view that a motivational work environment and possession of new ICT skills can facilitate internal innovation.

Combining the above-mentioned stakeholders' opinions on the innovation in medical device CROs and fitting them into Tether's (2005) argumentation regarding "hard" and "soft" innovation indicators in service firms, three dimensions of innovation, namely organizational innovation, social innovation, and technological innovation, are used to classify stakeholders' point of view, of which some common ideas from these stakeholders can be also generated. The interview findings are organized under Strambach's (2001) framework of innovation in KIBS firms as shown in Figure 5.3.

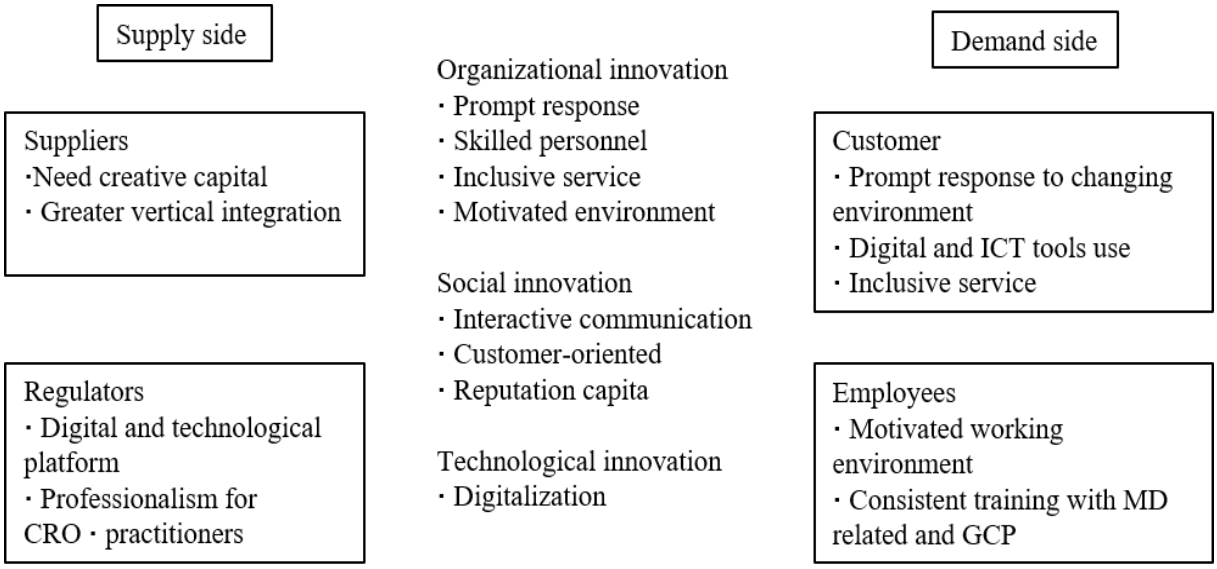

Figure 5.3 Contribution of KIBS firms to innovation in innovation systems

Based on the findings from interviews (twenty interviewees' key thoughts), the views in relation to Chinese CRO's innovation are analyzed, and then categorized into propositions (or lessons) according to the importance perceived by interviewees. To be more specific, key points more mentioned during the interview will be selected and concluded in the "author's proposition". The selected key points and the number of interviewees mentioning the key points are shown in Table 5.1.

Table 5.1 Overview of selected key points from interviewees for structuring proposition

Main factor of innovation	Key point delivered by interviewees regarding how Chinese CRO innovates	The number of interviewees mentioning the key point (out of 20 interviewees)
Technological innovation	Digitalization	10/20
	ICT skills	8/20
	Patents	3/20
	Licensing of IP	1/20

Social innovation	Wechat communication	18/20
	Customer oriented	13/20
	Reputation and image	8/20
	External networking	2/20
Organizational innovation	Prompt response	18/20
	Key skilled personnel	16/20
	Inclusive and one-stop services	10/20
	Motivational environment	10/20
	Learning atmosphere √	2/20
	Transparency	2/20

The above-mentioned interviewees' key points are then integrated into a total of six propositions which are the ways guiding Chinese CRO to innovate further. In the following section, these propositions are presented and interpreted in details.

Proposition 1: CRO can be extended by vertical integration, providing inclusive services

- **Why does vertical integration relate to innovation in the CRO business?**

From the perspective of knowledge-based, the process of developing new knowledge is crucial to the sustainable competitive advantage of an enterprise. This process originates from the unique combination of existing knowledge (Fleming, 2001). Some studies suggest that when it comes to complex interdependence, vertical integration can promote technological innovation by sharing common technological information at all stages of an industry's development; this can be achieved by promoting the implementation of new technologies and setting smarter research goals (Monteverde, 1995). Vertically integrated enterprises have many complementary assets. They will have better opportunities to apply the knowledge generated by R&D internally, thus promoting the spread of R&D (Kumar & Saqib, 1996). Therefore, it is very important to cooperate with customers with better understanding of their needs. Companies must also learn more about communication skills and provide services in an inclusive or one-stop pattern.

Vertically integrated companies have established processes to resolve conflicts and coordinate their innovation activities (Chesbrough & Teece, 1998). In other words, vertical integration promotes systematic innovation by promoting information flow and coordination of investment plans. Afuah (2001) also points out that in the early stage of the emergence of a new

technology, a "decision-making" decision is better than a "purchase" decision, mainly because the company's communication channel is the key to the success of innovation. More specifically, because of the lock-in effect of vertical integration on downstream enterprises, and since this vertical integration increases the expected value of enterprise R&D activities due to better distributivity, upstream enterprises will be more innovative, thus increasing the possibility of attracting other downstream enterprises (Brocas, 2003). Therefore, as the internal mechanism of knowledge transfer and integration, vertical integration is positively related to innovation.

- **Why is vertical integration important for CRO's innovation?**

Medical device CRO is one of the key components of the overall medical device industry, and the degree of industrial concentration is still low. Device CROs are equipped with their own core competitiveness, such as technological innovation, organizational innovation and market innovation, to better integrate the upstream and downstream stakeholders, open up the upstream and downstream industry chain of CRO, and provide customers with vertically integrated services. With the coordination of management and operation, it could shorten the time of clinical R&D outsourcing services, reduce the waste of manpower and capital in the process of services, reduce transaction costs and generate more benefits.

Medical device CRO adopts vertical integration strategy, which can continuously improve its competitiveness, keep and even expand the market share, and also set the bar high for potential competitors. Due to marked technology dependence in the upstream and downstream of the industrial chain of device CRO enterprises, the upstream and downstream must be organically integrated for higher overall efficiency and lower transaction costs. Therefore, enterprises should enhance the understanding of vertical integration, select suitable high-quality upstream and downstream enterprises, to achieve scale effect, integrate and improve their production links to tackle the fierce market competition. In the process of vertical integration, controlling transaction cost and enhancing strengths are the ultimate goals.

In the stakeholder interviews, it is found that the demand for better quality and progress of clinical trials is growing on a daily basis, which is not only limited to the monitoring of the quality of clinical trials, but also to provide the design of clinical trial scheme and medical writing, give priority to the analysis of clinical data, manage the clinical coordinator assigned by the SMO (hospital field management organization), and supervise the clinical coordinator to better assist researchers/doctoral students in their participation in the implementation of clinical research. It enables the stakeholders/participants of clinical trials to work together to ensure the quality of research and maximize the efficiency and benefit.

Proposition 2: CRO can be transformed by ICT and digitalization

- **Why does ICT and digitalization relate to innovation?**

ICT contributes to the generation, integration, development and enhancement of key resources over time. E-commerce, new production methods, new services, new business models, better supply chain management, customer relationship management and effective methods of decision-making are among the few ways in which ICT embodies its dynamic capabilities. This is in line with Schumpeter's view (Schumpeter, 1934), i.e. through innovative ways and complex processes as well as knowledge integration from various sources and continuous learning process (Prahalad & Hamel, 1990).

ICT improves the productivity and market share of enterprises (Cardona, Kretschmer, & Strobel, 2013; Tran et al., 2014). In addition, ICT provides many benefits for enterprises (Brynjolfsson, 2010), e.g., it can help enterprises introduce new products and services, be more customer-oriented, better respond to market changes, and thus innovate (Tran et al., 2014). As a result, ICT improves efficiency and innovation through the dynamic capabilities of enterprises (Melville, Kraemer, & Gurbaxani, 2001).

- **Why is ICT and digitalization important for CRO's innovation?**

Innovative digital technology can facilitate the creation and integration of system solutions to support the complete clinical trial process. In addition to a complete quality management system, CROs also need to adopt a variety of project management software, electronic data management system, medical literature retrieval software, data verification system and other platforms in the process of clinical trial management. Taking a CRO firm, Links CRO as an example, it has obtained 15 ICT-related patent licenses in subject enrollment management, medical trial product literature retrieval, medical trial product tracking management, medical image reading management, medical clinical trial training management, medical safety data management, quality control management, clinical trial audit management, etc.

Proposition 3: CROs need quick response through fast delivery

- **Why do customer needs relate to innovation?**

It has long been recognized that interaction with customers is a key prerequisite for innovation (Freeman, 1968; Hippel, 1976; Schumpeter, 1934). Hippel (1976) records the importance of this phenomenon and shows that more than 80% of innovations in the scientific instrument industry are invented, prototyped and first field tested by instrument users rather than instrument manufacturers. Then, an important literature appeared, which analyzes the main

benefits and obstacles of user participation in the innovation process. Laursen and Salter (2006) show that the two most important external sources of innovation in British enterprises are "supplier and customer" or "customer": 66% of the samples of British manufacturing enterprises show that customer or users is the source of knowledge or information of innovation, and 16% of enterprises say that they have a very high evaluation of this source. In addition, innovation and marketing scholars have pointed out the potential important role of customers and users in the innovation process. For example, Slater and Narver (1994) found that market research generally supports the link between market orientation and various innovative measures. Han (1998) empirically proves the mediating role of innovation between market orientation and financial performance.

- **Why is quick response through fast delivery important for CRO's innovation?**

In the stakeholder interviews, this study finds that for the highly informative society, we can quickly identify and respond to the needs of customers, especially in the key milestones, such as the approval by the hospital ethics committee, the screening and recruitment of the first subject/patient, and the clinical research data cleaning stage. CROs have taken a series of measures to quickly identify, analyze and respond to customer needs. For the promotion of daily work and interaction with customers, in addition to daily mails, CROs also use electronic data management system and non-official system such as Wechat and Dingding software, enabling real-time communication. According to the different stages of the project, monthly or biweekly project meetings will be conducted. At key milestones or in urgencies, the project leader will usually respond within 12 hours, and organize an emergency meeting on the same day according to the emergency degree, which is the response procedure in the corresponding risk management plan of each project pursuant to the company's SOP.

Proposition 4: CRO can be optimized by better resource allocation

- **Why does sound resource allocation relate to innovation?**

The enterprise is a bundle of resources, resources that determine enterprise performance. The resource-based view (RBV) holds that the sustainable competitive advantage of enterprises comes from valuable, rare, non-imitative and irreplaceable resources (Wernerfelt, 1984; Barney, 1991). The success of a series of innovative activities of a company depends on the quantity and quality of resources invested in this task (Crepon, Duguet, & Mairessec, 1998; Mairesse & Mohnen, 2002). Business uncertainty shortens the time for managers to confidently predict key determinants of innovation success, such as future customer preferences, technical standards,

or competitive landscape (Hauser, Tellis, & Griffin, 2006). However, given that only a small part of innovation efforts is successful, how to effectively allocate resources is particularly important. Therefore, when enterprises allocate scarce resources to innovation activities, they may misjudge the prospect of success. Projects that initially look promising may eventually fail, while projects that initially look unconvincing may eventually succeed (Hauser, Tellis, & Griffin, 2006).

- **Why is better resource allocation important for CRO's innovation?**

The monitoring process management provided by device CRO and the coordination of the whole clinical trial project are multi-party cooperation. However, in the stakeholder interview, it is found that the customers attach great importance to whether the results of device CRO can be delivered in time, which is not limited to process control. Therefore, the bonus system of the company is closely connected with the milestone of clinical trial, and the project team can receive the corresponding project bonus when the milestone of clinical trial is reached. This bonus mechanism ensures the consistency of the collective interests of the project team and the interests of customers.

Proposition 5: CROs need to provide an incentive scheme

- **Why does good employee treatment relate to innovation?**

Positive employee treatment programs have a good impact on the operation, finance and stock price performance of enterprises (Ertugrul, 2013). There are two major reasons that good employee treatment could trigger the success of enterprise innovation. First, innovation requires employee participation, active participation and teamwork (Dougherty, 1992). In multi-sectoral organizations, knowledge transfer between different departments provides opportunities for mutual learning and collaboration, thus stimulating the creation of new ideas and knowledge (Tsai & Ghoshal, 1998). Therefore, the participation and cooperation of employees in the process of innovation is a necessary condition for the success of enterprise innovation. Secondly, innovation is a long-term, multi-stage and complex process, which requires excellent employees with long-term commitment (Holmstrom, 1989). By providing employees with satisfactory workplace, such as a flexible work schedule, sound working conditions, and attractive retirement benefits, enterprises are better positioned to recruit and retain talents. Satisfactory workplace can also cultivate employee loyalty and improve employee productivity (Bloom et al., 2015). The social exchange model developed by Organ (1997) holds that employees regard happy working conditions as "gifts" of enterprises and respond with a more

engaged attitude. If a company can retain talented and dedicated employees, it will be more capable of innovating, and better meet the company's corporate goals and shareholders' interests.

- **Why are incentive schemes important for CRO's innovation?**

CROs can adopt the dynamic system of incentive scheme and virtual equity dividend scheme, which binds up the interests of employees with the interests of the company, i.e. the long-term and short-term interests of employees are linked with the company, and the employees share the benefits of the growth of the enterprise. In terms of exercise conditions, the rolling year is chosen to replace the fixed year as the base assessment year, so as to reduce the predictability of the assessment standard. In terms of individual performance exercise conditions, the company specially designs differentiated individual performance assessment conditions according to different departments, and makes timely adjustments with the dynamics of departments, so as to ensure the fairness of individual performance exercise conditions. According to the industry specific, the incentive object is biased towards the core technical personnel, and the gap between different personnel is appropriately widened according to the contribution.

Proposition 6: CROs need a focus of reputational capital

- **Why does reputation relate to innovation?**

Reputation is multifaceted, which means that organizations operate in different environments and evaluate signals for different groups. Lange, Lee, and Dai (2011) put forward a general concept that organizations are either "known by people", "known by something", or regarded as "generally beneficial". Reputation among customers, consumers and other participants is a subjective impression of the company, and of course, of its products (Shams, Alpert, & Brown, 2015). Therefore, it is an arduous task for enterprises to gain profits, especially technical reputation, but at the same time, it also provides many different opportunities, such as scientific leap, new products, design innovation, process innovation, etc. Innovation is regarded as "a new idea, practice or object considered by an individual or other adopter" (Kaminski, 2011). The success of an innovative company, i.e. its reputation, also depends on its ability to commercialize its innovation and creative knowledge into marketable solutions.

- **Why is reputational capital important for CRO's innovation?**

CROs can use management system certification to increase the reputational capital. For instance, Links CRO firm has adopted the ISO 13485, which is a BSI 's (British Standards

Institute) medical quality service system, to introduce high-standard and exclusive medical device clinical trial service system. At the same time, the company will become a high-tech enterprise in 2020. After weighing the reputation of the industry, the company considered to undertake the clinical trial projects that were in trouble due to the poor cooperation of the third party CRO, investing huge human resources and financial resources to break the ice, reshaping the project process and revitalizing the stakeholders, so as to get the projects going, bring them into a virtuous circle and achieve the milestones. Although the economic return is not high, the company has won the praise and trust of customers, gained good reputation in the industry, and increased the reputation capital of the enterprise.

In summary, this paper offers a total of six research propositions related to the ways leading innovative changes for Chinese medical device CRO sector. These propositions are emerged through authors' analysis from the findings of interview, with a systematic integration of KIBS innovation and stakeholder theory. The summary of research propositions of this study is shown in Table 5.2.

Table 5.2 Summary of propositions regarding medical device CRO's innovation

Proposition of this study	**Was concerned by which group of stakeholders**	**Belongs to which factor of innovation**
Proposition 1: CRO can be extended by vertical integration, providing inclusive services	Suppliers	Organizational innovation
Proposition 2: CRO can be transformed by ICT and digitalization	Regulators, Customers and Employees	Technological innovation
Proposition 3: CROs need quick response through fast delivery	Customers	Organizational innovation
Proposition 4: CRO can be optimized by better resource allocation	Suppliers, Customers and Employees	Organizational innovation
Proposition 5: CROs need to provide an incentive scheme	Employees	Organizational innovation
Proposition 6: CROs need a focus of reputational capital	Customers and employees	Social innovation

5.4 Conclusion of the chapter

This chapter associates with the results and discussion, where the information collected in interview and the analysis of these information is presented. Firstly, critical interviewers' thoughts and opinions, consisting of customers, regulators, suppliers, and employees are partly extract and used for further analysis. Secondly, the findings from interviews are analyzed on the theoretical ground of KIBS innovation and stakeholder theory. After categorizing key points delivered by stakeholders and integrating into a KIBS firm innovation system, we therefore generate six research proposition that could solve the research problem concerning appropriate innovation-driven strategies for CRO KIBS in China.

This chapter indicates the significant findings of interview results, and acts as a crucial element in this study because it moves forward arguments of the ways leading innovative changes for Chinese medical device CRO sector according to theoretical underpinnings. The next chapter it will go straight to the conclusion of this study.

[This page is deliberately left blank.]

Chapter 6: Conclusion

6.1 Introduction

This study aims to explore the development of the innovative performance of China's medical CRO knowledge-intensive business services. This chapter presents the conclusion of this study.

Sections of Chapter 6 are organized in the following ways. Section 6.2 discusses the results of the research including how research questions are answered and how research problems are explained. Section 6.3 provides the implication of the research. Section 6.4 proposes the limitations. Section 6.5 raises suggestions for further research.

6.2 Results of the research

6.2.1 Addressing the research questions

Two research questions are developed at the beginning of this study. The review of literature and the development of innovation in the Chinese context can address these research questions. Responses to the research questions are interpreted in detail as follows:

(1) The first research question addressed is:

RQ1: Which are the key stakeholder dynamics affecting knowledge-based evolution in medical device CROs?

The establishment of innovation and KIBS in modern economy is described in Section 3.2 and Section 3.3. How are KIBS acting in the innovation system and how do KIBS evolve in the healthcare system? Based on the stakeholder theory and in the Chinese context, there are three stages of key stakeholder dynamics affecting KIBS evolution in medical device CROs. First, four different kinds of key stakeholders are identified and selected on the basis of stakeholder theory (Cannon, Daryl, & David, 1994): clinical customer, authority, supplier and employee. Clinical customers care about the services and the sustainable quality provided by medical device CROs. Government authority cares about the compliance with regulation by medical device CROs. Suppliers' concerns include payment and long-term relationship. Employees are concerned with remuneration, training and job satisfaction. Twenty interviewees are selected based on the perspectives of four different groups of stakeholders.

(2) The second research question addressed is:

RQ2: **How are innovation-driven strategies more appropriate for medical device CRO KIBS to catch up with Chinese economy?**

CROs are playing an increasingly evident role in clinical research and clinical trial management due to surging medical device R&D costs and tighter government regulation. The contribution of KIBS to the medical R&D innovation system and the medical and health innovation system can fall into two highly interdependent parts: Chinese device CROs, as innovation activities in KIBS, directly affect the economic competitiveness of medical devices in China; on the other hand, device CROs, as KIBS, also have indirect effects on and positive responses to the demand side of medical device R&D. Customers can use services provided by KIBS to set up a company, which is a successful transfer of knowledge to clinical customers or a solution to their innovation problems, and improves their competitiveness.

The findings of the interviews are further combined with the theoretical framework of innovation in KIBS, and then a comprehensive figure which includes opinions of key stakeholders related to how CROs can sustainably innovate is generated. The twenty interviewees' key points are categorized into a total of six propositions guiding Chinese CROs to innovate further:

(1) CROs can be extended by vertical integration to provide inclusive services;

(2) CROs can be transformed by ICT and digitalization;

(3) CROs need quick response through fast delivery;

(4) CROs can be optimized by better resource allocation;

(5) CROs need to provide combined incentive schemes; and

(6) CROs need to focus more on reputational capital.

6.2.2 Clarifying the research problem

The research problem this study sets out to clarify is:

RP: The development of the innovative performance of China's medical CRO knowledge-intensive business services

According the theoretical basis of innovation from literature in KIBS and indicators in innovation, three major interview questions including "what will affect medical device CROs, how to innovate, what are the future perspectives" are chosen in this study.

Twenty key representatives of CRO stakeholders (clinical customers, regulators, suppliers and employees) of innovative medical devices are selected. They are all senior practitioners in

the clinical outsourcing service system of the medical device industry. Their commonality as interviewees is that they are pioneers or outstanding representatives of the innovative medical device industry. Sufficient evidence is obtained for further analysis and summary from these interviews.

Based on KIBS and KIBS in innovation theory and the stakeholder theory, the interviews are analyzed and the findings are summarized to solve the research problem: *the development of the innovative performance of China’s medical CRO knowledge-intensive business services.*

- In order to improve the innovative performance of China’s medical CRO KIBS, a compromise of the interests of each key stakeholder may be needed. As for suppliers, creative capital is necessary, hence, greater integration for more comprehensive services. On the supply side, digital technological platforms can ensure security and timely adverse event reporting. From regulators’ perspective, professionalism can make CRO practitioners stand out and enhance the regulatory compliance. On the demand side, as far as clinical customers are concerned, it requires prompt response when facing changing environments, inclusive services or one-stop service, and digital platforms for project management. From employees’ perspective, a motivational work environment and combined incentive scheme can be enabled by electronic information equipment.

6.3 Implications of the research

The status quos of medical device CROs are that the service quality and development level are uneven, the overall development level is low, and the innovation is insufficient. With the summary of studies related to China's CRO industry in the literature, we can know that China's CRO industry is facing a series of deficiencies and challenges, including the lack of talents and policy and system limitations.

For regulators and policy makers, the suggestion of this study is to build a group of CRO leading enterprises, standardize the market, follow laws and regulations, and improve the competitiveness of the CRO industry. There are two specific recommendations drawn from the research findings:

(1) For regulators, we propose to build up leading CROs, further standardize the medical CRO market, issue relevant certification of the industry, improve the industrial environment, and prevent bad players from driving out good;

(2) As for the management team and employees of medical device CROs, biometrics suppliers and SMOs, it is suggested to strengthen the development of technological platforms

for system innovation, use IT to extract and keep knowledge and experience within the enterprise, and share in time. An emphasis should be given to the influence of reputational capital on the credit of the industry or enterprise. CROs should actively give full play to and combine with the characteristics of the industry to design the equity incentive scheme, maximize the motivational effect of the scheme, and try combined incentive tools.

6.4 Limitations of this study

Limitations of this study consist of three points:

First, since semi-structure interviews are the main approach in this research, a certain degree of subjectivity might bias the findings and propositions.

Second, the number of interviewees is only twenty though they're very senior representatives of their territory as a stakeholder, indicating a limited sample size which makes the study subject to bias. The conclusion may not be solid enough.

Third, the investigation targets the closely related stakeholders of medical device CROs. However, only four different kinds of stakeholders have been interviewed. There might be other stakeholders not well considered or included, such as medical associations, shareholders and other organizations. The absence of all groups of stakeholders may have negative influence on the validity of the study.

6.5 Suggestions for further research

CRO studies in the future can look into how the eCRO or CRO Internet Plus plays in KIBS in the Information Age. Being connected to the Internet will create strong "chemical reactions" and earth-shaking changes in things.

Future research can also consider the combination of quantitative and qualitative research methods, so that both descriptive and exploratory research results can be obtained.

Another possible direction for further studies may be a deeper dig into other regions and countries where CRO business is more developed, for example, EU, the US.

6.6 Summary

In conclusion, this study explores medical device CRO innovation in China and discourses the KIBS innovation-driven strategies including the extension through vertical integration for

inclusive services, use of ICT and digitalization, fast delivery, better resource allocation, motivational incentive schemes and the accumulation of reputational capital.

[This page is deliberately left blank.]

Bibliography

Adner, R. (2012). *The Wide Lens: What Successful Innovators See that Others Miss*. New York: Penguin Group.

Afuah, A. (2001). Dynamic boundaries of the firm: are firms better off being vertically integrated in the face of a technological change? . *Academy of Management Journal, 44*(6), 1211-1228.

Backes, H., Dietsche, B., Nagels, A., Stratmann, M., Konrad, C., Kircher, T., et al. (2014). Increased neural activity during overt and continuous semantic verbal fluency in major depression: mainly a failure to deactivate. *Eur Arch Psychiatry Clin Neurosci, 264*(7), 631-645.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of management, 17*(1), 99-120.

Bloom, N., Liang, J., Roberts, J., & Ying, Z. J. (2015). Does working from home work? Evidence from a Chinese experiment. *The Quarterly Journal of Economics, 130*(1), 165-218.

Bo, T. (2016). Research on the development of China's film industry competitiveness in the context of "Internet plus". *Proceedings of the Second International Symposium-Management, Innovation and Development, 1*(1), 1-3.

Bonaccorsi, A. (2015). *The Changing Governance of Higher Education and Research*. Germany: Springer, Cham.

Brem, A., Sherif, M. H., Katzenstein, L., Voigt, K. I., & Lammer, D. M. (2011). *Research and Development, Innovation and Marketing: How to Convince Internal and External Stakeholders of Technological Innovations*. Berlin: Springer Berlin Heidelberg.

Breznitz, D. & Murphree, M. (2011). *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China*. New Haven: Yale University Press.

Brocas, I. (2003). Vertical integration and incentives to innovate. *International Journal of Industrial Organization, 21*(4), 457-488.

Brynjolfsson, E. (2010). Wired for innovation: how information technology is reshaping the economy. *Journal of the American Society for Information Science & Technology, 61*(11), 2375-2376.

Bullen, E., Fahey, J., & Kenway, J. (2006). The knowledge economy and innovation: certain uncertainty and the risk economy. *Discourse: Studies in the Cultural Politics of Education, 27*(1), 53-68.

Bullinger, H. J., Auernhammer, K., & Gomeringer, A. (2004). Managing innovation networks in the knowledge-driven economy. *International Journal of Production Research, 42*(17), 3337-3353.

Cannon, T. W., Daryl, R. M., & David, T. (1994). Technical overview of photovoltaic solar radiation research at NREL. *American Institute of Physics, 306*, 137-146.

Cao, W., Zhang, Y., & Qian, P. (2019). The effect of innovation-driven strategy on green economic development in China-an empirical study of smart cities. *International Journal of Environmental Research and Public Health, 16*(9), 1520.

Cardona, M., Kretschmer, T., & Strobel, T. (2013). ICT and productivity: conclusions from the empirical literature. *Information Economics and Policy, 25*(3), 109-125.

Carmeli, A., Gilat, G., & Weisberg, J. (2006). Perceived external prestige, organizational identification and affective commitment: a stakeholder approach. *Corporate Reputation*

Review, 9(2), 92-104.
Carmen, D., Beatriz, L., & Erezuela, E. (2021). Managing and keeping control: a qualitative synthesis of nursing and care staff strategies to prevent older people from falling. *Journal of Advanced Nursing, 5*, 3008-3019.
Castellaci, F., Grodal, S., Mendonca, S., & Wibe, M. (2005). Advances and challenges in innovation studies. *Journal of Economic Issues, 39*(1), 91-121.
Chapman, R. L., Soosay, C., & Kandampully, J. (2002). Innovation in logistic services and the new business model: a conceptual framework. *Managing Service Quality: An International Journal, 12*(6), 358-371.
Chen, J. & Han, X. (2014). The evolution of the housing market and its socioeconomic impacts in the post-reform people's republic of china: a survey of the literature. *Journal of Economic Surveys, 28*(4), 652-670.
Chesbrough, H. W. & Teece, D. J. (1998). When is virtual virtuous? Organizing for Innovation-ScienceDirect. *The Strategic Management of Intellectual Capital, 80*(8), 27-37.
Clarkson, M. (1995). A stakeholder framework for analyzing and evaluating corporate social responsibility. *The Academy of Management Review, 20*(1), 92-118.
Coase, Y. P. & Ning, W. (2013). How China became capitalist. *Public Choice, 158*, 289-291.
Coccia, M. (2014). Optimization in R&D intensity and tax on corporate profits for supporting labor productivity of nations. *The Journal of Technology Transfer, 43*(2), 1-23.
Consoli, D. & Mina, A. (2008). An evolutionary perspective on health innovation systems. *Journal of Evolutionary Economics, 19*(2), 297-319.
Costa, C. M. & Mendonça, S. (2019). Knowledge-intensive consumer services: understanding KICS in the innovative global health-care sector. *Research Policy, 48*(4), 968-982.
Crepon, B., Duguet, E., & Mairessec, J. (1998). Research, innovation and productivity: an econometric analysis at the firm level. *Economics of Innovation and New Technology, 7*(2), 115-158.
Creswell, J. W. (2008). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*. Upper Saddle River: NJ Merrill Prentice Hall.
Dakhli, M. & Clercq, D. D. (2004). Human capital, social capital, and innovation: a multi-country study. *Entrepreneurship & Regional Development, 16*(2), 107-128.
David, J. F. (1997). Interviews: an introduction to qualitative research interviewing: Steinar Kvale. Thousand Oaks, CA: Sage Publications.
De, V. R. (2015). China: the 29th most innovative economy on earth. *China Law Blog, 1*(1), 1.
Ding, J. X., Ji, N., Li, X. T., & Sun, X. D. (2012). Analysis of biomedical innovation investment and its policy causes in China: an empirical evaluation based on the current status of innovation investment in China, the United States and Europe. *Science Management Research, 30*(4), 10-14. In Chinese.
Dodgson, M. (2014). *Perspectives on Innovation Management*. Oxford: Oxford Handbooks Online.
Doloreux, D., Freel, M., & Shearmur, R. (Eds.). (2010). *Knowledge-Intensive Business Services: Geography and Innovation.* Burlington, VT: Ashgate.
Donaldson, T. & Preston, L. E. (1995). The stakeholder theory of the corporation: concepts, evidence, and implications. *Academy of Management Review, 20*(1), 65-91.
Dougherty, D. (1992). Interpretive barriers to successful product innovation in large firms. *Organization Science, 3*(2), 179-202.
Edquist, C. & Johnson, B. (1997). *Institutions and Organisations in Systems of Innovation*. Denmark: Aalborg University Press.
Edvardsson, B., Meiren, T., Schäfer, A., & Witell, L. (2013). Having a strategy for new service development – does it really matter? *Journal of Service Management, 24*(1), 25-44.
Eesley, C. & Lenox, M. J. (2006). Firm responses to secondary stakeholder action. *Strategic*

Management Journal, 27(8), 765-781.
Elfenbein, D. M. & Schwarze, M. L. (2020). Qualitative research methods. *Health Services Research,* (01), 249-260.
Ertugrul, M. (2013). Employee-friendly acquirers and acquisition performance. *Journal of Financial Research, 36*(3), 347-370.
Fagerberg, J. (2004). Innovation: a guide to the literature. *Georgia Institute of Technology,* (10), 23-24.
Fagerberg, J. (2010). *The Oxford Handbook of Innovation*. London: Oxford University Press.
Fan, P. (2014). Innovation in China. *Journal of Economic Surveys, 28*(4), 725-745.
Fleming, L. (2001). Recombinant uncertainty in technological search. *Management Science, 47*(1), 117-132.
Freeman, C. (1968). Chemical process plant: innovation and the world market. *National Institute Economic Review, 45*(1), 29-57.
Freeman, C. (1987). *Technology, Policy, and Economic Performance: Lessons from Japan*. London: Printer Publishers.
Freeman, E. & Liedtka, J. (1997). Stakeholder capitalism and the value chain-science direct. *European Management Journal, 15*(3), 286-296.
Gallouj, F. & Windrum, P. (2009). Services and services innovation. *Journal of Evolutionary Economics, 19*(2), 141-148.
Godinhoa, M. M. & Ferreira, V. (2012). Analyzing the evidence of an IPR take-off in China and India. *Research Policy, 41*(3), 499-511.
Gustafsson, A., Verma, R., Kristensson, P., & Witell, L. (2012). Customer cocreation in service innovation: a matter of communication? *Journal of Service Management, 23*(3), 311-327.
Harding, K. (2016). Global health innovation technology models. *Nanobiomedicine, 3*, 7.
Hauser, J., Tellis, G. J., & Griffin, A. (2006). Research on innovation: a review and agenda for marketing science. *Marketing Science, 25*(6), 687-717.
Hipp, C. & Tether, B. S. (2002). Knowledge intensive, technical and other services: patterns of competitiveness and innovation Compared. *Technology Analysis & Strategic Management, 14*(2), 163-182.
Hippel, E. V. (1976). The dominant role of users in the scientific instrument innovation process. *Research Policy, 5*(3), 212-239.
Holmstrom, B. (1989). Agency costs and innovation. *Journal of Economic Behavior & Organization, 12*(3), 305-327.
Huang, C. & Sharif, N. (2015). Global technology leadership: the case of China. *Science & Public Policy, 43*(1), 62-73.
Hung, H. F. (2008). Rise of China and the global overaccumulation crisis. *Review of International Political Economy, 15*(2), 149-179.
Ilavarasan, V. P. & Parthasarathy, B. (2012). Limited growth opportunities amidst opportunities for growth: an empirical study of the inter-firm linkages of small software firms in india. *Journal of Innovation & Entrepreneurship, 1*(1), 4.
Jain, R. K., Triandis, H. C., & Weick, C. W. (2010). *Managing Research, Development, and Innovation*. USA: New Jersey.
Janusz, K. (2012). *Bibliometric Analysis of Business and Economics in the Web of Science*. Germany: Springer Berlin Heidelberg.
Johne, A. & Storey, C. (1998). New service development: a review of the literature and annotated bibliography. *European Journal of Marketing, 32*(3-4), 84-251.
Johnson, D. M., Gustafsson, A., & Witell, L. (2014). The effect of customer information during new product development on profits from goods and services. *European Journal of Marketing, 48*(9/10), 1709-1730.
Kaminski, J. (2011). Diffusion of innovation theory. *Canadian Journal of Nursing Informatics,*

6(2), 1-6.
Kerr, G. (2013). *A Short History of China: From Ancient Dynasties to Economic Powerhouse*. U. K: Oldcastle Books.
Kindström, D., Brashear, T., Kowalkowski, C., & Nordin, F. (2012). Visualizing the value of service-based offerings: empirical findings from the manufacturing industry. *Journal of Business & Industrial Marketing, 27*(7), 538-546.
Makarenko, E. N., Kislaya, E. N., Chukhrova, O. V., & Makarenko, T. V. (2017). Multi-vector accounting concept in modern management. *European Research Studies,* (3B), 512-527.
Koschatzky, K. (2006). Structural couplings of young knowledge-intensive business service firms in a public-driven regional innovation system. *International Studies in Entrepreneurship, 14*, 171-193.
Kumar, N. & Saqib, M. (1996). Firm size, opportunities for adaptation and in-house R & D activity in developing countries: the case of Indian manufacturing. *Research Policy, 25*(5), 713-722.
Kuzu, Ö. H., Gökbel, H., & Güles, H. K. (2013). Developing sustainable relations with internal and external stakeholders in universities: vision and mission views. *Procedia Social and Behavioral Sciences, 103*, 281-289.
Laiyun, S. (2012). *China Statistical Yearbook*. Beijing: China Statistics Press.
Lamberti, M. J., Wilkinson, M., Harper, B., Morgan, C., & Getz, K. (2018). Assessing study start-up practices, performance, and perceptions among sponsors and contract research organizations. *Therapeutic Innovation & Regulatory Science, 52*(5), 572-578.
Lange, D., Lee, P. M., & Dai, Y. (2011). Organizational reputation: a review. *Journal of Management, 37*(1), 153-184.
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.
Lei, X., Wang, X. H., Li, J., Wang, B., Zhao, C., Yu, J. J., et al., (2018). Development and changes of CRO of clinical trials in China. *Chinese Journal of Evidence Based Medicine, 18*(8), 783-786. In Chinese.
Leiponen, A. (2006). Organization of knowledge exchange: an empirical study of knowledge-intensive business service relationships. *Economics of Innovation and New Technology, 15*(4-5), 443-464.
Li, H. R. (2009). *Reliability and validity in qualitative research*. Master Dissertation, Harbin Engineering University. In Chinese.
Liao, D. F. (2019). Current status and countermeasures of the development and application of domestic medical equipment. *Medical Equipment, 32*(4), 48-49. In Chinese.
Lusch, R. F. & Vargo, S. L. (2016). Service-dominant logic: reactions, reflections and refinements. *Marketing Theory, 6*(3), 281-288.
Macinko, J., Starfield, B., & Shi, L. (2003). The contribution of primary care systems to health outcomes within Organization for Economic Cooperation and Development (OECD) countries, 1970-1998. *Health Services Research, 38*(3), 831-865.
Mairesse, J. & Mohnen, P. (2002). Accounting for innovation and measuring innovativeness: an illustrative framework and an application. *American Economic Review, 92*(2), 226-230.
Dejonckheere, M. & Vaughn, L. M. (2019). Semistructured interviewing in primary care research: a balance of relationship and rigour. *Family Medicine and Community Health, 7*(2), 1-8.
Melton, H. L. & Hartline, M. D. (2010). Customer and frontline employee influence on new service development performance. *Journal of Service Research, 13*(4), 411-425.
Melville, N., Kraemer, K., & Gurbaxani, V. (2001). Information technology and organizational performance: an integrative model of IT business value. *MIS Quarterly, 28*(2), 283-322.

Mendonca, S., Crespo, N., & Simoes, N. (2015). Inequality in the network society: An integrated approach to ICT access, basic skills, and complex capabilities. *Telecommunications Policy, 39*(34), 192-207.

Michael, H. (2017). Current practice and perspectives in CRO oversight based on a survey performed among members of the German Association of Research-Based Pharmaceutical Companies (vfa). *GMS German Medical Science, 15*, 1612-3174.

Miles, I. & Kastrinos, N. (1998). Knowledge-intensive business services : users, carriers and sources of innovation. *Second National Knowledge Infrastructure Setp, 44*(4), 100-128.

Miles, I. (2008). Patterns of innovation in service industries. *IBM Systems Journal, 47*(1), 115-128.

Miozzo, M., Desyllas, P., Lee, H., & Miles, I. (2016). Innovation collaboration and appropriability by knowledge-intensive business services firms. *Research Policy, 45*(7), 1337-1351.

Monteverde, K. (1995). Technical dialog as an incentive for vertical integration in the semiconductor industry. *Management Science, 41*(10), 1624-1638.

Muller, E. (2001). Business services as actors of knowledge transformation: the role of KIBS in regional and national innovation systems. *Research Policy, 30*, 1501-1516.

O'Farrell, P. N., Wood, P. A., & Zheng, J. (1998). Regional influences on foreign market development by business service companies: elements of a strategic context explanation. *Regional Studies, 32*(1), 31-48.

Organ, D. W. (1997). Organizational citizenship behavior: it's construct clean-up time. *Human Performance, 10*(2), 85-97.

Oxley, C. (2014). The Chinese economy, past, present and future. *Journal of Economic Surveys, 28*(4), 595-599.

Pavitt, K. (1989). Technological accumulation, diversification and organisation in UK companies, 1945-1983. *Management Science, 35*(1), 81-99.

Power, D. (2005). Supply chain management integration and implementation: a literature review. *Supply Chain Management, 10*(4), 252-263.

Prahalad, C. K. & Hamel, G. (1993). The core competence of the corporation. *Organization of Transnational Corporations*, *11*, 359.

Que, S. & Li, C. H. (2003). Insider control and ownership reform of state-owned enterprises in China. *Journal of Wuhan University of Technology, 16*(3), 266-270. In Chinese.

Ramaswamy, V. & Gouillart, F. (2010). Building the co-creative enterprise. *Harvard Business Review, 88*(10), 109-150.

Rapport, F. (2010). Summative analysis: a qualitative method for social science and health research. *International Journal of Qualitative Methods, 9*(3), 270-290.

Richard, Y. & Chen, Z. Y. (2012). China healthcare sector handbook December 2012: leaders becoming better. *Citigroup Global Markets Inc, 1*(1), 1.

Rickne, A. (2000). New technology-based firms and industrial dynamics: evidence from the technological systems of biomaterials in Sweden. *Ohio and Massachusetts, 1*(1), 1.

Sariola, S., Ravindran, D., Kumar, A., & Jeffery, R. (2015). Big-pharmaceuticalisation: clinical trials and contract research organisations in India. *Social Science & Medicine, 131*, 239-246.

Sau, R. (2003). Innovation and employment: process versus product innovation. *IEEE Transactions on Engineering Management, 50*(2), 237-238.

Schilling, A. & Werr, A. (2009). Managing And Organizing for Innovation in Service Firms : A Literature Review with Annotated Bibliography. Sweden: VINNOVA-Swedish Governmental Agency for Innovation Systems.

Schreyögg, G. & Geiger, D. (2016). The significance of distinctiveness: a proposal for rethinking organizational knowledge. *Organization, 14*(1), 77-100.

Schulteß, P. & Satzger, G. (2010). Innovating for and with your service customers: an assessment of the current practice of collaborative service innovation in Germany. *Procedia Social and Behavioral Sciences, 2*(4), 6503-6515.

Schumpeter, J. A. (1934). The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle (1912/1934). *Transaction Publishers, 1*, 244.

Shams, R., Alpert, F., & Brown, M. (2015). Consumer perceived brand innovativeness: conceptualization and operationalization. *European Journal of Marketing, 49*(9/10), 1589-1615.

Shen, H., Yao, Y. F., Bu, X., & Liu, Y. (2019). Research on the application of fault tree analysis method in medical equipment renewal decision. *Medical and Health Equipment, 304*(10), 85-87+104. In Chinese.

Shi, L. Y., Liu, T., & Zhu, J. X. (2019). Analysis of post-marketing supervision risk and research on supervision countermeasures under the system of drug license holder. *China Pharmaceutical Affairs*, (8), 851-856. In Chinese.

Shi, Y. Z., Hu, H., & Wang, C. (2014). Contract research organizations (CROs) in China: integrating Chinese research and development capabilities for global drug innovation. *Globalization and Health, 10*(1),1-6.

Simmie, J. & Strambach, S. (2006). The contribution of KIBS to innovation in cities: an evolutionary and institutional perspective. *Journal of Knowledge Management, 10*(5), 26-40.

Slater, S. F. & Narver, J. C. (1994). Does competitive environment moderate the market orientation-performance relationship? *Journal of marketing, 58*(1), 46-55.

National Bureau of Statistics. (2010). *Compilation of Statistical Information on the Six Decades of New China*. Beijing: China Statistics Press. In Chinese.

Stough, R. R., Aberman, J., & Baycan, T. (2013). *Knowledge Commercialization and Valorization in Regional Economic Development*. Cheltenham, U. K: Edward Elgar.

Strambach, S. (2001). *Innovation Processes and the Role of Knowledge-Intensive Business Services (KIBS)*. Heidelberg: Physica-Verlag HD.

Tether, B. S. (2005). Do services innovate (differently)? insights from the european innobarometer survey. *Industry & Innovation, 12*(2), 153-184.

Tian, W. D. (2017). *Research on fiscal and tax policies to promote the development of biomedical industry in China*. Doctorial Thesis, Fuzhou University. In Chinese.

Tran, Q., Zhang, C., Sun, H., & Huang, D. (2014). Initial adoption versus institutionalization of e-procurement in construction firms: an empirical investigation in Vietnam. *Journal of Global Information Technology Management, 17*(2), 91-116.

Tsai, W. & Ghoshal, S. (1998). Social capital and value creation: the role of intrafirm networks. *Academy of Management Journal, 41*(4), 464-476.

Tucci, A., Bisceglia, M., Rugge, M., & Tucci, P. (2007). Clinical usefulness of gastric-juice analysis in 2007: the stone that the builders rejected has become the cornerstone. *Gastrointest Endosc, 66*(5), 881-890.

Wang, J. Y., Chen, Z., & Long, S. B. (2016). An empirical analysis of the pulling effect of "Belt and Road" infrastructure investment on China's economy-based on a multi-sectoral input-output perspective. *Journal of Jiangxi University of Finance and Economics*, (2), 11-19. In Chinese.

Wang, X., Yang, H., Duan, Z., & Pan, J. (2018). Spatial accessibility of primary health care in China: a case study in Sichuan Province. *Social Science & Medicine, 209*, 14-24.

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal, 5*(2), 171-180.

Wertime, D. (2014). China lags behind the US in research and development. *Tiempo*, 56-58.

Windrum, P. & Tomlinson, M. (1999). Knowledge-intensive services and international

competitiveness: a four country comparison. *Technology Analysis & Strategic Management, 11*(3), 391-408.

Woetzel, J. (2015). What you need to know about China's surprising strengths in innovation. *Huffington Post, 1*(1), 1.

Wood, G. & Mellahi, K. (2003). The role and potential of stakeholders in "hollow participation": conventional stakeholder theory and institutionalist alternatives. *Business & Society Review, 108*(2), 183-202.

Xia, C. & Gautam, A. (2015). Biopharma CRO industry in china: landscape and opportunities. *Drug Discovery Today, 20*(7), 794-798.

Yan, S. & Chen, Y. W. (2019). Exploring the development strategies of small and medium-sized cro enterprises in pharmaceutical industry. *China Pharmaceutical, 28*(22), 1-4. In Chinese.

Yang, C. J. & Zheng, D. C. (1988). Exploring the problem of economic growth rate in Guangdong. *Southern Economics, 6*, 28-34. In Chinese.

Yeoh, S. C., Hua, H., & Yepes, J. F. (2019). Oral manifestations of systemic diseases and their treatments: a comprehensive approach to clinical practice. *Contemporary Oral Medicine, 1*(1), 1.

Zeng, Z. & Liu, J. (2016). The State Council of the Central Committee of the Communist Party of China issued the "Health China 2030" planning outline. *Bulletin of the State Council of the People's Republic of China,* (32), 5-20. In Chinese.

Zhang, J. L. (2015). Rational development of the management module for the repair and maintenance of medical equipment. *Journal of Mathematical Medicine,* (10), 1535-1537. In Chinese.

Zhang, Y. P. & Deng, M. M. (2008). Enforcing pharmaceutical and biotech patent rights in China. *Nature Biotechnology, 26*(11), 1235-1240.

Zhao, D. X. & Zhao, L.Y. (2002). *A General History of Chinese Economy (Vol. Ten, Part II).* Hunan: Hunan Publishing House. In Chinese.

Zhou, K. Z. (2006). Innovation, imitation, and new product performance: The case of China. *Industrial Marketing Management, 35*(3), 394-402.

Zhou, L., Li, Y., Bosworth, H. B., Ehiri, J., & Luo, C. (2013). Challenges facing translational research organizations in China: a qualitative multiple case study. *Journal of Translational Medicine, 11*(1), 1-13.

Zhou, Y. B. (2007). Opportunities in biopharmaceutical outsourcing to China. *BioProcess International, 5*(1), 16-23.

Zimmer, T. (2014). In the name of world health and development: the world health organization and malaria eradication in India, 1949-1970. *In International Organizations and Development, 1945-1990*, 126-149.

[This page is deliberately left blank.]

Webliography

Xinhua News Agency. (2017, July 19). *Xi Jinping presided over the 37th meeting of the Central Leading Group for Comprehensively Deepening Reform*. Retrieved March 30, 2021, from http://www.gov.cn/xinwen/2017-2007/2019/content_5211833.htm

American Psychological Association. (2011, January 1). *National Bureau of Statistics raises the 2009 GDP growth by 0.1%*. Retrieved March 30, 2021, from https://news.2163.com/2011/0112/2009/2026Q2026GEKBV00014AED.html

Cai, X. (2018, October 10). *Chart of the day: another record year for China R&D spending*. Retrieved March 30, 2021, from https://www.caixinglobal.com/2018-2010-2010/chart-of-the-day-another-record-year-for-china-rd-spending-101333479.html

Beijing Youth Daily. (2016, February 15). *Li Keqiang: Determined to improve the quality of drugs.* Retrieved March 30, 2021, from http://www.ce.cn/xwzx/gnsz/szyw/201602/201615/t20160215_28841640.shtml

Guangming Daily. (2015, May 26). *International capacity cooperation: not simply sell products abroad*. Retrieved March 30, 2021, from https://epaper.gmw.cn/gmrb/html/2015-2005/2026/nw.D110000gmrb_20150526_20150521-20150508.htm

China Report Hall. (2017). *Global Contract Research Organization (CRO) Market Research Report 2016*. Retrieved March 30, 2021, from http://www.chinabgao.com/english/218164.html

First Essay Network. (2015, October 26). *The impact of the"Belt and Road" strategy on China's economic development*. Retrieved March 30, 2021, from https://www.2001lunwen.com/jjgllwdxfw/185167.html

Oriental Wealth Network. (2019, December 4). *Biopharmaceutical Industry 2020 Annual Strategy Report: Looking for the "paradise" in the storm [EB/OL]*. Retrieved Mar 14, 2021, from https://baijiahao.baidu.com/s?id=1651976083817569170

Le Deu, F., Parekh, R., Zhang, F., & Zhou, G. (2012, November 1). Health care in China: entering 'uncharted waters'. Retrieved March 3, 2021, from https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/health-care-in-china-entering-uncharted-waters

Shanghai Securities News. (2019, August 27). *The new version of the Drug Administration Law to release the system dividends - comprehensive incentives for new drug research and development*. Retrieved March 30, 2021, from http://www.flymote.com/stocknews-319079.html

National Medical Products Administration (NMPA). (2018, May 31). *2018 NMPA (CFDA) Medical Device Registration Report*. Retrieved March 30, 2021, from https://chinameddevice.com/nmpa-cfda-medical-device-registration/

Pharmarnet. (2016, April 5). *Tigermed: 600 million yuan acquisition of JETCO Terry quickly cut into medical device CRO*. Retrieved March 14, 2021, from http://news.pharmnet.com.cn/news/2016/2004/2005/441003.html

American Institute of Physics. (2018, July 16). *DOD R&D Chief Mike Griffin suggests US consider cold war stance toward China*. Retrieved March 30, 2021, from https://www.aip.org/fyi/2018/dod-rd-chief-mike-griffin-suggests-us-consider-cold-war-stance-toward-china

Rundo. (2021). *Company overview*. Retrieved March 14, 2021, from http://www.rundo-cro.com/en/about.aspx? Class_ID=2022&id=2248

Sohu. (2020, June 01). *Ge Junbo, academician: from imitation to innovation-the road of innovation of Chinese cardiovascular interventional devices*. Retrieved March 30, 2021, from https://www.sohu.com/a/399123093_120055034

National Bureau of Statistic. (2012, February 22). *Statistical Bulletin on National Economic and Social Development of the People's Republic of China in 2011*. Retrieved March 30, 2021, from https://news.zynews.cn/2012-2002/2022/content_1989803.htm

National Bureau of Statistic. (2013, February 22). *Statistical Bulletin on National Economic and Social Development of the People's Republic of China in 2012*. Retrieved March 30, 2021, from http://district.ce.cn/zt/zlk/bg/201302/201322/t20130222_24135097_20130225.shtml

National Bureau of Statistic. (2019, August 19). *What problems do Chinese doctors still face?* Retrieved March 30, 2021, from https://news.cgtn.com/news/2019-2008-2019/Graphics-What-are-the-problems-Chinese-doctors-still-face--JhrUpek2028hy/index.html

The Fierce Consultant. (2020, June 25). *The Chinese CRO market is predicted to reach $100 billion.* Retrieved March 26, 2021, from https://thefierceconsultant.com/chinese-cro-market-reach-100-billion/

Tigermed. (2021, February 28). *Who are we*? Retrieved March 14, 2021, from http://www.tigermed.net/en/about.php?classid=2032

Cision Pr Web. (2014, March 31). *Aptiv Solutions to be acquired by ICON*. Retrieved Mar 14, 2021, from https://www.prweb.com/releases/2014/2023/prweb11716448.htm

Pharmaceutical Processing World. (2013, August 14). *Quintiles to acquire Novella Clinical*. Retrieved March 14, 2021, from https://www.pharmaceuticalprocessingworld.com/quintiles-to-acquire-novella-clinical/

Yun, X. (2021, March 9). *2020 domestic medical device industry financing analysis: domestic replacement into the golden period Al and robotics or become a new windfall*. Retrieved March 30, 2021, from https://www.sgpjbg.com/baogao/31435.html

Zhang, J. (2017, October 30). *The Chinese CRO market is predicted to reach $100 billion in 2020*. Retrieved March 30, 2021, from http://thefierceconsultant.com/chinese-cro-market-reach-2100-billion/

Annex A: Relevant Figures

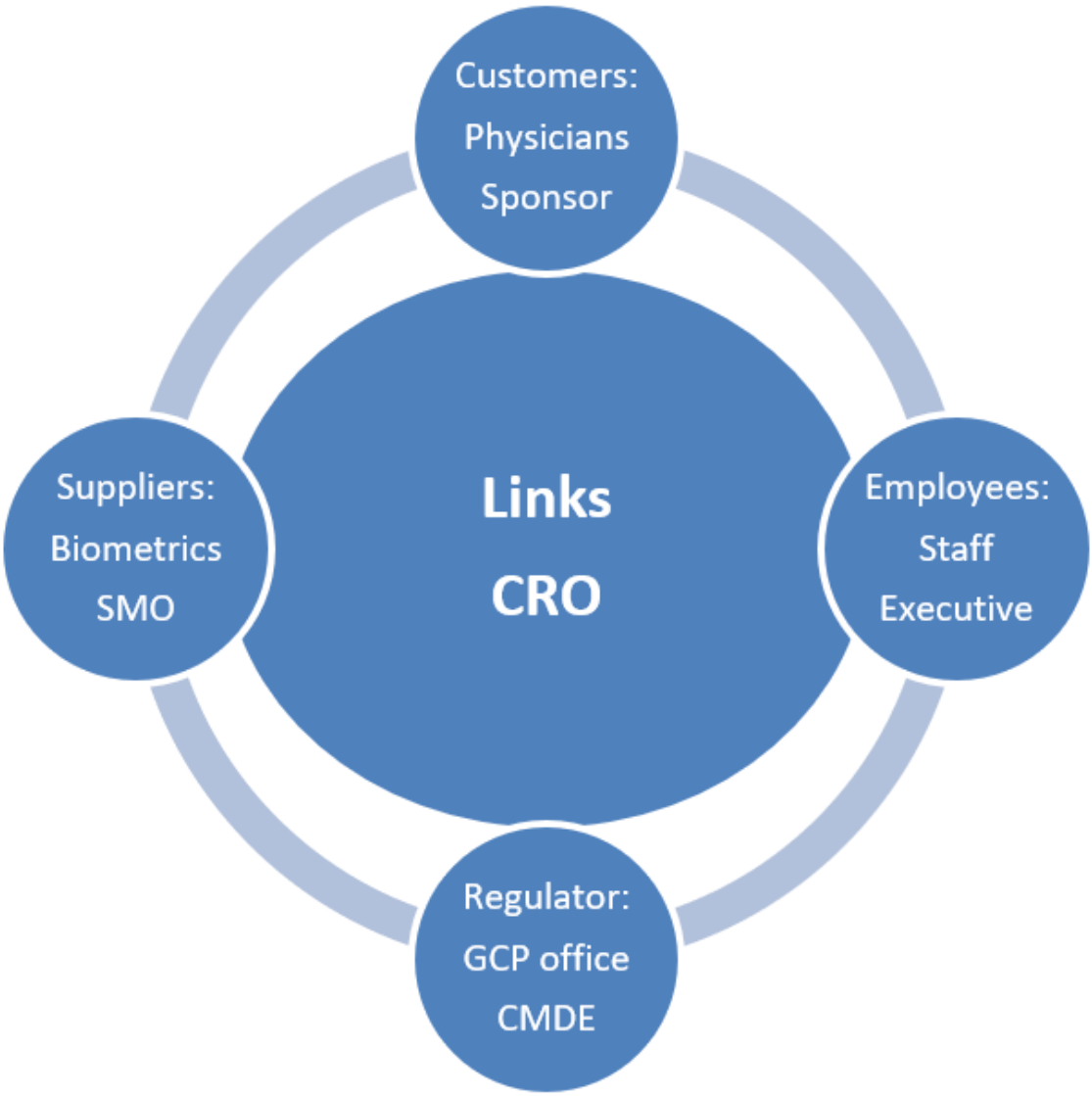

Figure a.1 Links CRO

Notes: Customers (physicians, sponsors/medical device enterprises), Suppliers (biometrics, SMO), regulatory authorities (Ethical Committee, GCP office, CMDE), employees (staff, management), SMO (site management organization), CMDE: Center for Medical Device Evaluation of the National Medical Products Administration, GCP office: Good Clinical Practice office.