

Beyond the Bayh-Dole Effect:
An Entrepreneurial Approach to Building Technology Transfer

Ye Jiang

A dissertation
submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

University of Washington

2018

Reading Committee:

Jane K. Winn, Chair

Sean M. O'Connor

Anita K. Krug

Program Authorized to Offer Degree:

School of Law

©Copyright 2018

Ye Jiang

University of Washington

Abstract

Beyond the Bayh-Dole Effect: An Entrepreneurial Approach to Building
Technology Transfer

Ye Jiang

Chair of the Supervisory Committee:

Professor Jane K. Winn

School of Law

This dissertation seeks to identify possible factors that might explain the relative success or lack of success of efforts to commercialize university-owned inventions by Chinese universities. The analytic framework for this study is based on an entrepreneurial theory that claims that there is no best way to manage an organization, the optimal course of management is contingent upon the internal structure and the external situation.

A review of the relevant literature shows that there has been a continuous effort to assess how internal factors such as university reputation and university initiatives or how external factors such as government policy and local geography could affect

technology transfer. Despite relevance, however, no empirical studies have examined the joint impact that internal and external factors might have on technology transfer. This dissertation makes an original contribution to the literature through empirical research on the joint effect of internal and external factors on technology transfer.

After providing an overview of the Bayh-Dole Act and its effects on technology transfer within U.S. universities, the institutional context of technology transfer in China including market-oriented reforms in the public and private sector in China, and PRC law governing technology transfer are considered. An empirical study of technology transfer activities of 111 Chinese universities using a multi-level regression model is used to assess the internal and external factors that influence technology transfer in China. The implications of that analysis for university technology transfer programs in China and other countries are then considered.

DEDICATION

To my parents, Hao and Xiang

ACKNOWLEDGMENTS

I would not have been able to complete this dissertation without the enormous guidance, support, and encouragement I received from many individuals. First and foremost, I would like to thank my dissertation committee, Professor Jane Winn, Professor Sean O'Connor, Professor Gary Hamilton and Dean Anita Krug.

One could not have a better dissertation chair than Professor Jane Winn. The many hours she spent along with me in discussing the directions, problems, and possibilities of this research are deeply appreciated. Her influence on my life extends far beyond this dissertation, and I am fortunate to have her as an advisor as well as a friend.

Professor Sean O'Connor has been a major influence on my education at the University of Washington. Without his encouragement and generous help, I would not have been admitted to the Ph.D. program of this law school. Much of my thinking on innovation and entrepreneurial university have been shaped by Professor O'Connor's knowledge and wisdom. He is indeed a leading scholar on intellectual property and innovation policy.

I am also deeply honored that Professor Gary Hamilton agreed to be the graduate school representative on my dissertation committee. Professor Hamilton is a world-renowned scholar in the field of sociology and Chinese studies, and I am especially grateful for the invaluable insights he offered to me on this research.

I took the course in securities regulation with Dean Anita Krug during the 2014-2015 academic year. I am grateful for her mentorship on this research that complemented the guidance I received from the other members of the committee. Her personal story of completing a dual Ph.D. degree at Harvard Kennedy School and a J.D. degree at Harvard Law School also inspires me to overcome any obstacles to achieve my academic dreams.

I have also benefited from the insights of many other scholars and colleagues. Professor Sean Pager, Professor Adam Candeub, Professor Bruce Bean, Professor Jennifer Carter-Johnson, Professor Michael Lawrence, and Professor Haifeng Qian helped shape this dissertation at its early stages. Professor Kyle Crowder, Professor Michael Townsend, Professor Dongsheng Zang, Professor Zahr Said, Dr. Ted Westling, Dr. Todd Wildermuth, and Dr. Bowen Wang deepened my understanding of empirical methods for this research.

Ms. Fiona Wills at the Center of CoMotion at the University of Washington and Ms. Jiaoli Li at the Office of Technology Transfer at Tsinghua University also provided me with invaluable guidance on several occasions early in the project.

I also greatly value the collegiality I have experienced among the staffs and students here at UW Law and many have had lasting influence on my work, notably Dr. Poliang Chen, Mr. Jay Hong Jiang, Ms. Jennifer Fan, Ms. Mie Murazumi, Dr. Melissa Kane, Dr. Tidarat Sinlapapiromsuk, Ms. Bingyan Jiang, Ms. Chris Lee, Mr. Pontus Niklasson, Dr. Sipim Wiwatwattana, Dr. Andy Omara, Dr. Hilary Soderland, Dr. Dayoung Chung, Dr. Watcharachai Jirajindakul, Dr. M. Bashir Mobasher, Ms. Dawn Bell, Ms. Yiwen Wang, Mr. Qichen Qing, Mr. Yutaka Ishida, Ms. Joanna Grace, and Ms. Sophie Jin.

I would like to thank my relatives and friends who have made this dissertation possible. I am deeply indebted to my parents for their unconditional love and support. My little cousin, Qiuyu Jiang (now a medical student), and my two beautiful nieces, Beiqi Ye and Yichu Lin (born during my doctorate study), have brought so much joy, laughter, and happiness into my life. My family has been especially supportive of my completing this research while far away from my hometown.

I am grateful to Dr. Sichun Sun, Ms. Lingxue Wu, Ms. Jingyi Zhuge, Mr. Lixing Xu, Mr. Daniel Larson, Ms. Mengxi Chen, Ms. Linda Oswald, Dr. Zhen Xu, Ms. Liuyi Jiang, Ms. Yangwen Fang, Ms. Qing Zhao, Ms. Mingxia Zang, Pastor Alex Cui, Ms. Qianmin Zhan, Mr. Alan Barr, Mr. Xiao Ma, Ms. Jiajia Ge, Mr. Joohan Lee, Mr. Peter Chen, Mr. Anthony Garcellano, Mr. Yu Jin, Ms. Yonglu Chen, Ms. Andrea Tu, Mr. Allen Tu, Dr. Chen Zou, Ms. Xu Guo, Ms. Ruiling Zhang, Mr. Richard Zheng, Mr. Zhiying Zheng, Ms. Wendy Dai, Ms. Juexiao Guo, Ms. Fei Xie, Ms. Qiuping Zhuo, Mr. Yuze Zheng, Dr. Shawn Hagan, Ms. Jiadan Song, Ms. Yujie Guo, Mr. Fanghua Qiao, Mr. Xin Zhou, Ms. Vicky Pan, Dean Joan Howarth, Ms. Le Chen, Ms. Siyu Lu, Mr. Jun Zhao, Ms. Lu Xue, Ms. Sophia Feng, Dr. Huaiwen He, Ms. Yuge Tong, Ms. Xinyi Zhou, Mr. Rundong Liu, Mr. Xinhong Hu, Ms. Peiming Yu, Dr. Fei Xu, Ms. Hua Lu, Mr. Yuyang Wang, Mr. Kelvin Wu, Ms. Vienna Weber, Mr. Jeff Cowan, Mr. John Wang, Mr. Jared Nelson, Ms. Shuhua Fu, Ms. Sarah Dunaway, and Dr. William Ho for their love and friendship to me.

I also gratefully acknowledge financial support for this dissertation research by the UW Office of Admissions, China Scholarship Council, and the UW Law School Ph.D. Program. This dissertation would not have been possible without the research fellowship from these institutions. All errors in this dissertation research are my own.

TABLE OF CONTENTS

	Page
Chapter 1 Introduction	1
1.1 University Technology Transfer	1
1.2 An Entrepreneurial Approach	4
1.3 Organization of the Dissertation	7
Chapter 2 Literature Review and Methodology	8
2.1 Theoretical Framework	8
2.2 Literature Review	11
2.2.1 Knowledge Spillover Theory	11
2.2.2 Empirical Studies in China	16
2.3 Research Questions	20
2.4 Methodology	21
Chapter 3 The Bayh-Dole Act and Technology Transfer in the U.S.	23
3.1 Introduction	23
3.2 The Bayh-Dole Act	26
3.3 The <i>Diamond v. Chakrabarty</i> Case	30
3.4 Technology Transfer Offices	34
3.5 New Trends of U.S. Universities	39
Chapter 4 Institutional Context of Technology Transfer in China	43
4.1 Background	43
4.2 Three-Stage Institutional Reforms	47
4.2.1 Republic China (Before 1949)	47
4.2.2 The Mao-Era (1949-1979)	49
4.2.3 Market-Oriented Reforms (1979-present)	52
4.3 Contemporary Technology Transfer Market	57
4.3.1 Technology Contracts	59
4.3.2 Patent Licensing	62
4.3.3 Equity Investment	66
4.4 Case Study: China's Biomedical Innovation	72

Chapter 5 Technology Transfer Laws and Cases in China	78
5.1 Introduction	78
5.2 Intellectual Property	85
5.2.1 Patentability of Genes	91
5.2.2 Experimental Use Exception	101
5.2.3 Employee Inventions	117
5.3 Technology Contracts	124
5.4 Criminal Prosecution	132
5.5 Tax Regulations	136
Chapter 6 An Empirical Study on Technology Transfer	140
6.1 Sample	140
6.2 Measures	145
6.2.1 Dependent Variable	145
6.2.2 Independent Variable	146
6.3 Model Specification	154
6.4 Results	161
6.4.1 Descriptive Statistics	162
6.4.2 Regression Results	165
6.5 Discussions and Implications	167
6.5.1 Implications for Practice	170
6.5.2 Implications for Future Research	171
Chapter 7 Conclusion	175
Appendix	184
References	228

LIST OF TABLES

Table	Page
Table 3.1 The U.S. Federal R&D Investment 1955-1985	28
Table 3.2 Ranking of U.S. University Technology Licensing	40
Table 3.3 University Technology Transfer Office Name Changes	42
Table 4.1 Western-sponsored Colleges in China 1864-1924.....	48
Table 4.2 Technology Transfer Contracts by Tsinghua University	61
Table 5.1 Technology Transfer Laws and Regulations 1949-2016.....	83
Table 5.2 Value-Added Tax Rate for University For-Profit Activities	139
Table 6.1 Technology Transfer Contracts by Vocational Schools	142
Table 6.2 Variables Included in This Dissertation	151
Table 6.3 Summary Statistics for Variables in the Regression.....	157
Table 6.4 Regression Results with Multilevel Variables Included	158
Table 6.5 Distribution of Two Sample Independent Variables	162

LIST OF FIGURES

Figure 2.1 A Conceptual Framework of Technology Transfer System	10
Figure 3.1 The Number of Issued DNA Patents in the U.S. 1971-2013	33
Figure 3.2 The Growth of Technology Transfer Offices in the U.S.	36
Figure 3.3 An Expanded Model of Technology Transfer	38
Figure 4.1 Estimated Gross Domestic R&D Spending by the U.S. and China	46
Figure 4.2 Distribution of Innovation Activities Under Central Planning	51
Figure 4.3 The Percentage of University R&D Spending in Basic Research	58
Figure 4.4 Patent Licensing Revenues by China Universities 2009-2014	66
Figure 4.5 Spatial Distribution of Venture Capital Offices and Investments	72
Figure 5.1 The Number of Intellectual Property Litigations in China	90
Figure 5.2 Patent (ZL200810219969.2): A Water-Pump Conduit Assembly	113
Figure 5.3 Patent (ZL200920059397.6): A Water Purifying Device	114

Chapter 1 Introduction

1.1 University Technology Transfer

Technology transfer is concerned with bringing technology from the source of innovation to the marketplace.¹ From the newest consumer gadgets to the explosive growth in artificial intelligence capability, technological innovation enhances our lives and drives global economic growth. One vibrant source of new technology is a university.

Historically, universities have been a critical enabler on national well-being for qualifying the human capital and for producing new knowledge. In the last thirty years, however, the role of higher education institutions has changed significantly.² Today, universities are regarded as having a third mission, which includes stimulating industrial innovation and promoting local economic growth.³

¹ U.S. Licensing Activity Survey: FY2008, at 7. ASSOCIATION OF UNIVERSITY TECHNOLOGY MANAGERS, accessible online at <https://www.autm.net/> (last visited on Jan. 2, 2018).

² In the early 1980s, universities as entrepreneurial entities became an accepted concept, and the literature began debating the role of higher education institutions in economic growth and social change in greater depth. See e.g., Henry Etzkowitz, *Entrepreneurial Scientists and Entrepreneurial Universities in American Academic Science*, MINERVA 21 (1983) 1573-1871. BURTON R. CLARK, *CREATING ENTREPRENEURIAL UNIVERSITIES: ORGANIZATIONAL PATHWAYS OF TRANSFORMATION: ISSUES IN HIGHER EDUCATION*. (Esis Publishing, 1998). DEREK BOK, *BEYOND THE IVORY TOWER: SOCIAL RESPONSIBILITIES OF THE MODERN UNIVERSITY*. (Harvard University Press, 1982). EUGENE P. TRANI & ROBERT D. HOLSWORTH, *THE INDISPENSABLE UNIVERSITY: HIGHER EDUCATION, ECONOMIC DEVELOPMENT, AND THE KNOWLEDGE ECONOMY*. (Rowman & Littlefield, 2010). DENNIS P. LEYDEN & ALBERT N. LINK, *PUBLIC SECTOR ENTREPRENEURSHIP: U.S. TECHNOLOGY AND INNOVATION POLICY*. (Oxford University Press, 2015).

³ JENNIFER WASHBURN, *UNIVERSITY INC.: THE CORPORATE CORRUPTION OF HIGHER EDUCATION*. (Basic Books, 2006). DEREK BOK, *UNIVERSITIES IN THE MARKETPLACE: THE COMMERCIALIZATION OF HIGHER EDUCATION*. (Princeton University Press, 2009). DAVID AUDRETSCH, *THE ENTREPRENEURIAL SOCIETY*. (Oxford University Press, 2007). David Audretsch, *Scientific Entrepreneurship: The Stealth Conduit of University Knowledge Spillovers*. 21 GEORGE MASON LAW REVIEW 1015-1026 (2014). ELIZABETH BERMAN, *CREATING THE MARKET UNIVERSITY: HOW ACADEMIC SCIENCE BECAME AN ECONOMIC ENGINE*. (Princeton University Press, 2015).

More specifically, the United States has long been a leader in the university's economic development role.⁴ In 1980, the U.S. government issued the forward-looking Bayh-Dole Act, which for the first time, empowered universities and federal research institutions to retain ownership of their inventions and commercialize public-funded projects in the marketplace.⁵ The Bayh-Dole has brought a remarkable change in the U.S. technology transfer industry. According to the AUTM, between 1980 and 2002 alone, member U.S. universities have generated a tenfold increase in patent licensing, launched 2,200 university spin-offs, created over 260,000 new jobs and contributed at least \$40 billion annually to the U.S. economy.⁶

China has mightily increased its capacity in university research while encouraging scientists to patent and commercialize their discoveries. In recent years, China has shown considerable interests in university research and development with the hopes of developing an indigenous new technology pipeline for industry innovation. Since 2012, the new political leadership of China has placed science, technology, and innovation at the core of the reform of its economic system.⁷ The central government of China has issued the Implementation Rules for Deepening the Science and Technology System

⁴ Michael Young, *Industry, Academia, and Government Collaboration: A Game Changer for U.S. Economic Future*, BUSINESS HORIZON QUARTERLY, Issue 7 (US Chamber of Commerce Foundation, 2013) at 16.

⁵ Rosa Grimaldi et al., *30 Years After Bayh-Dole: Reassessing Academic Entrepreneurship*, 40 RESEARCH POLICY 1045-1057 (2011). DAVID MOWERY ET AL., *IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH-DOLE ACT*. (Stanford University Press, 2004). Gene Quinn, *Exclusive Interview: Senator Birch Bayh on Bayh-Dole at 30*. IPWATCH.COM (Nov. 7, 2010), accessible online at <http://www.ipwatchdog.com/> (last visited Jan. 3, 2018).

⁶ U.S. Licensing Activity Survey: FY2015. ASSOCIATION OF UNIVERSITY TECHNOLOGY MANAGERS.

⁷ *UNESCO Science Report: Towards 2030*, United Nations (2015), at 14, accessible online at <http://unesdoc.unesco.org/> (last visited on Apr. 12, 2018).

Reform,⁸ which propose thirty-two administrative measures to promote innovation and technology transfer in China.⁹

The growing acceptance of the importance of university technology transfer has been reflected in burgeoning policy and research publications. Despite the varying degrees of such policy initiatives, however, most of the government initiatives in China cite the Bayh-Dole Act as one justification. Although the evidence on the Bayh-Dole Act suggests that its “catalytic” effects on technology transfer are limited, the Chinese government considers adopting multiple policies and laws emulating the provisions of the Bayh-Dole Act.¹⁰ The conception of the Bayh-Dole Act as the “golden goose¹¹” for the growth of the U.S. innovation industry has been so popular among lawmakers and university leaders in China.

But a critical question has never been asked that whether the Bayh-Dole system can be fit within the China context. The optimistic views of Chinese lawmakers mainly come from a misreading of the limited evidence concerning the effects of the Bayh-Dole Act,

⁸ Cheng Yingqi, *State Council offers science, tech plan*, CHINA DAILY (Sep. 25, 2015), accessible online at <http://www.chinadaily.com.cn/> (last visited on Jan. 03, 2018).

⁹ She Huimin, *A Summary of the Science and Technology System Reform in China since 2012: Create A New Engine for An Innovation-Driven Economy*, ECONOMY DAILY (Sep. 24, 2017), <http://www.most.gov.cn/> (last visited on Jan. 28, 2018).

¹⁰ In 2016, the Prime Minister of China, Mr. Li Keqiang, requires his cabinet to closely study why and how the Bayh-Dole Act transforms the U.S. high-tech industry in the 1980s. See Editor, *The Journey of Innovation: What Do You Know About the Bayh-Dole Act Before Prime Minister Li Praises It?* NEWS CHINA (June 4, 2016), <http://news.china.com.cn/> (last visited on Nov. 20, 2017).

¹¹ The term “golden goose” is first used to describe the Bayh-Dole Act in *The Economist* magazine. The Bayh-Dole Act itself has been touted by *The Economist* as “perhaps the most inspired legislation to be enacted in America over the past half-century.” See Editor, Opinion: *Innovation’s Golden Goose*, THE ECONOMIST (Dec. 12, 2002), <http://www.economist.com/> (last visited on Jan. 31, 2018).

along with a misunderstanding of the factors that have encouraged the long-standing and interactive relationship between U.S. universities and industry innovation.

Selective “borrowing” from another nation’s policies for implementation in an institutional context that differs significantly from that of the country being emulated might not suffice the policy proposals.¹² Besides, the success of technology transfer depends on various factors not limited to the legal context. This dissertation is an attempt to thoroughly examine the possible factors that might have an impact on technology transfer.

1.2 *An Entrepreneurial Approach*

The entrepreneurship literature can be traced back to Schumpeter who defines innovation broadly to include both putting inventions into practice and carrying out any new combination of productive resources that amount to “the setting up of a new production function.”¹³

In Schumpeter’s usage, a distinct feature of innovation is associated with the commercialization of inventions. Innovation is not an only *invention* but also the new commodity, the new technology, the new source of supply and the new type of organization.¹⁴ This dissertation adopts the Schumpeterian perspectives on innovation, which recognize the importance of change for economic growth.

¹² David Mowery & Bhaven N. Sampat, *The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments?* 30 JOURNAL OF TECHNOLOGY TRANSFER 115 (2005).

¹³ JOSEPH SCHUMPETER, *BUSINESS CYCLES*. (New York: McGraw Hill, 1939) at 87.

¹⁴ JOSEPH SCHUMPETER, *CAPITALISM, SOCIALISM AND DEMOCRACY*. (New York: Harper & Brothers, 1942) at 83, 132. In his doctorate dissertation *The Theory of Economic Development*, Schumpeter coined a

Modern universities are under growing pressure to provide a platform for technological innovations and ensure faculty and staff have sufficient opportunities and resources to reduce their inventions into the marketplace. There are many ways in which universities can make a positive contribution to technology commercialization, but each institution needs to organize and implement its technology transfer programs in an optimal manner that best suits its own resources and environment.

An entrepreneurial approach encourages academic technology transfer and streamlines the identification, protection, and commercialization of university intellectual property in an integrated mode. It is believed that only through the cultivation of institutional arrangements and supporting structures and policies can a university hope to break down the walls between ivory towers of innovation and the commercial world.

The governance of technology transfer offices (TTO) is of central importance in achieving and sustaining technology transfer success within universities. Given that academics may not be aware of the market opportunities that are available to their invention, it is imperative that the TTO professionals guide and help them invest in commercialization activity.

Promoting supportive programs and service such as developing an entrepreneurial culture on campus, a commitment to student leadership training, and an ability to attract

new phrase to describe the dynamic process of innovation, what called “creative destruction.” For Schumpeter, “creative destruction” is the same as the process of industrial mutation, that “incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one.” Schumpeter believes that capitalism is not a stationary process that administers existing structures but rather a dynamic process that creates, destroys and renews the existing structures. See also, JOSEPH SCHUMPETER, *THE THEORY OF ECONOMIC DEVELOPMENT*. (Cambridge: Harvard University Press, 1934) at 62-68.

substantial financial resources to fund leading-edge science and technology research is also crucial for technology commercialization.

There is also a need to develop coordinated structures to build an innovation ecosystem to support the rollout of engaged technology transfer programs across the universities. The right structures will enable commercial networks to emerge between academics, industries, and venture capitalists.¹⁵

Regional context provides another variable. Local connections between the university, industry, and government can provide the university with increased research funds and access to market-related opportunities.¹⁶ The essential ingredients of regional context for technology transfer include government policy, legal environment, financing community, and geographic proximity.

While all these factors contribute to a workable model of technology transfer, there is an excellent variation in resources, effort, and outcomes across universities. This dissertation is an attempt to identify the possible factors that could explain the relative success or lack of success of a university in technology transfer.

It is hoped that university administrators, technology transfer professionals, or even the policymakers can learn from this dissertation. However, it must be pointed out that

¹⁵ Bruce Katz & Julie Wagner, *The Rise of Innovation Districts: A New Geography of Innovation in America* (Brookings Institute, May 2014). Robert Huggins & Piers Thompson, *Entrepreneurship, Innovation and Regional Growth: A network Theory*, *SMALL BUSINESS ECONOMY* (45): 103-128 (2015). Heike Mayer, *Entrepreneurship in a Hub-and-Spoke Industrial District: Firm Survey Evidence from Seattle's Technology Industry*, *REGIONAL STUDIES* (47) 10: 1715-1733 (2013).

¹⁶ BRIAN CUNNINGHAM & JAMES HARNEY, *STRATEGIC MANAGEMENT OF TECHNOLOGY TRANSFER: THE NEW CHALLENGES ON CAMPUS*. (Oak Tree Press, 2006).

efforts at transposing or replicating single elements of a technology transfer model may only have limited success, given the dynamics lied behind the technology commercialization process.

1.3 Organization of the Dissertation

This dissertation is organized into seven chapters. It begins with an introduction of the research background. Chapter 1 introduces the origin and the objective of this dissertation. Chapter 2 summarizes the conceptual and empirical literature on technology transfer. Chapter 3 provides an overview of the Bayh-Dole Act and its effects on technology transfer within U.S. universities. Chapter 4 examines the institutional context of technology transfer in China including market-oriented reforms in the public and private sector. Chapter 5 discusses the legal provisions and judicial cases related to technology transfer in China. This dissertation then takes an empirical study drawing on data from 111 Chinese universities. Chapter 6 uses a multi-level Poisson regression model to assess the strength and weakness of factors that influence technology transfer. Finally, this dissertation analyzes the empirical results and presents some policy implications for future research. Chapter 7 makes a closing remark on this dissertation.

Chapter 2 Literature Review and Methodology

2.1 Theoretical Framework

Over the past several years, university entrepreneurship has become one of the most widely studied topics in the literature of technology transfer.¹⁷ Despite all the research that has been conducted, there have been relatively few systematic attempts to analyze the dynamics underlying the domain of technology transfer and the factors that influence the success or lack of success of efforts to commercialize university-owned inventions.

This dissertation seeks explanations of the dynamic factors that contribute to the relative success of university technology transfer. The author of this dissertation wants to know why some universities are more successful than others in technology transfer and how to improve technology commercialization programs within universities. For this aim, this author of this dissertation borrows a theory from the entrepreneurship literature for modeling the dynamics of university technology transfer.

The theoretical framework for this dissertation is based on Shane's entrepreneurial theory (2003), retaining that individual factors and environmental factors are jointly the most important determinants of entrepreneurial process¹⁸, or on Aldrich's organizational theory (2008), claiming that there is no best way to manage an organization, the optimal course of management is contingent upon the internal structure and the external

¹⁷ THOMAS J. ALLEN & RORY P. O'SHEA, *BUILDING TECHNOLOGY TRANSFER WITHIN RESEARCH UNIVERSITIES: AN ENTREPRENEURIAL APPROACH*. (Cambridge University Press, 2014).

¹⁸ SCOTT A. SHANE, *A GENERAL THEORY OF ENTREPRENEURSHIP: THE INDIVIDUAL-OPPORTUNITY NEXUS*. (Edward Elgar Publisher, 2004).

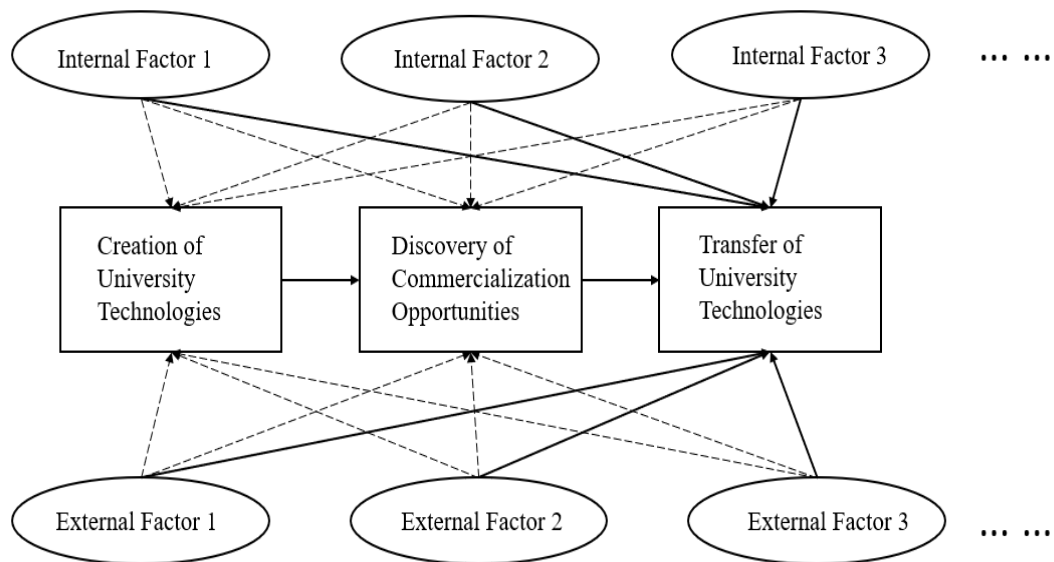
environment.¹⁹ Figure 2.1 shows a conceptual model of technology transfer based on an entrepreneurial approach. The internal or external factors in this diagram are merely symbols of those most critical determinants in technology transfer.

It can be seen from prior studies that the success of university technology transfer is related to the institutional arrangements such as patent regulations, resources allocation, and university reputation. It is also important to recognize that university technology transfer cannot be understood in isolation from external factors. The development of an entrepreneurial university concerning technology transfer requires considerable planning and external support in addition to the university's internal efforts.²⁰ External factors such as geographic distance, industry ties, and government policy might have an impact on university technology transfer. Chapter 6 discusses these factors in detail.

¹⁹ HOWARD E. ALDRICH, *ORGANIZATIONS AND ENVIRONMENTS*. (Stanford University Press, 2008).

²⁰ ALLEN & O'SHEA, *supra* note 15 at 356.

Figure 2.1 A Conceptual Framework of Technology Transfer System



Source: Created by the author.

2.2 Literature Review

2.2.1 Knowledge Spillover

Given the increasing need to transfer academic research and technology discoveries into the marketplace, universities are playing an increasingly important role in theories of regional economic development. Knowledge spillovers have been widely used to explain the increased rate of innovation that is found in technological clusters.²¹

The first study, led by Marshall in 1920, has discussed the knowledge spillover effect as one of the incentives for firms to cluster in a spatial context.²² Solow (1957) relates knowledge spillovers to economic growth and identifies an exogenous change of technological knowledge as the primary driving force of productivity growth.²³ Mansfield (1977) acknowledges that knowledge is not only given by external sources but also the result of education and R&D investments.²⁴

These conceptual studies are consistent with the empirical results. Jaffe (1986) finds compelling evidence to support the theory of geographic proximity and the knowledge spillover effects of universities on high-tech industry.²⁵ Saxenian (1994) compares the Silicon Valley and Boston Route 128 to show that knowledge exchanges and social

²¹ Knowledge spillovers is a pattern that occurs when knowledge that shared for an event or a project ultimately generates additional opportunities for application in other settings. It serves as the catalyst for the development of new ideas and new applications, often in ways that were never anticipated initially.

²² ALFRED MARSHALL, *PRINCIPLES OF ECONOMICS: AN INTRODUCTORY VOLUME*. (Macmillan, 1920 ed.).

²³ Robert M. Solow, *Technical Change and the Aggregate Production Function*, *THE REVIEW OF ECONOMICS AND STATISTICS* 39 (3) (1957) 312-320.

²⁴ Edwin Mansfield et al., *Social and Private Rates of Return from Industrial Innovations*, *THE QUARTERLY JOURNAL OF ECONOMICS* 91(2) (1977) 221-240.

²⁵ Adam Jaffe, *Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value*, *AMERICAN ECONOMIC REVIEW* 76(5) (1986) 984-1001.

networks are essential for creating new firms.²⁶ Maurseth and Verspagen (2002) analyzes the geographic location of patent citations between European regions to show that knowledge spillovers are geographically localized.²⁷ Cassiman (2009) finds empirical evidence to support that a close linkage to university research could enhance the innovation performance of a private company.²⁸

Acs (2009) examines knowledge spillovers from the perspective of entrepreneurship. He argues that a context that is rich in knowledge generates more entrepreneurial opportunities which ultimately leads to higher economic growth rate.²⁹ By commercializing knowledge spillovers from industry incumbents or research institutions, entrepreneurs not only serve as a conduit for the spillover of knowledge, but also for the ensuing innovative activity and enhanced economic performance.³⁰

Qian (2010) extends the literature of knowledge spillovers by introducing absorptive capacity³¹ as a critical determinant of knowledge-based entrepreneurial activity.³² The basic idea of absorptive capacity is that the extent to which entrepreneurship transmits knowledge spillovers into economic performance depends not

²⁶ ANNALEE SAXENIAN, *REGIONAL ADVANTAGE: CULTURE AND COMPETITION*. (Harvard University Press, 1994).

²⁷ Per B. Maurseth & Bart Verspagen, *Knowledge Spillovers in Europe: A Patent Citations Analysis*, 104 *THE SCANDINAVIAN JOURNAL OF ECONOMICS* 531-46 (2002).

²⁸ Bruno Cassiman et al., *Diversity of Science Linkages and Innovation Performance: Some Empirical Evidence from Flemish Firms*, Economics Discussion Paper (unpublished).

²⁹ Zoltan J. Acs et al., *The Knowledge Spillover Theory of Entrepreneurship*, *SMALL BUSINESS ECONOMICS* 32 (2009) 15-30.

³⁰ Id.

³¹ Wesley M. Cohen & Daniel A. Levinthal, *Absorptive Capacity: A New Perspective on Learning and Innovation*, *ADMINISTRATIVE SCIENCE QUARTERLY* 35(1) (1990) 128-152.

³² Haifeng Qian & Zoltan J. Acs, *An Absorptive Capacity Theory of Knowledge Spillover Entrepreneurship*, *SMALL BUSINESS ECONOMICS* 40(2) (2013) 185-197.

only on the productivity of knowledge but also on the entrepreneurial absorptive capacity which defined as “the ability of an entrepreneur to understand new knowledge, recognize its value and commercialize it by creating a firm.³³”

Based on this theory, technology transfer would require an entrepreneur not only have the scientific knowledge to understand those technologies, but also a certain level of business knowledge to recognize the market or profit opportunities behind them. However, there is a different view that excludes transferred technology from the scope of knowledge spillovers. Fallah et al. (2004) argue that knowledge spillovers are the transmission of knowledge beyond the intended boundary while knowledge transfer is an exchange of knowledge within the intended people or organizations. This argument overlooks the fact that knowledge transfer is a sub-concept of knowledge spillovers that can be exchanged at individual, firm or national level, be it intended or unintended.

Tacit Knowledge

Most studies on knowledge spillovers have focused on the exchange of explicit knowledge, such as patent citations. Tacit knowledge could play a significant role in knowledge spillovers as well. Polanyi (1967), a philosopher of science, once observed, “*We can know more than we can tell.*³⁴” This observation uncovered the subtle but crucial

³³ Id.

³⁴ “*I shall reconsider human knowledge by starting from the fact that we can know more than we can tell. This fact seems obvious enough; but it is not easy to say exactly what it means.*” See MICHAEL POLANYI, *THE TACIT DIMENSION* (University of Chicago Press, 1967). See also, MICHAEL POLANYI, *PERSONAL KNOWLEDGE: TOWARDS A POST-CRITICAL PHILOSOPHY* (University of Chicago Press, 1958); MICHAEL POLANYI, *SCIENCE, FAITH AND SOCIETY* (University of Chicago Press, 1964).

contribution of “tacit knowing” to the generation of social and scientific discoveries, where tacit knowledge is personal to an individual and cannot be put into words.³⁵

Based on the “tacit” and “explicit” taxonomy of knowledge, Teece (1986) argued from a business perspective that technology transfer includes information publicly available in the patent and the transfer of know-how, as well as the complementary assets and other peripheral disclosures.³⁶ He also argued that successful transfer of technology that drives innovation generally involves not simply patenting but also business transactions that exchange other types of valuable information assets.³⁷ This is in line with the claim by Von Hippel (1995) that highly contextual and uncertain knowledge, what he refers to as “sticky knowledge,” is best transmitted via face-to-face interactions.³⁸

These theories are consistent with the empirical study of Arora (1996), who conducted an empirical analysis of tacit knowledge based on evidence from 144 technology transfer contracts in India.³⁹ The results of this study showed that the successful transfer of know-how depends on the strength of the protection of the concomitant technology in the bundle license, and upon the connection between the know-how and the technology that is covered by the patent. It further suggests that, for

³⁵ In the technical context, tacit knowledge and know-how are often used interchangeably. See Margaret Chon, *Sticky Knowledge in Copyright*, 2011 WISCONSIN LAW REVIEW 177-217 (2011) at 187.

³⁶ David J. Teece, *Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy*, RESEARCH POLICY 15 (6) (1986) 285-305. JAMES BESSEN, *LEARNING BY DOING: THE REAL CONNECTION BETWEEN INNOVATION, WAGES, AND WEALTH*. (Yale University Press, 2015).

³⁷ Mark A. Lemley & Robin Feldman, *Patent Licensing, Technology Transfer & Innovation* (unpublished paper 2016) (on file with the author).

³⁸ Eric Von Hippel, “*Sticky Information*” and the Locus of Problem Solving: Implications for Innovation, 40 MANAGEMENT SCIENCE 429-439 (1994).

³⁹ Ashish Arora, *Contracting for tacit knowledge: the provision of technical services in technology licensing contracts*, JOURNAL OF DEVELOPMENT ECONOMICS 50 (1996) 233-256.

the transfer of technologically sophisticated know-how, there is a need for both patent rights and other warrantee institutions.

Babstista and Swann (1998) examined the relationship between tacit knowledge and geographic clusters. They argued that learning from new technologies can only happen through repeated use and informal personal contacts with the innovators, mainly when a technology is in the early stages of development.⁴⁰ They further reiterate that so long as much technological knowledge has a tacit nature and cannot be codified through plans, instructions or scientific articles, it seems reasonable to expect a greater geographic concentration of innovators.⁴¹

Mendi (2007) conducted an empirical study on the transfer of know-how based on a sample of over one hundred technology-importing contracts signed by Spanish firms in 1991.⁴² Mendi's research found that contract duration had a positive effect on the likelihood of transferring tacit knowledge to unaffiliated firms. Mendi explained the phenomenon that companies wanted to reduce the occurrence of moral hazard problems in the transfer of tacit knowledge by establishing a long-term contractual relationship.⁴³

Lee (2012) addressed tacit knowledge from the perspective of "patent relations," a new term referred to the transfer of tacit knowledge in the commercialization of university

⁴⁰ Rui Baptista & Peter Swann, *Do firms in clusters innovate more?* 27 RESEARCH POLICY 525-540 (1998).

⁴¹ Id. at 528.

⁴² Petro Mendi, *Contractual implications of international trade in tacit knowledge*, APPLIED ECONOMICS 39 (2007) 1173-1183.

⁴³ Benjamin E. Hermalin & Michael L. Katz, *Moral Hazard and Verifiability: The Effects of Renegotiation in Agency*, ECONOMETRICA 59 (1991) 1735-1753.

inventions.⁴⁴ He argued that while exclusive patent rights may be essential to motivate private investment in commercializing university technologies, they are often insufficient to transfer technology. In many cases, direct inventor involvement and tacit knowledge transfer are more critical to the success of technology commercialization.

2.2.2 Empirical Studies in China

Scholarly research on the role of universities in technology transfer has been increasingly popular in China.⁴⁵ Most research in China is conceptual studies about the history, function, or policy of technology transfer, except a few empirical studies. The following section is a review of the most recent empirical studies on technology transfer.

The first common issue confronted in the empirical studies is how to measure the volume of technology transfer. Gao et al. (2014) use patent licensing as an indicator of technology transfer activities.⁴⁶ They gathered the patent licensing documents of all Chinese universities from 2002 to 2012 in the online database of SIPO,⁴⁷ where a total of 354 universities were identified in the dataset. They then carefully examined the patterns of licensing behaviors of China universities using the variance technique (ANOVA). Their research finds that while China universities own an average number of 520 patents,

⁴⁴ Lee, *supra* note 30.

⁴⁵ Aihua Chen et al., *University technology transfer in China: a literature review and taxonomy*, 41 JOURNAL OF TECHNOLOGY TRANSFER 891-929 (2016).

⁴⁶ Xiaopeng Gao et al., *Technology Transferring Performance of Chinese Universities: Insights from Patent Licensing Data*, ADVANCES IN APPLIED SOCIOLOGY 4 (2014) 289-300.

⁴⁷ The State Intellectual Property Office of the P.R. China. Accessible online at <http://www.sipo.gov.cn/> (last visited on May 20, 2018).

however, only 16 patents per university have been licensed out.⁴⁸ In other words, less than six percent of university-owned patents have ever been licensed out to the industry.

Kroll and Liefner (2008) choose university spin-off enterprises as an indicator of technology transfer activities. Their research is based on 82 interviews with the spin-off enterprises in three metropolitan regions in China. In a four-month field study in early 2004, they interviewed with the CEO and managers of 82 spin-off companies in Beijing, Hangzhou, and Wuhan.⁴⁹ Because most interviewees did not speak much English, their interviews were supported by an interpreter. Qualitative evidence in their research suggests that a large part of the spin-off activity in Beijing and Wuhan results from a technology push strategy initiated and financed by the government and the university, whereas spin-off activity in Hangzhou is more oriented towards market opportunities and the for-profit interests of individual researchers.⁵⁰

Liu (2015) uses the efficiency of the national university science parks⁵¹ as an indicator of technology transfer activities in China. His research takes Data Envelopment Analysis to evaluate the relative performance of 95 national university science parks in China. The data for analyses is gathered from the Statistical Year Book of Torch Plan (2008-2013). The Statistical Year Book is an official database published by the Ministry

⁴⁸ Gao, *supra* note 112 at 291.

⁴⁹ Henning Kroll & Ingo Liefner, *Spin-off enterprises as a means of technology commercialization in a transforming economy – Evidence from three universities in China*, *TECHNOVATION* 28 (2008) 298-313.

⁵⁰ Kroll & Liefner, *supra* note 114 at 308.

⁵¹ In 1988, the Ministry of Science and Technology approved the “Torch Plan” and the “Spark Program,” attaching great importance to industrialization of new and high technology. Driven by the policy orientation, many China universities have launched science parks to accommodate the industrial innovation. Among these university science parks, the national university science parks are the most prominent districts for technology commercialization.

of Science and Technology. Evidence finds that there has been a steady decline in the efficiency of the national university science parks in China over six years, except for Zhejiang University and the China University of Petroleum.⁵² His research also shows that Tsinghua University has the best performance in venture capital solicitation, primarily due to the operations of TusPark Ventures, a venture firm affiliated with the National Science Park of Tsinghua University.⁵³

The second common issue confronted in the empirical studies is how to identify the explanatory variables that might predict the technology transfer output. Hong and Su (2013) select geographic distance as a predictor of technology transfer activities. They conducted 40 semi-structured interviews among academic scientists and technology transfer officers of five China universities to examine the problems encountered in technology transfer.⁵⁴ The results of their research found that geographic distance is an obstructive factor in the technology transfer process, but social proximity and university prestige could help offset the adverse effects of the geographic distance on university-industry collaboration.⁵⁵

Wang and Liu (2007) identify trust between university and industry as a key element for the success of technology transfer. Data was collected from 169 project-based

⁵² Hongyu Liu, *National University Science Parks in China and Their Efficiency – Analysis and Implications for Future Strategies*. 2015. Doctorate Dissertation. Tohoku University.

⁵³ Id. The TusPark Ventures has an investment in over seventy-six percent of the startup companies located in the National Science Park of Tsinghua University.

⁵⁴ Wei Hong & Yu-Sung Su, The effect of institutional proximity in non-local university-industry collaborations: An analysis based on Chinese patent data, *Research Policy* 42 (2013) 454-464.

⁵⁵ Id.

research teams in universities of Guangdong province in China.⁵⁶ They distributed a total of 350 surveys and received 205 responses. The response rate is 48.3 percent. The results of their research suggest that while trust is an essential factor for technology transfer, there is no relationship between trust and the depth of knowledge being transferred. Their study also finds that communication always plays a vital role in technology transfer, especially when tacit knowledge is included.

Wei et al. (2017) identify enterprise ownership as an essential factor in technology innovation. They use patent data to measure the innovation performance of state-owned enterprises and private-sector enterprises. Their research finds that domestic private enterprises and foreign-invested enterprises invest more in research and development and generate more patents than their state-owned counterparts.⁵⁷ Moreover, their investigation unfolds that state-owned enterprises tend to have much higher subsidies than either domestic private firms or foreign-invested firms, though state-owned firms' returns to investing in research and development are much lower than firms in the private sector.⁵⁸

In sum, the empirical studies have significantly extended the field of inquiry on technology transfer. However, they have carried certain drawbacks. Firstly, the cross-sectional field studies could not make causal inferences among variables. Secondly, most

⁵⁶ Liping Wang & Xiangyang Liu, *Determinants of Knowledge Transfer in the Process of University-Industrial Cooperation: An Empirical Study in China*, 2007 International Conference on Wireless Communications, Networking and Mobile Computing, at 5527-5531.

⁵⁷ Shang-Jin Wei et al., *From "Made in China" to "Improved in China": Necessity, Prospect, and Challenges*, JOURNAL OF ECONOMIC PERSPECTIVES 31 (2017) 49-70. Pp. 66.

⁵⁸ Id.

empirical studies have focused on a single university unable to take a further systematic analysis of the local context. Thirdly, the dataset used in these empirical studies did not include the most updated information, which degraded their accuracy to measure the variables.

2.3 Research Questions

This dissertation is an attempt to identify factors that might explain the relative success or lack of success of efforts to commercialize university-owned inventions by Chinese universities. An empirical analysis using data from 112 China universities is conducted to assess possible factors that might have an impact on technology transfer.

As has been widely accepted, promoting technology transfer from university to industry could improve productivity and drive economic growth in the long run.⁵⁹ This dissertation seeks to extend the field of inquiry on technology transfer and to make some strategic implications for university management.

Primarily, this dissertation answers three research questions:

- 1. What are the strongest internal or external factors that influence university performance of technology transfer?*
- 2. What are the weakest internal or external factors that affect university performance of technology transfer?*

⁵⁹ Joseph Friedman & Jonathan Silberman, *University Technology Transfer: Do Incentives, Management, and Location Matter?* JOURNAL OF TECHNOLOGY TRANSFER 28 (2003) 17-30.

3. Based on the results of research question 1 and 2, what strategies could universities in China adopt to improve their performance of technology transfer?

2.4 Methodology

This dissertation is an interdisciplinary research and adopts the historical approach, doctrinal analysis, and empirical methods to address the critical issues involved in technology transfer.

In using the method of historical approach, this dissertation provides historical information on the evolution of technology transfer and examines the critical decisions made by lawmakers to promote the progress of science and technology. The primary goal of this historical overview is to answer the question of how the general concept and real practices of technology transfer evolve.

In using the method of doctrinal analysis, this dissertation reduces the study on the legal framework of technology transfer to an essentially descriptive analysis of a series of legal rules. The primary goal of this “black letter” method is to collate, organize and describe legal regulations while at the same time offering reasonable commentary on the effects of these rules. Most legal rules and judicial opinions are to be found in primary sources, namely codified laws, and case laws. The goal of this doctrinal analysis is to provide a close examination of the legal context of technology transfer. Legal issues on intellectual property protection, such as gene-related patent, experimental use exception, and employee invention ownership, as well as issues that related to contract laws, criminal laws, and tax laws are thoroughly addressed in this dissertation.

This dissertation also uses an empirical method to address the factors that influence technology transfer. Both quantitative and qualitative methods are employed in this dissertation. As to the qualitative approach, the author of this dissertation attends several national industry conferences and exhibitions featuring university technology managers from the U.S. and Chinese universities. At these events, some critical issues about the challenges and achievements of university technology transfer have been discussed. During the conference time, the author also takes semi-structured interviews with a selected group of technology managers from top research universities in China. The median time for the meetings is 30 minutes, with a range of 20-40 minutes. As to the quantitative analysis, this dissertation uses a multi-level Poisson regression model to address whether university-level and province-level factors have an impact on technology contract formation between university and industry. The university-level dataset contains information on 111 colleges and universities for the 2013-2015 period. Only colleges and universities that report data for the full sample period are included in the dataset. The province-level dataset contains information on 31 provinces and municipalities in China for the 2013-2015 period.

Chapter 3 The Bayh-Dole Act and Technology Transfer in the U.S.

Introduction

The Bayh-Dole Act of 1980 was the first statute in the U.S. that intended to use higher education institutions to contribute to economic welfare.⁶⁰ It was designed to minimize the likelihood that publicly-funded inventions would languish for lack of incentives to license them to the industry for the development of marketable products and services.⁶¹

Before passage of the Bayh-Dole Act, the U.S. government had accumulated 30,000 patents, of which only approximately five percent were commercially licensed.⁶² The Bayh-Dole Act shifted the incentive structure for universities by clarifying that taking ownership of government-funded inventions and commercializing those inventions for retail development could be legitimate practice for academic institutions.

The broader purpose of the Bayh-Dole Act was to ensure that publicly-funded inventions should, whenever possible, enhance the public welfare of public health, job creation, economic growth, international competitiveness, and other public goods, through the commercialization of technology.⁶³

However, specific questions were raised concerning university ownership of patented technology arising from federally sponsored research. Most of the concerns centered on

⁶⁰ STEPHEN A. MERRILL & ANNE-MARIE MAZZA (ED.), *MANAGING UNIVERSITY INTELLECTUAL PROPERTY IN THE PUBLIC INTEREST*. (The National Academy Press, 2011).

⁶¹ *Id* at 17.

⁶² Federal Council for Science and Technology, 1978. *Annual Report on Government Patent Policy* 90565-5102). Washington D.C.: Government Printing Office.

⁶³ MERRILL & MAZZA, *supra* note 59 at 16.

whether there were delays in the publication of research results, changes in faculty promotion criteria, deleterious effects on the norms of the scientific community, and redirection of research efforts away from curiosity-driven topics in the basic science.⁶⁴

Despite the controversy, the Bayh-Dole Act together with several important changes in the patent legal system has stimulated extensive patenting and licensing activity among research universities in the U.S.⁶⁵ A recent study shows that the annual licensing income received by U.S. universities has reached \$1.26 billion in the fiscal year of 2000, and further jumped to \$2.96 billion in the fiscal year of 2016.⁶⁶

The combined effects of the Bayh-Dole Act, both institutional responsibilities and the economic incentives for patenting and licensing, have led more universities to engage in technology activities that otherwise would have been the case. The number of technology transfer offices (TTO) has also surged after the passage of the Bayh-Dole Act, although a few universities have established their TTOs before 1980.⁶⁷

In giving universities the right to retain the title, the U.S. government also imposed balancing conditions and limitations on university patent holders. First, the Bayh-Dole

⁶⁴ See e.g., Rebecca S. Eisenberg, *Proprietary Rights and the Norms of Science in Biotechnology Research*, YALE LAW REVIEW 177-231 (1987). Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, THE UNIVERSITY OF CHICAGO LAW REVIEW 1017-1086 (1989). Arti K. Rai, *Regulating scientific research: intellectual property rights and the norms of science*, NORTHWESTERN UNIVERSITY LAW REVIEW 94 (1999) 77-152. DONALD E. STOKES, PASTEUR'S QUADRANT: BASIC SCIENCE AND TECHNOLOGICAL INNOVATION (Brookings Institution Press, 1997). Rebecca Henderson et al., *Universities as a source of commercial technology: a detailed analysis of university patenting, 1965-1988*, THE REVIEW OF ECONOMICS AND STATISTICS 119-127 (1998).

⁶⁵ Opinion: *Innovation's Golden Goose*, THE ECONOMIST (Dec. 12, 2002), accessible online at <http://www.economist.com/> (last visited on Jan. 31, 2018).

⁶⁶ AUTM U.S. Licensing Activity Survey: FY2016.

⁶⁷ Gerard George, *Learning to be capable: patenting and licensing at the Wisconsin Alumni Research Foundation 1925-2002*, 14 INDUSTRIAL LAND CORPORATE CHANGE 119-151 (2005).

Act required that universities give an industrial preference to small business and firms that develop and manufacture domestically. Second, the Bayh-Dole Act retained a royalty-free compulsory license for government use of the university inventions. Third, the Bayh-Dole Act allowed research sponsoring agency to intervene the licensing of university inventions (“march-in rights”) if the institution or the licensee failed to develop and commercialize the device within a specific time.⁶⁸ The following sections discuss the Bayh-Dole Act in greater detail.

⁶⁸ Sean M. O’Connor et al., *Legal Context of University Intellectual Property and Technology Transfer*, in *Managing University Intellectual Property in the Public Interest*, The National Academies of Sciences, Engineering and Medicine (2010), accessible online at <https://sites.nationalacademies.org/cs/groups/pgasite/documents/> (last visited on Jan. 1, 2018).

3.2 The Legislative History

After World War II, there was an explosive growth in U.S. research and development (R&D) investment and expansion of the university role in public-funded research. Before World War II, private industry sponsored about two-thirds of the U.S. research estimated to involve USD 300 million in 1938, with the federal government and university research accounting for about USD 50 million each.⁶⁹ But within six years the positions were reversed, and towards the end of World War II, the federal government funded more than three-fourths of all research in the country and hired at least 20,000 scientists and technicians, and more than 15,000 other civilian employees in the federal government.⁷⁰

Despite some relative decline in the following decades, the U.S. federal government in 1972 still furnished about 55 percent of the money expended for research and development.⁷¹ In the late 1970s, the U.S. government annually spent billions of dollars funding more than half of all academic study and owned 28,000 patents.⁷²

Less than five percent of all the government-funded inventions eventually resulted in licenses for commercial use.⁷³ Frustrated by the inefficient use of government-funded inventions, especially the drugs and medical devices funded by the National Institutes of

⁶⁹ David Lloyd Kreeger, *The control of patent rights resulting from federal research*, 12 LAW AND CONTEMPORARY PROBLEMS 714-745 (1974).

⁷⁰ *Id.* See also, *Investigation of Government Patent Practices and Policies: Report and Recommendation of The Attorney General to The President* (U.S. Department of Justice, 1947) at 9. (on file with the University of California library).

⁷¹ N. B. Hannay, *Science and Industry: The Private Sector Using Science*, PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA, Vols. 71 (1974) at 2584.

⁷² Howard Markel, *Patents, Profits, and the American People – The Bayh-Dole Act of 1980*, N. Engl. J. Med. 2013; 369:794-796, accessible online at <http://www.nejm.org/> (last visited Jan. 25, 2018).

⁷³ *Id.*

Health (NIH), two Senators, Birch Bayh and Robert Dole, decided to collaborate on a technology-transfer bill to solve the ownership issues on government-funded research.⁷⁴ This legislative bill intended to allow the university to receive proprietary rights and grant licenses, even exclusive permits, on patents resulting from research funded by the federal government.

In the Congress, opponents of the Bayh-Dole Act questioned the reliability of the widely cited statistic of patent licenses in the 1970s by arguing that many public-funded inventions have limited value for the civilian market, and therefore the lower number of government-funded inventions resulted in licenses for commercial use does not reflect the economic contribution of those inventions to the society.⁷⁵ Table 3.1 shows the amount of the R&D investment by the U.S. Department of Defense.

⁷⁴ Joseph Allen, *When Government Tried March-in Rights to Control Health Care Costs*, IPWATCHDOG.COM (May 2, 2016), accessible online at <http://www.ipwatchdog.com/> (last visited on Jan. 23, 2018).

⁷⁵ Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, *Virginia Law Review* (1996) at 1703.

Table 3.1 The U.S. Federal Investment on Research and Development 1955-1985

Federal Investment on R&D (1955-1985) (USD in millions)

<i>Agency</i>	<i>1955</i>	<i>1960</i>	<i>1965</i>	<i>1970</i>	<i>1975</i>	<i>1980</i>	<i>1985</i>
Department of Agriculture	72.0	131.4	224.5	281.2	420.8	688.0	943.0
Department of Commerce	9.9	33.1	61.3	121.6	215.3	343.0	399.0
Atomic Energy Commission	289.8	989.5	1,241.0	1,345.9	...	...	...
Department of Defense	1,555.9	5,653.8	6,796.5	7,360.3	9,012.4	13,981.0	29,792.0
Department of Transportation	...	...	64.4	327.8	311.5	361.0	429.0
National Aeronautics and Space Administration	...	401.1	4,951.5	3,799.9	3,064.4	3,234.0	3,327.0
National Science Foundation	8.5	58.0	187.2	288.9	585.0	882.0	1,346.0
National Institutes of Health	...	...	523.0	873.0	1,846.0	3,182.0	4,828.0
Environmental Protection Agency	...	...	...	89.0	258.0	345.0	320.0

Source: adapted by the author based on the data from the U.S. Bureau of the Census and the National Science Foundation.⁷⁶

⁷⁶ See also, SYLVIA KRAEMER, SCIENCE AND TECHNOLOGY POLICY IN THE UNITED STATES (Rutgers University Press, 2006).

On April 23, 1980, with a 91-to-4 vote, the Bayh-Dole Act was approved by the U.S. Congress.⁷⁷ The Bayh-Dole Act, which for the first time, empowered nonprofit organizations to retain ownership of their inventions produced by taxpayer-sponsored research, was very popular among universities and research institutes.⁷⁸ These nonprofit organizations claimed that a clear policy giving them patent rights at the time of contracting would facilitate their efforts to transfer technology to industry.⁷⁹ It was also popular with small businesses, who claimed that they received discriminatory treatment under the prior discretionary policies of the government agencies, that they were, in fact, more innovative than their larger competitors.⁸⁰ They also stressed that the Bayh-Dole Act would allow them to compete more effectively with larger firms.⁸¹

⁷⁷ Markel, *supra* note 7.

⁷⁸ For interest reading the U.S. Patent Policy before the Bayh-Dole Act, see *Appendix: Excerpts from The Bush Report, The Biddle Report, and the Institutional Patent Agreement (IPA) Program*.

⁷⁹ THE UNIVERSITY AND SMALL BUSINESS PATENT PROCEDURES ACT: HEARINGS ON S. 414, Before the Senate Comm. on the Judiciary, 96th Cong. 51 (1979). Pp. 95-110. (Cited in Eisenberg, *supra* note 7, at 1693.)

⁸⁰ INDUSTRIAL INNOVATION AND PATENT AND COPYRIGHT LAW AMENDMENT: HEARINGS ON H.R. 2414, Before the Subcommittee on Courts, Civil Liberties, and the Admin. of Justice of the House Comm. on the Judiciary, 96th Cong. 286 (1980). Pp. 241-75. (Cited in Eisenberg, *supra* note 7, at 1693.)

⁸¹ *Id.*

3.3 *The Diamond v. Chakrabarty Case*

The Bayh-Dole Act was contemporaneous with the U.S. Supreme Court's decision in *Diamond v. Chakrabarty* (1980), which is a landmark case on the patent eligibility of genetically modified organisms.⁸² The issue in *Diamond* case is whether the human-made microorganism can be patented. The U.S. Supreme Court held that a genetically-modified microorganism might be patented for not being a naturally occurring composition.⁸³

The facts of this case were not very complicated. Ananda Chakrabarty was a microbiologist employed by General Electric Corporation. During Dr. Chakrabarty's research, he and an associate discovered a process by which four plasmids, capable of degrading camphor and octane, the two components of crude oil, could be transferred and maintained stably in a single bacterium.

In the field of biology, plasmids are genetic components that control the oil degradation abilities of certain bacteria. The microorganism carrying the four plasmids was a new species of a bacterium capable of metabolizing hydrocarbons. Chakrabarty developed the bacterium in a non-naturally occurring environment using recombinant DNA processes.⁸⁴

⁸² *Diamond v. Chakrabarty*, 447 U.S. 303 (1980).

⁸³ *Id.*

⁸⁴ Hallie Wimberly, Comment: *The Changing Landscape of Patent Subject Matter Eligibility and Its Impact on Biotechnological Innovation*, 54 HOUS. L. REV. 995 (2017). Philip Merksamer, *Ariosa Diagnostics v. Sequenom: Matastasis of Mayo and Myriad and the evisceration of patent eligibility for molecular diagnostics*, 31 BERKELEY TECH. L. J. 495 (2016). Michael Clancy, Case Comment: *Intellectual Property Law – The Future of Patent Eligibility Analysis on Medical Diagnostics and its Effects on Health Innovation – Ariosa Diagnostics, Inc. v. Sequenom, Inc.*, (809 F. 3d 1282 Fed. Cir.

Dr. Chakrabarty later sought a patent on this “genetic engineering” process.⁸⁵ The patent examiner in the U.S. Patent and Trademark Office allowed the other claims in his patent application but rejected the claims to the genetic-modified bacteria. This rejection was based on two reasons: first, the micro-organisms were “products of nature,” and second, the organisms were “living things.” In the patent examiner’s opinions, neither of these two were a patentable subject matter under 35 U.S.C. § 101.

Chakrabarty appealed. The Patent Office Board of Appeals reversed the first objection of the patent examiner, deciding that the micro-organisms were not “products of nature” because none of their unique qualities occurred without man’s intervention. But the Board did affirm the patent examiner’s second objection, reasoning that no living things other than plants were patentable as provided for in the Plant Patent Act of 1930.⁸⁶

Chakrabarty appealed again to the Court of Customs and Patent Appeal. The Court of Customs and Patent Appeals overturned the case in Chakrabarty’s favor, stating that whether the micro-organism was alive was insignificant for the U.S. patent law, which was designed to promote the progress of science and useful arts.⁸⁷

2015)., 12 J. HEALTH & BIOMED. L. 319 (2017). Christopher M. Holman, *Mayo, Myriad, and the Future of Innovation in Molecular Diagnostics and Personalized Medicine*, 15 N. C. J. L. & TECH. 639 (2014). Alexa Johnson, Note: *A Crisis of Patent Law and Medical Innovation: The Category of Diagnostic Claims in the Wake of Ariosa v. Sequenom*, 27 HEALTH MATRIX 434 (2017).

⁸⁵ Dr. Chakrabarty made the following claims in his application: “first, process claims for the method of producing the bacteria; second, claims for an inoculum comprised of a carrier material floating on water, such as straw, and the new bacteria; and third, claims to the bacteria themselves.” See *Diamond*, supra note 18.

⁸⁶ Ann A. Brennan, *Patentability of Micro-organisms: Diamond v. Chakrabarty*, 100 S. Ct. 2204 (1980), UNIVERSITY OF AKRON, accessible online at <https://www.uakron.edu/> (last visited on Jan. 5, 2018).

⁸⁷ *In re Bergy*, 563 F. 2d 1031 (1977). (The Court of Customs and Patent Appeal made the decision on *Diamond v. Chakrabarty* based on an earlier case in that court, *In re Bergy*.)

Sidney A. Diamond, Commissioner of Patents and Trademarks, appealed to the U.S. Supreme Court on behalf of the federal government.⁸⁸ By a vote of five to four, the U.S. Supreme Court affirmed the decision of the Court of Customs and Patent Appeals, thereby allowing Chakrabarty to receive the patent rights sought on the bacteria.⁸⁹

The Chakrabarty patent was not the first U.S. patent to issue on a living organism. The U.S. Patent and Trademark Office had granted patents on single-cell organisms on several occasions.⁹⁰ It was only after *Chakrabarty*, however, that the U.S. Patent and Trademark Office clarified what had been an inconsistent approach to patenting living organisms.⁹¹

At the time *Chakrabarty* was decided, biotechnology was a newly developing field. In the following decades since *Chakrabarty*, the biotechnology industry of the U.S. has seen exponential growth in the number of patent applications and patents issued on biotechnology-related inventions. Figure 3.1 shows the total number of issued patents by the U.S. Patent and Trademark Office for living micro-organisms and cells, as well as the related processes (hereby, “DNA patents”) between 1971 and 2013.⁹²

⁸⁸ *Diamond v. Chakrabarty*, supra note 18.

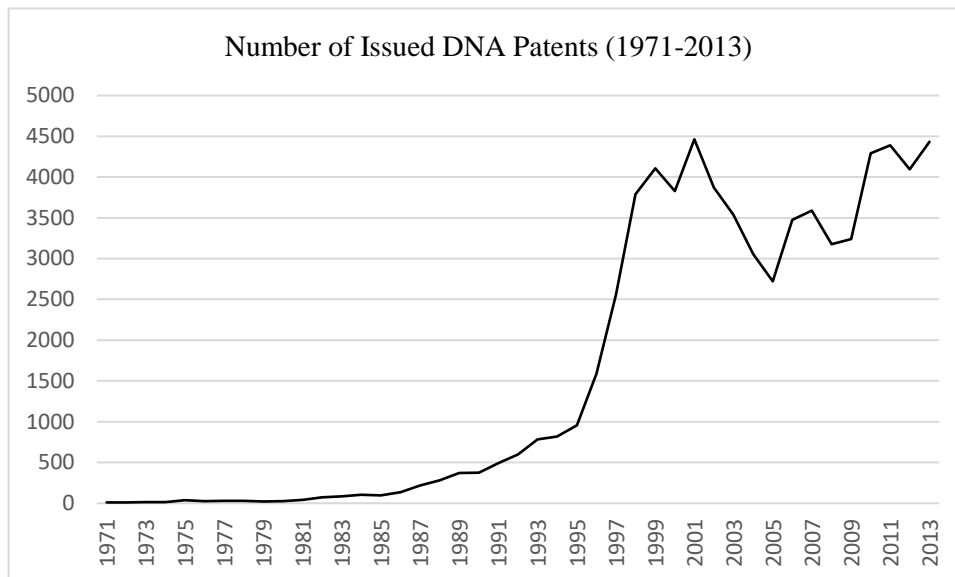
⁸⁹ *Id.*

⁹⁰ The first U.S. patent on a living organism was granted to Louis Pasteur in 1873. Louis Pasteur developed a purified yeast cell. (U.S. Patent No. 141,072).

⁹¹ Douglas Robinson & Nina Medlock, *Diamond v. Chakrabarty: A Retrospective on 25 Years of Biotech Patents*, INTELLECTUAL PROPERTY & TECHNOLOGY LAW JOURNAL (2005) 1-15.

⁹² Mark Hakkarinen & Bob Cook-Deegan, *Number of items loaded into the DNA Patent Database by year as of 2014*, DNA Patent Database (Feb. 12, 2014), accessible online at <https://dnapatents.georgetown.edu/> (last visited on Mar. 10, 2018).

Figure 3.1 The Total Number of Issued DNA Patents in the U.S. (1971-2013)



Source: adapted by the author based on data from the DNA Patent Database (2014).

3.4 Technology Transfer Offices

The Bayh-Dole Act and the *Diamond v. Chakrabarty* case were mostly independent; though, they carried along by the same policy stream. The modern era of new technology requires a proactive patent framework for the business implications.⁹³ Universities have benefited significantly from this shifting legal paradigm regarding patenting and licensing activities. The Cohen-Boyer patents (U.S. Patent No. 4,237,224) at the Stanford University exemplifies this phenomenon.

Stanley Cohen was a professor of medicine at the Stanford University. In 1972, he and his colleague developed a laboratory process for the cloning of genes of a higher organism.⁹⁴ Using the new method to transplant or amplify genes in bacteria would change the potential applications in the pharmaceutical industry.⁹⁵ Niels Reimers, the first administrator of the Stanford University Office of Technology Licensing, saw an opportunity to patent and license the new technology.⁹⁶

In 1974, the Stanford University and the University of California, San Francisco jointly applied for patents on the recombinant DNA process and any products that resulted from that process.⁹⁷ The Cohen-Boyer patents were not granted in the U.S. Patent and

⁹³ Robert Cook-Deegan & Christopher Heaney, *Patents in Genomics and Human Genetics*, ANNUAL REVIEW OF GENOMICS HUMAN GENETICS 11:383-425 (2010).

⁹⁴ Rajendra K. Bera, *Commentary: The Story of the Cohen-Boyer Patents*, CURRENT SCIENCE, Vol. 96, No. 6 (Mar. 25, 2009), Pp. 760-763.

⁹⁵ Sally Smith Hughes, *Making Dollars out of DNA: The First Major Patent in Biotechnology and the Commercialization of Molecular Biology, 1974-1980*, THE HISTORY OF SCIENCE SOCIETY, Vol 92, No. 3 (Sep. 2001), Pp. 541-575.

⁹⁶ Id.

⁹⁷ Bera, *supra* note 30.

Trademark Office in ten years until the final judgment of the *Chakrabarty* case.⁹⁸ Between 1980 and 1997, before the patents expired, the Cohen-Boyer patents have generated \$255 million in revenues for the Stanford University and the University of California.⁹⁹ The royalties come from 468 patent licenses covering 2,442 recombinant DNA products that had sold \$35 billion in gross sales by 2015.¹⁰⁰

Seeing the success of the Stanford University in the genetics patents, many other U.S. universities have taken actions likewise to accommodate greater faculty involvement in the outside business efforts to secure patent rights.¹⁰¹ Technology transfer offices (TTOs) thereby emerged at the U.S. research universities in the 1980s and 1990s.¹⁰² Before the Bayh-Dole Act, only a few universities had offices representing faculty on technology transfer. Until recently, more than 300 universities and research institutions in the United States have established their technology transfer office.¹⁰³ Figure 3.2 shows the growth of university technology transfer offices in the 1980s and 1990s.

⁹⁸ Tim Beardsley, *Biotechnology: Cohen-Boyer Patent Finally Confirmed*, NATURE 311 (Sep. 6, 1984).

⁹⁹ For patent applications filed before June 8, 1995 and for patents that were still in force on June 8, 1995, the patent term is either 17 years from the issue date or 20 years from the earliest filing date, whichever is longer. See Alan C. Marco et al., *The USPTO Historical Patent Data Files: Two Centuries of Inventions*, USPTO (2015), accessible at <https://www.uspto.gov/> (last visited on June 30, 2017).

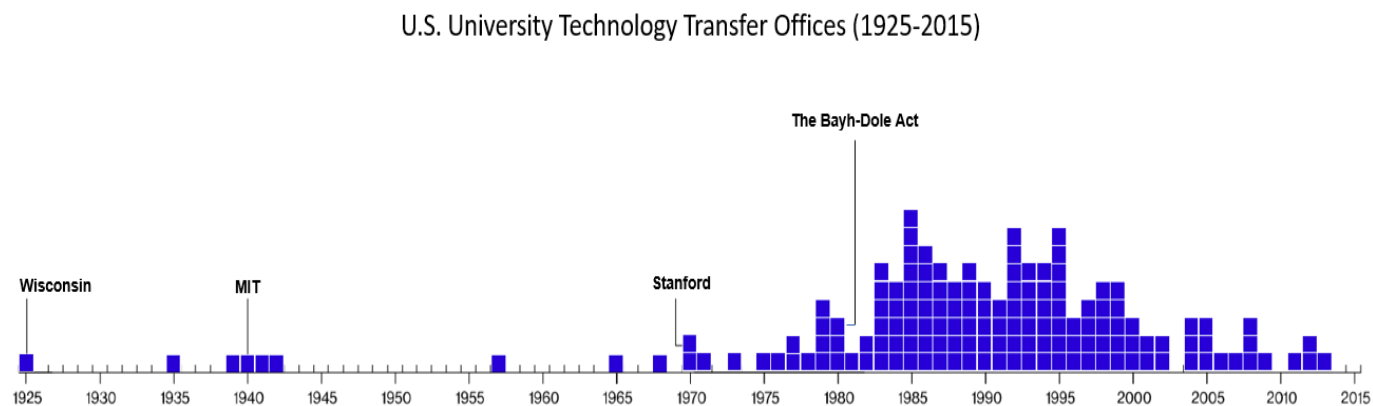
¹⁰⁰ Marie Godar, *History of Biotech: How the "First" Biotech Patent Generated Millions*, LABIOTECH.EU (Mar. 12, 2015), accessible online at <https://labiotech.eu/> (last visited on Mar. 01, 2018).

¹⁰¹ Sally Smith Hughes, *Making Dollars out of DNA: The First Major Patent in Biotechnology and the Commercialization of Molecular Biology, 1974-1980*, THE HISTORY OF SCIENCE SOCIETY, Vol 92, No. 3 (Sep. 2001), Pp. 541-575.

¹⁰² Donald S. Siegel, et al., *Toward a Model of the Effective Transfer of Scientific Knowledge from Academicians to Practitioners: Qualitative Evidence from the Commercialization of University Technologies*, Journal of England Technology Management, 21 (2004) 115-142.

¹⁰³ Donald S. Siegel et al., *Technology Transfer Offices and Commercialization of University Intellectual Property: Performance and Policy Implications*, Oxford Review of Economic Policy, Vol. 23, No. 4, at 640.

Figure 3.2 The Growth of U.S. University Technology Transfer Offices 1925-2015



Source: adapted from Janet Rae-Dupre, *When Academia Puts Profit Ahead of Wonder* (New York Times)¹⁰⁴

¹⁰⁴ Janet Rae-Dupre, *When Academia Puts Profit Ahead of Wonder*, NEW YORK TIMES (Sep.6, 2008), accessible online at <http://www.nytimes.com/> (last visited on Jan. 29, 2018).

In general, there are two forms of technology transfer office. One is a university department embedded in the central administration system, and the other is a separate for-profit entity designated to license university patents. In the U.S., most university TTOs operate as part of the central university administration.¹⁰⁵ Each university has its patent policy but follows a standard internal review process.

University patent policies often require faculty, staff, and students timely file an invention disclosure form and submit to the technology transfer office for review.¹⁰⁶ The personnel, notably the technology managers, in the technology transfer offices determine whether the disclosure represents an invention that eligible to file patent applications. Figure 3.3 shows the patent licensing procedure in the U.S. universities.

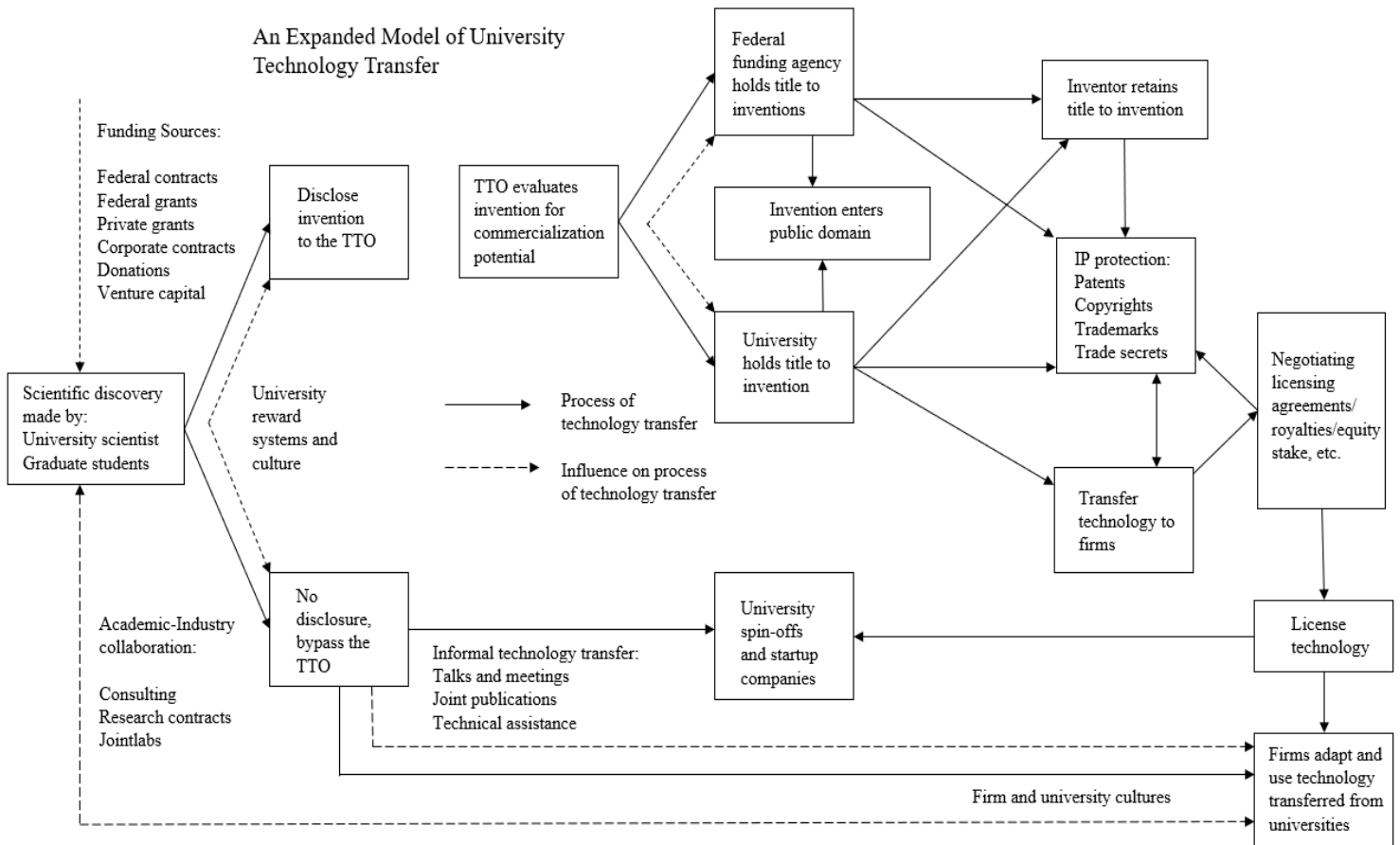
The staff size of technology transfer offices traditionally varies depending on the university budget. For a very small university with research expenditures less than 50 million dollars, the number of full-time employees involved with the patenting and licensing process ranges between 1 to 3, while in a large research university, the regular number of technology managers ranges between 10 to 24.¹⁰⁷

¹⁰⁵ An exception to most of university technology transfer offices, WARF, or The Wisconsin Alumni Research Foundation, is a private, nonprofit organization. It supports scientific research at the University of Wisconsin-Madison. It also patents university inventions, licenses technologies to companies for commercialization, and returns licensing fees to campus to support future research. See UW Foundation Website, accessible online at <https://www.supportuw.org/about-us/> (last visited on Apr. 10, 2018).

¹⁰⁶ See Appendix: Sample Invention Disclosure Form.

¹⁰⁷ Robin Rasor and Page Heller, *Administration of Large and Small Technology Transfer Offices*, accessible online at <https://www.autm.net/> (last accessed July 30, 2017).

Figure 3.3 An Expanded Model of University Technology Transfer.



Source: Adapted by the author from Leyden and Link (2015).¹⁰⁸

¹⁰⁸ DENNIS P. LEYDEN & ALBERT N. LINK, PUBLIC SECTOR ENTREPRENEURSHIP: U.S. TECHNOLOGY AND INNOVATION POLICY. (Oxford University, 2015).

3.5 New Trends of U.S Universities

For a long time, technology transfer activities have been predominantly patent-centric and revenue-driven, with a focus on generating licensing income and obtaining reimbursement for legal expenses.¹⁰⁹ Nevertheless, most university TTOs did not produce sufficient revenue to offset their operating expenses. In the U.S., fewer than half of the 300 technology transfer offices have managed to break even from the operating costs of their technology transfer efforts.¹¹⁰ Moreover, the distribution of university TTOs income was highly skewed, with a few blockbuster patents accounting for most revenues.¹¹¹ A recent study shows that two-thirds of licensing revenues go to only thirteen U.S. universities,¹¹² and nearly 70 percent of all the licensing revenues come from life science.¹¹³ Table 3.2 shows a list of the top U.S. universities in licensing revenues.

¹⁰⁹ Jay P. Kesan, *Transferring Innovation*, FORDHAM LAW REVIEW 2169-2223 (2009).

¹¹⁰ Janet Rae-Dupre, *When Academia Puts Profit Ahead of Wonder*, NEW YORK TIMES (Sep.6, 2008), accessible online at <http://www.nytimes.com/> (last visited on Jan. 29, 2018).

¹¹¹ Maryann Feldman et al., *Lessons from the Commercialization of the Cohen-Boyer Patents: The Stanford University Licensing Program*, in INTELLECTUAL PROPERTY MANAGEMENT IN HEALTH AND AGRICULTURAL INNOVATION: A HANDBOOK OF BEST PRACTICES (MIHR-USA, 2007).

¹¹² WALTER D. VALDIVIA, *UNIVERSITY START-UPS: CRITICAL FOR IMPROVING TECHNOLOGY TRANSFER* (Brookings Institute 2013).

¹¹³ Donald S. Siegel, et al., *Toward a Model of the Effective Transfer of Scientific Knowledge from Academicians to Practitioners: Qualitative Evidence from the Commercialization of University Technologies*, JOURNAL OF ENGLAND TECHNOLOGY MANAGEMENT 21 (2004) 115-142.

Table 3.2 The Ranking of Top U.S. Universities in Technology Licensing (2015)

The Ranking of Top U.S. Universities in Technology Licensing in 2015				
University	Licenses executed	Gross licensing revenues (USD)	NIH awards	NIH funding (USD)
University of Washington	284	31,417,733	896	434,224,865
University of California System	248	169,724,803	4,243	1,837,215,703
University of Texas System	128	48,083,097	1,551	593,905,525
Stanford University	88	88,573,239	929	422,361,283
Columbia University	70	181,400,000	899	372,199,488
Massachusetts Institute of Technology	68	17,000,000	257	100,256,843
New York University	53	209,000,000	542	233,587,462
University of Utah	49	59,495,096	358	135,962,482
University of Massachusetts	24	31,814,000	415	160,477,381
Northwestern University	22	61,565,351	652	268,677,008
Princeton University	4	136,541,760	127	44,551,983

Note: NIH stands for National Institutes of Health (NIH), online at <https://www.nih.gov/>

Source: adapted from Brady Huggett, *Top US universities, institutes for life sciences in 2015*.¹¹⁴

¹¹⁴ Brady Huggett, *Top US universities, institutes for life sciences in 2015*, NATURE BIOTECHNOLOGY 35, 203 (2017).

In recent years, many university TTOs have transformed from a “technology push” mode to a “technology pull” mode.¹¹⁵ Under the “technology push” model, university TTOs focus on patent and license by stockpiling knowledge created by the university researchers. Under the “technology pull” model, university TTOs must look for technology needs in the marketplace and cultivate a closer industry-university relationship.

For university TTOs that adopt the “technology pull” model, they may quickly face the problem of skill deficiencies in their organization, mainly due to the lack of personnel capable in training faculty members, post-doctors, and graduate students in starting new ventures or interacting with entrepreneurs.¹¹⁶ Table 3.3 shows the name changes of technology transfer offices, which can exemplify the evolving culture of entrepreneurship among the research universities.

¹¹⁵ Peter Lee, *Interface: The Push and Pull of Patents*, FORDHAM LAW REVIEW 2225-2235 (2009).

¹¹⁶ Valdivia, *supra* note 110.

Table 3.3 Examples of U.S. University Technology Transfer Office Name Changes, 2009-2015

Examples of U.S. University TTO Name Changes, 2009-2015		
Institution	Prior TTO Name	Current TTO Name, Date of Change
Columbia U.	Office of Science and Technology	Columbia Technology Ventures, 2009
U. of Cincinnati	Intellectual Property Office	Office of Entrepreneurial Affairs and Technology Commercialization, 2010
Northwestern U.	Office of Technology Transfer	The Innovation and New Ventures Office (INVO), 2010
Oregon State University	Office of Technology Transfer	Office for Commercialization and Corporate Development, 2011
U. of Virginia	Office of Virginia Patent Foundation	UVA Licensing and Ventures Group, 2011
U. of Rochester	Office of Technology Transfer	UR Ventures, 2013
U. of Pennsylvania	Technology Transfer Office	Penn Center for Innovation, 2014
U. of Utah	Technology Commercialization Office	Technology and Venture Commercialization, 2014
John Hopkins U.	Office of Technology Transfer	JHU Technology Venture, 2014
U. of Washington	Technology Transfer Office	UW CoMotion, 2015

Note : TTO=technology transfer office.

Source: adapted from Jacob H. Rooksby, *The Branding of the American Mind: How Universities Capture, Manage and Monetize Intellectual Property and Why It Matters* (John Hopkins University Press 2015)¹¹⁷

¹¹⁷ JACOB H. ROOKSBY, THE BRANDING OF THE AMERICAN MIND: HOW UNIVERSITIES CAPTURE, MANAGE, AND MONETIZE INTELLECTUAL PROPERTY AND WHY IT MATTERS, JOHN HOPKINS UNIVERSITY PRESS (2015), at 215.

Chapter 4 Institutional Context of Technology Transfer in China

4.1 Background

Since opening to foreign trade and the implementation of free-market reforms in 1979, China has been among the world's fastest-growing economies, with real annual gross domestic product (GDP) growth averaging 9.5 percent through 2017.¹¹⁸ The real per capita income of Chinese people increased about ten times from \$828 in 1980 to \$8,583 in 2017.¹¹⁹ No other major economy in the world grew as much like China in the same period.¹²⁰ The World Bank described the spectacular growth of China as “the fastest sustained expansion by a major economy in history.”¹²¹ Such growth has helped China, on average, to double its GDP every eight years and to raise an estimated 800 million people out of poverty.¹²²

Rapid economic ascendance has brought on many challenges as well, including high inequality, environmental pollutions, and external imbalances. China also faces demographic pressures related to an aging population and a shrinking workforce that demand a much higher wage year on year. For instance, Chinese wages are now about three times as high as India.¹²³ The recent trends showed that the annual growth rate of

¹¹⁸ Wayne M. Morrison, *China's Economic Rise: History, Trends, Challenges, and Implications for the United States*. (Congressional Research Service, February 2018).

¹¹⁹ China – Gross domestic product per capita in current prices, *knoema.com*, accessible online at <https://knoema.com/atlas/China/GDP-per-capita> (last visited on Jan. 20, 2018).

¹²⁰ Equatorial Guinea had an average real per capita GDP growth of 10.2 percent from 1980 to 2015. See Shang-Jin Wei et al., *From “Made in China” to “Innovated in China”*: *Necessity, Prospect, and Challenges*, *JOURNAL OF ECONOMIC PERSPECTIVES*, Vol. 31 (2017) 49-70.

¹²¹ The World Bank in China, accessible online at <http://www.worldbank.org/en/country/china/overview> (last visited on Mar.30, 2018).

¹²² Morrison, *supra* note 116.

¹²³ Wei, *supra* note 118.

China has slowed significantly, from 14.2 percent in 2007 to 6.9 percent in 2017 and that growth is projected by the International Monetary Fund (IMF) to fall to 5.8 percent.¹²⁴

The new political leadership of China has embraced slower economic growth, referring it as the “new normal” and affirmed the needs for China to take a new growth model that relies less on fixed investment and exports, and more on private consumption and innovation to drive economic growth.¹²⁵ Through some high-profile initiatives, the Chinese government has placed innovation a top priority in the economic reforms.¹²⁶ The main purpose of these policy initiatives, such as “Made in China 2025,” is to upgrade and modernize the domestic industry and turn China into an innovation-driven country.¹²⁷ However, such measures have increasingly raised concerns about global counterparts who regarded China as a significant rivalry in the technology race.¹²⁸

China’s efforts to revitalize indigenous innovation were first initiated in higher education and research. So far, China has established a network of 2,000 universities, colleges, and vocational schools, coupled with 30 science parks and more than 200 government operated research laboratories.¹²⁹ Moreover, China’s R&D spending has

¹²⁴ Editor, *China’s Growth Engine Stutters as Factories Slow Down*, THE GUARDIAN (Dec. 31, 2017), accessible online at <https://www.theguardian.com/> (last visited on Mar. 10, 2018).

¹²⁵ Editor, *President Xi holistically described the core values of “new normal”*, Xinhuanet.com (Nov. 09, 2014), accessible online at <http://www.xinhuanet.com/> (last visited on Mar. 10, 2018).

¹²⁶ UNESCO Science Report: Towards 2030. (United Nations Educational, Scientific and Cultural Organization, 2015).

¹²⁷ In 2015, the State Council of China published the “Made in China 2025” strategy that identifies 10 key sectors that China is looking to catch up with the United States, including robotics, aerospace and clean-energy cars. See *MADE IN CHINA, 2025*, accessible online at <http://english.gov.cn/> (last visited on Mar. 1, 2018).

¹²⁸ Cecilia Kang, *The New U.S.-China Rivalry: A Technology Race*, NEW YORK TIMES (Mar. 6, 2018), <https://www.nytimes.com/> (last visited on Apr. 25, 2018).

¹²⁹ Andreas Schleicher, *China Opens a New University Every Week*, BBC (Mar. 16, 2016), <http://www.bbc.com/> (last visited on Jan. 20, 2018).

grown by eighteen percent each year since 2008.¹³⁰ In 2015, China surpassed the European Union in gross domestic expenditures on research and development.¹³¹ Between 2012 and 2017, China's total spending on R&D increased by fourteen percent annually, whereas U.S. spending rose by about four percent.¹³² China now ranks as the second amongst the world's leading R&D investors. Figure 4.1 shows the recent trends.

The expansion in R&D capacity has led to a dramatic increase in patent filings. In 2017, China overtook Japan in global patent applications and is closing in on the U.S., the long-standing leader in global patent applications.¹³³ The increase in patent filings has a partial knock-on effect on technology transfers. In 2016, the number of technology transfer contracts between China universities and the industry has increased by more than twenty percent, generating a total of \$15.2 billion in revenues.¹³⁴ However, it is worth knowing that patent filings alone are not a sufficient proxy for technology transfers.¹³⁵

¹³⁰ Loren Grush, *China is catching up to the US on science and engineering spending, report finds*, THE VERGE (Jan. 19, 2016), accessible online at <https://www.theverge.com/> (last visited on Jan. 30, 2018).

¹³¹ Randy Showstack, *China Catching Up to United States in Research and Development*, EOS.ORG (Jan. 24, 2018), online available at <https://eos.org/> (last visited on Mar.20, 2018).

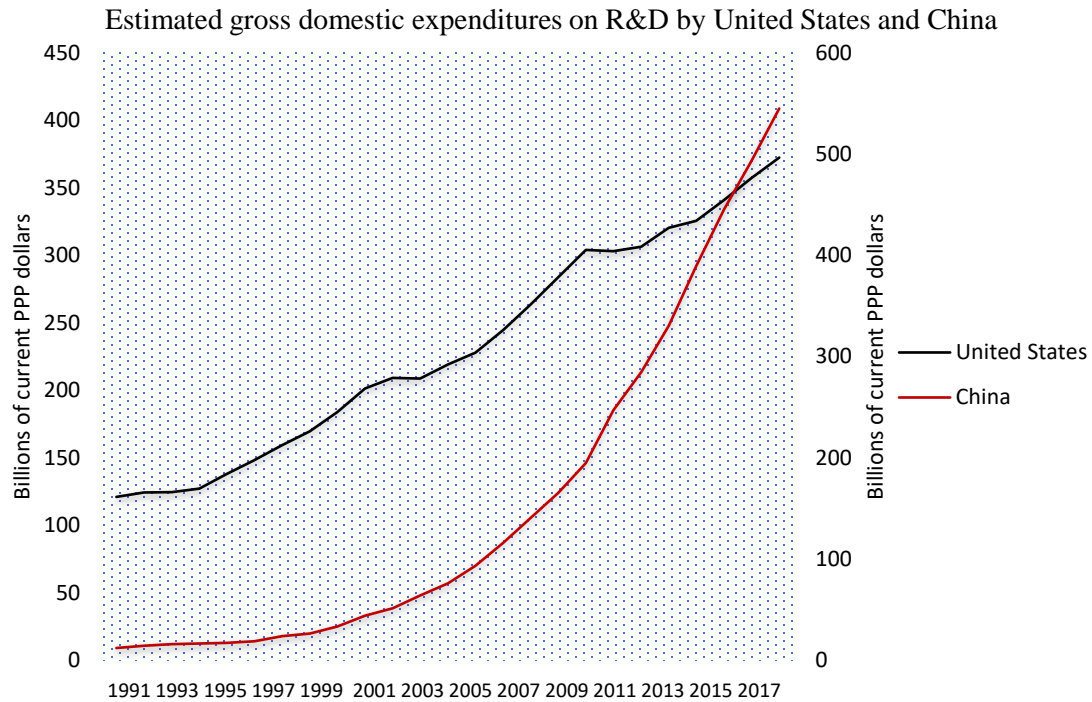
¹³² Reuters Staff, *China Spends \$279 Billion on R&D in 2017: Science Minister*, REUTERS.COM (Feb. 26, 2018), accessible online at <https://www.reuters.com/> (last visited on Apr. 1, 2018).

¹³³ Editor, *China overtakes Japan in global patent filings, takes aim at U.S.*, JAPAN TIMES (Mar. 22, 2018), accessible online at <https://www.japantimes.co.jp/> (last visited on Apr. 25, 2018).

¹³⁴ CHINA TECHNOLOGY MARKET STATISTICS SOURCEBOOK. (Ministry of Science and Technology, 2016).

¹³⁵ Clifford M. Gross, *The growth of China's technology transfer industry over the next decade: implications for global markets*, 38 JOURNAL OF TECHNOLOGY TRANSFER (2013) 716-747.

Figure 4.1 Estimated Gross Domestic Expenditures on R&D by the United States and China



Note 1: PPP=purchasing power parity;

Note 2: China is projected to surpass the United States in R&D spending in 2019.

Source: adapted from Science and Engineering Indicators 2018 (National Science Board).¹³⁶

¹³⁶ Science & Engineering Indicators 2018 (National Science Board), accessible online at <https://www.nsf.gov/> (last visited on Jan. 25, 2018).

4.2 An Overview of Market-Oriented Reforms

4.2.1 Nationalist China (Before 1949)

In the 1940s, most higher education institutes in China were private universities or sponsored by churches in the United States or Great Britain. By the mid-1920s, western missionaries had established more than thirteen Christian colleges in China, which later became the most prominent universities in pre-Communist China, providing advanced training in modern sciences for Chinese people.

The pioneers of missionary education in China believed that only when Chinese people were sufficiently educated in sciences, would they be away from endogenous superstitions. In the words of D. Z. Sheffield, the founder of North China College: “A man of culture and idea declines to be the servant of other men, simply because he feels in himself the power of self-government, the exact feeling that we want to develop, and must develop, before we have a church that can stand by itself.”¹³⁷

The Christian colleges have also taken an essential role in opening the doors of higher education for women.¹³⁸ Females in university education formed only 2.5 percent of the whole university student population in 1922, but this had grown to 15.2 percent by 1936.¹³⁹ Table 4.1 shows a sample list of church-sponsored colleges in early China.

¹³⁷ Kwang-Ching Liu, *Early Christian Colleges in China*, THE JOURNAL OF ASIAN STUDIES (1960).

¹³⁸ Terry Lautz, *Christian Higher Education in China: The Life of Francis C. M. Wei*, STUDIES IN WORLD CHRISTIANITY, Vol. 18 (2012) 21-40. See also e.g., PETER NG, CHANGING PARADIGMS OF CHRISTIAN HIGHER EDUCATION IN CHINA, 1888-1950 (Mellen Press, 2002). PHILIP WEST, YENCHING UNIVERSITY AND SINO-WESTERN RELATIONS, 1916-1952. (Harvard University Press, 1978).

¹³⁹ Wong Yin Lee, *Women's education in traditional and modern China*, WOMEN'S HISTORY REVIEW (1995) 345-367.

Table 4.1 The List of Western-sponsored Colleges in China 1864-1924

Western-sponsored Colleges in China, Established 1864-1924

Institution	Year of establishment	Location	Special field of training	Year of dissolution (mainland China)
Cheeloo University (Shantung Christian University)	1864	Jinan, Shandong	Medical science	1952
Yenching University	1870	Beijing	Social sciences	1952
St. John's University	1879	Shanghai	Medical science	1952
Lingnan University	1893	Guangzhou, Guangdong	Medical science and agronomy	1952
Chih-kiang University (Hangchow Christian University)	1897	Hangzhou, Zhejiang	Civil engineering	1952
Soochow University	1900	Suzhou, Jiangsu	Chemistry and law	1952
Shanghai Baptist College	1906	Shanghai	Business administration	1952
Hua Nan Women College	1908	Fuzhou, Fujian	Liberal arts	1952
Nanking University	1910	Nanjing, Jiangsu	Agronomy and electrical engineering	1952
West China Union University	1910	Chengdu, Sichuan	Medical science	1952
Ginling Women College	1915	Nanjing, Jiangsu	Physical education and home economics	1952
Fukien Christian University	1915	Fuzhou, Fujian	Natural sciences	1952
Hua Chung University	1924	Wuhan, Hubei	Natural sciences	1952

Source: adapted from Zheng (1965).¹⁴⁰

¹⁴⁰ See ZHUYUAN ZHENG, SCIENTIFIC AND ENGINEERING MANPOWER IN COMMUNIST CHINA, 1949-1963 (National Science Foundation, 1965) at 240.

4.2.2 The Mao-era (1949-1979)

After the People's Republic of China was founded in 1949, China replicated the Soviet system of central planning and complete state-ownership of higher educations. Private universities in China were either dissolved or merged into local state-owned universities. Most state-owned universities at that time were no longer involved in research, except Peking, Tsinghua, and a few other large institutions. Many specialized universities thereby focused on industry-specific technical education, such as textile industries, railroad, telecommunication, metallurgy, and printing skills.¹⁴¹

The primary objective of the policy changes was for China to mobilize national resources executing large and complex strategic tasks in the areas of defense and industrial technologies. In the early 1950s, the China government relied heavily on subsidized technology imports from the Soviet Union. During the first 5-year plan of industrialization, China imported 156 large technological projects, mostly in heavy industry, including power generation, mining, refining, chemicals and machine tools.¹⁴² To better accommodate these projects, China established more than 400 government research institutions (GRIs), with a primary emphasis on localizing the Soviet technology.¹⁴³

The State Science and Technology Commission (SSTC) was established during this period to supervise and monitor the technology development projects of research

¹⁴¹ YU ZHOU ET AL., *CHINA AS AN INNOVATION NATION* (Oxford University Press, 2016) at 36.

¹⁴² Xielin Liu & Steven White, *Comparing innovation systems: a framework and application to China's transitional context*, *RESEARCH POLICY* 30 (2001) 1091-1114.

¹⁴³ *Id.*

institutes as well as manufacturers specializing in production and dissemination of the Soviet technology. The research and development process was highly centralized and application-oriented. For instance, the SSTC-affiliated universities or research institutes undertook R&D, the state-owned enterprises manufactured the products, and the state business bureau distributed the products to end users under the central planning system.

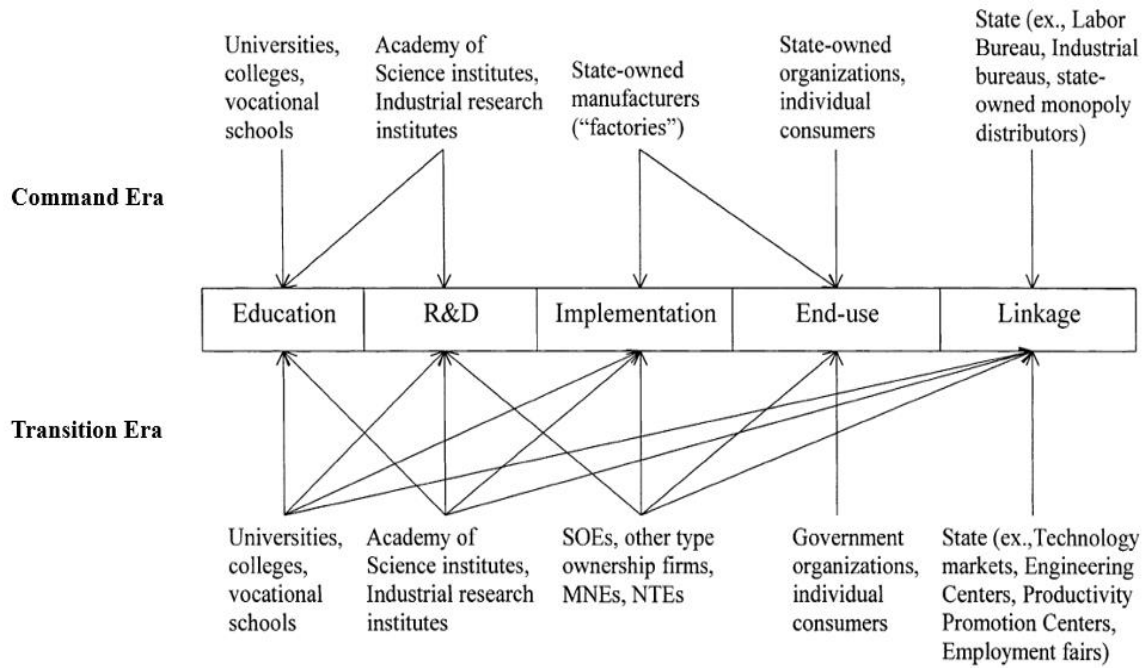
While some argued that China's centralized and hierarchical science and technology innovation system was more flexible and collaborative than its Soviet predecessor,¹⁴⁴ it was still fundamentally flawed without open market competition.¹⁴⁵ First, there were no incentives for researchers to introduce, diffuse or improve technologies.¹⁴⁶ There was neither market competition, profit generation, nor other efficiency-based criteria to evaluate their R&D performance. Second, there were no incentives for involved actors to initiate collaborations among each other for future R&D activities. Under the central planning system, researchers relied heavily on top-down resource allocation by the government and retained relatively little or no incentives to market their output resources to other organizations. The disastrous period of the Cultural Revolution of 1966-1976, further impeded China's research and development capacity as knowledge-based activities at universities and research institutions were disrupted. Figure 4.2 shows the distribution of innovation activities in China before and after the economic reforms.

¹⁴⁴ EVAN FEIGENBAUM, *CHINA'S TECHNO-WARRIORS: NATIONAL SECURITY AND STRATEGIC COMPETITION FROM THE NUCLEAR TO THE INFORMATION AGE* (Stanford University Press, 2003).

¹⁴⁵ Zhou, *supra* note at 24 at 37.

¹⁴⁶ An example of the innovation inertia is the Liberation Truck, whose design and production lines were imported by China from the Soviet Union in the 1950s. During the past 40 years, the design and production of the Liberation Truck have never been improved upon the imported technologies. See Liu & White, *supra* note 15.

Figure 4.2 Distribution of Innovation Activities During Command Era and Transition Era.



Source: Liu and White (2001).¹⁴⁷

¹⁴⁷ Xielin Liu & Steven White, *Comparing innovation systems: a framework and application to China's transitional context*, RESEARCH POLICY 30 (2001) 1091-1114.

4.2.3 Market-Oriented Reforms (1979-present)

By the late 1970s, with the end of the Cultural Revolution, the political leadership of China recognized the problems of a command economy. They also realized that science and technology were driven forces for economic growth in the future.¹⁴⁸ China began the market-oriented reforms in the late 1970s, which had a far-reaching impact on China's economic transformation. Changes were first initiated in agriculture, where farmers obtained more control over what crops to produce. The economic reforms later extended to the industrial sector.

China's state-owned enterprises (SOEs) have long suffered from poor efficiency. In the 1980s, the Chinese government implemented a three-stage plan to reform the SOEs.¹⁴⁹ The first step increased financial incentives for the SOEs management. The second step gave SOEs more autonomy and freedom in business decision-making, such as material supply, production outputs, and marketing. The third step diversified the ownership of SOEs through private investors. Private enterprises were encouraged to purchase SOEs equities or invest in SOEs-run projects.¹⁵⁰ As a result, the share of SOEs to China's total industrial output has dropped from 78 percent in 1978 to 26 percent in 1997.¹⁵¹

¹⁴⁸ In 1988, during his meeting with Czech President Husak, Deng Xiaoping observed the famous theory: "Science and technology are primary productive forces." See Deng Xiaoping, Science and Technology Constitute A Primary Productive Force. (Sep. 12, 1988), accessible online at <http://en.people.cn/> (last visited on Apr. 25, 2018).

¹⁴⁹ Fox Z. Y. Hu, *Deconstructing State-Owned Enterprises in Socialist China under Reform: A Scalar Examination*, ENVIRONMENT AND PLANNING A: ECONOMY AND SPACE 37 (2005) 703-722.

¹⁵⁰ Privatizing the SOEs is politically impossible in contemporary China. See Xinling Wang, *China's twenty-year dream of SOE reform still unfilled*, EASTASIANFORUM (Oct. 4, 2017), accessible online at <http://www.eastasiaforum.org/> (last visited on Mar. 15, 2018).

¹⁵¹ Hu, *supra* note 147.

Since the early 1980s, China also shifted its former plan-oriented science and technology policy to a market-oriented one.¹⁵² Meanwhile, China tried to build a national innovation system to satisfy the need of the market economy. Changes in the labor market reflected how these reforms had greatly influenced the technology market. Under the former command economy, university graduates had no freedom to choose their careers. The state labor bureau mandated job assignments to university graduates considering the available open positions and the remaining unemployed workers. The market-oriented reforms eliminated the labor bureau's role in allocating human resources and allowed university graduates more freedom in job choices.

As a result, qualified scientists and engineers were moving from state-owned institutes to foreign or private enterprises that offered them better working conditions. Some even determined to build their own companies. During the 1980s, for example, scientists from the Chinese Academy of Sciences (CAS) formed spin-off companies to commercialize CAS-developed technologies. The Chinese Academy of Sciences (CAS) is one of the largest state-run research institutions in China, originally set up in 1949 on the Soviet research model. It now encompasses eighty-four research units and employs a staff of nearly 50,000 people, of whom more than sixty-seven percent are science and technology researchers.¹⁵³

¹⁵² Jici Wang & Jixian Wang, *An Analysis of New-Tech Agglomeration in Beijing: A New Industrial District in the Making?* ENVIRONMENT AND PLANNING 30 (1998) 681-701.

¹⁵³ JOEL R. CAMPBELL, *BECOMING A TECHNO-INDUSTRIAL POWER: CHINESE SCIENCE AND TECHNOLOGY POLICY* (Brookings Institute, 2013) at 8.

In 1980, the first privately-owned technology company in China was created by CAS scientists.¹⁵⁴ New Technology Company, a CAS spin-off established in 1984, has developed into the world's largest computer manufacturing company, now the Lenovo Group.¹⁵⁵ Similarly, the Founder Group, a major Chinese technology conglomerate established in the 1980s, were spawned off from the Peking University. This spin-off period in the 1980s has left an imprint on China, as it produced China's first group of technology companies that combined technological competency with market savvy.¹⁵⁶

During this period in the 1980s, however, universities played a relatively limited role in research and development in China. One major problem that universities face was the shortage of research funding, where government research institutes (e.g., CAS) rather than universities had received the largest proportion of R&D funding. For example, in 1987 government research institutes (e.g., CAS) accounted for fifty-four percent of China's R&D expenditures, while universities accounted only sixteen percent.¹⁵⁷

Nevertheless, the success of early CAS spin-off companies helped pave the way for China's future reforms of its innovation capacity.¹⁵⁸ In 1988, the Ministry of Science and

¹⁵⁴ The name of this company was Beijing Huaxia Guigu Information System Corporation. See JOHN L. ORCUTT & HONG SHEN, *SHAPING CHINA'S INNOVATION FUTURE: UNIVERSITY TECHNOLOGY TRANSFER IN TRANSITION*. (Edward Elgar Publisher, 2011) at 26.

¹⁵⁵ Oscar Waterworth, *An Overview of the Beijing Startup Eco-System*, China Business Forum, accessible online at <https://www.cnbusinessforum.com/overview-beijing-startup-eco-system/> (last visited on Mar. 25, 2018).

¹⁵⁶ See e.g., QIWEN LU, *CHINA'S LEAP INTO THE INFORMATION AGE: INNOVATION AND ORGANIZATION IN THE COMPUTER INDUSTRY*. (Oxford University Press, 2000). SHULIN GU, *CHINA'S INDUSTRIAL TECHNOLOGY: MARKET REFORM AND ORGANIZATIONAL CHANGE*. (Routledge, 1999). YU ZHOU, *INSIDE STORY OF CHINA'S HIGH-TECH INDUSTRY: MAKING SILICON-VALLEY IN BEIJING*. (Rowman & Littlefield, 2008).

¹⁵⁷ MICHAEL T. ROCK & MICHAEL TOMAN, *CHINA'S TECHNOLOGICAL CATCH-UP STRATEGY: INDUSTRIAL DEVELOPMENT, ENERGY EFFICIENCY AND CO2 EMISSIONS*. (Oxford University Press, 2015) at 157.

¹⁵⁸ ORCUTT & SHEN, *supra* note 152.

Technology (MOST), formerly the State Science and Technology Commission (SSTC), launched the Torch Program. The primary object of this program was to increase the flow of technology from the government institutes to the commercial sector. The most notable impact of the Torch Program was the creation of high technology development zones, which aimed to cluster high-tech companies round a scientific research center.¹⁵⁹

In the developing process of the Torch Program, however, the local governments recognized that universities were the primary engine for research and development. Thus, the University Science Park Program was concurrently started in the 1990s.¹⁶⁰ In China, university science parks operate like a linkage platform for universities to commercialize academic research and to incubate innovative startups with the outside business sector.¹⁶¹ During this period, China also developed a legal framework that could support the business activities in the technology transfer market. For example, in the 1980s, China created a new system of contract law, of intellectual property laws, and of laws that regulate market-based organizations. Chapter 5 discusses this topic in greater detail.

Furthermore, to better organize the technology transfer activities, the Ministry of Science and Technology established the national technology transfer centers as a policy instrument. In 2008, the Ministry of Science and Technology nominated 76 institutions to be the first group of national technology transfer centers that had provided premier services to customers in the technology market. These nationally-recognized technology

¹⁵⁹ Id. at 34.

¹⁶⁰ Yonghua Zou & Wanxia Zhao, *Anatomy of Tsinghua University Science Park in China: Institutional Evolution and Assessment*, JOURNAL OF TECHNOLOGY TRANSFER 39 (2014) 663-674.

¹⁶¹ Hongyu Liu, *National University Science Parks in China and Their Efficiency – Analysis and Implications for Future Strategies*. (Tohoku University, Dissertation 2015).

transfer centers comprised a variety of institutions, including IP management agencies, technological and engineering companies, professional industry alliances, and university research and development institutes.¹⁶² Unlike technology licensing offices in the U.S., technology transfer centers in China functioned more like a consulting institution specialized in technological problem-solving.¹⁶³

Since the market-oriented reforms, central planning no longer controlled the innovation system in China. However, the Chinese government (e.g., the Ministry of Science and Technology) remained a dominant force in driving university and industry innovation. The state's engineering and organizational capacity has been apparent in recent mega-projects in the civilian sectors, including the development of high-speed rail, 5G telecommunications infrastructure, and the launch of the quantum satellite. However, these impressive achievements alone do not suffice for building a modern, multi-faceted innovation system, which requires China shift from a government-centered decision-making model to a market-based interaction model that coordinates multiple stakeholders in the private sector and the university sector.¹⁶⁴

¹⁶² Paul Miesing & Mingfeng Tang, *Technology Transfer Institutions in China: A Comparison of Value Chain and Organizational Structure Perspectives* (unpublished paper), accessible online at <https://www.albany.edu/> (last visited on Feb. 29, 2018).

¹⁶³ An officer of the national technology transfer center affiliated with Tsinghua University explained that, "The university-industry linkage in our national technology transfer center is rather loose. Because of limited budgets, we are seldom out of the office and just wait for firms to come to us..." See MING-FENG TANG, *TECHNOLOGY TRANSFER FROM UNIVERSITY TO INDUSTRY: INSIGHT INTO UNIVERSITY TECHNOLOGY TRANSFER IN THE CHINESE NATIONAL INNOVATION SYSTEM*. (Adonis & Abbey, 2009) at 119.

¹⁶⁴ See e.g., Henry Etzkowitz, *The Entrepreneurial University: Vision and Metrics*, *INDUSTRY AND HIGHER EDUCATION*, Vol. 30 (2016) 83-97. Henry Etzkowitz, *The triple helix: science, technology and the entrepreneurial spirit*, *JOURNAL OF KNOWLEDGE-BASED INNOVATION IN CHINA*, Vol. 3 (2011) 76-90.

4.3 Contemporary Technology Transfer Market

In the pre-reform period, the functions of China universities were limited mainly to educating and training. Only a small number of universities were involved in research, primarily in the areas of defense and military technology.¹⁶⁵ Even today, China universities have not become a primary vehicle of national R&D, counting for only about ten percent of total national R&D expenditures.¹⁶⁶ In 2012, 1,025 China universities received about \$12 billion in R&D funding, of which twenty-nine universities received nearly half of all the R&D funding.¹⁶⁷

Besides imbalances among universities in resource allocations, China universities steer much less of R&D funding to basic research than do many OECD countries. Figure 4.3 shows the percentage of university R&D spending on basic research by state. But things might evolve quickly as the China government vowed to provide more funding for basic research. More support will be granted for basic research in mathematics and physics, as well as other basic research involving universe evolution, the origin of life, brain science and cognition, quantum science and deep-ocean science, according to the State Council of China.¹⁶⁸

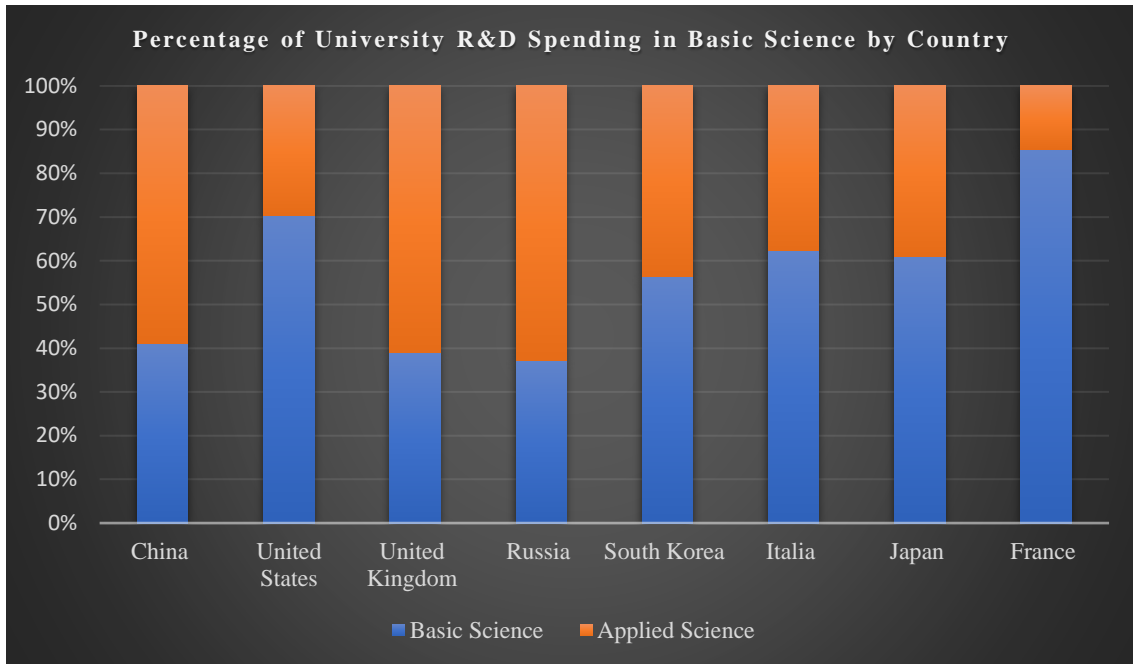
¹⁶⁵ JUE ZHANG, *THE DEVELOPMENT OF HIGH-TECH ENTERPRISES IN CHINA'S UNIVERSITIES* (Zhong guo gao xiao gao xin ji shu chan ye de fa zhan yan jiu). (Huazhong Science and Technology University Press, 2003).

¹⁶⁶ Weiping Wu, *Managing and incentivizing research commercialization in Chinese Universities*, *JOURNAL OF TECHNOLOGY TRANSFER* 35 (2010) 203-224.

¹⁶⁷ Xiaole Ni, *China's research & development spend*, *NATURE* 520 (2015) 58-59.

¹⁶⁸ Yojana Sharma, *Science ministry expands power over research funding*, *University World News* (Mar. 21, 2018), accessible online at <http://www.universityworldnews.com> (last visited on Apr. 28, 2018).

Figure 4.3 The Percentage of University R&D Spending in Basic Research by Country



Source: adapted by the author based on data from the HEI dataset (2016).¹⁶⁹

¹⁶⁹ HIGHER EDUCATION INSTITUTES INNOVATION CAPACITY MONITOR REPORT. (中国普通高校创新能力监测报告) (Ministry of Education and Ministry of Science and Technology, 2016).

4.3.1 Technology Contracts

Despite its limited role in research and development, China universities have seen a dramatic increase in technology commercialization activities over the past two decades. Unlike the U.S. universities using patents as the primary vehicle for technology transfer, China universities commonly use technology contracts. A recent study shows that, in 2015, China universities executed about 54,362 technology contracts with industry, generating more than \$45 billion in revenues.¹⁷⁰ In China, technology contracts are divided into four categories, including technology development contracts, technology transfer contracts, technology consulting contracts, and technology services contracts.¹⁷¹

Technology services contracts that include technical training and intermediary services constituted the largest proportion of technology contracts in China. Technology development contracts, such as commissioned research contracts or joint research contracts, ranked the second regarding total transaction revenues. By contrast, technology transfer contracts¹⁷² and technology consulting contracts played a relatively immaterial role in university-industry collaborations. For example, in 2012, Tsinghua University generated a total of 1,939 technology contracts, of which only 6.63 percent were technology transfer contracts. Among these technology transfer contracts, 28 were patent

¹⁷⁰ Quan Guo Ji Shu Shi Chang Tong Ji Bao Gao (全国技术市场统计报告) [CHINA TECHNOLOGY MARKET STATISTICS SOURCEBOOK] (Ministry of Science and Technology, 2015).

¹⁷¹ Contract Law of China § 322.

¹⁷² Id. The subject of the technology transfer contract includes trade secrets, patent, licensing, software copyright, and design copyright.

licensing contracts, 13 patent assignment contracts, and 6 trade secret contracts. Table 4.2 shows a sample distribution of technology contracts by Tsinghua University.

Table 4.2 Distribution of Technology Transfer Contracts by Tsinghua University in 2012

Distribution of Technology Contracts by Tsinghua University

Category	Number of Contracts	Percentage of Total Contracts	Total Revenues (RMB)	Percentage of Total Revenues
Technology Development	602	31.05	609,054,500	48.93
Technology Services	905	46.67	399,360,700	32.09
Technology Consultancy	385	19.86	153,694,700	12.35
Technology Transfer	47	2.42	82,525,100	6.63

Source: Tsinghua University Technology Transfer Office

The largest recipient of such technology contracts in China were state-owned enterprises, which had signed close to one-half of the agreements with universities.¹⁷³ The dominant role of state-owned enterprises in the technology transfer market has made several implications. Firstly, it revealed the lack of in-house R&D capability in the state-owned enterprises who have long been blamed for being inefficient in the production process. Secondly, it affirmed the existing institutional channels in the state sector that had facilitated connections between universities and state-owned enterprises, since most universities in China were state-owned as well. Thirdly, it suggested the continued difficulty of private enterprises in accessing state-owned resources including those of universities. Foreign-invested enterprises, on the contrary, have drawn the least upon university research in China. As an officer from a leading university commented on it,

“Our university has signed many technology contracts with state-owned enterprises because state-owned enterprises offer a higher price for the contracts. Private enterprises want the contracts, but they cannot afford them. A multimillion-RMB contract would exceed the financial budgets of many small and medium private enterprises in China. Besides, our university has many connections in the science and engineering fields. If you check the resumes of the CEOs and principal engineers in the state-owned enterprises, eighty percent of them have graduated from our university. State-owned enterprises can make an endowment to our university through technology contracts which are tax exempted. Furthermore, the government has appointed many professors of our university as an expert appraiser for government procurement programs or national development projects, such as Belt and Road. State-owned enterprises or other private firms that acquired consulting services from our university would have better odds to win the government contracts.”¹⁷⁴

¹⁷³ Xielin Liu & Nannan Lundin, *Toward a Market-based Open Innovation System of China* (unpublished paper, 2007), accessible online at <http://www.globelicsacademy.org/> (last visited on Feb. 20, 2018).

¹⁷⁴ On-site interview with an anonymous by the author (transcribed and translated on March 10, 2018).

4.3.2 Patent Licensing

Although patent licensing has not been commonly used by Chinese universities in technology transfers, recent decades have seen a rapid increase in the volume of university patenting and licensing activities. From 2006 to 2014, total patent applications filed by Chinese universities have increased tenfold, from roughly 23,000 in 2006 to 184,000 in 2014.¹⁷⁵ The growing number of patent applications, however, has raised specific concerns among audiences about the quality of those granted patents.

One of the major issues is the “double counting” strategy used by patent applicants. Because the review process of an invention patent at the State Intellectual Property Office (SIPO) usually takes three to four years, some applicants will apply for a utility patent spontaneously with an invention patent with hopes to obtain legal protection sooner by reducing the time length of patent issuance.¹⁷⁶ SIPO will not issue “double patents” on the same invention, but it is far from clear whether SIPO can filter out the repeated patent filings due to large volumes of patent applications stocked. This potential “double counting” problem has caused some observers to question the number of patent applications by Chinese universities. Even faculty members of universities felt annoyed by the “double counting” strategy. As one professor from a major university complained that,

¹⁷⁵ Zhong Guo Pu Tong Gao Xiao Chuang Xin Neng Li Jian Ce Bao Gao (中国普通高校创新能力监测报告) [HIGHER EDUCATION INSTITUTES INNOVATION CAPACITY MONITOR REPORT] (Scientific and Technical Documentation Press, 2016).

¹⁷⁶ ORCUTT & SHEN, *supra* note 152 at 66.

“I myself am confused about the number of patents I have because the technology transfer office always asks me to apply for two patents on the same invention. They just want a higher number to show off.”¹⁷⁷

Whether the “double counting” problem was accountable for the explosive growth of patent applications in China has remained unclear, however, the increase in patent filings has seen a partial knock-on effect on patent licensing. For example, with the rise in patent filings, the number of patents licensing by Chinese universities has increased from 1,602 in 2009 to 2,293 in 2014, with a compound annual growth rate of twelve percent.¹⁷⁸

Despite the rapid growth in patent filings, patent licensing income remained modest for Chinese universities. In 2014, Chinese universities generated a total of \$90 million in patent licensing revenues¹⁷⁹, paled in comparison with \$93 million in 2009.¹⁸⁰ Figure 4.4 shows the recent trends of patent licensing income generated by Chinese universities. The lack of high-value transactions in the patent licensing market is mainly due to inefficient patent enforcement systems in China. Recent research shows that pure patent licensing or know-how-based technology transfer is much more difficult to promote in China than complete solutions or commercially-ready technologies, where a significant proportion of the patent licensing deals in China have been based on patent pools or assertion claims.¹⁸¹

¹⁷⁷ See Wei Hong, *Technology Transfer of Chinese Universities: Forms and Implications* (2005), paper presented at the annual meeting of the American Sociological Association. Cited in ORCUTT & SHEN, *supra* note 152 at 143.

¹⁷⁸ MONITOR REPORT, *supra* note 173.

¹⁷⁹ This number includes both patent licensing and patent sales.

¹⁸⁰ *Id.*

¹⁸¹ Ting Zhang, *Technology Transfer and IP Licensing in China*, IPR Bulletin 40 (2008), accessible online at <http://www.chinabusinesssolutions.com/> (last visited on Mar. 15, 2018).

The modest patent licensing results by Chinese universities might also be attributable to the insufficiency of commercialization capabilities in universities.¹⁸² Many Chinese universities do have technology transfer departments. However, their role and actual functions within the university system are different from that of technology transfer offices (TTOs) in the U.S. universities. In many cases, TTOs in China universities focus more on helping faculties file patent applications for their inventions. Sometimes this role is limited to selecting and connecting with an outside patent agency, which then takes care of the entire drafting and prosecution of the patent application.¹⁸³

The decisions about whether, where and how to file claims for inventions are not always made by TTOs, but are left to the academics, and most commonly rests with the academic who heads the specific laboratory or department.¹⁸⁴ As a result, the actual commercialization efforts of TTOs in China universities are quite limited. TTOs in Chinese universities seldom actively scout for research projects or identify high-potential inventions that may lead to products with high commercial value.¹⁸⁵ It is probably due to lack of experience, resources, and understanding of the commercialization process.¹⁸⁶

¹⁸² ORCUTT & SHEN, *supra* note 34 at 151.

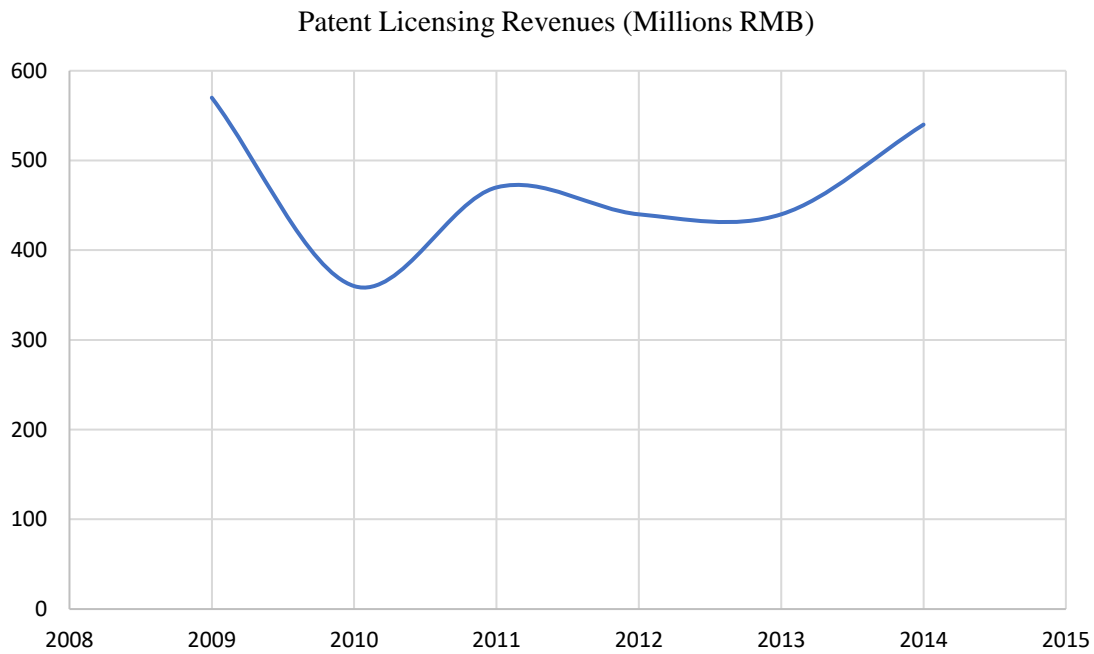
¹⁸³ Ziv Rotenberg, *Where next for university IP commercialization in China?* INTELLECTUAL ASSET MANAGEMENT 79 (2016), accessible online at <http://group8consultants.com/> (last visited on Mar. 30, 2018).

¹⁸⁴ *Id.* If the value of the technology transfer contracts exceeds certain amounts, the president of the university system will make the final decision.

¹⁸⁵ *Id.* Some insiders mention that patents can be easily acquired from China universities for as little as RMB 10,000 (which only covers the application and registration costs), which is quite contrast to negotiations with the TTOs in U.S. universities. TTOs in U.S. universities prefer to license inventions rather than sell them. This case suggests that TTOs in China universities have made less emphasis on reaping long-term rewards and more on short-term returns.

¹⁸⁶ The Ministry of Education conducted a survey on 3,626 persons involved in university technology transfer projects. The survey listed seven barriers that might affect university technology transfers. Respondents of the survey thereby ranked the seven barriers in the following priorities: lack of

Figure 4.4 Patent Licensing Revenues by Chinese Universities 2009-2014



Source: adapted by the author based on data from the RIC dataset.

information (32.7%), lack of incentives (26.5%), lack of policy supports (15.4%), lack of financial supports (14.5%), inventions not marketable (7.5%), inefficient IP agencies (2.1%), other factors (1.3%). See MONITOR REPORT, *supra* note 173 at 71.

4.3.3 Equity Investment

Although imperfect, university TTOs in China has slowly become more active and more systematic in their efforts to identify opportunities for the commercial exploitation of university inventions. For example, Peking University has combined their technology transfer and investment office with student entrepreneurship training programs that teach students how to scale businesses based on university technologies.¹⁸⁷ Shanghai Maritime University has established a separate corporate entity to manage portfolios of university intellectual property.¹⁸⁸ Zhejiang University has also launched a \$1.5 million seed fund to finance university spin-offs.¹⁸⁹

The potential shift in technology transfer from the patent-centric mode to the start-up mode coincides with the surge in China's venture capital markets. Before 1985, venture capital did not exist in China. But after three decades of development, China now receives the second largest venture capital investment in the world.¹⁹⁰ According to Zero2IPO, while there were only 10 active VC/PE firms in China in 1995, the number increased to 500 in 2005, and 5,000 in 2012.¹⁹¹ Figure 3.5 shows the geographic distribution of

¹⁸⁷ Christopher Laing, *China's technology transfer landscape – the new frontier*, MEDCITY NEWS (Feb. 22, 2016), accessible online at <https://medcitynews.com/> (last visited on Sep. 09, 2017).

¹⁸⁸ In 2016, Shanghai Maritime University established a joint venture company with a university-based research team to commercialize a telecommunication technology that worth at least \$3 million. See Editor, Intangible IP assets owned by a Shanghai-based university were recognized as an equity investment in a startup company, Shanghai.gov (Jul. 31, 2016), <http://www.shanghai.gov.cn/> (last visited on Jan. 2, 2018).

¹⁸⁹ Editor, *Zhejiang University Zi-Jin Innovation Fund was launched*, zju.edu (Dec. 30, 2015), accessible online at <http://www.zju.edu.cn/> (last visited on Jan. 30, 2018).

¹⁹⁰ Lin Lin, *Engineering A Venture Capital Market: Lessons from China*, 33 COLUMBIA JOURNAL OF ASIAN LAW (2017).

¹⁹¹ YU ZHOU ET AL., CHINA AS AN INNOVATION NATION (Oxford University Press, 2016) at 71.

venture capital firms in China.¹⁹² In 2016 alone, 636 new venture capital funds were set up in China, collectively raising more than \$52.07 billion of fresh capital for investment, a 79.4 percent rise over the prior year.¹⁹³ Also, more than a quarter of new unicorns have been created in China since 2010.¹⁹⁴ In 2016, 12 of the 33 new \$1 billion startup companies that created around the world were in China.¹⁹⁵

The reasons behind this phenomenon include a flood of private capital that has lifted startup valuations around the world, and that China's economy has matured into a more advanced service economy.¹⁹⁶ In response to the expansion of the venture capital market, China universities have launched their funds to invest in high-potential startups with hopes to better commercialize university technologies. For example, in 2017, the Office of Technology Transfer in Tsinghua University proposed to launch a \$500 million fund for start-ups, named after the LotusPool Venture Fund.¹⁹⁷

The efforts made by China universities for equity investment in startup companies have raised specific concerns. One major problem with startup formation is the lack of an exit route. For start-ups investors, the most common way to cash out is through an exit. Most venture capital firms will seek to exit their investment in a reasonable timeframe

¹⁹² Jun Zhang, *Venture Capital in China*, in YU ZHOU ET AL., *CHINA AS AN INNOVATION NATION* (Oxford University Press, 2016).

¹⁹³ Lin, *supra* note 73.

¹⁹⁴ Michael J. Cohen, *One in three Unicorns is now being born in China*, QZ.COM (Oct. 2, 2017), accessible online at <https://qz.com/> (last visited on Jan. 20, 2018).

¹⁹⁵ *Id.* Example like Tencent versus Google, Didi versus Uber, and WeChat versus Facebook.

¹⁹⁶ *Id.* Some believe China has an unrivaled set of local markets for startups: the U.S. has 11 cities with more than one million people, while China has more than 100.

¹⁹⁷ Investment Platform – Innovation Fund (*he tang chuang xin ji jin*), accessible online at <http://ott.tsinghua.edu.cn/> (last visited on Mar. 10, 2018).

(typically two to five years).¹⁹⁸ There are two primary techniques that venture capital firms employ to exit their start-up investment: acquisition exits, and IPO exits.¹⁹⁹ Regarding China universities that involved in startup investment, however, it is unclear whether they have had a planned strategy to exit their investment in five years.

The second problem with startup formation is the lack of capable personnel. The successful operation of venture capital firms is highly dependent on the ability of its management. In the business world, venture capital managers tend to come from either “operational” or “financial” background. Managers with an operational background tend to be former entrepreneurs with experience building and exiting start-ups, and managers with a financial background tend to be former investment bankers. It is doubtful whether the TTOs in China universities have had such a business-savvy team. As one official from a leading China university commented on it,

“In our office, we have people with science and engineering degrees. But we do not have enough people with accounting or financial backgrounds, who understand the metrics and the logic of investment.”²⁰⁰

The third problem is the lack of a robust IPO environment. In the U.S., the most common practice of exiting from investment in start-ups is through an initial public offering (IPO).²⁰¹ In China, there has yet been a well-developed stock market, and the

¹⁹⁸ ORCUTT & SHEN, *supra* note 152 at 206.

¹⁹⁹ *Id.* Acquisition exits involve the sale of the entire start-up to a third party. IPO exits involve an initial public offering in the stock market. Thereby, venture capital firms can sell their stock in the start-up through the secondary market.

²⁰⁰ Interview with an anonymous by the author (transcribed and translated on March 10, 2018).

²⁰¹ Ronald J. Gilson & Bernard S. Black, *Venture Capital and the Structure of Capital Markets: Banks Versus Stock Markets*, 47 *JOURNAL OF FINANCIAL ECONOMICS* 243-277 (1998).

channels for start-ups to go public in China were quite limited.²⁰² Currently, China's securities laws do not allow firms that have yet to turn profitable to go public in the domestic stock market.²⁰³ As a result, many Chinese companies determine to arrange initial public offerings in the overseas markets. For example, in 2017, sixteen Chinese firms went public in the U.S. market, collectively raising \$3.4 billion on U.S. exchanges, and tech IPOs were among the best performers of the year.²⁰⁴ To embrace the tech boom in China, Hong Kong stock market recently reformed its listing system, which would permit pre-revenue biotech companies to list and would allow dual-class shares that give founding shareholders greater voting power.²⁰⁵

Despite the overseas competition, China has taken measures to modernize its stock market to better serve the high-growth, though smaller, tech companies. In 2009, China launched its first particular stock market, a NASDAQ-style market named ChiNext.²⁰⁶ To attract innovative and fast-growing enterprises, especially high-tech firms, the listing standards of ChiNext were less stringent than those of the Shanghai Stock Exchanges and the Shenzhen Stock Exchanges.²⁰⁷ In 2016, there were 531 companies listed on the ChiNext board, with a cumulative market capital of RMB 5.32 trillion.²⁰⁸ In 2018, the

²⁰² ORCUTT & SHEN, *supra* note 152 at 221.

²⁰³ Securities Laws of P.R. China, §13.

²⁰⁴ Rebecca Fannin, *Investors readying for a surge in blockbuster China IPOs*, CNBC (Jan. 29, 2018), accessible online at <https://www.cnbc.com/> (last visited on Mar. 1, 2018).

²⁰⁵ Editor, *Hong Kong Stock Market Reforms: Will Hong Kong Stock Market be the next favorite market for China Biotech companies to go public?* sina.com (Jan. 29, 2018), accessible online at <http://finance.sina.com.cn/> (last visited on Apr. 20, 2018).

²⁰⁶ ORCUTT & SHEN, *supra* note 152 at 222.

²⁰⁷ Shenzhen Stock Exchange (SZSE) ChiNext Market Overview, HKEX (Nov.14, 2016), accessible online at <http://www.hkex.com.hk/> (last visited on Apr. 20, 2018).

²⁰⁸ *Id.* Of these listed companies, 70% are from the manufacturing industry and 18% are from the IT industry, which account for 61% and 23% of the aggregate market capitalization respectively.

government increased policy support for emerging industries, which would allow overseas-listed firms or pre-revenue start-ups to raise funds in the domestic market.²⁰⁹

Innovation requires more than technology. It also needs capital to commercialize itself. Hence, it is increasingly important for companies with proprietary innovation to sustain funds in the capital markets.²¹⁰ The recent surge in venture capital and the current reforms of the IPO market have exemplified this trend. It is difficult to extrapolate from existing data the future size of China's technology transfer market, but the best guess would be that at the current rate of growth China tech firms will benefit much from the venture capital market and the IPO market to invigorate its domestic innovation efforts. Figure 4.5 shows the spatial distribution of venture capital offices and investments.

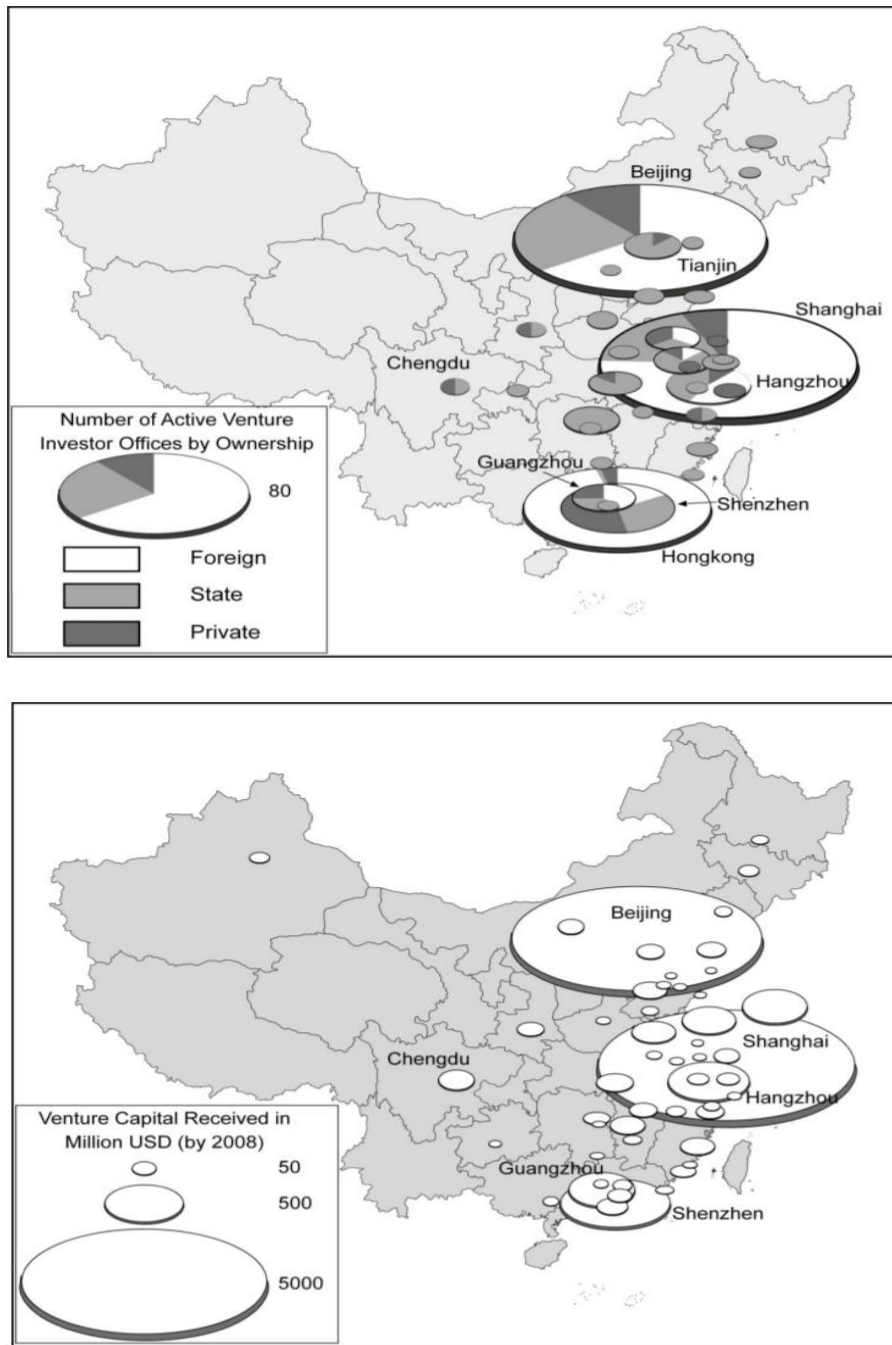
To achieve the outputs of technology transfers would require an increase in the current skill set of university technology transfer offices or require the development of a class of business-savvy intermediaries that can bring the university sector and the industry sector together.²¹¹ Chapter 6 discusses this topic in greater detail.

²⁰⁹ Shidong Zhang, *China's stocks slip as official support for tech firms triggers sell-off in traditional sectors*, SOUTH CHINA MORNING POST (Apr. 02, 2018), accessible online at <http://www.scmp.com/> (last visited on Apr. 10, 2018).

²¹⁰ Gross, *supra* note 18 at 744.

²¹¹ *Id.*

Figure 4.5 Spatial Distribution of VC Offices and Investments in 2008



Source: Jun Zhang (2016).²¹²

²¹² Jun Zhang, *Venture Capital in China*, in YU ZHOU ET AL. (EDS.), *CHINA AS AN INNOVATION NATION* (Oxford University Press, 2016) at 72.

4.4 Case Study: China's Biomedical Innovation

Biomedical drugs are the world's fastest-growing class of medicines. Of the top 10 therapeutics on the market today, eight are biomedical drugs.²¹³ China's biomedical innovation has made great leaps in the last decade, including exponential growth in academic publications, patent filings, international exchanges, and drug R&D activities.

Recent studies show that China's progress in basic scientific research, particularly in the biomedical and healthcare fields, is one of the fastest in the world.²¹⁴ The number of biomedical research articles published by Chinese scientists since 2002 has been increased by roughly eighteen percent annually, whereas the number of biomedical publications by U.S. scientists increased by only 0.6 percent.²¹⁵ Regarding biomedical patents, China filed thirty percent of global life science patent applications in 2011, increasing from poorly one percent of global applications in 1991.²¹⁶

China's new drug R&D capabilities have also improved significantly in the past decade. Some of the leading Chinese pharmaceutical companies are now expanding from a manufacturing focus to investing more in innovative portfolios. Other leading Chinese pharmaceutical companies that historically-focused on generic drugs have started building R&D capabilities on innovative drugs using the latest biotechnologies. Smaller, newly-founded biotech companies over the past five years have focused on addressing

²¹³ Editor, *GE aims to foster emerging biopharma market in Guangzhou*, China Daily (Dec. 6, 2017), accessible online at <http://www.chinadaily.com.cn/> (last visited on Mar. 3, 2018).

²¹⁴ Xiaolin Tang & Jian Du, *The performance of China's biomedical innovation: a scientometric analysis*, 59 SCIENCE CHINA 1074-1082 (2016)

²¹⁵ Yu Xie et al., *China's Rise as a Major Contributor to Science and Technology*, PNAS 111:6 (2014).

²¹⁶ Eric Warner, *Patenting and Innovation in China* (Rand Graduate School, Dissertation 2015).

global unmet medical needs. For example, in 2015, Shenzhen Chipscreen Biosciences successfully launched a new drug on the market, which is the first modern oncology drug that can be used to treat a rare lymph-node cancer.²¹⁷ In 2017, another biotech company in Beijing, Beigene, signed a deal worth up to \$1.4 billion with Celgene, licensing a cancer immunotherapy drug to the U.S. counterpart, which is the first and largest ever transaction that brought a China-discovered cancer drug to U.S. patients.²¹⁸

Moreover, the Chinese government's pro-innovation policies have made huge contributions to the development of China's biomedical industry. In one of the high-profile initiatives, such as "Made in China 2025," biomedical industry is named one of the ten key sectors where China wants to revitalize indigenous innovation.²¹⁹ More specifically, the ongoing reforms of the China Food and Drug Administration (CFDA) have accelerated the regulatory timeline of new drug development in China.²²⁰ For example, in 2016, the application backlog of new drug approval in CFDA has quickly been reduced from 22,000 in mid-2015 to about 8,000.²²¹ Biomedical service companies have also mushroomed in China over past years, providing new possibilities for open-source drug innovation to lower the R&D costs and shorten the timeline of new drug

²¹⁷ Ge Li et al., *The transformation and future of China's biomedical innovation*, THE BUSINESS TIMES (Jul. 18, 2016), accessible online at <http://www.businesstimes.com.sg/> (last visited on Jan. 30, 2018).

²¹⁸ Ben Hirschler & Adam Jourdan, *China biotech's coming out party' masks long road ahead*, REUTERS (Oct. 18, 2017), accessible online at <https://www.reuters.com/> (last visited on Apr. 27, 2018).

²¹⁹ Made in China 2025, the State Council of China, accessible online at <http://english.gov.cn/> (last visited on Jan. 30, 2018).

²²⁰ Brian Yang, *How China Regulatory Reforms Ring in International Biotechs' New Year*, INFORMA.COM (Jan. 31, 2018), accessible online at <https://pink.pharmaintelligence.informa.com/> (last visited on Mar. 30, 2018).

²²¹ Fangning Zhang & Josie Zhou, *What is next for pharma innovation in China*, MCKINSEY&COMPANY (Sep. 2017), accessible online at <https://www.mckinsey.com/> (last visited on Mar. 1, 2018).

discovery. These positive moves on the regulatory side as well as the technological advances at companies have given Chinese biomedical industry an advantage in the global competition for new drug discovery.²²²

China is now the world's second-largest pharmaceutical market after the United States, with more cases of diabetes and cancers fueled by fast food, smoking, and pollution. In 2016, for example, China has 114 million diabetic patients, and more than 700,000 new cases of lung cancer diagnosed each year.²²³ Despite the mounting medical needs, China's domestic pharmaceutical industry R&D investment was only \$6.3 billion, compared to \$157 billion worldwide by pharmaceutical companies in 2016.²²⁴ Many of the new drugs discovered in China are follow-on medicines in established therapeutic classes rather than ground-breaking first-in-class treatments, according to experts in the pharmaceutical industry.²²⁵

Unlike U.S. universities where innovation in drug discovery can flourish,²²⁶ China universities play a relatively limited role in biomedical innovation. Between 1998 and 2007, U.S. universities and their spin-offs produced 56 percent of the new small molecule and biologic drugs reviewed by the FDA, according to an early survey.²²⁷ No data available for China universities in the late 1990s, but the results might still look

²²² Ben Hirschler & Adam Jourdan, *China biotech's coming out party' masks long road ahead*, REUTERS (Oct. 18, 2017), accessible online at <https://www.reuters.com/> (last visited on Apr. 27, 2018).

²²³ Zhang & Zhou, *supra* note 96.

²²⁴ Li Yan, *China's burgeoning biotech industry pioneers discovered-in-China medicines*, ECNS.cn (Nov. 7, 2017), accessible online at <http://www.ecns.cn/> (last visited on Jan. 30, 2018).

²²⁵ Hirschler & Jourdan, *supra* note 98.

²²⁶ Stephen Frye et al., *Academic Drug Discovery in the US: A Survey and Analysis*, 10 NATURE REVIEWS DRUG DISCOVERY 409-410 (2011).

²²⁷ *Id.*

disappointing today. In 2016, China contributed only 4 percent of global drug innovation, as measured by the number of products in new drug development and new drug launches, compared to 50 percent from the United States. A recent study also shows that there is a big gap in clinical research between China universities and the U.S. universities in drug discovery,²²⁸ evidenced by the rare number of China-authored publications in the human science magazines like *Lancet* or the *New England Journal of Medicine*.²²⁹

The lack of clinical research might have contributed to the low rate of drug development in China universities.²³⁰ Clinical research is critical in drug development as the goal of drug development is to bring a new drug with proven therapeutic effects on the market.²³¹ Without clinical research on the human body, a new drug cannot turn into a marketable product. For most China universities, another hurdle in the process of drug discovery is the lack of R&D spending. While China universities have significantly increased R&D expenditures on life science, the total inputs are under-represented, due to the rising costs of biomedical research and development.²³² In the U.S. universities, over fifty percent of biomedical R&D expenditures come from the private sector, while in China it made only 2.5 percent.²³³ The immature venture capital investment in

²²⁸ Clinical research refers to studies, or trials, that are done in people. See Shahin Akhondzadeh, *The Importance of Clinical Trials in Drug Development*, AVICENNA JOURNAL OF MEDICAL BIOTECHNOLOGY 8 (2016) 151.

²²⁹ Zhang & Zhou, supra note 96. Chinese scientists are publishing other leading science journals such as *Cell*, *Nature*, or *Science*, but these publications are mostly about nonhuman basic research.

²³⁰ Editor, *New Models of Technology Transfer in the Biomedical Sector*, SOHU.COM (Dec. 6, 2017), accessible online at <http://www.sohu.com/> (last visited on Mar. 1, 2018).

²³¹ Akhondzadeh, supra note 104.

²³² Matthew Herper, *The Cost of Developing Drugs is Insane. That Paper That Says Otherwise Is Insanely Bad*, FORBES (Oct. 16, 2017), accessible online at <https://www.forbes.com/> (last visited on Mar. 18, 2018).

²³³ Supra note 106.

biomedical research is another factor accountable for the insufficiency of the R&D capabilities of China universities in new drug development.²³⁴

Despite an under-developed academic ecosystem for drug development, China universities have taken active measures to translate R&D results into new products. For example, in 2017, Tsinghua University, Bill & Melinda Gates Foundation, and the Beijing Municipal Government have jointly founded a \$100 million R&D institute in Beijing, named the Global Health Drug Discovery Institute (GHDDI).²³⁵ The new institute will focus on early drug discovery to combat diseases such as tuberculosis, malaria, and HIV.²³⁶ Similarly, Peking University and Bayer HealthCare have renewed a three-year strategic partnership from 2017 to 2020 in new drug research and development.²³⁷

Still, it is a long cycle for China universities, if they want to discover and develop new drugs from scratch, which normally takes 12 to 15 years.²³⁸ University and industry collaboration might be the best solution for the increasing costs, both financial and time cost, in drug discovery and development. As upstream research will not automatically translate into downstream commercialization, Chinese universities will also need the infrastructure to efficiently manage and transfer research from the lab to the marketplace,

²³⁴ Id.

²³⁵ Editor, *Beijing-based Global Health Drug Discovery Institute to Develop Accessible Innovative Drugs for Developing Nations*, GHDDI (Mar. 24, 2017), accessible online at <http://www.ghddi.org/> (last visited on Mar. 20, 2018).

²³⁶ Jordyn Dahl, *How China is On Course to Unseat U.S. As the Next Leader in Global Health*, FORBES (Apr. 26, 2017), accessible online at <https://www.forbes.com/> (last visited on Jun. 30, 2017).

²³⁷ Bayer provided \$1.5 million for R&D expenditures. See Youle Liang & Liangdi Xu, Peking University and Bayer HealthCare Signs Strategic Partnership Renewal Agreement, pku.edu (Dec. 7, 2016), accessible online at <http://newsen.pku.edu.cn/> (last visited on Mar. 5, 2018).

²³⁸ Hirschler & Jourdan, *supra* note 98.

Chapter 5 Technology Transfer Laws and Cases in China

5.1 Introduction

Before 2002, China did not have a well-formed technology transfer policy regarding inventions generated from the government-funded research. The Interim Provisions on Technology Transfer issued by the State Council of China in 1985 allowed universities to make income from their inventions but led the government to retain the title of the inventions.²³⁹ For almost two decades, it was unclear and undefined under the China legal system who should own the intellectual property of the government-funded research within the universities.

In March 2002 China's Ministry of Finance and China's Ministry of Science and Technology co-issued the Regulations on the Management of Intellectual Property Arising from Government-Funded Scientific and Research Programs (hereby "the Regulations to improve the efficiency of technology transfer."²⁴⁰ Article 1 of the Regulations states that,

Except in cases where national security, national interests, or significant public interests are involved, the state granted the intellectual property developed in scientific research programs sponsored by government funding to the performing organization so that it can implement, license, or transfer the intellectual property independently. The state retained the right to use the intellectual property freely. If the performing organization does not enforce the intellectual property or obstructs the public from

²³⁹ Guan Yu Ji Shu Zhuan Rang De Zan Xing Gui Ding (关于技术转让的暂行规定) [The Interim Provisions on Technology Transfer] (published by the State Council, Jan. 10, 1985).

²⁴⁰ Guan Yu Guo Jia Ke Yan Ji Hua Xiang Mu Yan Jiu Cheng Guo Zhi Shi Chan Quan Guan Li De Ruo Gan Gui Ding (关于国家科研项目研究成果知识产权管理的若干规定) [Several Regulations on the Management of Intellectual Property Arising from Government-Funded Scientific and Research Programs] (jointly published by the Ministry of Finance and the Ministry of Science and Technology, Mar.5, 2002).

utilizing the intellectual property, the state can intervene by licensing the intellectual property right to a designated third party.²⁴¹

This provision, called by some as “Chinese Bayh-Dole Act,” has officially specified the undertakers (e.g., universities) of research programs as the owners of intellectual property resulting from the government-financed research.²⁴² Under this provision, China universities were authorized to have the legal rights to deal with the intellectual property and to enjoy income producing from the intellectual property.²⁴³ In 2007, in the hope of further improvement, the Ministry of Science and Technology, the Ministry of Education, and the Chinese Academy of Sciences released the National Technology Transfer Promotion Action Program, with an emphasis on creating an enterprise-centric technology transfer system.²⁴⁴

Also, in 2007, the National People’s Congress of China (NPC) revised the Scientific and Technological Progress Law, yet again, to enhance technology transfer and encourage local government support for collaborations between industry and universities.²⁴⁵ The new Scientific and Technological Progress Law, which rectifies the Regulations of 2002 at the national law level, explicitly grants the ownership of

²⁴¹ Max Lin, *China Bayh-Dole Act: A Framework Fundamental to Achieving the Economic Potential of China’s National Patent Development Strategy (2011-2020)*, FOLEY & LARDNER LLP (Apr. 22, 2011), accessible online at <https://www.foley.com/intelligence/> (last visited on Jan. 2, 2018).

²⁴² MINGFENG TANG, *TECHNOLOGY TRANSFER FROM UNIVERSITY TO INDUSTRY* (Adonis & Abbey, 2009) at 86.

²⁴³ Id. Under this Chinese “Bayh-Dole Act,” as some called it, China universities could commercialize their R&D results through creating spin-offs, licensing or transferring intellectual property, making equity investments, and so on.

²⁴⁴ Guo Jia Ji Shu Zhuan Yi Cu Jin Xing Dong Shi Shi Fang An (国家技术转移促进行动实施方案) [National Technology Transfer Promotion Act Program] (promulgated by the Ministry of Science and Technology, Ministry of Education, and the Chinese Academy of Sciences on Dec. 5, 2007).

²⁴⁵ Aihua Chen et al., *University technology transfer in China: a literature review and taxonomy*, 41 *JOURNAL OF TECHNOLOGY TRANSFER* 891-929 (2016).

intellectual property resulting from government-funded research to the research undertakers.²⁴⁶ In 2010, the National Patent Creation Strategy (2011-2020) was issued by the State Intellectual Property Office (SIPO) to encourage intellectual property creation further.²⁴⁷

Under the new political leadership since 2012, China continued its concerted efforts to improve technology transfer between university and industries. In 2016 the State Council issued two other high-profile documents regarding technology transfers. One is the Action Plan for Promoting the Transformation of Scientific and Technological Achievements, and the other is the Regulations on the implementation of the Law on Promoting the Transformation of Scientific and Technological Achievements.²⁴⁸ These two policy initiatives are primarily designed to enhance the awareness of local governments and universities towards technological innovation and entrepreneurship. The National People's Congress, the highest legislative authority of China, has also drawn much attention upon technology transfer, currently reviewing the draft amendment to the Law on Promoting the Transformation of Scientific and Technological Achievements.²⁴⁹ One of the significant revisions in the draft amendment is to increase

²⁴⁶ Ke Xue Ji Shu Jin Bu Fa (科学技术进步法) [The Scientific and Technological Progress Law] (promulgated by the STANDING COMM. NAT'L PEOPLE'S CONG., Dec. 29, 2007).

²⁴⁷ Quan Guo Zhuan Li Shi Ye Fa Zhan Zhan Lue (全国专利事业发展战略 2011-2020) [National Patent Creation Strategy 2011-2020] (promulgated by the State Intellectual Property Office on Nov. 18, 2010).

²⁴⁸ Shi Shi Cu Jin Ke Ji Cheng Guo Zhuan Hua Fa Ruo Gan Gui Ding (实施促进科技成果转化法若干规定) [Regulations on the Implement of the Law on Promoting the Transformation of Scientific and Technological Achievements] (published by the State Council, Mar. 1, 2016).

²⁴⁹ Cu Jin Ke Ji Cheng Guo Zhuan Hua Fa (Xiu Zheng An) Cao An (促进科技成果转化法 (修正案) 草案) [The draft amendment to the Law on Promoting the Transformation of Scientific and Technological Achievements] (published by the STANDING COMM. NAT'L PEOPLE'S CONG., Mar. 05, 2015).

the percentage of net revenues be distributed among university researchers from twenty percent to fifty percent.²⁵⁰ Table 5.1 shows a series of laws and policies implemented by the government that focused on promoting technology transfers in China.

The actual improvements in technology transfer laws realized from these legislative efforts might be meager. The current reforms of technology transfer laws primarily concentrated on clarification of ownership and redistribution of pecuniary rewards, and it overlooked the enormity of hurdles on legal institutions that exist inseparably within the context of technology transfers. For instance, an extensive legal framework of intellectual property, such as an updated definition of patentability on life science, is needed to handle cases related to intellectual property rights resulting from university research. The public must generally comply with judicial rulings, and legal orders must be backed by effective sanctions when compliance is not forthcoming. Employee and employer inventions must be discerned by the court. Experimental use exception is necessary to enable researchers to employ components that otherwise excluded by private intellectual property rights. University spin-offs must be aware of regulations on armed export-control, accounting fraud and corporate corruption to avoid potential criminal probes. Law officers and prosecutors must restrain from being overly simplistic when bringing criminal charges against university faculty on embezzlement of university property during technology transfers. Founders of university spin-offs must not be subject

²⁵⁰ Editor, *The Draft Amendment to the Law Promoting the Transformation of Scientific and Technological Achievements will increase the amount of remunerations to Researchers*, NPC.PEOPLE.COM.CN (Aug. 24, 2015), accessible online at <http://npc.people.com.cn/> (last visited on Mar. 10, 2018).

to constant intimidation or threats for being accused of or jailed for theft of state-owned intellectual property or other assets. The government must encourage universities to reduce their debts through tax-exempted university bonds. Tax incentives to individuals and venture capital firms, such as income tax deduction, are also essential to stimulate technology commercialization.

This basic list of the conditions necessary for a functioning technology transfer system exposes the daunting scope of the task. Each aspect is contingent upon other factors that reach beyond law itself. Legal reform of the technology transfer system does not take effect aftermath if it focuses solely on one single piece of legislation in isolation.²⁵¹ The idealized legal environment of a technology transfer system assumes that a host of supportive legal institutions must also transpire in proper functions, including intellectual property law, financial law, criminal law, tax law and so on. The following sections will discuss the legal context of technology transfers by closely examining relevant court cases.

²⁵¹ Brian Z. Tamanaha, *The Primacy of Society and the Failures of Law and Development*, 44 CORNELL INTERNATIONAL LAW JOURNAL 209-247 (2011) at 222.

Table 5.1 A list of technology transfer laws and regulations between 1949-2016

A list of technology transfer laws and policies between 1949 and 2016

Time	Main legislation	Goal
September, 1949	Common Program of the Chinese People's Political Consultative Conference	Basic definition of the role of science in developing China's economy and society
January, 1975	Constitutional Law	Research should be combined with productive labor
March, 1984	Patent Law	Granted inventors the right to patent inventions
January, 1985	Interim Provisions on Technology Transfer	Established a technology market for state-funded research and development
November, 1986	High-technology Research and Development Plan Outline ("863" Program)	Program funded to stimulate the development of defense-oriented technologies
May, 1987	Opinions on Science and Technology Reform in Universities	University education and research should contribute to production and industry should cooperate with universities
June, 1987	Technology Contract Law	Protected legal rights and interests of technology contracting parties and facilitated the freedom and rule of law in technology markets
August, 1988	China Torch Program	Established high-tech development zones and provided governmental supports to attract foreign direct investment in these special zones
July, 1993	Scientific and Technological Progress Law	Granted universities the rights to commercialize government-funded research and technology
May, 1996	Law on Promoting the Transformation of Scientific and Technological Achievements	Provided a guidance to promote technology commercialization within universities and government research institutions
May, 1998	Policies on Creating World-Class Universities ("985" Project)	Provided massive funding to selected China universities to support them in building a world-class university.
March, 1999	Regulations on Promoting Scientific and Technological Achievement Transformation	Encouraged science and technology personnel to invent new technologies and transfer them to high-tech industries

Table 5.1 (continued)

A list of technology transfer laws and policies between 1949 and 2016

Time	Main legislation	Goal
April, 1999	Regulations on University Intellectual Property Protection and Management	Granted university IP rights and encouraged them to contribute to science and technology industrialization
November, 1999	"211 Project"	Aimed at funding 100 China universities to improve their research capability in the 21st century
June, 2002	Opinions on Improving the Role of University in Scientific and Technological Innovation	Promoted the combination of science and education in order to improve national innovation system
December, 2007	National Technology Transfer Promotion Action Program	Aimed at building an innovation system of industry-university-government to promote the transformation of science and technology into productivity
June, 2008	National Intellectual Property Strategy Outline	Aimed at improving China's Intellectual Property development and management ability
November, 2010	National Patent Development Strategy (2011-2020)	Declared 2020 goal to turn China into a nation with high-quality patent application and protection
September, 2012	Opinions on Deepening the Reform of Scientific and Technological System and Speeding up the Development of National Innovation System	Supported enterprises and universities in working with each other by setting up an R&D platform and innovation strategy alliance
August, 2015	A Proposed Amendment to the Law of Promoting Scientific and Technological Achievements (Draft 2015)	Meant to accelerate the translation of science and technology achievements into economic benefits
March, 2016	Regulations on the Implement of the Law on Promoting the Transformation of Scientific and Technological Achievements	Increased the percent of net revenues resulting from technology transfers that be distributed among researchers from 20 percent to 50 percent
April, 2016	An Action Plan for Promoting the Transformation of Scientific and Technological Achievements	Aimed at enhancing the public awareness of the importance of technology innovation and commercialization

Source: adapted from Chen et al. (2016).²⁵²

²⁵² Aihua Chen et al., *University technology transfer in China: a literature review and taxonomy*, 41 JOURNAL OF TECHNOLOGY TRANSFER 891-929 (2016).

5.2 Intellectual Property

The recent five years have seen significant growth in intellectual property lawsuits in China. From 2013 to 2017, intellectual property lawsuits have increased from 100,000 to 203,000 at a compound annual growth rate of twenty percent. Figure 4.1 shows the recent trends of intellectual property litigations in China. It is also estimated that more than ninety-eight percent of all intellectual property litigations in China involves domestic firms suing other local firms.²⁵³ To deal with increasing intellectual property litigation cases, in late 2014, China established three specialized intellectual property courts in Beijing, Shanghai, and Guangzhou.²⁵⁴ After more than three decades of rapid development, China now wants domestic companies as well as international corporations to have the benefit of an intellectual property system protecting their technology positions.

China did not enact the first patent law until 1984 and revised it in 1992. In the 1990s, the rampage of piracy of intellectual property in China, especially the illegal copy of computer software, prompted the U.S. to carry on a Section 301 investigation against China.²⁵⁵ The U.S. government threatened to impose punitive tariffs on imported Chinese goods if China did not agree to enhance its intellectual property system.²⁵⁶ After multiple rounds of negotiations, China and the U.S. concluded the Memorandum of Understanding,

²⁵³ GEORGE HAOUR & MAX VON ZEDTWITZ, *CREATED IN CHINA: HOW CHINA IS BECOMING A GLOBAL INNOVATOR* (Bloomsbury, 2016).

²⁵⁴ Guizeng Liu, *China: First ever Intellectual Property Court in Beijing*, INTA Bulletin (Dec. 1, 2014), accessible online at <https://www.inta.org/> (last visited on Mar. 10, 2018).

²⁵⁵ Deming Liu, *Now the Wolf Has Indeed Come! Perspective on the Patent Protection of Biotechnology Inventions in China*, 53 *AMERICAN JOURNAL OF COMPARATIVE LAW* 207 (2005).

²⁵⁶ *Id.*

which prompted China to undertake stronger protections of intellectual property rights.²⁵⁷ Under the Memorandum of Understanding, China then revised the 1984 patent law and broadened the scope of patentable subject matter to include chemicals, pharmaceuticals, footwear, beverages and artificial flavors.²⁵⁸ The new patent law also extended the term of the invention patent from fifteen years to twenty years and imposed more limitations on the grant of compulsory license than those in the 1984 patent law.²⁵⁹

Since re-entry to the WTO, China has been trying hard to bring the China patent law more in line with the requirements of international treaties and standards, notably the TRIPS Agreement.²⁶⁰ For instance, the Pharmaceutical Product Administrative Protection Regulations and the Chemical Products Used in Agriculture Administrative Regulations were separately published and enforced in China. The main content of these regulations is the same as Article 70 of the TRIPS Agreement.²⁶¹ The difference is that the TRIPS Agreement merely requires its members to grant the owner exclusive rights to reduce products to the market, whereas the Chinese regulations grant the owner a series of intellectual property rights such as producing, selling, using, and so on.²⁶²

The development of biotechnology has also galvanized the revision of Chinese patent law. In 2001, the government published the Regulations on the Implement of the Patent

²⁵⁷ Id.

²⁵⁸ L. Mark Wu-Ohlson, *A Commentary on China's New Patent and Trademark Laws*, 6 NORTHWESTERN JOURNAL OF INTERNATIONAL LAW & BUSINESS 86-147 (1984).

²⁵⁹ Ming Q. Lu et al., *Pharmaceutical Intellectual Property Rights*, in Ming Q. Lu (ed.), *APPROACHING CHINA'S PHARMACEUTICAL MARKET* (Springer 2015).

²⁶⁰ Chengsi Zheng, *The TRIPS Agreement and Intellectual Property Protection in China*, 9 DUKE JOURNAL OF COMPARATIVE & INTERNATIONAL LAW 219-227 (1998).

²⁶¹ Id. at 221.

²⁶² Id.

Law to include intellectual property rights of biotechnology inventions.²⁶³ As one senior scientist said in a letter written to the political leaders of China in 1997:

“A gene is a kind of wealth. If China does not get its own gene patents, then in the next century its biotechnology industry and, its pharmaceutical industry will be like ‘the Admiral of the Northern Fleet who saw all his ships capsize and sink beneath the waves.’”²⁶⁴

Before the 2001 amendment, China has already made remarkable achievements in transgenic planting techniques, including pest and disease resistance, quality improvement, and herbicide resistance. Today, China has become a leading transgenic planting country in the world second to the United States, with a total cultivation area exceeding 2.1 million hectares for transgenic crops.²⁶⁵ In the area of human disease treatment, China was the first country to create precision medicine for the gene causing high-frequency nerve deafness. Currently, there are already 150 types of biological pharmaceuticals in the process of clinical research.²⁶⁶ Besides bio-agricultural and biomedical research, China was also reported to have reached the world’s most advanced levels in transgenic animal cloning techniques. In 2017, for example, Chinese scientists have cloned two identical long-tailed monkeys, Zhong Zhong and Hua Hua, making them the first primates in the world ever to be cloned from a non-embryonic cell.²⁶⁷

²⁶³ Zhuan Li Fa Shi Shi Xi Ze (专利法实施细则) [The Regulations on the Implement of the Patent Law] (promulgated by the State Council of China on Jun. 15, 2001).

²⁶⁴ David Dickson, *Back on Track: The Rebirth of Human Genetics in China*, 396 NATURE 303,305 (1998), cited in Liu, *supra* note 255.

²⁶⁵ Alice Wong & Albert Chan, *Genetically modified foods in China and the United States: A Primer of regulation and intellectual property protection*, 5 FOOD SCIENCE AND HUMAN WELLNESS (2016) 124-140.

²⁶⁶ Yvonne Wu, *The Next Phase: Opportunities in China’s Pharmaceuticals Market*, DELOITTE (2015), accessible online at <https://www2.deloitte.com/> (last visited on Mar. 20, 2018).

²⁶⁷ Ben Hirschler, *Chinese scientists break key barrier by cloning monkeys*, REUTERS (Jan. 24, 2018), accessible online at <https://www.reuters.com/> (last visited on Mar. 20, 2018).

The Chinese government provided the most significant sponsorship to the biotechnology research. Government research institutions and universities are the two largest developers of biotechnology inventions. For instance, in 2016, Zhejiang University has retained the third largest number of issued patents on DNA-sequencing techniques.²⁶⁸ If the trend were to continue, it may be justifiable to predict for the future that universities and government research institutions in China could sooner make themselves the principal patent owners of biotechnology inventions. The question remains, however, whether, beneath these foreseeable achievements, there are problems, real or potential, which may hinder the commercialization of these biotechnology inventions.

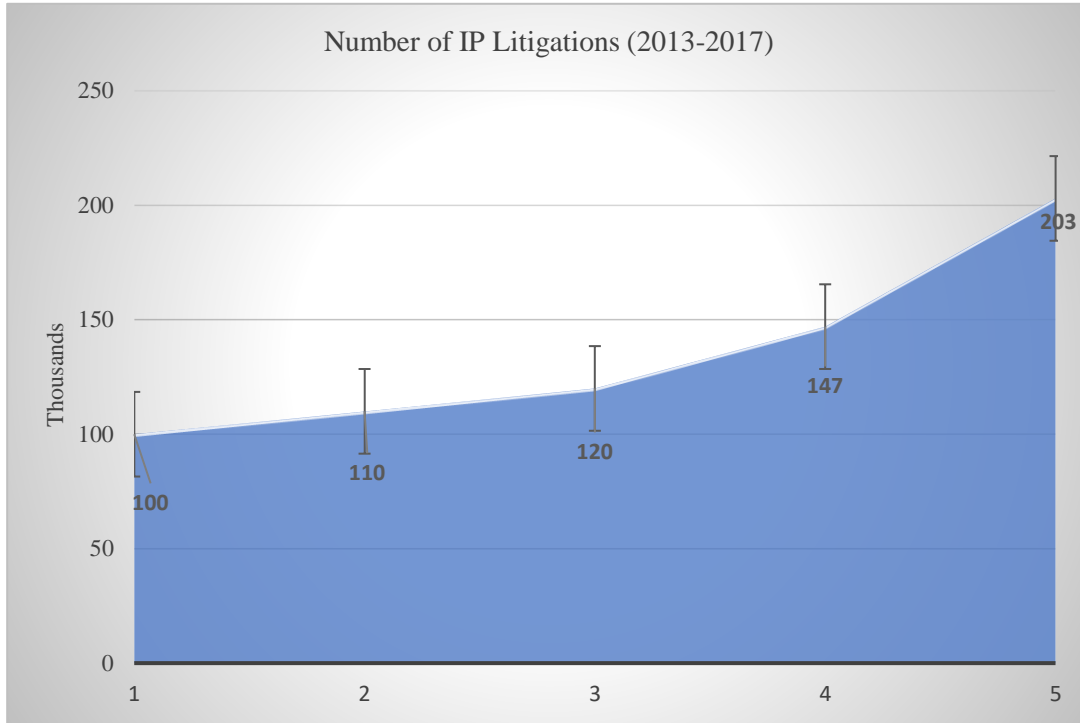
Seemingly, while some have argued that the main problem regarding commercialization of biotechnology research lies in the dearth of venture capital in China,²⁶⁹ it is not within the scope of this chapter to further address this problem. The primary concern of this chapter is whether there exists the legal environment that would promote the commercialization of university inventions, particularly genetic inventions. To answer this question, the following sections will first explore the patent protection of transgenic inventions under the Chinese patent law. Also, the following sections will examine whether the two common legal issues encountered in the U.S. arising from the

²⁶⁸ Editor, *Analysis of China DNA Sequencing Patents (zhong guo ji yin ce xu zhuan li fen xi)*, BIODISCOVERY.COM (Aug. 29, 2016), accessible online at <http://www.biodiscover.com/> (last visited Apr. 30, 2018).

²⁶⁹ Both domestic and foreign venture capital firms lack good “exit strategies” for cashing out their investments in the Chinese startups. Liu, *supra* note 255 at 225.

patenting of biomedical inventions, such as Bolar exception and the ownership of employee inventions, are likewise emergent in China universities.

Figure 5.1 Number of Intellectual Property Litigations in China 2013-2017



Source: Created and collected by the author.²⁷⁰

²⁷⁰ See also, Editor, *2016-2017 China Intellectual Property Litigation Trends Forecast (Excerpt)*, Lexology.com (Feb. 2, 2018), accessible online at <https://www.lexology.com/> (last visited on Apr. 30, 2018). Editor, *2017 China Intellectual Property Protection Whitepaper*, gov.cn (Apr. 25, 2018), accessible online at <http://www.gov.cn/> (last visited on Apr. 30, 2018).

5.2.1 The Patentability of Gene-Related Inventions

Article 25 of the Chinese Patent Law excludes a list of subject matter from patent protection. This list includes the following:

- (1) scientific discoveries,
- (2) rules and methods for mental activities,
- (3) methods for the diagnosis or the treatment of diseases,
- (4) animal and plant varieties,
- (5) substances obtained using nuclear transformation,
- (6) designs that are mainly used for marking the pattern, color or the combination of the two of prints.

The patent right may, by the provisions of this Law, be granted for the production methods of the products specified in Subparagraph (4) of the preceding paragraph.²⁷¹

Under this section, a material which is merely discovered in its natural existence cannot be patented under the Chinese patent law. As a result, a gene or its DNA fragment which is found in nature existing in its natural state is excluded from patent protection as they are regarded as scientific discovery. However, when a gene or a DNA fragment, whose base sequence is not recorded in the existing technology, and is first separated or extracted from nature, and is a useful application to the society, the process method as well as the modified gene or the DNA fragment itself is patentable.²⁷² However, there are some exceptions. The technology of human cloning is not patentable, for example, if it merely changes the genetic unity of the human cells. Biological methods are not

²⁷¹ Article 25 of Chinese Patent Law, accessible online at <http://www.wipo.int/> (last visited on Apr. 25, 2018).

²⁷² Wei Li, *Patenting Genes in China, the U.S., and the EU: How Does It Differ? Could It Get Out of Control?* 35 BIOTECHNOLOGY LAW REPORT 165 (2016).

patentable if they violate some traditional ethical concepts, such as research on human embryos. Genetic screening diagnostic methods for “the diagnosis or for the treatment of diseases,” are not patentable subject matter by Section 3 of Article 25 of the Chinese patent law. But the instruments or apparatus for implementing diagnostic methods or treatment, or substances or materials used in such processes, do constitute patentable subject matter.²⁷³ Nevertheless, the protection of biotech and Internet-related innovations remains a grey area in China. The emerging legal disputes on the patentability of genes and DNA-related inventions have exemplified this. The following section summarizes the current legal arguments related to DNA patents.

²⁷³ Guidelines for Patent Examination, Section 4.3, Chapter 1, Part II.

Case 1: the *University of California v. Broad Institute, Inc. (2017)*²⁷⁴

The CRISPR case is a high-profile patent dispute between two of the invention's originators, in one side Dr. Jennifer Doudna (U.C. Berkeley and University of Vienna) and Dr. Emmanuelle Charpentier (The Max-Planck Institute), and in the other side Dr. Feng Zhang (The Broad Institute, a Boston-based company backed by MIT and Harvard University).²⁷⁵ The CRISPR-Cas9, discovered by Doudna and Charpentier, is a gene editing tool that uses a protein found in *Streptococcus* bacteria to chop and rearrange viral DNA with precision. The CRISPR-Cas9 gene editing technology has a potential application in medical treatments that might ultimately develop to cure genetic diseases, according to the Nobel Prize Nomination Board (Chemistry) in 2014.²⁷⁶

Doudna and Charpentier first filed their original patent application covering CRISPR-Cas9 on May 25, 2012, including over 150 claims but was notably unspecific concerning cell type applications.²⁷⁷ During the pendency of Doudna and Charpentier's patent application in the USA, Dr. Zhang also filed a U.S. patent application, which directed explicitly to eukaryotic applications of CRISPR-Cas9. In April 2014, Zhang's patent application was issued first in the U.S. Patent and Trademark Office.

²⁷⁴ *University of California v. Broad Institute, Inc.* Fed. Cir. No. 17-1907 (2017).

²⁷⁵ Jacob S. Sherkow, *Patent protection for CRISPR: an ELSI Review*, 4 JOURNAL OF LAW AND THE BIOSCIENCES 565-576 (2017).

²⁷⁶ See e.g., Glen Martin, *The Current CRISPR Patent Dispute, Explained*, BERKELEY.EDU (Apr. 27, 2017), accessible online at <https://alumni.berkeley.edu/> (last visited on Apr. 20, 2018). Sarah Buhr, *CRISPR loses Nobel to tiny machines*, TECHCRUNCH.COM (Oct. 5, 2016), accessible online at <https://techcrunch.com/> (last visited on Apr. 30, 2018).

²⁷⁷ Sarah Zhang, *How the CRISPR Patent Dispute Became So Heated*, THE ATLANTIC (Dec. 6, 2016), accessible online at <https://www.theatlantic.com/> (last visited on Mar. 10, 2018).

Doudna and Charpentier then appealed to the U.S. Patent Trial and Appeal Board (“the Board”). Throughout the administrative proceeding, Doudna and Charpentier argued that their patent, which explicitly describes the use of CRISPR-Cas9 gene editing in non-eukaryotes, rendered applications in eukaryotic cells “obvious” and therefore Zhang’s invention was unpatentable. Zhang countered that the UC Berkeley’s inventiveness needed significant and non-obvious innovation before it could be used in eukaryotes. In 2017, the Board ruled in favor of Zhang in the rationale that although Doudna and Charpentier had first laid claim to the use of CRISPR to cut DNA in a test tube, the use of the method on human cells by Zhang was an advanced, separate invention.

Doudna and Charpentier then filed a complaint to the U.S. Court of Appeals for the Federal Circuit (“the Federal Circuit”), alleging that the Board made “fundamental errors of law” that would allow Zhang to unfairly claim rights to the most important and valuable applications of CRISPR-Cas9 gene editing. At the initial hearing before the Federal Circuit²⁷⁸, a lawyer for Doudna and Charpentier argued that the CRISPR technique would not require innovation to enable it in eukaryotic cells because evidence showed that within six months of Zhang’s invention, six different groups of scientists successfully applied CRISPR to eukaryotic cells.²⁷⁹ Although the case has not been finally resolved as of this writing, the manifest tenor of the Circuit’s decision is that the

²⁷⁸ The Federal Circuit heard oral arguments in the appeal on Monday, April 30, 2018. See Lee McGuire, *For Journalists: Statement and Background on the CRISPR Patent Process*, BROAD INSTITUTE (Apr. 30, 2018), accessible online at <https://www.broadinstitute.org/> (last visited on May 8, 2018).

²⁷⁹ Jon Cohen, *Federal Appeals Court Hears CRISPR Patent Dispute*, SCIENCEMAG.ORG (Apr. 30, 2018), accessible online at <http://www.sciencemag.org/> (last visited on May 3, 2018). See also, Editor, *Federal Circuit Hears Argument in CRISPR Patent Priority Dispute*, JDSUPRA.COM (May 2, 2018), accessible online at <https://www.jdsupra.com/> (last visited on May 4, 2018).

use of the CRISPR gene editing method on human cells required creative efforts that were nonobvious.²⁸⁰

Notwithstanding the pending verdict in the U.S. federal court, China's State Intellectual Property Office (SIPO) has announced that it will grant UC Berkeley, in conjunction with the University of Vienna and Dr. Charpentier, a patent for its CRISPR gene-editing technology, which broadly covers CRISPR-Cas9 methods and compositions.²⁸¹ The patent rights will also allow genome editing company Intellia Therapeutics (Co-founder: Dr. Jennifer Doudna), an exclusive licensee of the CRISPR patent by UC Berkeley, to market any human therapy it develops from CRISPR in China. China's decision to award the patent to UC Berkeley comes after two Chinese clinical trials using the gene-editing technology.²⁸² The SIPO's decision on the CRISPR patent was based on the same underlying international patent application with the same U.S. priority date filed by Doudna and Charpentier.²⁸³

²⁸⁰ According to Reuters, one of the three judges hearing the case in the Federal Circuit said she will probably side with the Board and upheld its ruling. The two others did not indicate how they would rule. See Jim Daley, *CRISPR Patent Dispute Heard in Federal Circuit*, THE-SCIENTIST.COM (May 1, 2018), accessible online at <https://www.the-scientist.com/> (last visited on May 6, 2018). See also, Heidi Ledford, *Bitter CRISPR patent war intensifies*, NATURE (Oct. 26, 2017), accessible online at <https://www.nature.com/> (last visited on May 3, 2018). See also, Richard Harris, *Scientists Battle in Court Over Lucrative Patents for Gene-Editing Tool*, NPR.org (Dec. 5, 2016), accessible online at <https://www.npr.org/> (last visited on Mar. 20, 2018).

²⁸¹ Douglas House, *Intellia up 8% premarket after CRISPR/Cas9 patent arguments*, SEEKINGALPHA.COM (May 1, 2018), accessible online at <https://seekingalpha.com/> (last visited on May 3, 2018). See also, Editor, *Intellia Therapeutics Announces Patent for CRISPR/Cas Genome Editing in China*, INTELLIA.COM (Jun 19, 2017), accessible online at <https://ir.intelliactx.com/> (last visited on Feb 3, 2018).

²⁸² The first clinical trial in October 2016 was led by researchers from Sichuan University's West China Medical Center, and the second clinical trial took place in Nanjing University's Drum Tower Medical Center. Both clinical types of research focused on modifying genes in Chinese cancer patients. See Sydney Johnson, *China will grant CRISPR patent to UC*, DAILYCAL.ORG (Jun. 23, 2017), accessible online at <http://www.dailycal.org/> (last visited on May 3, 2018).

²⁸³ Robby Berman, *China's already tested CRISPR on A Human, and the U.S. is Next*, BIGTHINK.COM (Dec. 25, 2017), accessible online at <http://bigthink.com/> (last visited on May 2, 2018).

Case 2: *Novozymes Co., Ltd. v. Jiangsu Boli Bioproducts Co., Ltd. (2016)*²⁸⁴

The enzyme case is a patent invalidation dispute between a Danish company and a Chinese company. In one side is Novozymes, one of the largest enzyme producers in Denmark, and in the other side is Jiangsu Boli Bioproducts Co. Ltd, a major company in China producing glucose-added food and beverages.²⁸⁵ This case involves an invention patent entitled “Thermostable Glucoamylase (ZL98813338.5),” and issued by SIPO to Novozymes in June 2006. It is related to a unique thermostable glucoamylase that was isolated, purified and characterized from a strain of *Talaromyces emersonii* CBS 793.97, a thermophilic fungus. Compared with the prior art glucoamylases, the isolated glucoamylases produced by Novozymes had higher thermal stability and could be used to convert hydrolyzed corn starch to glucose.²⁸⁶ According to the published patent description, the half-life of the isolated enzyme is between 100 and 140 minutes at 70 degrees Celsius, an improvement over prior art glucoamylases.

The patent dispute began in 2011, when Novozymes discovered two Chinese companies, Jiangsu Boli Bioproducts Co. Ltd. (hereby “Boli”) and Shandong Longda Bioproducts Co. Ltd. (hereby “Longda”), produced and sold a proprietary Novozymes glucoamylase enzyme for use in the bioenergy and beverage industries that violated one of Novozymes’ Chinese patents. The infringement was about “Thermostable

²⁸⁴ *Novozymes Co., Ltd. v. Jiangsu Boli Bioproducts Co., Ltd.* State Supreme People’s Court No. 85 (诺维信公司与江苏博立生物制品有限公司专利再审, (2016) 最高法行再 85 号).

²⁸⁵ Tianyi Wu & Xiaoyang Wang (trans.), *The Supreme People’s Court’s Annual Report on Intellectual Property Cases (2016)*, 27 WASHINGTON INTERNATIONAL LAW JOURNAL 295-316 (2017).

²⁸⁶ Eric Lane, *Novozymes Asserts Glucoamylase Patents Against Enzyme Distributor*, GREEN PATENT BLOG (Jul. 15, 2011), accessible online at <http://www.greenpatentblog.com/> (last visited on Apr. 20, 2018).

Glucoamylase” that contained the glucoamylase T-AMG that Novozymes used as an ingredient in products of fuel ethanol and beverage alcohol. Novozymes filed a complaint against Longda and Boli in two courts in Tianjin, a city near Beijing. Tianjin courts ruled in favor of Novozymes and ordered Longda and Boli to stop making and selling infringing products and pay statutory damages totaling USD 300,000 to Novozymes.²⁸⁷

Boli and Longda filed a request to the Patent Reexamination Board of the State Intellectual Property Office (“the Board”) to invalidate the Novozymes patent. They argued that the Novozymes patent violated Article 22, Article 26 and Article 33 of the Chinese patent law on two aspects: (1) The claims were not supported by the description of the invention that enabled a skilled person to make the invention falling within the terms of the applications; (2) The invention did not satisfy the requirement of creativity under Article 22 of the Chinese patent law to sustain the patentability of the subject matter. The claims on disputes included claim 1, claim 2, claim 3, claim 6, claim 10, claim 11, claim 12, claim 13, and claim 14.²⁸⁸ The following section is an excerpt of the claims in the patent application as filed.

²⁸⁷ Jenny Eagle, *Novozymes wins landmark case for biotech patent in alcohol beverages*, BEVERAGE DAILY (Feb. 16, 2017), accessible online at <https://www.beveragedaily.com/Article/2017/02/16/Novozymes-wins-landmark-case-for-biotech-patent> (last visited on Nov. 30, 2017).

²⁸⁸ *Novozymes vs. Jiangsu Boli Bioproducts Co. Ltd.* S. Ct. No. 85 (2016). See also, Editor, *A Thermostable Glucoamylase Patent Invalidation Case*, UNITALEN ATTORNEYS AT LAW (Sep. 13, 2017), accessible online at <http://www.unitalen.com/html/report/17090525-1.htm> (last visited on Jan. 15, 2018).

Claim 1: An isolated enzyme with glucoamylase activity, wherein the glucoamylase *comprises* an amino acid sequence in full length shown in SEQ ID NO:7.

Claim 2: The enzyme of claim 1, wherein the enzyme is derived from *Talaromyces* and has a $T_{1/2}$ (half-life) of at least 100 minutes in 50 mM NaOAc, 0.2 Novo Amyloglucosidase Unit (AGU)/ml, pH 4.5, at 70 °C.

Claim 3: The enzyme of claim 1 or claim 2 has a $T_{1/2}$ (half-life) of 100-140 minutes.

.....

Claim 6: An isolated enzyme with glucoamylase activity, wherein the enzyme has an amino acid sequence in full length that is at least 99% identical with the glucoamylase of SEQ ID NO:7, and has an isoelectric point below 3.5 determined by isoelectric focusing.

.....

Claim 10: The enzyme of claim 6 to claim 9 is derived from a *Talaromyces* strain, wherein the filamentous fungus is a *Talaromyces emersonii* strain.

Claim 11: The enzyme of claim 10, wherein the filamentous fungus is *Talaromyces emersonii* CBS 793.97.

Claim 12: The invention relates to a cloned DNA sequence encoding an enzyme exhibiting glucoamylase activity of the invention, which DNA sequence *comprises*:

- (1) the glucoamylase encoding part of the DNA sequence shown in SEQ ID NO:33;
- (2) the DNA sequence is shown in positions 649-2724 in SEQ ID NO:33 or its complementary strand;
- (3) an analog of the DNA sequence defined in (a) or (b) which is at least 80% homologous with said DNA sequence;
- (4) a DNA sequence which hybridizes with a double-stranded DNA probe comprising the sequence shown in 649-2724 in SEQ ID NO:33 at low stringency;
- (5) a DNA sequence which, because of the degeneracy of the genetic code, does not hybridize with the sequences of (b) or (f), but which codes for a polypeptide having precisely the same amino acid sequence as the polypeptide encoded any of these DNA sequences²⁸⁹

.....

²⁸⁹ See ZL98813338.5, US 6,255,084 B1 and US 7,060,468 B2.

Claim 13: The DNA sequence of claim 12 is derived from a *Talaromyces* strain, wherein the filamentous fungus is a *Talaromyces emersonii* strain.

Claim 14: The DNA sequence of claim 12, wherein the filamentous fungus is *Talaromyces emersonii* CBS 793.97.

.....

During the administrative proceeding, the Board concluded that Claims 1 and 12 were not supported by the description of the invention in the rationale that the term of “comprising” used in the patent claims is a catch-all term, which includes any additional components that are not excluded from an amino acid sequence shown in SEQ ID NO:7, and any number or any types of amino that could be added at the ends of an amino acid sequence. As a result, a person skilled in the art would not be able to decide which sequence falls within the scope of the claims.²⁹⁰ The Board also held that Claim 6 was not supported by the description of the invention as it did not enable a skilled person to predict which protein sequence that has a degree of at least 99% of homology shown in SEQ ID NO:7 falls into the terms of the claims.²⁹¹

Regarding Claims 10 and 11, opposite to Claim 6, the Board held that Claim 10 and 11 were valid. The Board reasoned that dependent claims 10 and 11 specified the species source of the enzyme as from a strain of the filamentous fungus *Talaromyces emersonii*. Therefore, the scope of claims was significantly limited, which allowed one person

²⁹⁰ *Novozymes vs. Jiangsu Boli Bioproducts Co. Ltd.* S. Ct. No. 85 (2016). See also, Tao Jiang, *China’s Recent Development on Granting Biological Sequence Claims*, MONDAQ.COM (Jan. 9, 2018), accessible online at <http://www.mondaq.com/> (last visited on Feb. 20, 2018).

²⁹¹ The Board elaborated that whether two highly homologous proteins have similar spatial structures and the functions depends on components of their amino acid residues. The common situation is that when the amino acid changes, the spatial structures and the functions of the protein sequences also changes, irrelevant to the homology degree of the polypeptides. See *Novozymes vs. Jiangsu Boli Bioproducts Co. Ltd.* S. Ct. No. 85 (2016).

skilled in the art to understand the specific protein sequence of the invented enzyme.²⁹² Based on the explicit description of the enzyme strain in the patent Specification, the Board concluded that Claims 10 and 11 were valid under the Chinese patent law.

Boli and Longda disagreed with the Board's decision and later filed a lawsuit in the Beijing court, requiring the court to revoke the Board's decision on the enzyme patent. The case passed through several levels of lower courts before it reached the Supreme People's Court (SPC), the highest court in China. The first instance court, the Beijing Intermediate People's Court, revoked the Board's decision, stating that although the disputed claims specified the *Talaromyces emersonii* strains, the amino acid sequence and the DNA sequence could still include other types of sequences that were unforeseeable to a skilled person in the art, given the absence of relevant experimental data in the patent Specification. The second instance court, the Beijing High People's Court, affirmed the judgment by the first instance court.

The SPC overturned the lower courts' decisions and held that Claims 10 and 11 were valid. The SPC recognized the dual limitations in the claims, of which the enzyme must have an amino acid sequence of more than 99% homology with the glucoamylase of SEQ ID NO:7, and of which the species source of the enzyme must derive from the *Talaromyces emersonii* strains. The SPC reasoned that the limitations in Claim 10 and 11, combined with the limitations in Claim 6 (i.e., enzymes isoelectric point and the function of glucoamylase), had reduced the scope of the patentable enzymes to fairly-

²⁹² Id.

limited ranges, and therefore a person of skills in the art could identify the specific enzyme within the scope of the patent claims. The SPC further concluded that when determining whether the description of the invention supports the claims of a biological sequence patent, the courts need to consider the integrated effects of the polypeptides homology, the species source, the functions and activities of the glucoamylase, and other technical factors that related to the characteristics of a biological sequent. If the limitations of the patent specification result in an insufficient number of biological sequences, the patent claims of the invention are valid.²⁹³

In this case, the Supreme People's Court of China has clarified the rules in judging whether biological sequence claims with use of homology and the species source are valid allegations supported by the description of the invention. It has provided guiding principles to the writing and examination of gene-related patents applications in China and has also been conducive to promote technology innovation in the biotechnology industry.

²⁹³ Editor, *A Thermostable Glucoamylase Patent Invalidation Case*, UNITALEN ATTORNEYS AT LAW (Sep. 13, 2017), accessible online at <http://www.unitalen.com/> (last visited on Jan. 15, 2018).

5.2.2 The Experimental Use Exception

The experimental use exception is first introduced as a common law principle, first applied in *Whittemore v. Cutter*, where the U.S. Supreme Court stated that acts of using patent only for scientific experimentation were exempted from patent infringement.²⁹⁴ In the following decades, the experimental use exception was upheld in the U.S. courts. Since the 1980s, however, the U.S. courts have been narrowing the coverage of the experimental use exception, largely due to a shifting pro-patent legal framework.²⁹⁵ In *Roche Products, Inc. v. Bolar Pharmaceutical Co.*, the Federal Circuit refused to apply the experimental use exception to clinical trials before the expiry of a patent.

The defendant Bolar argued that if the experimental use exception did not apply, a generic drug manufacturer was unable to make clinical trials of expiring patents for the FDA approval. The Federal Circuit rejected the Bolar argument of which clinical trials should be exempted from patent infringement and concluded that the experimental use exception should not be expanded to applications for business purposes, be it an experiment or not.²⁹⁶ The Roche decision caused much uproar in the generic drug industry. In response, the U.S. Congress passed the Drug Price Competition and Patent Term Restoration Act in 1984, also known as the Hatch-Waxman Act. The Hatch-Waxman Act §202 allows a generic drug manufacturer to make clinical trials and obtain data necessary for the FDA's regulatory approval before a patent expires. If the FDA's

²⁹⁴ *Whittemore v. Cutter*, 29 F. Cas. 1120 (C.C.D.Mass.1813).

²⁹⁵ Yuhe Wu & Yanfeng Xiong, *Comparison of Bolar Exception in China and the United States*, 3 CHINA PATENTS & TRADEMARKS 13-23 (2008).

²⁹⁶ *Roche Products, Inc. v. Bolar Pharmaceutical Co.* 733 F.2d 858 (Fed. Cir. 1984).

regulatory approval takes too long, the term of a drug patent may be extended.²⁹⁷ The Hatch-Waxman Act §202 was also known as the Bolar exception provision.

The experimental use exception was further narrowed in *Madey v. Duke University*. The facts of the Madey case were not very complex. Dr. Madey was the former director of the Free Electron Laser (FEL) Laboratory at Duke University and the named inventor and owner of two U.S. patents that read on certain laser equipment in the FEL lab.²⁹⁸ After Madey resigned from Duke University, his colleagues continued to operate the laser equipment covered by Madey's patents. Along with some employment dispute, Madey sued Duke University for patent infringement on using the patented laser equipment.²⁹⁹ The Federal Circuit, for the first time, considered the issue of whether a nonprofit research institution accused of patent infringement should be treated any differently from a commercial company.³⁰⁰ The judges ruled that the non-profit, educational status of Duke University was not determinative in this case. They furthered that even if Duke University's use of the laser equipment per se was not for business purposes, the experimental use exception should not apply when such an application was not "solely for amusement, for idle curiosity, or for strictly philosophical inquiry." In this case, the court ruled that the use of the laser equipment was in furtherance of the Duke University's legitimate business objectives, such as increasing the status of the institution, or attracting

²⁹⁷ 35 U.S.C. §271 (e)(1).

²⁹⁸ *Madey v. Duke University*, 307 F. 3d 1351 (Fed. Cir. 2002).

²⁹⁹ Because the equipment was not owned by Duke University, Duke did not have an implied license to use the patented inventions based on ownership of the physical assets.

³⁰⁰ See e.g., Michelle Cai, *Madey v. Duke University: Shattering the Myth of Universities' Experimental Use Defense*, 19 BERKELEY TECHNOLOGY LAW JOURNAL 175-192 (2004); Janice M. Mueller, *The Evanescent Experimental Use Exemption from United States Patent Infringement Liability: Implications for University and Nonprofit Research and Development*, 56 BAYLOR LAW REVIEW 917-980 (2004).

research grants, students and faculty.³⁰¹ Therefore, the Federal Circuit concluded that the Duke University's use of the patented laser device in academic research fell outside the experimental use exception.³⁰² Since the *Madey* case, the experimental use exception has been narrowly limited in the U.S. case law that even non-profit institutions as universities would find it hard to use the experimental use exception as a patent infringement defense.³⁰³

Experimental use exception was included and codified in Chinese first patent law, promulgated in 1984. Article 62 (5) of the patent law as of 1984 mentioned that the use of a patent without authorization for scientific research and experimentation was exempted from patent infringement.³⁰⁴ The interpretation of the experimental use exception under the Chinese patent law of 1984 was very narrow and strictly limited. Only those acts made solely for scientific research and experimentation were exempted from patent infringement. However, how to define the boundary of scientific research and testing, especially those involving clinical trials, remains a grey area in legal practice.

³⁰¹ Major research universities, such as Duke, often sanction and fund research projects with arguably no commercial implications. However, these projects ultimately further the institution's legitimate business objectives. Duke's patent policy explicated that Duke was engaged in "obtaining grants and developing possible commercial applications for the fruits of its 'academic research.'" See *Madey v. Duke University*, 307 F. 3d 1351 (Fed. Cir. 2002).

³⁰² Before the Federal Circuit, Duke University also argued that if the court did not refer to the experimental use exception, the court should affirm Duke's argument that the government (encompassing Duke University) had a license to practice the patents at issue under the Bayh-Dole Act. Duke cited the statements on each of the patents noting that the government has march-in rights in the patents. By contrast, the Federal Circuit disagreed with Duke's assertion and held that the evidence cited by Duke is insufficient because the short notations on the patents do not define the scope of the government's rights, and none of the controlling contracts at issue that would define the scope of such government license rights were provided in the record nor discussed by Duke in its appeal. See *Madey v. Duke University*, 307 F. 3d 1351 (Fed. Cir. 2002).

³⁰³ Wu & Xiong, *supra* note 175.

³⁰⁴ Article 62, Chinese Patent Law.

In 2001, the Beijing Higher People’s Court developed a legal guideline on issues related to experimental use exception. Article 98 of the guidance provided that the use of the patent solely for scientific research and experimentation should include the act of manufacturing. This opinion was deemed as an expansion of the experimental use exception under Chinese patent law of 1984. Moreover, in 2002, the China Food and Drug Administration (CFDA) launched a “patent linkage” system through the Measures for the Registration and Administration of Drugs. Article 13 of the Measures allowed application for regulatory approval of a generic drug to be filed within two years before the expiry of the patent, which brought the usage of a patent for regulatory approval of a new within the coverage of experimental use exception.

Not until 2009 has China promulgated the new patent law, which added to the law a specific provision like the Bolar exception exempting clinical trials from patent infringement. Nevertheless, cases evaluating the experimental use defense are few, and those involving non-profit, educational alleged infringers such as universities are even fewer. Given that universities are a significant part of the research landscape in China, it will be interesting to see if the experimental use exception as applied to universities is tested in the courts.³⁰⁵ The following section is an overview of three cases related to the experimental use exception and the Bolar-type exception.

³⁰⁵ STEFAN LUGINBUEHL & PETER GANEA (ED.), PATENT LAW IN GREATER CHINA. (Edward Elgar Publisher, 2014) at 135-136.

Case 3 *Daiichi Sankyo Co. v. Wansheng Pharmaceutical Co. (2006)*³⁰⁶

This case involves a patent infringement dispute between a Japanese company, Daiichi Sankyo Corporation, and a Chinese company, Beijing Wansheng Pharmaceutical Company. The plaintiff, the Daiichi Sankyo Corporation (“Sankyo”), owned a process patent for making the pharmaceutical compound “Olmesartan” and the related compound. Sankyo learned that the defendant, Beijing Wansheng Pharmaceutical Company (“Wansheng”), produced some drug tablets of “Olmesartan medoxomil” during application for the registration of clinical trials and for the regulatory approval of manufacturing the drug. In 2006, Sankyo sued Wansheng in the Beijing Intermediate Court claiming that Wansheng’s Olmesartan tablets infringed Sankyo’s patent rights. Wansheng counterargued that its use of Sankyo’s patented technology was for the regulatory approval of a new drug and therefore was exempted from patent infringement.

Before the third amendment in 2009, the Chinese patent law had not stipulated whether using patented technology for regulatory approval of drugs constitutes patent infringement. In this case, the final judgment found no violation by Wansheng. The court reasoned that because Wansheng used the patented technology only to make the drug for clinical trials and to apply for regulatory approval, Wansheng did not make the drug on dispute directly for selling the product.³⁰⁷ Thus, the court held that using Sankyo’s

³⁰⁶ Sankyo Corporation v. Beijing Wansheng Pharmaceutical Co., Ltd. Beijing Higher People’s Court Appeal No. 907 (2006) (三共株式会社诉北京万生药业有限责任公司专利侵权纠纷案, (2006) 高民终字第 907 号).

³⁰⁷ Janet Xiao & Michael Vella, *China’s Bolar Exemption – Beware of the Uncertainties of Its Reach and Scope*, MORRISON & FOERSTER (Mar. 9, 2009), accessible online at <https://media2.mofo.com/> (last visited on May 1, 2018).

patented technology during the clinical trial was not an infringement act of “exploitation of the patent for production or business purposes” under Article 11 of the Chinese patent law. Sankyo did not appeal. The ruling, in this case, was final.

Discussion in the Epilogue

In deciding the *Sankyo* case, the court did not rely on the experimental use exception in Article 63 of the Chinese patent law but instead focused on the provision of “for the production and business purposes” in Article 11. Article 11 of the Chinese patent law grants patentee the right to exclude others from using the patent “for production or business purposes,” which is an implied exclusion for private use. The reason behind the court decision is that the court wants to avoid any potential conflicts with the third draft amendment to the Chinese patent law of 1984, which later introduced the Bolar exception. The third draft amendment to the Chinese patent law specifically distinguished between the experimental use exception and the Bolar exception. Under the third draft amendment in 2006, the experimental use exception was strictly limited to scientific research and experiment (clinical trials excluded), while the Bolar exception exempted clinical trial for regulatory approval from patent infringement as it fell outside of Article 11’s “for production or business purpose” definition.³⁰⁸

Three years after the *Sankyo* case, in 2009, the National People’s Congress of China promulgated the third amendment to the Chinese patent law, which officially added a

³⁰⁸ STEFAN LUGINBUEHL & PETER GANEA (ED.), *PATENT LAW IN GREATER CHINA*. (Edward Elgar Publisher, 2014) at 134.

Bolar-type provision to the Chinese patent law. The former Article 62(5) of the 1984 patent law on the experimental use exception was removed to the current Article 69(4) of the Chinese patent law, which also includes a new provision on the Bolar exception. Article 69(5) of the 2009 patent law, or the Chinese Bolar provision, states that “Any person produces, uses, or imports patented drugs or patented medical apparatus and instruments, to provide information required for administrative examination and approval” were exempted from patent infringement.³⁰⁹

Such a Bolar-type provision has drawn positive attention for making it easier for a pharmaceutical company to launch generic drugs before the expiry of patent protection. Furthermore, in the Administrative Measures for Drug Registration (Revised Draft) issued by China Food and Drug Administration on July 22, 2016, the restrictive provision on “register application for regulatory approval of generic drugs within two years before the expiry of the patent” was deleted. The revised Administrative Measures has yet been promulgated as the writing of this dissertation. If the revised edition is passed, it will be effectively linked to the Chinese Bolar provision in Article 69(5) of the Chinese patent law.³¹⁰ However, the scope and impact of the Chinese Bolar provision remain to be determined. The following cases that occurred after the introduction of the Chinese Bolar provision might shed some light on this problem.

³⁰⁹ Chinese Patent Law, accessible online at <http://english.sipo.gov.cn/lawpolicy/> (last visited on May 2, 2018).

³¹⁰ Fang Cheng & Shuman Zhang, *Drug registration and patent protection from a perspective on balance of interests*, ZHONGLUN LAW FIRM (Oct. 23, 2017), accessible online at <http://www.zhonglun.com/> (last visited on May 9, 2018).

Case 4 *Yiheng Pharmaceutical Co. v. Kanghai Pharmaceutical Co. (2010)*³¹¹

This case involves a patent dispute between two Chinese pharmaceutical companies. Plaintiff Nanjing Kanghai Pharmaceutical Company (“Kanghai”) was the owner of a patent (ZL03112908.0) issued on March 13, 2006, that claimed a method for the determination of molecular weight and molecular weight distribution in lentinan. Lentinan is a polysaccharide isolated from the fruit body of shiitake mushroom and is widely used in East Asian countries as an adjuvant to upregulating the immune system of cancer patients in chemotherapy.³¹² Defendant Nanjing Yiheng Pharmaceutical Company (“Yiheng”) was a manufacturer of lentinan powder injections. In September 2004, Yiheng applied for drug registration of the lentinan powder injections after the CFDA approved its phase III clinical trial. In June 2005, the CFDA approved Yiheng’s new drug titled “lentinan freeze-dried powder for injection.” In the Drug Manufacturing Certificate (YBH14462005), Yiheng specified a method for measuring the molecular weight in lentinan, with an average molecular weight (Mw) of 400,000 - 800,000 Daltons.

In 2007, Kanghai filed a lawsuit against Yiheng in the Nanjing Intermediate Court claiming that Yiheng’s lentinan powder injections infringed its patented method for measuring the molecular weight in lentinan. In the hearing, Yiheng admitted that it had used Kanghai’s patented method in the application dossier for drug registration of the lentinan powder injections but counterargued that its use of the patented method was

³¹¹ Nanjing Yiheng Pharmaceutical Co. v. Nanjing Kanghai Pharmaceutical Co., Jiangsu Higher People’s Court Appeal Judgment No. 0027 (2010). (南京易亨制药有限公司与南京康海药业有限公司侵犯专利纠纷上诉案, (2010) 苏知民终字第 0027 号).

³¹² See Lentinan, accessible online at <https://www.drugs.com/> (last visited on May 8, 2018).

exempted from patent infringement because it used the patented method solely for regulatory approval.

Yiheng also argued that it never practiced the patented method in manufacturing the lentinan powder injections, instead it had purchased the bulk drug substance of lentinan from a third-party manufacturer, Fuzhou Meifeng Pharmaceutical Company (“Meifeng”). The evidence showed that Yiheng signed multiple purchasing contracts with Meifeng to purchase the bulk drug substance of lentinan that had an average molecular weight of 400,000-800,000 Daltons. Conversely, Kanghai rejected Yiheng’s position as being self-contradicted. Kanghai collected an expert report on the quality of Meifeng’s lentinan substance. The report concluded that Meifeng’s lentinan substance was unqualified for producing the Yiheng’s lentinan powder injections because the molecular weight of Meifeng’s lentinan substance fell outside of the scope of 400,000-800,000 Daltons, a standard declared by Yiheng in its drug registration with the CFDA.

In the first instance, the Nanjing Intermediate Court ruled in favor of Kanghai and held that Yiheng’s production of the lentinan powder injections constituted patent infringement. The court rejected Yiheng’s position that the use of a patent during the application for regulatory approval was exempted from patent infringement. Instead, the court ruled that the use of the patented method during the request for drug registration fell into Yiheng’s legitimate business and this was an infringement act of “exploitation of the patent for production or business purposes” under Article 11 of the Chinese patent law. Furthermore, the court held that Yiheng’s defense that it had never practiced the patented method in manufacturing was inconsistent with the facts and cannot be

supported. The court explained that according to Yiheng's claim, there should be no difference between the lentinan substance of Meifeng and of Yiheng in terms of the molecular weight, but the evidence is showing there is a clear distinction, and thus Yiheng's claim was contradicted with the facts and cannot be adopted by the court.

Yiheng appealed to the Beijing Higher People's Court. In 2010, the Beijing Higher People's Court reversed the lower court's decision and held that Yiheng's use of the patented method was not an infringement. The court reasoned that although there was a prominent difference between the lentinan substance of Yiheng and Meifeng in molecular weight, it was unreasonable to conclude that the lentinan substance used in Yiheng's powder injections was not purchased from Meifeng. The court further ruled that the molecular weight and distribution of lentinan substance could be determined by various factors such as the raw materials (shiitake mushrooms), the lyophilized excipient, and the production processes, where even the same manufacturer may produce lentinan substance with different molecular weight, so it was normal to have variations in the lentinan substance of Yiheng and Meifeng. Therefore, the court found no infringement for merely purchasing the lentinan substance from a third-party manufacturer. The court also ruled that Yiheng's use of the patented method in the application of the drug registration was not a patent infringement because Yiheng did not implement the patented process in manufacturing the lentinan products. However, the court did not address the question whether Yiheng's use of the patented method during the application for drug registration should be exempted from patent infringement under the Chinese Bolar provision.

Case 5 *Kangyuan Chen v. South China Agricultural University (2017)*³¹³

This case involves a patent dispute between an individual inventor and a Chinese university. Plaintiff Kangyuan Chen (“Chen”) was the owner of an invention patent (ZL200810219969.2), a water treatment apparatus that titled “pneumatic inrush water pump conduit assembly and application thereof in water treatment technology.” The invention provided a water-pump conduit component for use in surface water treatment applications. Chen applied for the patent on December 9, 2008, and obtained the patent on March 21, 2012. Figure 5.2 shows a diagram of the pneumatic inrush water-pump conduit components. The main features of the conduit assembly included a water purification processor/ air bubble generator (1), a pipe elbow (2), a pipe nipple (3), a pipe tee (6), and a side inlet (9). South China Agricultural University (“SCAU”) was the owner of a patent (ZL200920059397.6) that claims mixed water and water purifying device. SCAU applied for a utility patent on June 29, 2009, and obtained the patent on March 31, 2010. Figure 5.3 shows a diagram of the water purifying device. The main features of the water purifying device included an ozone O₃ generator (1), a negative ion generator (2), a Venturi tube (3), a water pump (4), and air and water mixing tower (5).

³¹³ *Kangyuan Chen v. South China Agricultural University*, Guangdong Higher People’s Court Appeal No. 604 (2017). (陈康源诉华南农业大学侵害发明专利权纠纷案, (2017) 粤民终 604 号).

Figure 5.2 Patent (ZL200810219969.2): A Water-Pump Conduit Assembly

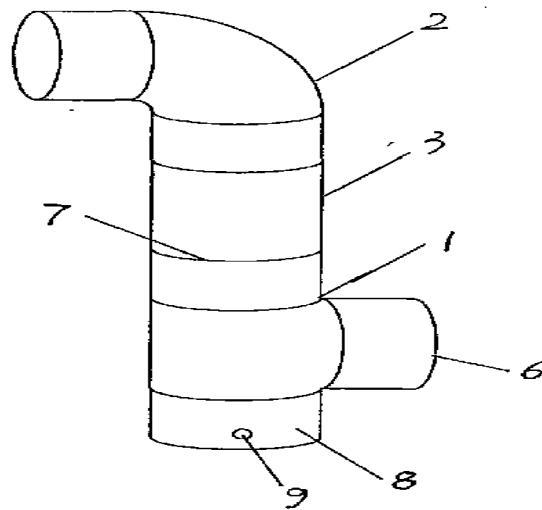
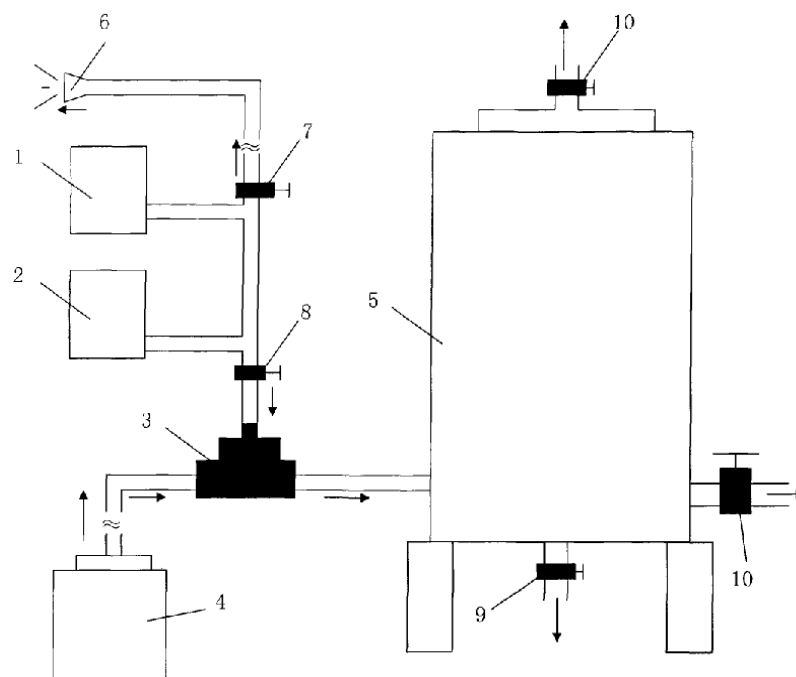


Figure 5.3 Patent (ZL200920059397.6): A Water Purifying Device



In 2014, after Chen learned that South China Agricultural University (“SCAU”) invented a water purifying device for breeding yellow colored carp fish, he sued SCAU in the Guangzhou Intellectual Property Court alleging that SCAU’s water purifying device infringed his patent rights in the conduit assembly. Chen also claimed that although SCAU was a non-profit institution, its research project on fish breeding was commercial exploitation for business purposes under Article 11 of the Chinese patent law. The claims on dispute included claim 1 and claim 5 in Chen’s application dossier.

Claim 1: A pneumatic inrush water-pump conduit assembly comprises a water purification processor, a pipe nipple, a pipe elbow, and a pipe tee. The water purification processor has a pipe tee and an air bubble generator at one end thereof. The water purification processor has a side inlet and an end outlet with features on that the end outlet (7) of the air bubble generator (1) is connected to the pipe elbow (2) through the pipe nipple (3). See the attached diagram.

Claim 5: The means for applying the Claim 1 conduit assembly in water treatment technology comprises the conduit components performing as a pipeline for lifting air flow and air injection in the water. Through the conduit assembly, the water pump can draw untreated water from a fresh water source to pre-filer means and circulate treated water from said pre-filer means. The conduit components comprise a water purification processor (1) connected to a pipe elbow (2) and a pipe tee through a pipe nipple (3).

In the hearing, defendant SCAU made two opposing arguments. First, SCAU argued that Chen did not provide evidence to prove that his patented conduit assembly was used in the water purification device, which had different features (e.g., Ozone generator) from Chen’s patent claims. Second, SCAU argued that the water purification device was designed and used solely for scientific research and experimentation, and thus should be exempted from patent infringement under Article 69(4) of the Chinese patent law. In the first instance, Guangzhou Intellectual Property Court ruled in favor of SCAU and held

that defendant's water purification device fell outside the scope of plaintiff's patent claims and thus was not an infringement of plaintiff's patented invention.

Chen appealed to the Guangdong Higher People's Court in 2017. The Guangdong Higher People's Court affirmed the lower court's decision. In the final judgment, the Court reasoned that according to Article 61 of the Chinese patent law, if the patent dispute involves an invention for the method of manufacturing a new product, the burden of proof shifts to the defendant; in this case, however, the dispute merely involved an invention for the method of using a new product rather than "the method of manufacturing a new product," and therefore Article 61 of the Chinese patent law was excluded in this case, the burden of proof remaining upon the plaintiff. The court further explained that because plaintiff failed to prove that defendant's patent fell into plaintiff's claim scope, the court rejected plaintiff's argument that defendant's patent was an infringement of his invention.

It is worth noting that in the court filings, both plaintiff and defendant mentioned the experimental use exception as applied to universities. However, neither the Guangzhou Intellectual Property Court (trial-level) nor the Guangdong Higher People's Court (appellate level) addressed this question in their judgment. The question whether the experimental use exception as applied to Chinese universities need to be tested in the court for future cases.

5.2.3 Employee Inventions

Article 6 of the Chinese patent law defines employee inventions (also known as service inventions) as patentable subject matters that “created in the execution of employment tasks” or that “primarily by using the material and technical resources of the employer.”³¹⁴ If an employee invention falls into the first category, the intellectual property underlying the employee invention belongs to the employer, which has the right to apply for patents or other intellectual property rights to it. According to the Chinese patent law, employment tasks cover not only tasks assigned and undertaken during employment but also tasks conducted by the individual in a related field within one year after termination of employment.³¹⁵ If an employee invention falls into the second category, whereas the employee merely used the material and technical resources of the employer, the contract between the employee and the employer governs the provision of the invention ownership unless the parties agree otherwise.

Article 16 of the Chinese patent law requires that an employer ought to provide the inventor-employee with a reward upon the granting of a patent for the employee invention. The current compensation levels for patentable subject matters created by employees are specified in Article 78 of the Implementing Rules of the Chinese patent law. An employer may enter into agreements with its employees regarding the compensation payable for employee inventions or may set them out in internal policies and procedures. If there is

³¹⁴ Charles Feng, *Employee Inventions in China*, MONDAQ.COM (Feb. 16, 2016), accessible online at <http://www.mondaq.com/> (last visited on May 9, 2018).

³¹⁵ Grace Chen et al., *Service Inventions in China*, COVINGTON & BURLING LLP (Jul. 10, 2015), accessible online at <https://www.cov.com/> (last visited on May 09, 2018).

no agreement or company policy, the default guidelines of the Chinese patent law govern the remuneration amounts, such as no less than 2 percent of operating profit of the employer generated from exploiting an invention or utility model patent (no less than 0.2 percent for a design patent), or no less than 10 percent from the licensing royalty fees. These statutory standards apply to both Chinese and foreign-owned enterprises.

However, the compensation levels, especially the 2 percent cut on profits and the 10 percent of royalty received, are often considered by employers as to be commercially unreasonable.³¹⁶ Such a regulatory standard could make it difficult for employers to determine the long-term investments regarding research facilities and human talent.³¹⁷ The Draft Regulation on Employment Inventions tackles this issue by stipulating that the cumulative remuneration paid to employee inventors shall not exceed half of the aggregate profits derived from the intellectual property, but it is not clear whether salary can be counted as part of the aggregate compensation.³¹⁸

Unlike the regulatory standard in Article 78 of the Implementing Rules of the Chinese patent law, Article 45 of the Law on Promoting the Transformation of Scientific and Technological Achievements (“the Law”)³¹⁹ has imposed a higher statutory standard on state-owned enterprises, public universities and research institutions regarding

³¹⁶ Cedric Lam et al., *How Employee-Inventors Are Protected in China*, MANAGING INTELLECTUAL PROPERTY (Mar. 1, 2013), accessible online at <http://www.managingip.com/> (last visited on May 08, 2018).

³¹⁷ Weifeng Zhang v. 3M China and 3M Innovative Properties Co., Ltd. Shanghai Higher People’s Court Appeal No. 120 (2014) (张伟锋、3M 中国公司与 3M 创新有限公司职务发明人奖励纠纷案, (2014) 沪高民三 (知) 终字第 120 号).

³¹⁸ Chen, *supra* note 74.

³¹⁹ The Law was revised by the National People’s Congress of China on August 29, 2015. The former Article 29 of the Law was revised and merged into Article 45 of the new Law.

inventor remunerations. Article 45 of the Law has significantly increased the measure of reward for technology transfer stating that the employee-inventor shall take no less than fifty percent of the net income from technology transfer, compared to only twenty percent in former Article 29. Under Article 45 of the Law, the parties are not allowed to agree upon a lower distribution percentage of the net income contradicting with the existing regulatory standard. This provision does not apply to private or foreign companies. Moreover, Article 45 also addressed the issue of whether equity income belongs to technology transfer income. Under Article 45, both equity income and licensing income count for the distributable revenues of technology transfer. The following two cases involve relevant disputes between employee inventors and public institutions.

Case 6 *Cuiying Yang v. Sichuan Orthopedic Hospital (2010)*³²⁰

This case involves an invention dispute between the invention originator and a public institute. Plaintiff Cuiying Yang (“Yang”) was the inventor of an herbal sports medicine “RJ San” for orthopedic injury treatment. Yang worked as a physician at the Chengdu Sports Academy Medical Center from 1967 to 1988. After 20 years of research, Yang developed an herbal medicine effective for treating soft tissue injury and swelling. In 2006, Sichuan Orthopedic Hospital, an affiliated institution to the Chengdu Sports Academy, applied to the Chengdu Food and Drug Administration for marketing registration of the herbal sports medicine “RJ San.” In 2008, Yang sued Sichuan Orthopedic Hospital in the Chengdu Intermediate Court for permanent injunctive relief and pecuniary damages for unauthorized exploitation of his intellectual property rights.

The main issues, in this case, included whether the defendant owned the herbal sports medicine as an employee invention and whether the defendant could be held legally liable for infringing the intellectual property rights of the plaintiff. Defendant Sichuan Orthopedic Hospital claimed that the herbal sports medicine was an employee invention owned by his parent institution, the Sichuan Sports Academy, where Yang worked as a physician using the employer’s resources to develop the herbal sports medicine. Defendant Sichuan Orthopedic Hospital also argued that the herbal sports medicine did not deserve intellectual property protection because the pill was invented in the 1980s, which had already become a part of the public domain.

³²⁰ *Cuiying Yang v. Sichuan Orthopedic Hospital (2010)*, Sichuan Higher People’s Court Appeal No. 292. (杨翠英与四川省骨科医院发明权纠纷案, (2010) 川民终字第 292 号).

The Court rejected the defendant's responses and ruled in favor of Yang. The Court reasoned that although the plaintiff had worked for the defendant during the invention development, the scope of his employment tasks determined whether his work fell into the definition of employee invention. Here, the plaintiff worked as a physician, whose primary job duties were to diagnose and treat injuries of the patients, rather than engaging in drug discovery. The court also ruled that the plaintiff did not use the defendant's resources in the invention development because the defendant never provided extra funding or materials to Yang specifically for developing the herbal medicine. The defendant's resources were used by the plaintiff solely for treating the patients in his ordinary business course as a physician. Therefore, the Court concluded the invention of the dispute was not an employee invention and was belonged to the plaintiff.

Regarding the pecuniary losses of the inventor, the Court ruled that the Sichuan Orthopedic Hospital was not liable for unauthorized exploitation of the invented herbal sports medicine "RJ San" because the ingredients of the herbal sports medicine had already been published in the 1980s and transformed into the public knowledge of the public domain. But the Court did find the defendant liable for infringing the moral rights of the plaintiff in the invention under Article 118 of the Chinese Civil Law. The Court reasoned that because the defendant did not cite the name of the plaintiff as the originator of the invention when registering the medicine with the state authority, this action constituted an infringement of the moral rights of the plaintiff in the invention. The plaintiff appealed. The appellate court affirmed the judgment of the first instance.

Case 7 *Yiting Peng et al. v. Hubei University of Technology (2014)*³²¹

This case involves a dispute over inventor remuneration. The plaintiff Dr. Yiting Peng (“Peng”) was a professor of chemistry with the Hubei University of Technology (“University”). In the late 1990s, Peng and his colleagues developed a technology to produce mica-based pearlescent pigments. In 1999, the State Intellectual Property Office (SIPO) issued a patent to the University, the owner of the employee inventions. The University then provided an exclusive license with a chemical company, Hebei Oxen Special Chemicals Co., Ltd. (“Oxen”), in exchange for one million RMB. In addition to the lump sum payment of one million RMB, the agreement between the University and the licensee Oxen also stipulated that Oxen issue ten percent of the company shares (worth one million RMB) to the University for the exclusive license of the pearlescent pigments technology.

In 2001, after receiving the down payment of one million RMB from Oxen, the University distributed 860,000 RMB to Peng and his research team as remuneration for commercializing the pigment invention. Eight years later, in 2009, the University sold all the shares of the Oxen company to a Shenzhen-based tech company for 5.45 million RMB. Peng immediately sued the University in the court claiming ownership of the monetary gains from the equity income of the Oxen company. The University disagreed and

³²¹ *Yiting Peng et al. v. Hubei University of Technology (2014)*, Hubei Higher People’s Court Appeal No. 109. (彭义霆、田晓辉与湖北工业大学职务技术成果完成人奖励、报酬纠纷案, (2014)鄂民三终字第 109 号).

counterargued that the plaintiffs were not eligible for the distribution of the equity shares as they had already been compensated by the lump sum payment of Oxen in 2001.

The court ruled in favor of the plaintiffs and held that the defendant should distribute the technology transfer income to the plaintiffs. Based on Article 29 of the Law on Promoting the Transformation of Science and Technology (“S&T law”) and the 2009 University Presidential Memorandum, the court held that the equity income belongs to the technology transfer revenues and should be distributed among inventors of the technology. The court further reasoned that although the University as a shareholder of the company had contributed to the business operation of the company, the value of the invention counted for seventy-six percent of the initial equity investment. Thus, the accomplishers of the invention should be entitled to the monetary gains from the equity sale of the company. The court, therefore, concluded that the plaintiffs were entitled to receiving a substantial portion of the 5.4 Million RMB equity income from the technology transfer between the university and the private company. The defendant appealed. The appellate court affirmed the lower court’s judgment.

5.3 Technology Contracts

Article 322 of the Chinese Contract Law defines a technology contract as a contract whereby the parties prescribe their rights and obligations in the development or the transfer of technology or the technology consulting or service. According to the Chinese Contract Law, technology contracts can be divided into four categories: (1) technology development contract³²², (2) technology transfer contract³²³, (3) technology consulting contract³²⁴, and (4) technology service contract.³²⁵ Technology contracts must be in writing. The Chinese Contract Law also prescribes that the conclusion of a technology contract shall be conducive to the progress of science and technology, and to the application and dissemination of scientific and technological achievements. This provision reveals the primary legislative purpose of the technology contract to facilitate technology development and technology transfer activities.

Furthermore, under the Chinese Contract Law, a technology contract is invalid if it includes terms that are contrary to the mandatory provisions of the law and regulations. They could be void in their entirety or unenforceable concerning the offending clauses.

³²² Article 330 of the Chinese Contract Law states that: A technology development contract is a contract concluded in respect of the development of a new technology, product, technique or material and the associated system. Technology development contracts include commissioned development contracts and cooperative development contracts.

³²³ Article 342 of the Chinese Contract Law states that: Technology transfer contracts include contracts for the assignment of patent, assignment of patent application rights, transfer of technical secrets, and patent licensing.

³²⁴ Article 356 of the Chinese Contract Law states that: Technical consulting contracts include contracts for provision of feasibility studies, technical forecast, specialized technical investigation, and analysis and evaluation report with respect to a technological project.

³²⁵ Article 356 of the Chinese Contract Law states that: A technical service contract means a contract whereby one party solves a technical problem for the other party by utilizing its technical knowledge, excluding a contract for construction project or a contract of hired work.

Invalid technology contracts include, for example, (1) contracts obtained by fraud, (2) contracts that cause an infringement of a third party's intellectual property rights, and (3) contracts that illegally monopolize or impairs the technological advancement.³²⁶ The parties are discharged from performing the contract if a technology contract is found to be invalid. When a technology contract has been adequately executed, the law requires the court to restore the parties to their pre-contract state as if the agreement had never been entered. The party at fault for rendering the contract invalid is liable for damages caused to the other party.

Besides, the Regulating Measures on Technology Contract Registration (“Measures”) prescribes that a technology contract should be registered with a local agency of science and technology. Under Article 6 of the Measures, recording the technology contracts (except the patent assignment) with the government agency is not compulsory, but without the registration, the parties of the technology contract will not be entitled to tax discounts, bank credits, and merit rewards from the government. If the technology contract involves a foreign entity, without the registration it may be difficult for the foreign entity to remit royalty payments out of China.³²⁷ Registration certificate of the technology contracts may be required by the bank at the time when the foreign body remits royalty payments overseas.³²⁸ For technology contracts involving the assignment of patent rights or patent application, Article 10 of the Chinese patent law articulated that

³²⁶ Article 329 of the Chinese Contract Law

³²⁷ Wendy Zeldin, *China: New Measures on Registration of Technology Import and Export Contracts*, LIBRARY OF CONGRESS (Mar. 9, 2009), accessible online at <http://www.loc.gov/> (last visited on May 11, 2018).

³²⁸ Editor, Licensing and Technology Transfer, CHINA IPR HELPDESK, accessible online at <http://www.china-iprhelpdesk.eu/> (last visited on May 10, 2018).

the technology contract is not legally enforceable until the assignment has been approved and registered by the State Intellectual Property Office (SIPO).

With respect to the ownership of improvements to licensed technology, China adopts a significantly different approach from foreign counterparts. Technology contracts in the west often have grant back clauses for the licensor to gain ownership of improvements without separate consideration.³²⁹ By contrast, the Chinese technology regulations provide that during the term of a technology contract, ownership of improvements to the licensed technology belongs to the improving party. Thus, if a licensee makes improvements to the licensed technology, the improvements belong to the licensee. The State Supreme People's Court of China has addressed this issue through the promulgation of a Judicial Interpretation on Litigation Issues Relating to Technology Contract Disputes³³⁰, which took effect on January 1, 2005. However, implementing the technology contracts in China is subject to a myriad of laws, regulations, and judicial interpretations, which may vary case by case. The following two cases show the disputes over the technology contracts.

³²⁹ Benjamin Bai et al., *Traps for the Unwary*, CHINA IP FOCUS (2008), accessible online at <http://www.jonesday.com/> (last visited on May 10, 2018).

³³⁰ Zui Gao Fa Yuan Guan Yu Shen Li Ji Shu He Tong Jiu Fen An Jian Shi Yong Fa Lv Ruo Gan Wen Ti De Jie Shi (最高人民法院关于审理技术合同纠纷案件适用法律若干问题的解释) [Judicial Interpretation on Litigation Issues Relating to Technology Contract Disputes] (Promulgated by the Supreme People's Court on May 15, 2005).

Case 8 *Guzhang-Daying Vanadium Co. v. Zhongnan University (2015)*³³¹

This case involves a technology contract dispute between a mining company and a Chinese university. The plaintiff, Guzhang-Daying Vanadium Company (“GD Company”) signed a technology development and service contract with the defendant, Zhongnan University in 2010. The two parties agreed that the defendant collaborated with the plaintiff to develop an industrial production line capable of manufacturing fifty tons of vanadium pentoxide per day, and based on this technology, upgrade the production line to a level capable of producing five hundred tons of vanadium per day.

Under the technology development and service agreement, the defendant promised to complete the development of the vanadium production line and transfer the technology to the GD company within five months after receiving the down payment by the plaintiff. After almost two years, however, the vanadium production line had yet been built. The plaintiff sued the defendant in the court claiming the damages caused by the defendant’s breach of contract. The defendant denied the charges of breach of contract and made a counterclaim that the plaintiff breached the contract by not providing the necessary materials for the development of the vanadium production line and by making an unauthorized disclosure of the university-owned technologies.

The court ruled in favor of the plaintiff and held that the defendant breached the contract by not establishing the production line within five months as prescribed in the

³³¹ *Guzhang-Daying Vanadium Co., Ltd. v. Central South University (2015)*, Hunan Higher People’s Court Appeal No. 185 (2015). (古丈大盈矿业有限公司与中南大学技术服务合同纠纷案, (2015)湘高法民三终字第 185 号).

technology contract. The court further held that the defendant failed to prove that the plaintiff had falsely disclosed the university-owned technology, and thus the defendant's claim was not adopted by the court. The defendant appealed. The appellate court partially supported and partially revised the judgment of the lower court. The appellate court affirmed the lower court's decision on the trade secret and ruled that no evidence showed that the plaintiff had made any unauthorized disclosure of the university-owned technology.

But the appellate court revised the lower court's decision on the breach of contract and ruled that the defendant had an excuse for the non-performance of the deal as the plaintiff failed to provide the materials and instruments necessary for the development of the vanadium production line. The court held that damages claimed by the plaintiff should be distributed evenly to the plaintiff and the defendant. Thus, the court concluded that the plaintiff and the defendant were liable to fifty percent of the economic losses caused by the unfulfilled contract obligations, respectively. According to the court judgment, Zhongnan University paid 258,289 RMB to the plaintiff GD company, an amount much less than the initial one, where the court in the first instance required Zhongnan University pay 1,391,984 RMB as damages to the plaintiff GD company.

*Case 9 Ruifeng Iron Mining Co. v. Beijing University of Aeronautics and Astronautics (2015)*³³²

This case involves a technology contract dispute between an iron mining company and a Chinese university. In 2010, the plaintiff, Ruifeng Iron Mining Company (“Ruifeng”), signed a technology development contract with Beijing University of Aeronautics and Astronautics (“Beihang”) to develop an industrial production line for extracting iron, titanium, and vanadium from high-titanium iron magnetite. Beihang University was the owner of a method patent (CN101487067A) titled “Industrial production method for directly producing iron and vanadium-titanium-aluminum alloy from vanadium-titanium magnet placer deposits.” The agreement between the two parties requires that Beihang complete the equipment design, construction, and installation for the industrial production facilities within one year after the entry of the contract and provide follow-up technical supports to Ruifeng for industrial test and process optimization within five years after the entry of the contract. Ruifeng paid 57,960,000 RMB to Beihang University in accordance with the technology development contract effective from 2010 to 2015.

The industrial production line was not established within the contractual timeline due to technological infeasibility. In 2013, the plaintiff Ruifeng sued the defendant Beihang University in the Beijing Higher People’s Court with an aim to terminate the contract.

³³² Ruifeng Mining Co., Ltd. v. Beijing University of Aeronautics and Astronautics, State Supreme People’s Court No. 8. (钦州锐丰钒钛铁科技有限公司与北京航空航天大学技术合同纠纷案, (2015)民三终字第 8 号).

The main issue, in this case, was whether the defendant committed fraudulent acts or misrepresentation of the facts that rendered the contract formation invalid. The plaintiff claimed that the contract was not formed because the defendant committed a false representation of material facts by not disclosing the industrial conditions to implement the technology. The plaintiff displayed to the court an expert opinion declaring that the production method developed by Beihang University was impracticable and fundamentally flawed according to industrial standards. Beihang University counterargued that the expert advice provided by the plaintiff was biased and should not be adopted as evidence. By contrast, Beihang provided an early appraisal report issued in 2010 claiming that at the time of contract formation, the technical problems occurred later in the development of the industrial production facilities was not foreseeable. The defendant Beihang University also provided evidence to prove that the plaintiff did not meet the environmental requirements for the construction of the chemical plant, which caused a significant delay for the university to carry out the contract obligations.

The Beijing Higher People's Court ruled in favor of the defendant Beihang University and held that the defendant was not liable for fraudulent acts or misrepresentation of material facts. The court ruled that when determining whether there was fraud in contract formation, it was necessary to distinguish between the legal risk and the commercial risk. According to the Judicial Interpretation on Litigation Issues Relating to Technology Contract Disputes, the legal risk of the contract refers to the legal aspects of the agreement, including fraud, coercion, or other hazards that affect the validity of the contract. The commercial risk relates to the business aspects of the deal including

profitability, marketability or other risks that affect the performance of the contract. The court reasoned that in this case, the technical problems were not foreseeable at the time when the parties formed the contract, and thus the defendant was not fraudulent in transferring the technology to the plaintiff.

The plaintiff appealed to the State Supreme People's Court, the highest judicial authority in China. The court affirmed the lower court's decision and ruled that the defendant did not commit fraudulent acts or misrepresentation of material facts during the formation of the contract. The court reasoned that technology R&D activities are often divided into several stages due to high risks of failure. The latter step of technology R&D activities is not a simple reproduction or amplification of the previous scenes. Here, the technical problems occurred during the second stage of the development of the industrial production facilities for the extraction of iron and vanadium from the vanadium-titanium magnet placer deposits. The technical problems of the second stage were hardly anticipated at the beginning of the technology development, and thus the defendant should not be held as fraudulent for not disclosing the technical problems during contract formation. Therefore, the court concluded that the defendant was not liable for the damages claimed by the plaintiff and the contract was upheld by the court.

5.4 Criminal Prosecution

In China, a lack of transparency and checks on administrative power in public universities, which depend heavily on government funding, has led to corruption in areas such as campus buildings, R&D funds, and the admission procedure.³³³ Concerning the university R&D activities, criminal violations often take the form of private coffers, concealed accounts, embezzlement, misappropriation of research funds, or bribery in the transfer of research results.³³⁴ Article 382 (2) of the Chinese criminal law defines the crime of embezzlement in the public sector as a person authorized by a state agency, state-owned enterprises or public institutions to administer the state-owned property which, by taking advantage of her office, unlawfully takes the said property into her possession. Article 271 of the Chinese criminal law defines the crime of misappropriation of the employer's property as an employee who, taking advantage of her position, unlawfully takes possession of the money or property of her employer.

A severe violation of Article 271 or Article 383 of the Chinese criminal law, where the value of the possessed property exceeds 100,000 RMB, could sentence the suspect to 10 years in jail. For example, in 2014, a professor at Zhejiang University was sentenced to 10 years in prison for the embezzlement of 9.45 million RMB of research funding.³³⁵ However, the criminal charges against university professors for theft or misappropriation

³³³ Editor, *China arrests university official in new graft crackdown*, REUTERS (Dec. 24, 2013), accessible online at <https://www.reuters.com/> (last visited on May 20, 2018).

³³⁴ Jianming Ren, *Educational Corruption in China*, in DONGPING YANG (ED.), THE CHINA EDUCATIONAL DEVELOPMENT YEARBOOK (Volume 1). (Brill Academic Publishers, Inc. 2009) at 251-258.

³³⁵ Editor, *A Professor of Zhejiang University was sentenced to 10 years in jail for embezzling 10 million RMB of research funding*, PEOPLE.COM (Jan. 10, 2014), accessible online at <http://edu.people.com.cn/> (last visited on Mar. 10, 2018).

of research funds by fabricating receipts and contracts, especially in the process of technology transfer, have been controversial in China. Some have concerns with the broad definition of embezzlement and the harsh deterrence effect on university R&D activities and argue that the grantees of university research funding should be decriminalized so long as the legal boundary of embezzlement remains to be determined when applying to the university sector.³³⁶ In response to these challenges, in 2016, the Supreme People’s Procuratorate of China launched a regulatory initiative titled “An Opinion on Implementing the Procuratorate Function to Protect and Promote Scientific and Technological Innovation (“the Opinion”).”³³⁷

Article 7 of this regulatory initiative provides that to protect the legitimate interests of scientific researchers in innovative activities the accused researcher shall not be prosecuted for criminal violations when judicial interpretations of a criminal statute or boundaries between crimes and non-crimes are not clear. So far, cases that evaluate the effect of the Opinion on prosecuting university professors are few. It will be interesting to see how this regulatory initiative is to change the future practices of criminal prosecution against university researchers. The following section involves a brief description of a case happened before the issuance of the Opinion.

³³⁶ Zhonghua Xiao, *Scientific researchers’ misappropriation of the national research funding shall not be deemed as a corruption*, THE SUPREME PEOPLE’S PROCURATORATE (May 19, 2015), accessible online at <http://www.spp.gov.cn/> (last visited on Mar. 20, 2018).

³³⁷ Guan Yu Chong Fen Fa Hui Jian Cha Zhi Neng Yi Fa Bao Zhang He Cu Jin Ke Ji Chuang Xin De Yi Jian (关于充分发挥检察职能依法保障和促进科技创新的意见) [An Opinion on Implementing the Procuratorate Function to Protect and Promote Scientific and Technological Innovation] (Promulgated by the Supreme People’s Procuratorate on Jul. 15, 2016).

Case 10 *The People's Republic of China v. Yingxu Chen (2013)*³³⁸

This case involves a criminal prosecution against a prestigious university professor for embezzling millions of research funds. The defendant, in this case, was a well-known professor of environmental engineering and Director of the Water Resources Research Institute of the Zhejiang University. Between 2008 and 2011, the defendant was the director and the chief scientist of a national research project on water pollution decontamination technologies. The total investment in this R&D project was 312.5 million RMB, where the government granted the funding of 105.4 million RMB.

In 2012, the defendant was arrested and prosecuted for embezzling research funds through fabricating transaction invoices and contracts. The evidence provided by the prosecutor showed that the between 2008 and 2011, the defendant had remitted and transferred 10.2 million RMB from the research funds to two companies, Gaobo Environmental Engineering Technology Co., Ltd (“Gaobo”) and Boyi Environmental Engineering Co., Ltd. (“Boyi”). Both companies were established and controlled by the defendant. Therefore, the prosecutor accused the defendant of unlawful possession of the research funds through wholly-owned companies.

The defense attorney objected the prosecution and argued that the defendant was innocent because Gaobo and Boyi were business partners with the Water Resources Institute and the remittance of the 10.2 million RMB research funds to Gaobo and Boyi was merely payment for their committed service to the current research project. The

³³⁸ *The People's Republic of China v. Yingxu Chen (2013)*, Hangzhou Intermediate People's Court No. 36 (2013). (陈英旭贪污罪刑事判决书, (2013) 浙杭刑初字第 36 号).

evidence provided by the defense attorney showed that the defendant had signed written agreements with the two companies for technology research and development on behalf of the Water Resources Institute. The court rejected the argument of the defendant and found him guilty of embezzling research funds by false invoices and contracts. The defendant appealed. The appellate court affirmed the lower court's decision and sentenced the defendant to 10 years in jail.

5.5 Tax Regulations

Apart from U.S. laws that explicitly grant tax-exempt status to universities,³³⁹ there are no specific laws or systems in China that manifest taxation on universities. The relevant provisions can be found among laws and regulations applicable to almost all types of organizations.³⁴⁰ In effect, Chinese universities must pay taxes for a wide range of activities, from property sales to technology licenses.³⁴¹ The most common grounds for taxation on university are enterprise income tax, business tax, and value-added tax.³⁴²

Enterprise income tax (EIT) covers the net profits derived from production, operations, transfers of property, interest, leasing, royalties, dividends, and other sources.³⁴³ Under income tax laws, the term “enterprises” has a broad definition, which comprises companies, business units, social enterprises, and other for-profit/non-profit organizations.³⁴⁴ The standard tax rate on resident enterprises is 25 percent with certain high-tech enterprises taxed at a reduced rate of 15 percent.³⁴⁵ Non-profit organizations are tax exempted,³⁴⁶ however, except for income earned from profit-making activities by

³³⁹ See U.S. Internal Revenue Code section 501 (c)(3). Under section 501 (c)(3), entities “organized and operated exclusively for religious, charitable, scientific, testing for public safety, literary or educational purpose” can qualify as tax-exempt institutions. See also, O’Connor et al., *supra* note 67 at 74-78.

³⁴⁰ Leon E. Irish et al., *China’s Tax Rules for Not-For-Profit Organizations*, A STUDY PREPARED FOR THE WORLD BANK (2004).

³⁴¹ JIE YU, *CHINESE UNIVERSITY TAX MANAGEMENT AND TAXATION RULES* (Southwestern University of Finance and Economics Press, 2016) at 18-23.

³⁴² Kui Yu, *Problems and Implications for Taxation on Chinese Universities*, 33 *ECONOMIC RESEARCH AND STUDY* 21-25 (2015) at 22.

³⁴³ Article 6, *Qi Ye Suo De Shui Fa Shi Shi Tiao Li* (企业所得税法实施条例) [The Implementation Rules of the Enterprise Income Tax Law] (Promulgated by the State Council on Nov. 28, 2007).

³⁴⁴ Article 3, *Id.*

³⁴⁵ Article 28, *Qi Ye Suo De Shui Fa* (企业所得税法) [The Enterprise Income Tax Law] (Promulgated by the National People’s Congress on Mar. 16, 2007).

³⁴⁶ Article 26, *Id.* Tax-exempt income shall include: (1) Interest income from government bonds; (2) Dividend income and other distributions with respect to equity interests paid between resident enterprises;

non-profit organizations.³⁴⁷ Regarding technology transfer, Article 27 of the Enterprise Income Tax Law specifies that income tax incurred from the transfer of technologies may be exempted or reduced.³⁴⁸ The Implementation rules of the Enterprise Income Tax Law further stipulates that parties of technology transfer are entitled to a tax credit up to RMB 5 million.³⁴⁹ If the net profits of technology transfer exceed RMB 5 million, a 50% enterprise income tax deduction on the excess of income may be granted to the transferor.

Business tax (BT) covers the gross revenues derived from the provision of services (excluding processing, repair, and replacement services), the transfer of intangible assets, and the sale of real estate properties.³⁵⁰ The tax rates that apply to these business transactions range from three percent to twenty percent. For instance, the gross revenues from the transfer of intangible assets (i.e., intellectual property) are subject to a five percent tax rate, whereas labor services are subject to a three-percent tax rate.³⁵¹ For many years, nearly all types of enterprises, agencies, institutions, administrative units, and social organizations must pay business tax based on their gross sales.³⁵²

(3) Dividend income and other distributions with respect to equity interests derived from resident enterprises and paid to a non-resident enterprise; (4) Income received by non-profit organizations.

³⁴⁷ Article 85 supra note 340.

³⁴⁸ Article 27 supra note 342. Income subject to tax exemptions and deductions shall include: (1) Income earned by enterprises from their activities in agriculture, forestry, animal husbandry and fishery; (2) Income earned from major state-owned public infrastructure facility projects; (3) Income earned from qualifying environment protection projects, water or energy saving projects; (4) Income earned from transfer of technologies ...

³⁴⁹ Article 90 supra note 340. In the case of technology transfer income below RMB5 million, enterprise income tax is exempted, while technology transfer income over RMB5 million, a 50% enterprise income tax deduction is granted.

³⁵⁰ Article 4, Ying Ye Shui Zan Xing Tiao Li (营业税暂行条例) [The Provisional Regulations of Business Tax] (promulgated by the Ministry of Finance on Jan. 1, 1994 and Abolished on Nov. 19, 2017).

³⁵¹ Appendix, Id.

³⁵² Article 1, Id.

Value-added tax (VAT) is calculated on the value of production added at each stage of the supply chain.³⁵³ China's indirect tax systems (or tax on transactions) has historically been a bifurcated system with value-added tax (VAT) broadly applying to the goods sector, and business tax (BT) pertaining to the services sector.³⁵⁴ In 2016, China replaced the business tax (BT) with the value-added tax (VAT).³⁵⁵ The expansion of the VAT system is designed to encourage low-end manufacturers to upgrade their technology through tax deductions across the supply chains.³⁵⁶ China's new VAT system uses multiple tax rates rather than a single rate.³⁵⁷ The VAT rate for technology transfer is set at six percent.³⁵⁸ Table 5.2 shows the VAT rates for university profit-making activities.³⁵⁹

³⁵³ Article 4, Zeng Zhi Shui Zan Xing Tiao Li (增值税暂行条例) [The Provisional Regulations of Value Added Tax] (promulgated by the Ministry of Finance on Jan. 27, 1995 and Amended on Nov. 19, 2017).

³⁵⁴ Peter Ng et al., *Major Taxes in the PRC*, PwC (2016), accessible online at <https://www.pwccn.com/en/> (last visited on May 30, 2016).

³⁵⁵ Dezan Shira, *An Overview of China's VAT Reform*, CHINA BUSINESS REVIEW (Feb. 24, 2017), accessible online at <https://www.chinabusinessreview.com/> (last visited on May 20, 2018).

³⁵⁶ Editor, *China's new VAT rates and rules – high level policies and general impacts across all industries*, CHINA TAX ALERT (2016), accessible online at <https://assets.kpmg.com/content> (last visited on May 20, 2018).

³⁵⁷ Article 2 supra note 350.

³⁵⁸ University as the regular taxpayer for value added taxes (学校认定为增值税一般纳税人通知) (*xue xiao ren ding wei zeng zhi shui yi ban na shui ren de tong zhi*), Office of Accounting (Jun. 07, 2016), accessible online at <http://www.sjtu.edu.cn/info/1736/67946.htm> (last visited on June 1, 2018).

³⁵⁹ Guan Yu Quan Mian Gai Zheng Zeng Zhi Shui Shi Dian De Tong Zhi (关于全面推开营业税改征增值税试点的通知) [Appendix 3 of the Notice on Implementing the Pilot Program of Levying Value Added Tax In lieu of Business Tax] (Promulgated by the Ministry of Finance on Mar. 23, 2016). Caishui [2016] 36 allows certain types of technology contracts to be exempted from value added taxes.

Table 5.2 Value-Added Tax (VAT) Rates for University For-Profit Activities

Value Added Tax Rates for University For-Profit Activities

	17%	13%	11%	6%
University For-Profit Activities	Tangible Personal Property Rental Services	Sale of Books, Newspapers, and Magazines	Real Estate Leasing Services	Technology Contracts (Technology Development, Technology Services, Technology Transfer, Technology Consultancy)
	Processing, Repair, and Replacement Services			Conference and Exhibition Services
	Sale of Regular Goods			

Source: Office of Accounting, Shanghai Jiao Tong University.³⁶⁰

³⁶⁰ The Small-Scale Taxpayer VAT rate (3%) does not apply to large universities. See Article 12, *supra* note 350.

Chapter 6 An Empirical Study on Technology Transfer

This dissertation uses a multi-level Poisson regression model to examine the impact of internal and external factors on technology transfer. The university-level dataset contains information on 111 colleges and universities for the 2013-2015 period. Only colleges and universities that report data for the full sample period are included in the dataset. The province-level dataset contains information on 31 provinces and municipalities in China for the 2013-2015 period.

6.1 Sample

Observations are taken from a combined dataset of the Higher Education Institutes Science and Technology Assessment Index (STAI),³⁶¹ the Higher Education Institutes Innovation Capacity Monitor Report (HEI),³⁶² and the Regional Innovation Capacity Monitor Report (RIC).³⁶³ The STAI data, the HEI data, and the RIC data are self-reported and not audited.

Given the increase in media coverage surrounding the data, there is an incentive for that personnel completing the STAI, HEI and RIC survey questionnaires to be more accurate in the later years compared with the earlier years of the data collection. Besides,

³⁶¹ Gao Deng Xue Xiao Ke Ji Tong Ji Zi Liao Hui Bian (高等学校科技统计资料汇编) [HIGHER EDUCATION INSTITUTES SCIENCE AND TECHNOLOGY ASSESSMENT INDEX] (Published by the Department of Science and Technology and the Ministry of Education), accessible online at <http://www.moe.gov.cn/> (last visited on Jun. 18, 2017).

³⁶² Pu Tong Gao Xiao Chuang Xin Neng Li Jian Ce Bao Gao (中国普通高校创新能力监测报告) [HIGHER EDUCATION INSTITUTES INNOVATION CAPACITY MONITOR REPORT] (Scientific and Technical Documentation Press, 2016).

³⁶³ Qu Yu Chuang Xin Neng Li Jian Ce Bao Gao (中国区域创新能力监测报告) [CHINA REGIONAL INNOVATION CAPACITY MONITOR REPORT] (Scientific and Technical Documentation Press, 2017).

the STAI data, the HEI data, and the RIC data are collected and published by the Ministry of Education, a central government branch that has direct political power to nominate that personnel completing the survey questionnaires. The political pressures on that personnel completing the survey questionnaire might also ensure the quality of the outcome.

The updated STAI dataset contains 1,497 cases for the most recent years available. The updated HEI dataset comprises 1,762 examples for the most recent years available. Observations were eliminated for two reasons. First, institutes that did not have a bachelor's degree program or did not affiliate with the Ministry of Education were excluded because of the difficulty in assessing independent variables in such cases. Institutes that only had an associate degree program or operated under the local government were often vocational colleges directed at an occupation. These institutes were seldom engaged in technology transfer. Table 6.1 shows that in a sample of 627 vocational colleges, the majority (577, 91.48%) had never entered any technology transfer contracts, and those (39, 6.76%) that had ever entered technology transfer contracts before had no more than five contracts per year. Second, if a university was plagued by missing data for any of the variables of interest, it was not included. After these exclusion rules were imposed, an *N* of 222 was arrived at for the updated dataset.

Table 6.1 The Frequency of Technology Transfer Contracts by Sample Vocational Colleges, 2016

Frequency of Technology Transfer Contracts by Sample Vocational Colleges, 2016

	Number of Technology Transfer Contracts Per Year						
	None	1 - 5	6 - 15	16 - 25	26 - 35	36 - 45	> 45
Number of Vocational Colleges	577	39	8	1	0	0	2
Percent of Vocational Colleges	91.48%	6.76%	1.28%	0.16%	0%	0%	0.32%

Note : The two vocational colleges that entered more than 45 technology transfer contracts were the Wenzhou Vocational & Technical College (52 contracts) and the Zhangzhou College of Science and Technology, formerly the Zhangzhou TianFu Tea College (51 contracts).

Source: adapted by the author based on the data from the STAI dataset.

6.2 Measures

6.2.1 Dependent Variable

The dependent variable of this study is technology transfer output, which represents the flow of technology from university to the private sector. In the prior literature, the measurement of technology transfer output varies among researchers. Patent licensing and start-up formation are the most selected indicators of technology transfer output.

Technology Transfer Contract. This dissertation uses the number of the technology transfer contracts to measure technology transfer output.³⁶⁴ In the Chinese patent law, “technology transfer contract” is a generic term referring to a set of agreements, classified by the underlying intellectual property rights.³⁶⁵ Technology transfer contract has a broad application domain, including patent licensing, know-how transfer, and copyright assignment.³⁶⁶ These forms of contracts give the negotiators more flexibility to implement their technology transfer strategies. But the outcome of technology transfer might differ over time and among regional areas. This dissertation does not use the number of university spin-offs as an indicator because the data available to monitor startup creation within China universities are insufficient. Data regarding

³⁶⁴ “In China, patents are not the only output from university-industry collaboration. The ideal proxy should be university-industry contracts.” See Wei Hong & Yu-Sung Su, *The effects of institutional proximity in non-local university-industry collaborations: An analysis based on Chinese patent data*, RESEARCH POLICY 42 (2013) 454-464. Pp.457.

³⁶⁵ Article 342 (Types of Technology Transfer Contract), Contract Law of the People’s Republic of China (translated by WIPO), accessible online at <http://www.wipo.int/> (last visited on Mar. 01, 2018). The transcript of Article 342: “Technology transfer contracts include contracts for the assignment of patent, assignment of patent application right, transfer of technical secrets, and patent licensing. A technology transfer contract shall be in writing.”

³⁶⁶ See Appendix: Sample Technology Transfer Contract (published and released by the Nanjing University of Aeronautics and Astronautics).

technology transfer contracts can be obtained from the Higher Education Institutes Science and Technology Assessment Index (2015-2016).³⁶⁷

6.2.2 Independent Variables

In statistical modeling, the dependent variable represents the output whose variation is being studied, and the independent variable is the variable changed or controlled in a scientific experiment to test the effects on the dependent variable.³⁶⁸ Since this dissertation primarily focuses on the relationship between technology transfer output and the factors that affect technology transfer output, it includes only variables that are theoretically connected with the technology transfer process. The inclusion of the control variables is justified since their relation to both the dependent variable and the independent variables suggests a potential confounding impact on the findings. A brief discussion and description of these control variables will suffice the purpose of this dissertation.

This dissertation identifies three sets of independent, time-variant variables as predictors of technology transfer output. The first set, which is labeled university-level control variables, refers to endogenous university features. This set of variables primarily includes university size and university reputation. The second set, which is marked by university-level factors, applies to the university organizations and policies that affect commercial exploitation of research results. This set of variables primarily includes

³⁶⁷ Supra note 358.

³⁶⁸ JOHN W. CRESWELL, RESEARCH DESIGN: QUALITATIVE, QUANTITATIVE AND MIXED METHODS APPROACHES (SAGE, 4th ed., 2014).

resource allocation, patenting regulation, and industry networking. The third set, which is labeled province-level factors, refers to the local-context factors that affect transferring technology from university to the industry sector. This set of variables primarily includes skilled workforce, legal environment, economic freedom, industry clustering, government subsidy, and entrepreneurial financing. Also, this dissertation does not lag the independent variables at the time of assessment because it is widely expected that current-year independent variables influence the outcome of technology transfer. Table 6.3 reports the descriptive information on the variables.

(1) University-level Variables

University size. University size can be measured from multiple aspects, such as the campus size, the undergraduate enrollment or the faculty and staff number. This study uses the number of R&D faculty and staff to measure university size. Data can be obtained from the Higher Education Institutes Science and Technology Assessment Index (2016).³⁶⁹

University reputation. University reputation refers to the public views on excellence in research and teaching of a university. In China, there is a national ranking of university reputation, known as the “985” project or the “world first-class university” project, an endorsement of 39 universities as being the best research universities in China. This dissertation uses the “985” project membership (yes/no) as a measurement of university

³⁶⁹ Supra note 358.

reputation. Data can be obtained from the List of Universities of “211” and “985” project (2017).³⁷⁰

Resource allocation. Resource allocation is a plan for using available resources in the near term to achieve specific goals. In the university setting, it often refers to how universities distribute resources, usually financial resources, to fulfill the educational and R&D requirement. In this dissertation, resource allocation is measured by the amount of public funding expended by universities on R&D activities. The other usages of the public grants, such as for the education programs and the administrative operations, are controlled from the analyses. Data can be obtained from the China Higher Education Institutes Science and Technology Assessment Index (2016)³⁷¹.

Patenting regulations. Patenting regulations refer to a policy framework adopted by a university to develop and manage its intellectual property portfolios. While there is no data directly addressing patenting regulation, this dissertation uses the number of issued patents as an alternative data source. For most universities, IP management essentially means filing patent applications.³⁷² Therefore, patenting regulations is measured by the total number of patents issued to universities between 1985 and 2010. Data can be obtained from Chinese Universities Intellectual Property Report (2010)³⁷³.

³⁷⁰ List of Universities of “211” project and “985” project, BESTEDUCHINA.COM, accessible online at <http://www.besteduchina.com/> (last visited on Jun. 20, 2017).

³⁷¹ Supra note 358.

³⁷² Clifford M. Gross, *The Growth of China’s Technology Transfer Industry Over the Next Decade: Implications for Global Markets*, 38 JOURNAL OF TECHNOLOGY TRANSFER (2013) 716-747.

³⁷³ Zhong Guo Gao Xiao Zhi Shi Chan Quan Bao Gao (中国高校知识产权报告) [CHINESE UNIVERSITIES INTELLECTUAL PROPERTY REPORT] (Tsinghua University Press, 2010).

Industry Networking. Industry networking refers to a process of establishing a mutually beneficial relationship with other business people and potential clients through symbolic ties and contacts. In the university setting, industry networking means forming the business connections between the university and the industry sector. More specifically, universities need to adopt a networking approach to enhancing collaboration with the industry sector when exploiting the commercial value of university-owned inventions. While there are no data directly addressing the frequency of networking events between university and industry, this dissertation uses the number of national science parks operated by universities as a measurement of industry networking, given the fact that national science park run by Chinese universities is a new hub/hotspot for the flow of technology between university faculty and industry experts. Data can be obtained from the List of National University Science Parks (2002-2014)³⁷⁴.

(3) Province-level factors

Skilled workforce. A skilled workforce is a segment of the workforce with specialized know-how, training, and experience to carry out more complex physical or mental tasks than routine job functions.³⁷⁵ A skilled workforce is generally characterized by higher education and higher wages. Many countries regard the skilled workforce as an essential ingredient to increase productivity and growth.³⁷⁶ In this dissertation, a skilled

³⁷⁴ Hongyu Liu, *National University Science Parks in China and Their Efficiency: Analysis and Implications for Future Strategies*. 2015. Ph.D. Dissertation, Tohoku University, Japan.

³⁷⁵ What is “Skilled Labor”, INVESTOPEDIA, accessible online at <https://www.investopedia.com/> (last visited on Apr. 20, 2018).

³⁷⁶ A Skilled Workforce for Strong, Sustainable and Balanced Growth (2011), International Labor Office, online accessible at <https://www.oecd.org/> (last visited on Apr. 20, 2018).

workforce is measured by the total number of residents with a college degree in each China province. Data can be obtained from the Regional Innovation Capacity Monitoring Report of China (2016-2017).³⁷⁷

Legal environment. Legal environment refers to the role of law and legal system in economic development.³⁷⁸ In the business of technology transfer, the legal environment is often examined by the strength of intellectual property protection.³⁷⁹ China has long been criticized by foreign investors for weak intellectual property protection and selective application of the law.³⁸⁰ In this dissertation, the legal environment is measured by the total number of intellectual property cases adjudicated at the local jurisdictions from the year of 2014 to the year of 2017. Data can be obtained from the China Judgements Online database.³⁸¹

Economic freedom. Economic freedom refers to the free flow of labor, capital, and goods in a society.³⁸² In China, economic freedom is often used interchangeably with the term “marketization,” which describes China’s achievements in the market-oriented

³⁷⁷ Supra note 360.

³⁷⁸ Hao Jiao et al., *Legal environment, government effectiveness and firm’s innovation in China: Examining the moderating influence of government ownership*, TECHNOLOGICAL FORECASTING & SOCIAL CHANGE 96 (2015) 15-24.

³⁷⁹ Doing Business 2018 (World Bank Group, 2018), accessible online at <http://www.doingbusiness.org/> (last visited on Apr. 20, 2018).

³⁸⁰ Lucy Hornby, *U.S. Warns China over Intellectual Property Risks*, FINANCIAL TIMES (Apr. 21, 2015), accessible online at <https://www.ft.com/> (last visited on Jan. 13, 2018).

³⁸¹ China Judgements Online (中国裁判文书网) (*Zhong guo cai pan wen shu wang*), accessible online at <http://wenshu.court.gov.cn/> (Since 2013, judgement documents from more than 3,000 courts across China were made accessible and searchable to the public through an online database, China Judgements Online, a database set and operated by the Supreme People’s Court (SPC) of China.) See also, An Executive Summary of Intellectual Property Litigations in China 2014-2017 (*Zhi Shi Chan Quan Su Song Bao Gao 2014-2017*), Sohu.com (Sep. 04, 2017), accessible online at <http://www.sohu.com/> (last visited on Dec. 30, 2017).

³⁸² 2018 Index of Economic Freedom, THE HERITAGE FOUNDATION, accessible online at <https://www.heritage.org/index/> (last visited on Mar. 12, 2018).

economic reform.³⁸³ From the perspectives of marketization, the state-owned enterprises have long been criticized for market inefficiency, such as monopolizing the allocation of scarce capital and restricting the flow of banking loans going to the nonstate sector.³⁸⁴ This dissertation uses the number of state-owned enterprises as a measurement of economic freedom at the province level in China. Data can be obtained from each province's bureau of statistics databases from 2014 to 2015.³⁸⁵

Industry Clustering. Industry clustering is the phenomenon where firms from the same industry gather together in proximity.³⁸⁶ By clustering together, firms can benefit from the neighborhood's pool of expertise, skilled employees, and easy access to component suppliers or information channels.³⁸⁷ While there are no data directly addressing the level of industry clustering in each region, this dissertation uses the number of employees working in the high-tech industry as a proxy to measure industry

³⁸³ Yang Zhou & Joshua C. Hall, *The Impact of Marketization on Entrepreneurship in China: Recent Evidence*, Working Paper (2017), accessible online at <http://busecon.wvu.edu/> (last visited on Mar. 10, 2018).

³⁸⁴ See, e.g., James A. Dorn, *State-Owned Enterprises Continue to Hinder Chinese Growth*, CATO INSTITUTE (Sep. 21, 2000), accessible online at <https://www.cato.org/> (last visited on Mar. 10, 2018). FAN GANG ET AL., *NERI INDEX OF MARKETIZATION OF CHINA'S PROVINCES: 2016 REPORT* (Social Sciences Academic Press, 2017). Kevin Z. Zhou et al., *State Ownership and Firm Innovation in China: An Integrated View of Institutional and Efficiency Logics*, ADMINISTRATIVE SCIENCE QUARTERLY, Vol.62, Issue 2 (2017). Chen Zhang et al., *Corruption, Marketization and Corporate Tax Management in China: Evidence from Listed Firms*, MALAYSIAN JOURNAL OF ECONOMIC STUDIES 54 (2): 281-299 (2017). Shang-Jin Wei, *From "Made in China" to "Innovated in China": Necessity, Prospect, and Challenges*, JOURNAL OF ECONOMIC PERSPECTIVES 32(1): 49-70 (2017).

³⁸⁵ See e.g., Jiangsu Bureau of Statistics database, accessible online at <http://www.jssb.gov.cn/> (last visited on Jan.05, 2018).

³⁸⁶ Idea: Clustering, THE ECONOMIST (Aug. 24, 2009), accessible online at <https://www.economist.com/> (last visited on Feb. 14, 2018).

³⁸⁷ Id. See also, e.g., Bruce Katz & Julie Wagner, *The Rise of Innovation Districts: A New Geography of Innovation in America* (Brookings Institute, May 2014). Robert Huggins & Piers Thompson, *Entrepreneurship, Innovation and Regional Growth: A network Theory*, SMALL BUSINESS ECONOMY (45): 103-128 (2015). Heike Mayer, *Entrepreneurship in a Hub-and-Spoke Industrial District: Firm Survey Evidence from Seattle's Technology Industry*, REGIONAL STUDIES (47) 10: 1715-1733 (2013).

clustering. Data can be obtained from the Regional Innovation Capacity Monitoring Report of China (2017).³⁸⁸

Government subsidy. Government subsidy is a benefit given by the government to an individual, business or institution with the aim of promoting certain economic and social policies. Government subsidy is usually in the form of a cash payment or a tax deduction. In many cases, firms use government subsidies to offset the cost of production. In this dissertation, the government subsidy is measured by the total amount of tax deduction awarded by the provincial government to the local high-tech industry. Data can be obtained from the Regional Innovation Capacity Monitoring Report of China (2017)³⁸⁹.

³⁸⁸ Supra note 360.

³⁸⁹ Id.

Table 6.2 Variables included in the Multi-level Poisson Model

Table 6.3 Variables Included in This Dissertation

Class	Variable	Type of Variable	Time Span	Measurement	Data Source
Dependent variable	Technology transfer output	Continuous	2013-2015	Number of technology transfer contracts	STAI
University-level factors	University size	Continuous	2013-2015	Number of R&D faculty and staff	STAI
	University reputation	Dummy	2013-2015	Membership of the "985" project	Collected by author
	Resource allocation	Continuous	2013-2015	R&D expenditures	STAI
	Patenting regulation	Continuous	1985-2010	Number of issued patents	IPR
	Industry networking	Dummy	2002-2014	National university science parks	Collected by author
Province-level factors	Skilled workforce	Continuous	2014-2015	Number of people with College Degrees	RIC
	Legal environment	Continuous	2014-2016	Number of IP cases adjudicated at local jurisdictions	Collected by author
	Economic freedom	Continuous	2013-2015	Number of state-owned enterprises	Collected by author
	Industry clustering	Continuous	2014-2015	Number of employees in the high-tech industry	RIC
	Government subsidy	Continuous	2014-2015	Tax deduction awarded to high-tech companies	RIC

6.3 Model Specification

The primary analyses will be undertaken using a quantitative method to determine the joint effects of the university-level and province-level factors on technology transfer output. Because the unit of analysis in this dissertation is obtained in universities nested within regions, a Multi-Level Model (MLM) will be used in this study.

The Multi-Level Model (MLM), also known as the nested data model or the random effects model, is designed for explanatory variables (also called independent variables or covariates) from multiple levels.³⁹⁰ In the specification of multilevel models, a level is a set of units or equivalently a system of classification in a statistical design.

The first decision in specifying a multilevel model is whether a set of units qualifies as a non-trivial level in the multilevel analysis. To be eligible as a non-trivial level, the dependent variable in a multilevel regression model must show some residual variance (sometimes called error terms) associated with these units.³⁹¹ In this dissertation, residual variance in the multilevel analysis means that the phenomenon that sample universities (level-one units) in some regions (level-two units) have the higher performance of technology transfer (dependent variable) than in other areas cannot be explained by the effect of measured variables.

³⁹⁰ The “level” signifies the position of a unit of observation within the hierarchy of data. For instance, in my study, the dependent variable (technology transfer activity) is at the lowest level, solely from the university level. My independent variable (legal environment) is at the advanced level, within the province level.

³⁹¹ Tom Snijders, *Fixed and Random Effects*, in BRIAN S. EVERITT & DAVID HOWEL (EDS.), *ENCYCLOPEDIA OF STATISTICS IN BEHAVIORAL SCIENCE*. (Wiley, 2005).

The second decision in specifying a multilevel model is whether the explanatory variables in the multilevel analysis have fixed or random effects. The fixed effects of a variable assume that there is an average effect in the clusters, while the random effects of a variable assume that the effect varies randomly within the clusters and that the researcher is interested in testing the variance of these random effects across the clusters.³⁹²

In the model specification, random effects could be specified as both random intercepts and random coefficients, and fixed effects could be specified as identical parameters.³⁹³ This dissertation models the explanatory variables with random effects and investigates the differences between regions in the effect of university-level variables on technology transfer.

Modeling an effect as random usually goes with the assumption of a normal distribution for the random effects.³⁹⁴ In general, continuous variables tend to follow a normal distribution. However, not all distributions in statistics are continuous.³⁹⁵ Count variables, for instance, are numerical and discrete but not continuous. Not only are count variables discrete, but they also cannot be negative.³⁹⁶ In statistical modeling, count variables tend to follow a Poisson distribution, which is discrete and bounded at 0.³⁹⁷ In

³⁹² Id. In this dissertation, such a variable could be the R&D expenditures of a university, a level-one variable, which varies over universities, the level-one units. A multilevel analysis examines whether the effect of R&D expenditures on technology transfer (i.e., the regression coefficient of R&D expenditures) could be different across regions (level-two units).

³⁹³ RABE-HESKETH, *supra* note 39.

³⁹⁴ Snijders, see *supra* note 394.

³⁹⁵ Karen Grace-Martin, *Differences Between the Normal and Poisson Distributions*, accessible online at <https://www.theanalysisfactor.com/> (last visited on May 6, 2018).

³⁹⁶ The number of technology transfer contracts can be 0 or 4, but not -8.

³⁹⁷ Snijders, see *supra* note 394.

this dissertation, the dependent variable is a count variable, and thus it is appropriate to model the variables as a Poisson distribution.³⁹⁸

The multilevel regression model is not the only model in statistics. There are two other commonly used models, including the ordered logit model and the event history model. The ordered logit model assumes that the intervals of ordinally ranked variables are not equally distributed.³⁹⁹ This assumption is not consistent with the explanatory variables in this dissertation, which are either continuous or discrete with intervals equally distributed. For this reason, the ordered logit model is not appropriate for this research. The event history model is also excluded from this dissertation because the unit of analysis in the event history model is not an individual or a social group but a historically significant event or a long-standing life event.⁴⁰⁰ In this dissertation, a calendar year rather than a lifespan is an adequate period to explore the patterns of technology transfer.

For the above reasons, this dissertation adopts a multilevel Poisson model with random effects at both the university and the province levels. This model can be specified

³⁹⁸ Unlike a normal distribution, which is always symmetric (the “Bell shape”), a Poisson distribution with a low mean is highly skewed. All the data are pushed against 0, with a flat tail extending to the right. In this dissertation, the data shows an asymmetric distribution.

³⁹⁹ Here is an example of the ordinally ranked variable: A marketing research firm wants to investigate what factors influence the size of soda (small, medium, large or extra-large) that people bought at a fast-food chain. While the dependent variable, size of soda, is obviously ordered, the difference between the various sizes is not constant. The difference between small and medium is 10 ounces, between medium and large 8, and between large and extra-large 12. See e.g., *Ordered Logistic Regression*, UCLA INSTITUTE FOR DIGITAL RESEARCH AND EDUCATION, accessible online at <https://stats.idre.ucla.edu/> (last visited on Jan. 10, 2018).

⁴⁰⁰ JOHN SCOTT, *A DICTIONARY OF SOCIOLOGY* (Oxford University Press, 1998). See also, *Event-History Analysis*, ENCYCLOPEDIA.COM, accessible online at <https://www.encyclopedia.com/> (last visited on Mar. 12, 2018).

with a general equation: $Y_{ij} = \beta_0 + \beta_1 X_{1ij} + u_j + \varepsilon_{ij}$ (Equation 6.1).⁴⁰¹ Dependent variable Y_{ij} represents the outcome for units at level one “i” and at level two “j.” X_{1ij} represents the independent variable that influences the outcome for units at level one “i” and at level two “j.” β_0 is the constant term in a linear regression analysis (or the expected mean value of Y when all $X=0$). β_1 is the estimated coefficient of the independent variables. This model estimation also includes two-level residuals u_j for the between-level error (level-two residual) and ε_{ij} for the within-level error (level-one residual)⁴⁰².

More specifically, this dissertation is interested to find the most important determinants in technology transfer. The theoretical framework discussed in Chapter 2 provides a guideline about which variables should be used to determine the outcome of technology transfer. The success of technology transfer within universities is contingent upon both the institutional arrangement and the external environment. Only variables that are theoretically connected with the technology transfer process are included in the multiple regression analysis.

Consistent with the model specifications, three equations are built to estimate the most critical factors in technology transfer. In these equations, resource allocation (ResourceAll), patenting regulation (PatentReg), industry networking (IndusNet), university size (UniSize), and university reputation (UniRep) are examined as the

⁴⁰¹ See SOPHIA RABE-HESKETH & ANDERS SKRONDAL, *MULTILEVEL AND LONGITUDINAL MODELING USING STATA* (Stata Press, 2012).

⁴⁰² In a single-level model, the equation is $Y_{it} = \beta X_{it} + \alpha + \varepsilon_{it}$. Only a level-one residual exists in this model.

university-level independent variables, whereas skilled workforce (*SkillWork*), legal environment (*LegalEnv*), economic freedom (*EconFree*), industry clustering (*IndustryCluster*), and government subsidy (*GovSubsidy*) are included as the province-level independent variables. Table 6.4 shows the descriptive statistics of these variables.

The equations of the multiple regression analysis can be specified as follows.

$$E(\text{TechTransfer}_{\text{Model I}}) = \beta_0 + \beta_1 \text{ResourceAll} + \beta_2 \text{PatentReg} + \beta_3 \text{IndustryNet} + \beta_4 \text{UniSize} + \beta_5 \text{UniRep} + u_j + \varepsilon_{ij}$$

(Equation 6.2)

$$E(\text{TechTransfer}_{\text{Model II}}) = \alpha_0 + \alpha_1 \text{SkillWork} + \alpha_2 \text{LegalEnv} + \alpha_3 \text{EconFree} + \alpha_4 \text{IndustryCluster} + \alpha_5 \text{GovSubsidy} + u_j + \varepsilon_{ij}$$

(Equation 6.3)

$$E(\text{TechTransfer}_{\text{Model III}}) = \delta_0 + \delta_1 \text{ResourceAll} + \delta_2 \text{PatentReg} + \delta_3 \text{IndustryNet} + \delta_4 \text{UniSize} + \delta_5 \text{UniRep} + \delta_6 \text{SkillWork} + \delta_7 \text{LegalEnv} + \delta_8 \text{EconFree} + \delta_9 \text{IndustryCluster} + \delta_{10} \text{GovSubsidy} + u_j + \varepsilon_{ij}$$

(Equation 6.4)

The above equations regard technology transfer process as a result of university-level random effects (Model I), of province-level random effects (Model II), and of both university-level and province-level random effects (Model III). Overall, these models aim to find the relationship between independent variables and a dependent variable. Table 6.5 summarizes the empirical results for this multilevel Poisson regression model.

Table 6.3 Summary Statistics for Variables Included in the Regression Model.

Descriptive statistics for variables included in the regression model.

Variable	Obs	Mean	Median	Std. dev.	Min	Max
Dependent Variable						
Number of Technology Transfer Contracts	222	52.284	10.000	124.481	0.000	785.000
Independent Variables						
University-level Factors						
R&D Expenditures (ten million RMB)	222	51.498	31.816	56.243	0.157	309.127
R&D Faculty and Staffs (thousand)	222	1.412	0.973	1.447	0.041	8.055
Membership of "985" Project	222	0.342	0.000	0.476	0.000	1.000
Number of Patents Issued (thousand)	222	1.032	0.885	1.253	0.000	7.779
National University Science Parks	222	0.550	1.000	0.499	0.000	1.000
Province-level Factors						
Number of Residents with College Degrees (million)	222	7.278	7.494	2.965	0.211	12.300
Number of Employees working in the High-tech Industry (million)	222	0.642	0.270	0.922	0.001	3.890
Number of IP Litigations (thousand)	222	10.974	8.482	10.247	0.006	44.680
Number of State-owned Enterprises (thousand)	222	12.482	11.111	4.815	0.937	20.962
Number of Private Enterprises (thousand)	222	484.061	390.178	355.555	6.464	1252.077
Tax Deduction Awarded to High-Tech Companies (million RMB)	222	1953.876	969.000	2522.645	0.200	10868.000

Table 6.4 Regression results with multilevel variables included.

Dependent variable: technology transfer output (number of technology transfer contracts)

Independent variables	Model I: Random Slope		Model II: Random Slope		Model III: Random Slope	
	Estimate	[SE]	Estimate	[SE]	Estimate	[SE]
University size (R&D staffs)	0.008	[0.007]			0.006	[0.007]
University reputation (Membership of 985Project)	-21.969	[22.871]			-26.845	[22.353]
Resource allocation (R&D expenditures (ln))	-9.638	[9.483]			-17.667 *	[9.591]
Patenting regulation (Patents Issued)	0.061 ***	[0.008]			0.083 ****	[0.010]
Industry networking (University science parks)	-12.449	[23.039]			-18.739	[22.234]
Skilled workforce (People with College Degrees)			2.90e-06	[6.57e-06]	1.20e-06	[7.31e-06]
Legal environment (IP Litigations)			-0.002	[0.001]	-0.006 ****	[0.0017]
Economic freedom (State-owned enterprises)			0.001	0.004	0.012 ***	[0.004]
Industry Clustering (Employees in high-tech industry)			-0.00004 *	[0.00003]	0.00005 *	[0.00003]
Government Subsidy (Tax deduction to high-tech companies)			0.00002 **	[0.00001]	-3.74e-06	[0.00001]
Observations	222		222		222	
R-Squared	0.278		0.031		0.354	

Standard errors in square brackets. Number of universities: 111. Number of regions: 32. Period: 2013-2015.

* $p \leq 0.01$.

** $p \leq 0.05$.

*** $p \leq 0.005$.

**** $p \leq 0.001$.

6.4 Results

6.4.1 Introduction

This dissertation uses a multi-level Poisson regression model to examine the impact of internal or external factors on technology transfer. Because the independent variables show some time-variant characteristics, this dissertation assumes that all variance is explained by random effects, which means the influence is unique to each university.⁴⁰³

The university-level dataset contains information on 111 colleges and universities for the 2013-2015 period. Only colleges and universities that report data for the full sample period are included in the dataset. The province-level dataset contains information on 32 provinces and municipalities in China for the 2013-2015 period.

This dissertation exhibits three sets of regressions depicting the multilevel Poisson models: university-level variables predicting the outcome of technology transfer (Model I), province-level variables predicting the outcome of technology transfer (Model II), and a fully specified model that encompasses the whole set of predictors (Model III).

⁴⁰³ A fixed effect generally refers to effects that are shared by all universities in the sample.

6.4.2 Descriptive Statistics

The summary of the descriptive statistics of the independent and dependent variables is included in Table 6.4, as shown in the above section. The mean, median, maximum, minimum, and the standard deviation for each variable are listed in this table. It is worth noting that the mean for the dependent variable is significantly larger than the median (median of 10, mean of 52) and the standard deviation is also much larger than the mean for the dependent variable (standard deviation of 124, mean of 52).

This observation points to a single conclusion that the distribution of the dependent variable is strongly skewed to the right, with a few significant outliers for the variable of interest. This result correlates with the current perspectives on technology transfer that a small portion of universities makes the most significant market share in technology transfer.

As to the independent variables, the mean for virtually all the university-level variables is larger than the median.⁴⁰⁴ The maximum values for these variables are also higher than the median. This observation reveals that the distribution of the independent variables at the university level is strongly skewed to the right, with a few significant outliers.

The data distribution of independent variables at the province level also exhibits similar patterns. One of the independent variables, the number of employees working in

⁴⁰⁴ The mean for all the university-level independent variables is much larger than the median, except for one dummy variable - industry networking, which is measured by the existence of national university science parks (yes/no). The result indicates that most of Chinese universities have established a national university science park.

the high-tech industry in each province, is strongly skewed to the right. It indicates that a few regions encompass the most substantial number of workers (3.89 million, Guangdong Province). Another independent variable, tax deductions to high-tech companies at each province is also skewed to the right, with a few regions granting the most substantial amount of tax credits (10.8 billion RMB, Guangdong Province) to the high-tech industry. Table 6.6 provides a supplement exhibition of these variables.

Table 6.5 A partial summary of the distribution of two variables

Distribution of Two Independent Variables
(only top five regions included)

Year 2015	Employees in the high-tech industry		Tax deduction to the high-tech industry	
Rank	Number	Province	Amount (RMB)	Province
1	3,890,100	Guangdong	10,868,000,000	Guangdong
2	2,474,000	Jiangsu	5,965,000,000	Jiangsu
3	766,000	Henan	5,146,000,000	Zhejiang
4	731,800	Shandong	4,238,000,000	Shanghai
5	691,900	Zhejiang	1,925,000,000	Hubei

Source: adapted by the author based on the data from the RIC dataset.

6.4.3 Regression results

This dissertation performs multilevel Poisson regressions to find the relationship between dependent and independent variables. Table 6.5 exhibits the regression results of three analytical models for the dependent variable at issue.

Model I examines the university-level variables predicting the outcome of technology transfer. Controlling for the other university-level variables, Model I shows a positive effect of patenting regulations on technology transfer activities. One unit increase in the number of university-owned patents, on average, would produce 0.061 unit increase in the number of technology transfer contracts. This result is statistically significant through the specification, with a p-value smaller than 0.001. By contrast, controlling for the other university-level variables, resource allocation as well as industry networking have limited impact on the rate of technology transfer. The two control variables, university size, and university reputation have shown some effects on the dependent variable. However, these results are not statistically significant, with a p-value higher than 0.05.⁴⁰⁵

Model II examines the province-level variables predicting the outcome of technology transfer. Controlling for the other province-level variables, Model II shows a positive effect of government subsidy on technology transfer activities. One unit increase in the amount of tax deduction to the high-tech industry, on average, would produce 0.00002 unit increase in the number of technology transfer contracts. This result is statistically significant, with a p-value smaller than 0.05. By contrast, the other province-level

⁴⁰⁵ In most of statistical analyses, a p-value of 0.05 is used as the cutoff for significance.

variables, such as skilled workforce, legal environment, economic freedom, and industry clustering, have limited impact on technology transfer output throughout Model II.

Model III examines the whole set of predictors including both the university-level and the province-level factors. Controlling for all other independent variables, Model III reveals that the outcome of technology transfer contracts strongly correlates to patenting regulations at the university level, the legal environment at the province level, and economic freedom at the province level.

More specifically, university-level patenting regulations have a positive impact on technology transfer output. When the number of university-owned patents increases by one unit, the number of technology transfer contracts increases by 0.083 unit.

The regression results also show that economic freedom has a mixed effect on technology transfer output. When the number of state-owned enterprises increases by one unit, the number of technology transfer contracts increases by 0.012 unit.

Besides, the legal environment at the province level has a negative impact on technology transfer activities. When the number of IP litigations increases by one unit, the number of technology transfer contracts decreases by 0.006 unit.

It is also worth noting that when adding university-level variables in Model III, the positive correlation to government subsidy seen in Model II drops out and two other variables of the legal environment and economic freedom, once insignificant in Model II,

become statistically significant with a p-value smaller than 0.01. There are several possible causes.⁴⁰⁶

One possible cause is that adding new variables increases the model fit (R-squared), and thus transforms weak effects to significant predictors in the multiple regression analysis. This notion is consistent with the regression results at present. Adding university-level variables has made the model fit (R-squared) increase ten times from 0.031 in Model II to 0.354 in Model III. Therefore, Model III is more appropriate than Model II to estimate the possible correlations with the dependent variable.

6.5 Discussions and Implications

As corroborated by empirical evidence, the success of technology transfer is related to internal arrangements as well as external mechanisms. Internal factors include university size, university reputation, resource allocation, patenting regulations, and industry networking. External factors include skilled workforce, legal environment, economic freedom, industry clustering, and government subsidy.

At the university level, the strongest internal factor that influences university performance of technology transfer is a university's patenting regulations. Universities with proactive patenting regulations (measured by the number of issued patents) tend to have better performance of technology transfer than other universities. The other internal

⁴⁰⁶ One possible cause is that the newly-added variables are confounders, which are common causes of the studied factors and the outcome. Another possible cause is that the newly-added variables have a linear association with the other independent variables.

variables, such as industry networking, university size, and university reputation, have limited impact on technology transfer for lacking statistical significance.

The weakest internal factor that influences university performance of technology transfer is a university's resource allocation (measured by R&D expenses). Empirical evidence finds that R&D expenses have a negative impact on technology transfer. Universities with a smaller amount of R&D expenses tend to generate more technology transfer contracts. While it is reasonable to assume that a larger amount of R&D expenses should facilitate the creation of technology transfer contracts, this study indicates the opposite. One possible explanation for this adverse effect is that a substantial amount of R&D expenses by universities have been distributed to research projects that are not suitable for technology commercialization.⁴⁰⁷

At the provincial level, the most influential external factor that influences university performance of technology transfer is a province's legal environment (measured by the number of IP litigations). A careful analysis of the dataset shows that the number of IP litigations in the local jurisdictions strongly correlates with the number of technology transfer contracts generated by universities. Specifically speaking, a drastic increase in the number of IP litigations in a province tends to see a decline in the number of technology transfer contracts within universities located in the same territory. One possible explanation is that the growth of IP litigations may impose a deterrent effect on

⁴⁰⁷ For example, the R&D expenditures of Peking University is five times greater than that of Beijing University of Science and Technology, however, the number of technology transfer contracts generated by Peking University is only one-eighth of that of Beijing University of Science and Technology.

firms, with concerns on the high costs of IP enforcement after licensing university inventions.⁴⁰⁸

The second strongest external factor that influences university performance of technology transfer is a province's economic freedom (measured by the number of state-owned enterprises). An increase in the number of state-owned enterprises in a province accounts for the increasing number of technology transfer contracts within universities. This empirical evidence confirms prior interview experience that state-owned enterprises have given a great impetus to transferring technology from university to industry.⁴⁰⁹

Industry clustering in a province (measured by the number of employees working in the high-tech sector) is the weakest external factor shown in the regression analysis. Universities, which located in a province with a larger high-tech industry sector, tend to generate more technology transfer contracts. The other external factors, such as a skilled workforce and government subsidy, have limited impact on technology transfer for lacking statistical significance. However, it is worth noting that if not controlling for university-level factors, tax subsidy programs at the province level have a strong correlation with university performance of technology transfer.

⁴⁰⁸ Yongwook Paik & Feng Zhu, *The Impact of Patent Wars on Firm Strategy: Evidence from the Global Smartphone Market*, Harvard Business School Working Paper (Mar. 14, 2016), accessible online at <https://www.hbs.edu/> (last visited on Mar. 30, 2018).

⁴⁰⁹ Chapter 4 discusses this phenomenon.

6.5.1 Implications for Practice

Multiple internal and external factors have proved crucial in influencing university performance of technology transfer. The analysis and discussion presented in prior sections suggest significant implications for university administrators or policymakers.

First, patenting regulations within universities is a compelling institutional arrangement in fostering the productivity of technology transfer. For this cause, Chinese universities should invest in improving their patenting rules and acquiring more patents on behalf of faculty and researchers. In addition to that, rather than sell university-owned patents to industry for short-term returns, universities should make long-term planning to maximize licensing revenues from patented university inventions. Besides, technology transfer personnel within universities should develop a business skill set that enables them to evaluate and identify high-potential designs that may lead to products with high commercial value.

Second, the volume of IP litigations in a province has a negative impact on contracting behavior between industry firms and universities. For small and medium-sized enterprises that are vulnerable and sensitive to the high costs and uncertainty of implementing university inventions, universities should invest in making patent licensees informed of the status of university-owned inventions. If necessary, universities should also provide kinds of clinical legal assistance to licensees or entrepreneurs when patent disputes arise during the commercialization of university inventions. Such efforts may lower the legal risks of technology transfer and create a greater impetus for industry firms to license technology from universities.

Third, as empirical evidence illustrates, state-owned enterprises play an important role in acquiring or licensing university-owned inventions. For universities that locate in a province which has a relatively smaller number of state-owned enterprises, universities should invest in promoting collaboration with private enterprises. It would be wise for universities to scout out for the technological needs of private enterprises as well as create university spin-offs to commercialize university-owned inventions. For universities that locate in less developed provinces, they should also consider establishing technology transfer operations in multiple regions where private enterprises cluster. This type of expansion would allow universities to overcome geographical restrictions and cooperate with out-of-state enterprises in technology transfer.

6.5.2 Implications for Future Research

This empirical study, being of an exploratory and interpretive nature, raises several opportunities for future research. More research will be necessary to refine and further elaborate the original insights in this dissertation.

First, how to measure the volume of technology transfer often lacks universal criteria and varies across studies for data convenience. This empirical research identifies the number of technology transfer contracts as the measurement of technology transfer output. Future studies could follow different research designs and address other indicators of technology transfer including the size of technology transfer contracts, the number of university spin-offs or the amount of licensing revenues generated by universities.

Also, although this empirical research allows for investigating the full technology transfer process, from creation to commercialization of university technologies, due to time constraints, this study does not gauge the effects of university-level and regional-level factors on the earlier stages of technology transfer. In fact, the empirical analysis in this study mainly focuses on assimilation rather than the creation of university-owned technologies, with an emphasis given to the contracting relationship between university and industry. Future research should investigate in more detail the possible mechanisms that influence the relative success of universities in the earlier stages of technology transfer, such as during the creation of university inventions or the discovery of commercialization opportunities for university technologies.

Moreover, further exploration of the explanatory variables and how they link to a broader analytical framework in the field of technology transfer is needed in future studies. For instance, empirical results in this dissertation show that state-owned enterprises play a crucial role in the success of technology transfer. This conclusion runs afoul with the findings in prior studies, which implies that state-owned enterprises have higher subsidies but lower returns to investing in R&D activities than private enterprises.⁴¹⁰ Future research should investigate in depth on how state-owned enterprises implement university inventions and what kind of disparity between state-owned enterprises and private enterprises changes the way they exploit the commercial value of university technologies.

⁴¹⁰ Wei et al., *supra* note 387.

Furthermore, inconsistent with previous empirical research, this empirical study does not find empirical evidence that proves the impact of industry networking, industry clustering or tax subsidy on technology transfer. The lack of data for an accurate measurement of these factors is one possible cause of this situation. In future research, a detailed qualitative analysis of the interactions between these factors and the response variable could shed some light on the dynamics of technology transfer.

Finally, due to lack of data, this empirical analysis does not include entrepreneurial financing as an explanatory variable for university performance of technology transfer. Entrepreneurial funding refers to a wide range of financing options that allow entrepreneurs to raise money for their business.⁴¹¹ In China, the most common ways of entrepreneurial funding are getting money from banks, friends, and family, or personal savings.⁴¹² The most recent years have seen a growth of private equity funds, venture capitalists, and angel investment groups investing in the China high-tech industry and funding university-based startups.⁴¹³ Future studies on technology transfer should address the impact of entrepreneurial financing on technology transfer and its changes together.

Regarding research methodology, this empirical study uses multi-level Poisson model to assess the random effects of explanatory variables. This model also recognizes

⁴¹¹ Entrepreneurial Finance, EWING MARION KAUFFMAN FOUNDATION, accessible online at <https://www.kauffman.org/> (last visited on Mar. 01, 2018).

⁴¹² See e.g., Jane K. Winn, *Relational Practices and the Marginalization of Law: Informal Financial Practices of Small Businesses in Taiwan*, 28 LAW AND SOCIETY REVIEW 193-232 (1994); KELLE S. TSAI, *BACK-ALLEY BANKING: PRIVATE ENTREPRENEURS IN CHINA* (Cornell University Press, 2004).

⁴¹³ Louise Lucas, *China tech emerges as the global hotspot for VC capital*, FINANCIAL TIMES (May 23, 2017), accessible online at <https://www.ft.com/content/> (last visited on Sep. 30, 2017). (Entrepreneurial financing, which includes professional investors, brings not only money but also the top-tiered business insights to a startup company.)

the correlation among observations from within the same levels. Although this regression analysis controls for possible confounding effects on the empirical results, it could not precisely disentangle the magnitude of these effects. Future studies on technology transfer should also address the problem of multicollinearity in regression analysis. Multicollinearity refers to the linear correlation that not just between independent and dependent variables, but also between each other independent variables. In other words, multi-collinearity occurs when the regression analysis includes explanatory variables that are a bit redundant.⁴¹⁴

The multi-level regression model in this dissertation not only estimates the individual factors of technology transfer process but also considers the environmental factors that influence the own behaviors within the context. The methodology employed in this dissertation may provide a template for future research on other similar issues.

⁴¹⁴ Editor, *Enough is Enough! Handling Multicollinearity in Regression Analysis*, MINITAB BLOG (Apr.16, 2013), accessible online at <http://blog.minitab.com/> (last visited on May 30, 2018).

Chapter 7 Conclusion

This dissertation explores the possible determinants of the relative success or lack of progress in commercializing university-owned inventions by Chinese universities. The analytic framework for this study is based on an entrepreneurial theory that claims that there is no best way to manage an organization, the optimal course of management being contingent upon the internal structure and the external situation.

The literature review presents that there has been a continuous effort to evaluate how internal factors such as university reputation and university initiatives or how external factors such as government policy and local geography affect technology transfer. Despite the relevance of the individual elements, however, no empirical studies have examined the joint impact that these factors might have on technology transfer. This dissertation makes an original contribution to the literature through empirical research on the collective effect of internal and external factors on technology transfer.

7.1 Summary of Research

Technology transfer is concerned with bringing technology from the source of innovation to the marketplace. University has been regarded as a vibrant source of new technology. In the last thirty years, the role of higher education has changed in a way where university becomes a new powerhouse of local innovation and economic growth. Among countries, the United States has long been a leader in the university's economic development role. In 1980, the U.S. government issued the forward-looking Bayh-Dole Act which for the first time, empowered universities and research institutions to retain ownership of public-funded research.

The combined effects of the Bayh-Dole Act, both institutional impetuses and economic incentives for patenting and licensing, have led more universities to engage in technology activities. As a result, the number of technology transfer offices has increased significantly since the passage of the Bayh-Dole Act. Moreover, technology transfer offices in the U.S. have been undergoing a transition from a "technology push" mode to a "technology pull" mode. Under the "technology push" mode, university technology transfer offices focus on patenting and licensing university technologies, while under the "technology pull" mode, technology transfer offices must scout out for technological needs in the market and build a closer university-industry relationship. Evidence finds that a growing number of universities in the U.S. have changed the name and status of technology transfer offices to celebrate an evolving culture of entrepreneurship.

Likewise, China has demonstrated considerable interests in university technology

transfer with the hopes of developing an indigenous new technology pipeline for industry innovation. In recent years, China has mightily increased her capacity in university research and development (R&D) while encouraging scientists to patent and commercialize their inventions. So far, China has established a network of 2,000 universities and colleges, coupled with 30 science parks and more than 200 government operated research institutions. In the meantime, China's R&D spending has been growing steadily by eighteen percent each year. The expansion in R&D capacity has led to a dramatic increase in patent filings. In 2017, China overtook Japan in global patent applications and is closing in on the U.S. This growth in patent filings also has a partial kick-on effect on technology transfers.

Unlike technology transfer activities by U.S. universities that historically prefer patent licensing, however, Chinese universities commonly use technology contracts, a standardized contract, to transfer technologies. The largest recipient of technology contracts in China is state-owned enterprises, which have signed nearly one-half of technology contracts between university and industry. The dominant role of state-owned enterprises in the technology transfer market has specific implications. First, it implies the lack of in-house R&D capability in the state-owned enterprises which have long been blamed for being inefficient in the production process. Second, it affirms the existing institutional channels in the state sector that facilitate connections between universities and state-owned enterprises, since most universities in China are state-owned as well. Third, it suggests the continued difficulty of private enterprises in accessing state-owned resources including those of universities. Interview evidence

collected by the author of this dissertation has confirmed some of these implications.

Although Chinese universities in technology transfers have commonly used patent licensing, recent decades have seen the rapid growth in university patenting and licensing activities. From 2006 to 2014, total patent applications filed by Chinese universities have increased tenfold. Nevertheless, interview evidence collected by the author of this dissertation finds that Chinese universities tend to use a “double counting” strategy to inflate the number of their patent applications. Universities often encourage faculty inventors to apply for a utility patent spontaneously with an invention patent. But whether the “double counting” problem is accountable for the explosive growth of patent applications in China has remained unclear. The increase in patent filings, indeed, has seen a kick-off effect on patent licensing among universities.

In addition to patent licensing, Chinese universities have been more involved in equity investment in startup companies. Innovation requires more than technology. It also needs capital to commercialize itself. Many Chinese universities have established separate corporate entities to manage the portfolios of university intellectual property or launched new venture funds to invest in high-potential university spin-offs. The potential shift in technology transfer from the patent-centric mode to the start-up mode coincides with a surge in China’s venture capital market, now the world’s second largest recipient of venture capital investment.

However, the efforts made by Chinese universities for equity investment in startup companies have particular problems. One primary concern with startup formation is

the lack of an exit route. For startup investors, the most common way to cash out is to exit their investment through acquisition or IPO exits in a reasonable timeframe, typically two to five years. In China, it is unclear whether universities that invest in startup companies have developed a planned strategy to exit their investment in a fixed period of five years.

The second problem with startup formation is the lack of capable personnel. The successful operation of venture firms is highly dependent on the ability of its management. It is doubtful whether technology managers within universities have the required business skills to identify and implement equity investment in university spin-offs. The third problem is the lack of a robust IPO environment. In China, there has yet been a well-developed stock market, and the channels for startups to go public are quite limited. Despite imperfect, China has taken measures to modernize its stock market to better serve the high-growth, though smaller, tech companies.

Furthermore, the growing acceptance of the importance of university technology transfer can also be inferred from the burgeoning government policies and laws related to technology transfer. Most technology transfer laws and policies in China cite the Bayh-Dole Act as one justification. For many years now, China has adopted multiple policies and regulations that emulate the provisions of the U.S. Bayh-Dole Act. Notwithstanding the current progress, selective “borrowing” from another nation’s policies for implementation in an institutional context that differs significantly from that of the country being emulated might not suffice the policy initiatives. The current reforms of technology transfer laws primarily focus on clarification of ownership and

redistribution of pecuniary rewards; however, it overlooks the enormity of hurdles on legal institutions that preexist within the context of technology transfers.

Several legal issues must be considered in implementing technology transfer laws and policies. Regarding intellectual property, an updated definition of patentability on life science is needed to handle cutting-edge DNA cases resulted from university research. Experimental use exception is also necessary to enable researchers to employ components that other excluded by private intellectual property rights. Moreover, employee and employer inventions should be discerned in judicial rulings. Judicial orders must also be backed by sanctions when compliance is not forthcoming.

Regarding technology contract, a clarification of the ownership of technological improvements to licensed technology is necessary when drafting the technology contracts. Unlike technology contracts in common law countries that have grant back clauses for the licensor to gain ownership of improvements without a separate consideration, Chinese contract laws articulate that during the valid term of a technology contract, ownership of improvements to the licensed technology belongs to the improving party, often the licensees. Nonetheless, implementing technology contracts in China is subject to a myriad of laws, regulations, and judicial interpretations, which may vary case by case.

Regarding criminal prosecution, university researchers must be aware of regulations on armed export-control, accounting fraud or corporate corruption to avoid potential criminal probes. The criminal charges against university professors for embezzlement or misappropriation of research funds, especially in the process of

technology transfer, have been increasingly controversial in China. As a response, the Supreme People's Procuratorate of China has issued a regulatory initiative to decriminalize the grantees of university research funding if the legal boundary of embezzlement in the university context remains ambiguous. It will be interesting to see how this new policy initiative is to change the future practices of criminal prosecution against university researchers.

Regarding tax regulations, evidence finds that tax incentives to universities and high-tech firms are important to stimulate technology commercialization. Apart from U.S. laws that explicitly grant tax-exempt status to universities, there are no specific laws or regulations in China that manifest taxation on universities. In effect, Chinese universities must pay taxes like all the other business organizations for a wide range of activities, from property sales to patent licenses. The most common grounds for taxation on universities are enterprise income tax (EIT), business tax (BT), and value-added tax (VAT). China replaced the BT system with the VAT system in 2016, with hopes to encourage low-end manufacturers to upgrade their technology through tax deductions across the supply chains. It will be interesting to see how the expansion of the VAT system might affect technology transfer in the future.

Despite the abovementioned issues, the success of technology transfer by Chinese universities depends on multiple factors, not limited to the legal context. The empirical study of this dissertation finds that the success of technology transfer is related to both university-level and regional-level factors. At the university level, the strongest internal factor that influences university performance of technology transfer is a

university's patenting regulations. Universities with proactive patenting regulations tend to have better performance of technology transfer than other universities. The weakest internal factor that influences university performance of technology transfer is a university's resource allocation. The other internal variables, industry networking, university size, and university reputation, have shown the limited impact on technology transfer in this empirical research for lacking statistical significance.

At the province level, the most influential external factor is the legal environment in a province. A drastic increase in the number of patent litigations in a province tends to see a decline in technology transfer within universities locating in the same territory. The weakest external factor that influences university performance of technology transfer is industry clustering in a province. Universities that establish in a region with a larger high-tech industry sector tend to generate more technology transfer contracts than other universities. The other external variables, skilled workforce and government subsidy, have shown the limited impact on technology transfer in this empirical study for lacking statistical significance. More research will be necessary to refine and further elaborate on the findings of this empirical study.

7.2 Summary of Implications

This dissertation, being of exploratory and interpretive nature, also raises several opportunities for future research. First, the empirical study of this dissertation has mainly focused on the exchange of explicit knowledge, such as patent licenses. As tacit knowledge or know-how also plays a significant role on technology transfer, future studies could follow a different research design and explore the factors that influence university performance of the exchange of tacit knowledge.

Second, startup formation as an alternative patent licensing in technology transfer has drawn more attention from recent scholarship. Many universities get involved in venture capital business and granting seed funds to startup firms. Future research may address university initiatives to foster an entrepreneurial culture on campus and enable faculty and students to attract venture funds for university spin-offs.

Third, universities, often situated at the center of innovative clusters, have been an essential driver of economic growth. This dissertation does not explicitly address the correlation between university innovation strength and regional economic development. Future studies may extend the scholarship of university innovation from the triple helix position of university-industry-government relationships.

In conclusion, an entrepreneurial approach to building technology transfer streamlines the identification, protection, and commercialization of university technologies in an integrated mode. Only through the systematic cultivation of institutional arrangements and supporting structures can a university hope to break down the walls between ivory towers of innovation and the commercial world.

APPENDIX A

An Excerpt of the Bush Report (1945)

In November 1944, Dr. Vannevar Bush received a letter from President Franklin D. Roosevelt.⁴¹⁵ In the letter, President Roosevelt praised the critical role of scientific research that led to America's victory in the World War II and referred the government-university partnership as a "unique experiment of teamwork and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of the technical problems paramount in war."⁴¹⁶

In his letter, President Roosevelt asked Bush to recommend actions that the U.S. federal government could take to encourage research activities by public and private organizations in the days of peace.⁴¹⁷ Unfortunately, President Roosevelt died in April 1945, before Bush could submit his final report.⁴¹⁸ On July 25, 1945, Bush submitted to President Truman a completed report *Science, The Endless Frontier*, which became an iconic piece of American science policy.⁴¹⁹

In *Science, The Endless Frontier*, Bush addressed the importance of science to national security, health and medicine, and the public's well-being. The labor market was

⁴¹⁵ Roger Pielke Jr. In Retrospect: *Science – The Endless Frontier*, NATURE 466, 922-923 (2010).

⁴¹⁶ A Letter from Franklin D. Roosevelt to Vannevar Bush. November 17, 1944. (archive copy) accessible online at <http://scarc.library.oregonstate.edu/coll/pauling/war/corr/sci13.006.4-roosevelt-bush-19441117.html> (last visited on May 30, 2018).

⁴¹⁷ Id.

⁴¹⁸ Pielke, *supra* note 415.

⁴¹⁹ VANNEVAR BUSH, *SCIENCE, THE ENDLESS FRONTIER* (1945). National Science Foundation. accessible online at <https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm> (last visited on Jun. 5, 2018).

taken in the report as an example:

“In 1939 millions of people were employed in industries which did not even exist at the close of the last war – radio, air conditioning, rayon and other synthetic fibers, and plastics are examples of the products of these industries. But these things do not mark the end of progress – they are but the beginning if we make full use of our scientific resources...Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past.⁴²⁰”

He referred to scientific research as “scientific capital,” expressing his view that the funding of research should be considered not as a cost but as an investment in America’s future, its economy, and the well-being of its citizens.

“Our population increased from 75 million to 130 million between 1900 and 1940. In some countries comparable increases have been accompanied by famine. In this country the increase has been accompanied by more abundant food supply, better living, more leisure, longer life, and better health. This is, largely, the product of three factors – the free play of initiative of a vigorous people under democracy, the heritage of great national wealth, and the advance of science and its application.⁴²¹”

Bush is specific about what it takes to increase scientific capital and strengthen the competitive advantage of U.S. economy:

“First, we must have plenty of men and women trained in science, for upon them depends on the creation of new knowledge and its application to practical purposes. Second, we must strengthen the centers of basic research, which are principally the colleges, universities, and research institutes. These institutions provide the environment which is most conducive to the creation of new scientific knowledge and least under

⁴²⁰ Id. Chapter 1 Introduction.

⁴²¹ Id.

pressure for immediate, tangible results.⁴²²”

It is remarkable how well this recipe for scientific capital still characterizes the U.S. society half-century after the report was written. For decades, the recipe worked, and led to many of America’s universities being ranked among the best in the world. Their research output has created new industries, jobs, and wealth.⁴²³

⁴²² Id. Chapter 3 Science and The Public Welfare.

⁴²³ Restoring the Foundation: The Vital Role of Research in Preserving the American Dream (2014). American Academy of Arts and Science. accessible online at <https://www.amacad.org/content/publications/> (last visited on Jun. 10, 2018).

APPENDIX B

President Roosevelt's Letter (1944)

THE WHITE HOUSE

Washington, D. C.

November 17, 1944

Dear Dr. Bush:

The Office of Scientific Research and Development, of which you are the Director, represents a unique experiment of team-work and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of the technical problems paramount in war. Its work has been conducted in the utmost secrecy and carried on without public recognition of any kind; but its tangible results can be found in the communiques coming in from the battlefronts all over the world. Some day the full story of its achievements can be told.

There is, however, no reason why the lessons to be found in this experiment cannot be profitably employed in times of peace. The information, the techniques, and the research experience developed by the Office of Scientific Research and Development and by the thousands of scientists in the universities and in private industry, should be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living.

It is with that objective in mind that I would like to have your recommendations on the following four major points:

First: What can be done, consistent with military security, and with the prior approval of the military authorities, to make known to the world as soon as possible the contributions which have been made during our war effort to scientific knowledge?

The diffusion of such knowledge should help us stimulate new enterprises, provide jobs for our returning servicemen and other workers, and make possible great strides for the improvement of the national well-being.

Second: With particular reference to the war of science against disease, what can be done now to organize a program for continuing in the future the work which has been done in medicine and related sciences?

The fact that the annual deaths in this country from one or two diseases alone are far in excess of the total number of lives lost by us in battle during this war should make us conscious of the duty we owe future generations.

Third: What can the Government do now and in the future to aid research activities by public and private organizations? The proper roles of public and of private research, and their interrelation, should be carefully considered.

Fourth: Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?

New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war we can create a fuller and more fruitful employment and a fuller and more fruitful life.

I hope that, after such consultation as you may deem advisable with your associates and others, you can let me have your considered judgment on these matters as soon as convenient - reporting on each when you are ready, rather than waiting for completion of your studies in all.

Very sincerely yours,

/s/

Franklin D. Roosevelt

Dr. Vannever Bush,
Office of Scientific Research and Development
Washington, D.C.

APPENDIX C

President Kenney's Memorandum on Patent Policy (1963)

Memorandum of October 10, 1963

Government Patent Policy

Memorandum for the Heads of

Executive Departments and Agencies

Over the years, though executive and legislative actions, a variety of practices has developed within the executive branch affecting the disposition of rights to inventions made under contracts with outside organizations. It is not feasible to have complete uniformity of practice throughout the Government in view of the differing missions and statutory responsibilities of the several departments and agencies engaged in research and development. Nevertheless, there is need for greater consistency in agency practices in order to further the governmental and public interests in promoting the utilization of federally financed inventions and to avoid difficulties caused by different approaches by the agencies when dealing with the same class of organizations in comparable patent situation.

From the extensive and fruitful national discussions of Government patent practices, significant common ground that has come into view. First, a single presumption of ownership does not provide a satisfactory basis for Government-wide policy on the allocation of rights to inventions. Another common ground of understanding is that the Government has a responsibility to foster the fullest exploitation of the inventions for the public benefit. Attached for your guidance is a statement of Government patent policy,

which I have approved, identifying common objectives and criteria and setting forth the minimum rights that Government agencies should acquire with regard to inventions made under their grants and contracts. This statement of policy seeks to protect the public interest by encouraging the Government to acquire the principal rights to inventions in situations where the nature of the work to be undertaken or the Government's past investment in the field of work favors full public access to resulting inventions. On the other hand, the policy recognizes that the public interest might also be served by according exclusive commercial rights to the contractor in situations where the contractor has an established nongovernmental commercial position and where there is greater likelihood that the inventions would be worked and put into civilian use than would be the case if the invention were made more freely available.

Wherever the contractor retains more than a nonexclusive license, the policy would guard against failure to practice the invention by requiring that the contractor take effective steps within 3 years after the patent issues to bring the invention to the point of practical application or to make it available for licensing on reasonable terms. The Government would also have the right to insist on the granting of a license to others to the extent that the invention is required for public use by governmental regulations or to fulfill a health need, irrespective of the purpose of the contract.

The attached statement of policy will be reviewed after a reasonable period of trial in the light of the facts and experience accumulated. Accordingly, there should be continuing efforts to monitor, record, and evaluate the practices of the agencies pursuant to the policy guidelines.

This memorandum and the statement of policy shall be published in the Federal Register.

John F. Kennedy

Appendix D

President Nixon's Memorandum About Government Patent Policy (1971)

THE WHITE HOUSE

Memorandum About Government Patent Policy

August 23, 1971

Memorandum for Heads of Executive Departments and Agencies:

On October 10, 1963, President Kennedy forwarded to the Heads of Executive Departments and Agencies a Memorandum and Statement of Government Patent Policy for their guidance in determining the disposition of rights to inventions made under Government-sponsored grants and contracts. On the basis of the knowledge and experience then available, this Statement first established Government-wide objectives and criteria, within existing legislative constraints, for the allocation of rights to inventions between the Government and its contractors.

It was recognized that actual experience under the Policy could indicate the need for revision or modification. Accordingly, a Patent Advisory Panel was established under the Federal Council for Science and Technology for the purpose of assisting the agencies in implementing the Policy, acquiring data on the agencies' operations under the Policy, and making recommendations regarding the utilization of Government-owned patents. In December 1965, the Federal Council established the Committee on Government Patent Policy to assess how this Policy was working in practice, and to acquire and analyze

additional information that could contribute to the reaffirmation or modification of the Policy.

The efforts of both the Committee and the Panel have provided increased knowledge of the effects of Government patent policy on the public interest. More specifically, the studies and experience over the past seven years have indicated that:

- (a) A single presumption of ownership of patent rights to Government-sponsored inventions either in the Government or in its contractors is not a satisfactory basis for Government patent policy, and that a flexible Government-wide policy best serves the public interest;
- (b) The commercial utilization of Government-sponsored inventions, the participation of industry in Government research and development programs, and commercial competition can be influenced by the following factors: the mission of the contracting agency; the purpose and nature of the contract; the commercial applicability and market potential of the invention; the extent to which the invention is developed by the contracting agency; the promotional activities of the contracting agency; the commercial orientation of the contractor and the extent of his privately financed research in the related technology; and the size, nature and research orientation of the pertinent industry;
- (c) In general, the above factors are reflected in the basic principles of the 1963 Presidential Policy Statement.

Based on the results of the studies and experience gained under the 1963 Policy Statement certain improvements in the Policy have been recommended which would provide (1) agency heads with additional authority to permit contractors to obtain greater rights to inventions where necessary to achieve utilization or where equitable circumstances would justify such allocation of rights, (2) additional guidance to the agencies in promoting the utilization of Government-sponsored inventions, (3) clarification of the rights of States and municipal governments in inventions in which the Federal Government acquires a license, and (4) a more definitive data base for evaluating the administration and effectiveness of the Policy and the feasibility and desirability of further refinement or modification of the Policy.

I have approved the above recommendations and have attached a revised Statement of Government Patent Policy for your guidance. As with the 1963 Policy Statement, the Federal Council shall make a continuing effort to record, monitor and evaluate the effects of this Policy Statement. A Committee on Government Patent Policy, operating under the aegis of the Federal Council for Science and Technology, shall assist the Federal Council in these matters.

This memorandum and statement of policy shall be published in the Federal Register.

Richard Nixon

Appendix E

An Excerpt of the University and Small Business Patent Procedures Act: Hearings on S. 414, Before the Senate Committee on the Judiciary, 96th Congress (May 16, and June 6, 1979).

Opening Statement of Hon. Birch Bayh, A U.S. Senator

from

The State of Indiana

I might say to our witnesses, I apologize for the fact that the previous committee business took time away from all of us.

We appreciate the special effort that has been made by the Comptroller General, Mr. Staats, to be here this morning. I appreciate the fact that my colleague, Senator Dole, is able to attend this important piece of legislation.

This morning the Senate Judiciary Committee is holding its first day of hearings on S. 414, the University and Small Business Patent Procedure Act.

I have become very concerned that the United States is rapidly losing its preeminent position in the development and production of new technologies, which historically has been our strong suit. Some examples of this disturbing trend are the following facts:

Importation of foreign manufactured goods are second only to foreign imported oil as the biggest drain on U.S. dollars. In the first half of 1978 we suffered a \$14.9 billion deficit on this importation. Countries like Japan and West Germany with fewer natural

resources than the United States are paying for their imported oil with money that they receive from exporting goods.

The number of patents issued each year has declined steadily since 1971;

The number of U.S. patents granted to foreigners has risen since 1973 and now accounts for 35 percent of all patents filed in the United States;

Investment in research and development over the past 10 years, in constant dollars, has failed to increase;

American productivity is growing at a much slower rate than that of our free world competitors;

Small businesses, which have compiled a very impressive record in technological innovation, are receiving a distressingly low percentage of Federal research and development money; and

The number of patentable inventions made under federally supported research has been in a steady decline.

There are a number of theories on the cause of this trend, but one area where progress could be made immediately is with inventions arising from federally supported university and small business research.

Presently, there are over 20 different statutes and regulations in existence which govern ownership of inventions that are reported to the Government each year from its research programs. The underlying philosophy of these policies is that the funding agency

should retain title to these inventions even if the agency has provided only a small percentage of the funding. Unfortunately, the agencies have had very little success attracting private industry to develop and market these inventions because when the agencies retain the patent rights there is little incentive for any company to undertake the risk and expense of trying to develop a new product.

This problem is especially serious in the field of biomedical research programs where delays by the agencies in granting patent waivers for new drugs and processes have condemned many people to needless suffering. Unless universities and small business receive the right to retain the patent on these inventions, valuable discoveries wind up wasting away on the funding agency's shelves, benefiting no one.

The Departments of Energy and HEW frequently take months, and in some cases even years, to review these petitions for patent rights. Many inventions could make significant contributions to the health and welfare needs of our country if they were utilized. When the Government decides to retain patent rights on these inventions there is a very great chance that they will never be developed. Of the 30,000 patents that the Government presently holds, less than 4 percent are ever successfully licensed. This is very little return on the billions of dollars that we spend every year on research and development.

Another problem that this legislation addresses is the distressingly low percentage of Federal research money that goes to small businesses. The Office of Management and Budget released a study which said that firms with 1,000 employees or less are credited with almost half of the industrial innovations made between 1953 and 1973. Small

businesses have been found to get more from each research and development dollar than larger contractors. In light of these facts it is very disturbing to learn that small business receives less than 4 percent of the Federal research and development expenditure. One major reason that many of these innovative small companies have avoided Federal grants is the uncertainty over whether or not they will be allowed to retain patent rights on resulting inventions. The University and Small Business Patent Procedures Act will end this uncertainty.

The bill that we are considering today would allow universities, small businesses, and nonprofit organizations to retain patent rights to inventions that they make under federally supported research and development programs when they are willing to spend the needed money to develop and market these inventions. The bill also protects the legitimate rights of the funding agency to use the invention on behalf of the Government. A section of the bill would also require the patentholder to reimburse the Government whenever a subject invention achieves a certain level of success in the marketplace within 10 years. S. 414 would create for the first time a uniform patent policy for every agency and thus end the confusion caused by over 20 different, and sometimes even contradictory, policies.

The United States has built its prosperity on innovation. That tradition of unsurpassed innovation remains our heritage, but without continued effort it is not necessarily our destiny. There is no engraving in stone from on high that we shall remain NO. 1 in international economic competition. In a number of industries we are no longer even No.2. New incentives and policies are needed to reverse this trend. The University and Small

Business Patent Procedure Act will be a step in the direction of encouraging innovation and productivity in the United States. I am pleased that 26 of my Senate Colleagues have joined me in support of this important bill.

Today the committee will hear from a number of witnesses who have had firsthand experiences in research and development and who should be able to shed much light on what would constitute an effective, efficient Government patent policy.

It is in everyone's interest to insure that the fruits of American inventive genius are delivered to the marketplace as quickly as possible, and are not simply left to rot because of indifference or bureaucratic delays.

Appendix F

An Excerpt of the Law of the People's Republic of China on Progress of Science and Technology (Adopted on July 2, 1993 and amended on December 29, 2007).

Chapter II

Research, Development and Application

of

Science and Technology

Article 16 The State shall establish a natural science fund to finance basic research and frontier science exploration and help people become scientists and technicians through training. The State shall establish an innovation fund for the small and medium-sized science- and technology-oriented enterprises to finance small and medium-sized enterprises in technological innovation. The State may, when necessary, establish other funds to finance activities for scientific and technological progress.

Article 17 An entity that is engaged in the following activities shall enjoy preferential tax policies in accordance with the relevant regulations of the State: (1) engaging in technological development and transfer, and providing technological advice and services; (2) importing devices for scientific research or technological development, which cannot be produced at home or devices that can be produced at home but the properties of which fail to satisfy the requirements; (3) importing key equipment, raw and semi-finished materials or components and parts, which cannot be produced at home, for the launching of the major special scientific and technological projects of the State or major projects

covered by national scientific and technological plans; or (4) engaging in other activities for scientific research and technological development, or application of scientific and technological advances as provided for in laws and relevant State regulations.

Article 18 The State shall encourage financial institutions to carry out the business of hypothecation of intellectual property rights, encourage and give guidance to such institutions in supporting the application of scientific and technological advances and the development of high and new technology industries by granting loans, etc., and encourage insurance agencies to introduce insurance products in light of the need for development of high and new technology industries. Policy-oriented financial institutions shall, within the scope of their business, give priority to the application of scientific and technological advances and the development of high and new technology industries in offering financial services.

Article 19 The State shall abide by the principle of combining service rendered by scientific and technological activities to national goals with encouragement of free explorations, make far-sighted arrangements, and develop basic research, research of frontier technologies and technological research for public welfare and support sustained and stable development of the same. Scientific research and technological development institutions, institutions of higher education, enterprises and other institutions as well as citizens shall, in accordance with law, have the right to independently select subjects for basic research, research of frontier technologies and technological research for public welfare.

Article 20 Patents of invention obtained in projects covered by the scientific and

technological fund established with government funds or by scientific and technological plans, copyrights of computer software, patent rights of wiring design of integrated circuits and rights of new plant strains shall, except where national security and interests and vital public interests are involved, be granted to the authorized undertakers of projects according to law.

Project undertakers shall, according to law, exercise the intellectual property rights provided for in the preceding paragraph and, at the same time, take protective measures, and shall submit annual reports on such exercise and protection to project administration authorities; if they fail to exercise their rights within the reasonable time limit, the State may do it without compensation, or may permit another person to do it with or without compensation.

For the benefit of national security and interests or vital public interests, the intellectual property rights, provided for in the first paragraph of this Article, granted to project undertakers according to law may be exercised by the State without compensation, or the State may permit another person to do it with or without compensation.

The benefits arising from the exercise of the intellectual property rights, provided for in the first paragraph of this Article, shall be distributed among the project undertakers in accordance with the provisions of relevant laws and administrative regulations; and where such provisions are lacking in laws, or administrative regulations, the benefits shall be distributed as agreed upon.

Appendix G

The Law of the People's Republic of China on Promoting the Transformation of Scientific and Technological Achievements (Adopted on May 15, 1996 and amended on August 29, 2015)

Chapter I General Provisions

Article 1 This Law is developed for purposes of promoting the transformation of scientific and technological achievements into real productive forces, standardizing such transformation, accelerating scientific and technological progress, and promoting economic and social development.

Article 2 For the purpose of this law, “scientific and technological achievements” means the applicable achievements made through scientific research and technological development. “Job-related scientific and technological achievements” means the scientific and technological achievements made through completing the work tasks of research and development institutions, institutions of higher education, enterprises, and other entities or mainly utilizing the material and technical conditions of the aforesaid entities.

For the purpose of this Law, “transformation of scientific and technological achievements” means the entire process of the follow-up tests, development, application, and promotion of the scientific and technological achievements, through to the final creation of new technologies, new techniques, new materials, and new products, as well as development of new industries -- all for the purpose of enhancing the level of productive forces.

Article 3 The transformation of scientific and technological achievements shall be conducive to accelerating the implementation of innovation-driven development strategies, promoting the combination of technology and economy, improving economic returns and social benefits, protecting the environment, making rational use of resources, promoting economic construction and social development, and safeguarding national security.

In the transformation of scientific and technological achievements, the market discipline shall be respected, the role of enterprises as main players shall be brought into play, the principles of free will, mutual benefit, fairness and good faith shall be followed, and interests shall be enjoyed and risks shall be borne in accordance with the provisions of laws and regulations and the contracts. Intellectual property rights involved in the transformation of scientific and technological achievements shall be protected by law.

In the transformation of scientific and technological achievements, laws and regulations shall be observed, state interests shall be safeguarded, and no public interests or lawful interests of others shall be damaged.

Article 4 The state shall reasonably arrange financial funds and direct investment of social funds for the transformation of scientific and technological achievements, to promote diversified capital investment in the transformation of scientific and technological achievements.

Article 5 The State Council and local people's governments at all levels shall intensify synergy of policies on science and technology, public finance, investment, tax,

talents, industry, finance, government purchase, and military and civilian integration, among others, to create a favorable environment for the transformation of scientific and technological achievements.

Local people's governments at all levels may, under the principles specified herein and in light of actual conditions, adopt measures that are more conducive to promoting the transformation of scientific and technological achievements.

Article 6 The state shall encourage the implementation of scientific and technological achievements firstly in China. Chinese entities or individuals that assign scientific and technological achievements to overseas organizations or individuals or license them to implement the scientific and technological achievements shall comply with the relevant laws and administrative regulations, and the relevant provisions of the state.

Article 7 For national security, national interests and major public interests, the state may organize the implementation of or license others to implement relevant scientific and technological achievements according to the law.

Article 8 The administrative department of science and technology, the comprehensive economic administrative department, and other relevant administrative departments under the State Council shall, within their functions and responsibilities as prescribed by the State Council, administer, guide and coordinate the work of transforming scientific and technological achievements.

The local people's governments at all levels shall be responsible for administering, guiding and coordinating the work of transforming scientific and technological achievements within their respective administrative regions.

Chapter II Organization of Implementation

Article 9 The State Council and the local people's governments at all levels shall incorporate the transformation of scientific and technological achievements into their national economic and social development plans, and organize and coordinate the transformation of the relevant scientific and technological achievements.

Article 10 In utilizing financial funds to establish applicable science and technology projects and other relevant science and technology projects, relevant administrative departments and regulatory authorities shall improve the scientific research organization and management style, and, when developing relevant science and technology plans or planning, and developing project guidelines, solicit opinions of relevant industries and enterprises; and in organizing the implementation of applicable science and technology projects, they shall specify the obligations of project undertakers in transforming scientific and technological achievements, strengthen intellectual property rights management, and regard transformation of scientific and technological achievements, as well as creation and utilization of intellectual property rights as an important content and basis for project initiation and acceptance.

Article 11 The state shall establish and improve the scientific and technological reporting rules and the scientific and technological achievements information systems,

announce the implementation of science and technology projects, scientific and technological achievements, and relevant intellectual property right information to the public, and provide scientific and technological achievements information inquiry, screening, and other public services. No state secrets or trade secrets shall be disclosed in the announcement of relevant information. For the information not to be announced, relevant departments shall notify relevant science and technology project undertakers in a timely manner.

Undertakers of science and technology projects established with financial funds shall, in accordance with the relevant provisions, submit relevant scientific and technical reports in a timely manner, and summarize and submit the scientific and technological achievements and relevant intellectual property right information to the information system of scientific and technological achievements.

The state shall encourage undertakers of science and technology projects not established with financial funds to submit relevant scientific and technological reports, and summarize and submit the scientific and technological achievements and relevant intellectual property right information to the information system of scientific and technological achievements. Departments of the people's governments at or above the county level in charge of relevant work shall provide convenience thereto.

Article 12 The state shall, through government purchase, subsidies for research and development, issuance of catalogue of industrial technology guidance, demonstration and popularization, and other ways, provide support to the following projects of transformation of scientific and technological achievements:

(1) Projects that are able to significantly raise the industrial and technical level, increase economic results, or form new industries that are able to promote sound social and economic development.

(2) Projects that are able to significantly improve national security ability and public safety level.

(3) Projects that are able to rationally develop and utilize resources, save energy, reduce consumption, prevent and control environmental pollution, protect ecology, and improve the capacity of tackling climate changes and capacity of preventing and reducing disasters.

(4) Projects that are able to improve people's livelihood and enhance the level of public health.

(5) Projects that are able to promote the development of modern agriculture or rural economy.

(6) Projects that are able to accelerate the social and economic development in areas inhabited by ethnic groups, remote and border areas, and poverty-stricken areas.

Article 13 The state shall adopt appropriate policies and measures to promote and encourage the use of advanced technology, techniques and equipment, and to continuously improve, restrict the use of or eliminate backward technology, techniques and equipment.

Article 14 The state shall strengthen standards preparation, develop national standards and industrial standards for new technologies, new techniques, new materials, and new products in a timely manner according to the law, actively participate in the development of international standards, and push forward the promotion and application of advanced applicable technologies.

The state shall establish an effective military and civilian scientific and technological achievements mutual transformation system, and improve the collaborative innovation system and mechanism of defense-related science and technology. Priority shall be given to the adoption of advanced applicable standards for civil use according to the law for scientific research and production of military products, to promote the mutual transfer and transformation of technologies for military use and civil use.

Article 15 When organizing the implementation of transformation of major scientific and technological achievements, the people's governments at all levels may have relevant departments organize the transformation through public bidding. Relevant departments shall provide the bid winners with the funds or other conditions that they decided to offer at the time of inviting bids.

Article 16 Holders of scientific and technological achievements may have their achievements transformed in the following ways:

- (1) Investing in the transformation themselves.
- (2) Assigning their achievements to others.
- (3) Licensing others to use their achievements.

(4) Carrying out the transformation together with others, with their achievements as the conditions for cooperation.

(5) Investing with their achievements as trade-in, which will be converted into shares or proportion of capital contributions.

(6) Other ways determined by negotiations.

Article 17 The state shall encourage research and development institutions and institutions of higher education to transfer scientific and technological achievements to enterprises or other organizations by assignment, license, investment as a trade-in, and other means.

State-maintained research and development institutions and institutions of higher education shall strengthen management, organization and coordination of transformation of scientific and technological achievements, promote the building of teams for the transformation of scientific and technological achievements, optimize the process of transformation of scientific and technological achievements, and transfer technologies through their own institutions in charge of technology transfer or independent service agencies for the transformation of scientific and technological achievements entrusted by them.

Article 18 State-maintained research and development institutions and institutions of higher education may make independent decisions on assignment, license, or investment as a trade-in of scientific and technological achievements they hold; however, with prices to be determined by pricing in agreement, listing on the technology exchange

market, auction, and other ways. In the case of pricing in agreement, they shall disclose the names of scientific and technological achievements and the proposed transaction prices in their entities.

Article 19 For job-related scientific and technological achievements obtained in state-maintained research and development institutions and institutions of higher education, the accomplisners and participants may, without changing the ownership of the job-related scientific and technological achievements, transform the scientific and technological achievements according to the agreements reached with their employers and enjoy the rights and interests as stipulated in the agreements. Their employers shall provide support for the transformation of the aforesaid scientific and technological achievements.

The accomplisners of scientific and technological achievements or persons in charge of research projects may not obstruct transformation of the job-related scientific and technological achievements, take into their own possession the job-related scientific and technological achievements and the relevant technical materials and data, or infringe upon the lawful rights and interests of their employers.

Article 20 The competent departments of the research and development institutions and institutions of higher education, the administrative departments of public finance, and science and technology, and other relevant administrative departments shall establish a performance assessment system in favor of promoting the transformation of scientific and technological achievements, regard the transformation of scientific and technological achievements as one of the important contents and bases for evaluation of relevant entities

and personnel, and financial support for scientific research, and increase financial support in respect of scientific research for relevant entities and personnel with outstanding performance in transformation of scientific and technological achievements.

State-maintained research and development institutions and institutions of higher education shall establish professional title appraisal, post management, and examination and evaluation rules commensurate with the characteristics of the transformation of scientific and technological achievements and improve the income distribution incentive and restraint mechanism.

Article 21 State-maintained research and development institutions and institutions of higher education shall submit annual reports on the transformation of scientific and technological achievements to the competent departments, specifying the quantity of the scientific and technological achievements they have obtained according to the law, the implementation of transformation, and distribution of relevant income. The competent departments shall, according to the relevant provisions, submit the annual reports on the transformation of scientific and technological achievements to the administrative departments of public finance, and science and technology, and other relevant administrative departments.

Article 22 An enterprise may, for the purpose of adopting new technologies, new techniques and new materials and manufacturing new products, publish information on its own or authorize an intermediary scientific and technological service institution to solicit the scientific and technological achievements that it needs or to find partners for the transformation of scientific and technological achievements.

The administrative departments of science and technology of the local people's governments at or above the county level and other relevant departments shall, according to the division of responsibilities, provide assistance and support to enterprises for obtaining the necessary scientific and technological achievements.

Article 23 An enterprise shall be entitled to transform scientific and technological achievements independently or jointly with domestic or foreign enterprises, public institutions, or other cooperators.

Through fair competition, an enterprise may, independently or jointly with other entities, undertake the projects of scientific and technological research and development or transformation of scientific and technological achievements arranged by governments.

Article 24 For science and technology projects that are established with financial funds, have market application prospects, and have specific industrial goals, relevant government departments and regulatory authorities shall give full play to the leading role of enterprises in the selection of research and development directions, implementation of projects, and application of achievements, and encourage enterprises, research and development institutions, institutions of higher education, and other organizations to jointly implement them.

Article 25 The state shall encourage research and development institutions and institutions of higher education to cooperate with enterprises in jointly transforming scientific and technological achievements.

Research and development institutions and institutions of higher education may participate in the bidding or tendering organized by relevant government departments or enterprises for the transformation of scientific and technological achievements.

Article 26 The state shall encourage enterprises to conduct research and development, achievements application and promotion, standards research and development, and other activities jointly with research and development institutions, institutions of higher education, and other organizations, by means of cooperation among industry, universities and research institutes such as jointly establishing research and development platforms, technology transfer institutions, or technological innovation alliances.

All partners shall enter into an agreement, to specify the organizational form of cooperation, division of tasks, capital investment, intellectual property rights ownership, equity allocation, risk sharing, responsibilities for breach of contract, and other matters.

Article 27 The state shall encourage research and development institutions and institutions of higher education to conduct exchange of scientific and technological personnel with enterprises and other organizations, employ scientific and technological personnel of enterprises and other organizations to take part-time jobs of teaching and scientific research according to the professional characteristics and technological development needs of industries and fields, and support their scientific and technological personnel in transforming scientific and technological achievements in enterprises and other organizations.

Article 28 The state shall support enterprises, research and development institutions, institutions of higher education, vocational colleges, and training institutions in jointly establishing internship and training bases for students and scientific research agencies for postgraduates, to jointly train professional and technical talents and high-skilled talents.

Article 29 The state shall encourage agricultural scientific research institutions and agricultural experiment and demonstration entities to transform scientific and technological achievements in agriculture independently or jointly with other entities.

Article 30 The state shall cultivate and develop the technology market, and encourage the establishment of intermediary scientific and technological service institutions to provide technology trading places, information platforms, information retrieval, processing and analysis, assessment, brokerage, and other services.

Intermediary scientific and technological service institutions that provide services shall follow the principles of impartiality and objectiveness, shall not provide false information or certificate, and have the obligation to keep confidential the state secrets and the trade secrets of the parties to which they have access in the course of providing services.

Article 31 The state shall, in light of industrial and regional development needs, establish a public research and development platform, to provide technology integration, common technology research and development, intermediate experiment and industrial tests, systematic and engineering development of scientific and technological

achievements, technology promotion and demonstration, and other services for the transformation of scientific and technological achievements.

Article 32 The state shall support the development of such institutions for the incubation of science and technology enterprises as scientific and technological enterprise incubators and university science parks, to provide incubation spaces, business startup counseling, research and development, management consulting, and other services to small- and medium-sized scientific and technological enterprises at the start-up stage.

Chapter III Guarantee Measures

Article 33 The financial funds for the transformation of scientific and technological achievements shall be chiefly used as guidance funds, loan interest subsidies, subsidy funds, risk investment and other funds for promoting the transformation of scientific and technological achievements.

Article 34 The state shall, in accordance with the provisions of the relevant tax laws and administrative regulations, implement tax preference for the activities of transformation of scientific and technological achievements.

Article 35 The state shall encourage banking financial institutions to conduct innovation in organizational form, management mechanism, financial products and services, and other respects, and encourage the provision of intellectual property right pledge loans, equity pledge loans, and other loan services to provide financial support for the transformation of scientific and technological achievements.

The state shall encourage policy financial institutions to take measures to provide more financial support for the transformation of scientific and technological achievements.

Article 36 The state shall encourage insurance institutions to develop insurance products commensurate with the characteristics of the transformation of scientific and technological achievements to provide insurance services for the transformation of scientific and technological achievements.

Article 37 The state shall improve the multi-level capital market and support enterprises in financing for projects of transformation of scientific and technological achievements through equity transaction, issuance of stocks and bonds according to the law, and other direct financing ways.

Article 38 The state shall encourage venture capital institutions to make investment in projects of transformation of scientific and technological achievements.

Venture capital investment guidance funds established by the state shall guide and support venture capital institutions in investing in small- and medium-sized scientific and technologic enterprises at the start-up stage.

Article 39 The state shall encourage the establishment of funds or venture funds for transformation of scientific and technological achievements. Such funds shall be raised by the state, local governments, enterprises, public institutions and other organizations or individuals, and shall be used to support transformation of scientific and technological achievements that need substantial investment, involve considerable risks and promise

high yields, and to accelerate the application of major scientific and technological achievements in industrial production.

Funds and venture funds for transformation of scientific and technological achievements shall be established and used in accordance with relevant provisions of the state.

Chapter IV Technological Rights and Interests

Article 40 Where an entity completing a scientific and technological achievement transforms the scientific and technological achievement in cooperation with other entities, the ownership of the rights and interests relevant to the scientific and technological achievement shall be specified in a contract according to the law. If it is not specified in the contract, the following principles shall be observed:

(1) Where there is no invention or creation from the cooperative transformation of the scientific or technological achievement, the rights and interests of the scientific and technological achievement shall belong to the entity completing the achievement.

(2) Where a new invention or creation is generated from the cooperative transformation of the scientific and technological achievement, the rights and interests of the new invention or creation shall belong to all parties to the cooperative transformation.

(3) As to any scientific and technological achievement generated through cooperative transformation, all parties to the cooperative transformation shall be entitled to put into practice such scientific and technological achievement; and transfer of such scientific and technological achievement shall be subject to consent of all parties.

Article 41 Where an entity completing a scientific and technological achievement cooperates with other entities in transforming the scientific and technological achievement, all parties to the cooperative transformation shall reach an agreement on protection of the technical know-how; and the parties may not violate the agreement or the requirements of the obligee on keeping the technical know-how confidential or disclose or allow others to use the technology.

Article 42 Enterprises and public institutions shall establish and improve the technical know-how protection rules to protect their technical know-how. Employees shall comply with the technical know-how protection rules of their employers.

Enterprises and public institutions may enter into an agreement with relevant employees who participate in the transformation of scientific and technological achievements, specifying that they should keep confidential the technical know-how of the entities during the period when they are on job or within a specified period of time after they leave office or retire; and the said employees may not violate the agreement, disclose the technical know-how of their employers, or engage in transformation of the scientific and technological achievements same as those of their employers.

No employees may transfer job-related scientific and technological achievements without authorization or in disguise.

Article 43 Income obtained by state-maintained research and development institutions and institutions of higher education from the transformation of scientific and technological achievements shall be totally retained thereto and be mainly used for

science and technology research and development, achievement transformation, and other relevant work after rewards and remunerations are granted to people who have made significant contributions to the completion and transformation of job-related scientific and technological achievements.

Article 44 After job-related scientific and technological achievements are transformed, the entities completing the scientific and technological achievements shall grant rewards and remunerations to people who have made significant contributions to the completion and transformation of the scientific and technological achievements.

The entities completing the scientific and technological achievements may specify or reach an agreement with scientific and technical personnel on the methods, amount, and time limit of rewards and remunerations. In developing relevant provisions, the entities shall fully solicit opinions from their scientific and technical personnel and announce relevant provisions in their entities.

Article 45 The entities completing the scientific and technological achievements that have not specified or have not reached any agreement with scientific and technical personnel on the method and amount of rewards and remunerations shall grant rewards and remunerations to people who have made significant contributions to the completion and transformation of the scientific and technological achievements according to the following criteria:

(1) Where a job-related scientific and technological achievement is assigned or licensed to others, not less than fifty percent of net income from assignment or license of such scientific and technological achievement shall be withdrawn.

(2) Where a job-related scientific and technological achievement is used as a trade-in in investment, not less than fifty percent of shares or capital contributions formed from such scientific and technological achievement shall be withdrawn.

(3) Where a job-related scientific and technological achievement is implemented independently or in cooperation with others, not less than five percent of business profits from the implementation of the scientific and technological achievement shall be withdrawn consecutively for three to five years after the transformation and successful production thereof.

The method and amount of rewards and remunerations that state-maintained research and development institutions and institutions of higher education specify or agree upon with scientific and technical personnel shall comply with the criteria specified in item (1) to item (3) of the preceding paragraph.

State-owned enterprises and public institutions shall, in accordance with the provisions of this Law, include the expenditures of rewards and remunerations granted to people who have made significant contributions to the completion and transformation of the job-related scientific and technological achievements into their total wages in the current year, but the said expenditures shall not be subject to the restriction of their total wages in the current year and shall not be included into their total wage base.

Chapter V Legal Liability

Article 46 Undertakers of science and technology projects established with financial funds that fail to submit scientific and technical reports, or summarize and submit scientific and technological achievements and relevant intellectual property right information according to this Law shall be ordered to make correction by relevant government departments and regulatory authorities organizing the implementation of the projects; and if the circumstances are serious, notices of criticism shall be circulated, and the project undertakers shall be prohibited from undertaking any science and technology projects established with financial funds within a certain period.

State-maintained research and development institutions or institutions of higher education that fail to submit annual reports on the transformation of scientific and technological achievements in accordance with the provisions of this Law shall be ordered by competent departments to make correction; and if the circumstances are serious, notices of criticism shall be circulated.

Article 47 Whoever, in violation of the provisions of this Law, obtains awards and honorary titles, fraudulent money or illegal profits by practicing fraud and resorting to deception in transformation of scientific and technological achievements shall be ordered to make correction by relevant government department according to its management responsibilities; the awards and honorary titles shall be cancelled; the illegal gains shall be confiscated; and fines shall be imposed thereupon. If economic losses are caused to others, he or she shall assume civil liability for compensation according to the law. If a crime is constituted, he or she shall be subject to criminal liability according to the law.

Article 48 Science and technology service institutions and their employees that, in violation of the provisions of this Law, deceive parties concerned by deliberately providing false information, experimental results, or assessment opinions, among others, or collude with one party to deceive the other party shall be ordered to make correction by relevant government departments according to their management responsibilities, be subject to confiscation of illegal gains, and be fined; and if the circumstances are serious, their business licenses shall be revoked by the administrative departments of industry and commerce according to the law. Those who cause economic losses to others shall assume civil liability for compensation according to the law; and if a crime is constituted, the offender shall be subject to criminal liability according to the law.

Intermediary scientific and technological service institutions and their employees that disclose state secrets or trade secrets of parties in violation of the provisions of this Law shall assume corresponding legal liabilities according to the provisions of the relevant laws and administrative regulations.

Article 49 Where the administrative departments of science and technology and other relevant departments, and their employees abuse power, neglect duties, practice favoritism or make falsifications in the transformation of scientific and technological achievements, the organs in charge of appointment and removal or the supervisory organs shall impose punishment on the directly responsible persons in charge and other directly liable persons according to the law; and if a crime is constituted, the offender shall be subject to criminal liability according to the law.

Article 50 Whoever, in violation of the provisions of this Law, usurps others' scientific and technological achievements by means of instigation, luring or coercion, thus infringing upon others' lawful rights and interests, shall assume civil liability for compensation according to the law and may be fined; and if a crime is constituted, the offender shall be subject to criminal liability according to the law.

Article 51 If, in violation of the provisions of this Law, an employee discloses the technical know-how of his or her employer without permission of the employer, or transfers a job-related scientific and technological achievement without authorization or in disguise, or if a person who took part in the transformation of a scientific and technological achievement violates the agreement reached with his or her employer by engaging in the transformation of the scientific or technological achievement same as that of the employer during the agreed period of time after leaving office or retiring, he or she shall assume civil liability for compensation according to the law if economic losses are caused to the employer; and if a crime is constituted, he or she shall be subject to criminal liability according to the law.

APPENDIX H

Semi-structured Interview Protocol

Name: _____

Institute: _____ Position: _____

1. What's your job duty as a technology manager in the university?
2. How often do you receive invention disclosures from university faculty and staff each year?
3. Which school in your university generates the most licensing income each year?
4. Can you list the name of blockbuster inventions that generate licensing income of over one million RMB for your university in past ten years?
5. In which scenario, do you need to hire a lawyer to assist with the licensing process?
6. For licenses, particularly those worth more than one million RMB, how do you decide their price?
7. How long does it take to find a proper licensee company and license out an invention?
8. How do you allocate the income between university, school, faculty, staff and many other parties involved in the licensing process?
9. What role do you (or your colleagues in the TTO) often play in the formation of university start-ups?
10. Do you plan to hire more people in your office?
11. Does the local economy and entrepreneurial culture impact on the licensing activity of your university?
12. Do you see any correlation between government research funding and technology transfer activities of your university?
13. If there is a scale of ten scores, how many scores are you willing to assign to your university for the technology transfer activities?

10	9	8	7	6	5	4	3	2	1
----	---	---	---	---	---	---	---	---	---

Very Good Very Poor

REFERENCES

Cases, Regulations, and Laws:

Diamond, Commissioner of Patents and Trademarks v. Chakrabarty, 447 U.S. 303 (United States Supreme Court, 1980).

Roche Products, Inc. v. Bolar Pharmaceutical Co., 733 F. 2d 858 (U.S. Court of Appeals for the Federal Circuit, 1984).

Madey v. Duke University, 307 F. 3d 1351 (U.S. Court of Appeals for the Federal Circuit, 2002).

Stanford University v. Roche Molecular Systems, Inc., 563 U.S. 776 (United States Supreme Court, 2011).

Mayo Collaborative Services v. Prometheus Laboratories, Inc., 132 S. Ct. 1289 (Supreme Court of the United States, 2012).

Association for Molecular Pathology v. Myriad Genetics, Inc., 133 S. Ct. 2107 (Supreme Court of the United States, 2013).

Ariosa Diagnostics, Inc. v. Sequenom, Inc., 788 F. 3d 137 (U.S. Court of Appeals for the Federal Circuit, 2015).

University of California v. Broad Institute, Inc. Fed. Cir. No. 17-1907 (U.S. Court of Appeals for the Federal Circuit, 2017).

Nuo Wei Xin Gong Si Yu Jiangsu Bo Li Sheng Wu Zhi Pin You Xian Gong Si Zhuan Li Zai Shen (诺维信公司与江苏博立生物制品有限公司专利再审) [Novozymes Co., Ltd. v. Jiangsu Boli Bioproducts Co., Ltd.], No. 85 Supreme People's Court, 2016 (China).

San Gong Zhu Shi Hui She Su Beijing Wan Sheng Yao Ye You Xian Gong Si (三共株式会社诉北京万生药业有限公司专利侵权纠纷) [Sankyo Corporation v. Beijing Wansheng Pharmaceutical Co., Ltd.], No. 907 Beijing High People's Court, 2006 (China).

Nanjing Yi Heng Zhi Yao You Xian Gong Si Su Kang Hai Yao Ye You Xian Gong Si Qin Fan Zhuan Li (南京易亨制药有限公司与南京康海药业有限公司侵犯专利纠纷上诉) [Nanjing Yiheng Pharmaceutical Co. v. Nanjing Kanghai Pharmaceutical Co.], No. 0027 Jiangsu High People's Court, 2010 (China).

Chen Kang Yuan Su Hua Nan Nong Ye Da Xue Qin Hai Fa Ming Zhuan Li Quan Jiu Fen (陈康源诉华南农业大学侵害发明专利权纠纷) [Kangyuan Chen v. South China Agricultural University], No. 604 Guangdong High People's Court, 2017 (China).

Zhang Wei Feng 3M Zhong Guo Yu 3M Chuang Xin You Xian Gong Si Zhi Wu Fa Ming Ren Jiang Li Jiu Fen (张伟锋、3M 中国与 3M 创新有限公司职务发明人奖励纠纷) [Weifeng Zhang v. 3M China and 3M Innovative Properties Co., Ltd.], No. 120 Shanghai High People's Court, 2014 (China).

Yang Cui Ying Yu Sichuan Gu Ke Yi Yuan Fa Ming Quan Jiu Fen (杨翠英与四川省骨科医院发明权纠纷) [Cuiying Yang v. Sichuan Orthopedic Hospital], No. 292 Sichuan High People's Court, 2010 (China).

Peng Yi Ting Tian Xiao Hui Yu Hubei Gong Ye Da Xue Zhi Wu Ji Shu Cheng Guo Wan Cheng Ren Jiang Li Jiu Fen (彭义霆、田晓辉与湖北工业大学职务技术成果完成人奖励纠纷) [Yiting Peng and Xiaohui Tian v. Hubei University of Technology], No. 109 Hubei High People's Court, 2014 (China).

Gu Zhang Da Ying Kuang Ye You Xian Gong Si Yu Zhong Nan Da Xue Ji Shu Fu Wu He Tong Jiu Fen (古丈大盈矿业有限公司与中南大学技术服务合同纠纷) [Guzhang-Daying Vanadium Mining Co., Ltd. v. Central South University], No. 185 Hunan High People's Court, 2015 (China).

Qinzhou Rui Feng Fan Tai Tie You Xian Gong Si Yu Beijing Hang Kong Hang Tian Da Xue Ji Shu He Tong Jiu Fen (钦州锐丰钒钛铁有限公司与北京航空航天大学技术合同纠纷) [QinZhou Ruifeng Iron Mining Co., Ltd. v. Beijing University of Aeronautics and Astronautics], No. 8 Supreme People's Court, 2015 (China).

Chen Ying Xu Tan Wu Zui Xing Shi Pan Jue Shu (陈英旭贪污罪刑事判决书) [The People's Republic of China v. Yingxu Chen], No. 36 Hangzhou Intermediate People's Court, 2013 (China).

Guan Yu Ji Shu Zhuan Rang De Zan Xing Gui Ding (关于技术转让的暂行规定) [The Interim Provisions on Technology Transfer] (Promulgated by the State Council on Jan. 10, 1985).

Guan Yu Guo Jia Ke Yan Ji Hua Xiang Mu Yan Jiu Cheng Guo Zhi Shi Chan Quan Guan Li De Ruo Gan Gui Ding (关于国家科研项目研究成果知识产权管理的若干规定) [Several Regulations on the Management of Intellectual Property Arising from Government-Funded Scientific and Research Programs] (Promulgated by the Ministry of Finance and the Ministry of Science and Technology on Mar. 5, 2002).

Guo Jia Ji Shu Zhuan Yi Cu Jin Xing Dong Shi Shi Fang An (国家技术转移促进行动实施方案) [National Technology Transfer Promotion Act Program] (Promulgated by the Ministry of Science and Technology on Dec. 5, 2007).

Ke Xue Ji Shu Jin Bu Fa (科学技术进步法) [The Scientific and Technological Progress Law] (Promulgated by the National People's Congress on Dec. 29, 2007).

Quan Guo Zhuan Li Shi Ye Fa Zhan Zhan Lue (全国专利事业发展战略 2011-2020) [National Patent Creation Strategy 2011-2020] (Promulgated by the State Intellectual Property Office on Nov. 18, 2010).

Shi Shi Cu Jin Ke Ji Cheng Guo Zhuan Hua Fa Ruo Gan Gui Ding (实施促进科技成果转化法若干规定) [Regulations on the Implementation of the Law on Promoting the Transformation of Scientific and Technological Achievements (Promulgated by the State Council on Mar. 1, 2016).

Cu Jin Ke Ji Cheng Guo Zhuan Hua Fa (促进科技成果转化法) [The Law on Promoting the Transformation of Scientific and Technological Achievements] (Promulgated by the Standing Committee of the National People's Congress on Oct. 1, 1996 and Amended on Aug. 29, 2015).

Zhuan Li Fa (专利法) [Patent Law] (Promulgated by the Standing Committee of the National People's Congress on Mar. 12, 1984 and Amended on Sep. 4, 1992, Aug. 25, 2000, and Dec. 28, 2008).

Zhuan Li Fa Shi Shi Xi Ze (专利法实施细则) [The Regulations on the Implementation of the Patent Law] (Promulgated by the State Council on Jun. 15, 2001 and Amended on Dec. 28, 2002 and Jan. 19, 2010).

Guan Yu Shen Li Ji Shu He Tong Jiu Fen An Jian Ruo Gan Wen Ti De Jie Shi (关于审理技术合同纠纷案件适用法律若干问题的解释) [Judicial Interpretation on Litigation Issues Related to Technology Contracts Disputes] (Promulgated by the Supreme People's Court on Jan. 1, 2005).

Guan Yu Chong Fen Fa Hui Jian Cha Zhi Neng Yi Fa Bao Zhang He Cu Jin Ke Ji Chuang Xin De Yi Jian (关于充分发挥检察职能依法保障和促进科技创新的意见) [An Opinion on Implementing the Procuratorate Function to Protect and Promote Scientific and Technological Innovations] (Promulgated by the Supreme People's Procuratorate on Jul. 15, 2016).

Qi Ye Suo De Shui Fa (企业所得税法) [The Enterprise Income Tax Law] (Promulgated by the National People's Congress on Mar. 16, 2007).

Qi Ye Suo De Shui Fa Shi Shi Tiao Li (企业所得税法实施条例) [The Implementations Rules of the Enterprise Income Tax Law] (Promulgated by the State Council on Nov. 28, 2007).

Ying Ye Shui Zan Xing Tiao Li (营业税暂行条例) [Provisional Regulations on the Business Tax] (Promulgated by the Ministry of Finance on Jan. 1, 1994 and Abolished on Nov. 19, 2017).

Zeng Zhi Shui Zan Xing Tiao Li (增值税暂行条例) [Provisional Regulations on the Value-Added Tax] (Promulgated by the Ministry of Finance on Jan. 27, 1995 and Amended on Nov. 19, 2017).

Guan Yu Quan Mian Tui Kai Ying Ye Shui Gai Zeng Zhi Shui De Shi Dian (关于全面推开营业税改征增值税试点的通知) [The Notice on Implementing the Pilot Program of Levying Value-Added Tax in Lieu of the Business Tax] (Promulgated by the Ministry of Finance on Mar. 23, 2016).

Books, Journals, and Articles:

Acs, Z.J. et al. (2009). The knowledge spillover theory of entrepreneurship. *Small Business Economics* 32: 15-30.

Agrawal, A. (2001). University-to-Industry knowledge transfer: Literature review and unanswered questions. *International Journal of Management Reviews* 3: 285-297.

Aldrich, H. (2008). *Organizations and environments*. Palo Alto: Stanford University Press.

Allen, T., and O'Shea, R. (2014). *Building Technology Transfer within Research Universities: An Entrepreneurial Approach*. Cambridge: Cambridge University Press.

Arora, A. (1995). Licensing tacit knowledge: Intellectual property rights and the market for know-how. *Economics of Innovation and New Technology* 4 (1): 41-60.

Arora, A. (1996). Contracting for tacit knowledge: The provision of technical services in technology licensing contracts. *Journal of Development Economics* 50: 233-256.

Arora, A., Fosfuri, A., and Gambardella, A. (2002). *Markets for Technology: the Economics of Innovation and Corporate Strategy*. Cambridge, Mass: MIT Press.

Audretsch, D. B. (2007). *The Entrepreneurial Society*. New York: Oxford University Press.

Audretsch, D. B. (2014). Scientific entrepreneurship: The stealth conduit of university knowledge spillovers. *George Mason Law Review* 21 (4): 1015-1026.

Audretsch, D.B., Hulsbeck, M., and Lehmann, E.E. (2012). Regional competitiveness, university spillovers, and entrepreneurial activity. *Small Business Economics* 39: 587-601.

Bagley, C., and Tvarnoe, C. (2016). Promoting “academic entrepreneurship” in Europe and the United States: Creating an intellectual property regime to facilitate the efficient transfer of knowledge from the lab to the patient. *Duke Journal of Comparative & International Law* 26: 1-78.

Baldini, N. (2006). University patenting and licensing activity: A review of the literature. *Research Evolution* 15 (3): 197-207.

Baptista, R. and Swann, P. (1998). Do firms in clusters innovate more? *Research Policy* 27:525-540.

Belussi, F. and Orsi, L. (2016). Innovation, alliances, and networks in high-tech environments. New York: Routledge.

Bessen, J. (2015). *Learning by doing: The real connection between innovation, wages, and wealth*. New Haven: Yale University Press.

Berman, E. (2015). *Creating the market university: How academic science became an economic engine*. Princeton: Princeton University Press.

Bok, D. (1982). *Beyond the ivory tower: social responsibilities of the modern university*. Cambridge: Harvard University Press.

Bok, D. (2009). *Universities in the Marketplace: The Commercialization of Higher Education*. Princeton: Princeton University Press.

Burk, D. L., and Lemley, M.A. (2003). Policy levers in patent law. *Virginia Law Review* 89: 1575-1696.

Burk, D. L. (2008). The role of patent law in knowledge codification. *Berkeley Technology Law Journal* 23(3): 1009-1034.

Campbell, J. (2013). *Becoming a techno-industrial power: Chinese science and technology policy*. Washington D.C.: Brookings Institute.

Carter-Johnson, J. (2014). Beyond Einstein and Edison: Claiming space for non-faculty inventions in technology transfer. *Indiana Law Review* 47: 645-688.

Cassiman, B. et al. (2009). Diversity of science linkages and innovation performance: Some empirical evidence from Flemish firms. Economic Discussion Paper (unpublished).

Chon, M. (2011). Sticky knowledge in copyright. *Wisconsin Law Review* 2011:177-217.

Cohen, W.M. and Levinthal, D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly* 35 (1): 128-152.

Chandler, A.D. (1977). *The visible hand: The managerial revolution in American business*. Cambridge: Harvard University Press.

Chen, A. et al. (2016). University technology transfer in China: A literature review and taxonomy. *Journal of Technology Transfer* 41:891-929.

Choi, A., and Triantis, G. (2013). Market conditions and contract design: Variations in debt contracting. *New York University Law Review* 88(1): 51-82.

Clark, B. R. (1998). *Creating entrepreneurial universities: Organizational pathways of transformation: issues in higher education*. Amsterdam: Elsevier Science Publisher.

Cohen, W.M., Nelson, R.R., and Walsh, J.P. (2002). Links and impacts: The influence of public research on industrial R&D. *Management Science* 48(1): 1-23.

Correa, C. M. (1981). Legal nature and contractual conditions in know-how transactions. *Georgia Journal of International and Comparative Law* 11(3): 449-494.

Cunningham, B and Harney, J. (2006). *Strategic management of technology transfer: The new challenges on campus*. Oxford: Oak Tree Press.

Dreyfuss, R.C. (2013). Double or nothing: technology transfer under the Bayh-Dole Act. In Marilyn Pittard, Ann L. Monotti & John Duns (Eds.), *Business Innovation and the Law: Perspectives from Intellectual Property, Labour, Competition and Corporate Law* (pp. 52-73). Cheltenham, UK: Edward Elgar.

Drivas, K. (2011). *Essays on University Technology Management*. Ph.D. Dissertation, University of California, Berkeley.

Eisenberg, R.S. (1987). Proprietary rights and the norms of science in biotechnology research. *Yale Law Review* 97 (2): 177-231.

Eisenberg, R. S. (1989). Patents and the progress of science: Exclusive rights and experimental use. *University of Chicago Law Review* 56: 1017-1086.

Elfenbein, D. (2007). Publications, patents, and the market for university inventions. *Journal of Economic Behavior & Organization* 63: 688-715.

Etzkowitz, H. (1983). Entrepreneurial scientists and entrepreneurial universities in American academic science. *Minerva* 21:1573-1871.

Etzkowitz, H., and Leydesdorff, L. (2000). The dynamics of innovation: from national systems and “Mode 2” to a Triple Helix of university-industry-government relations. *Research Policy* 29(2):109-123.

Etzkowitz, H. (2002). *MIT and the rise of entrepreneurial science*. New York: Routledge.

Etzkowitz, H., et al. (2008). Pathways to the entrepreneurial university: towards a global convergence. *Science and Public Policy* 35(9): 681-695.

Feigenbaum, E. (2003). *China's Techno-Warriors: National security and strategy competition from the nuclear to the information age*. Palo Alto: Stanford University Press.

Feldman, M., Feller, I., Bercovitz, J., and Burton, R. (2002). Equity and the technology transfer strategies of American research universities. *Management Science* 48(1): 105-121.

Feldman, R., and Nelson, K. (2008). Open science, open access, and open transfer: Market approaches to research bottlenecks. *Northwestern Journal of Technology and Intellectual Property* 7 (1): 14-32.

Fini, R., Grimaldi, R., Santoni, S., and Sobrero, M. (2011). Complements or Substitutes? The role of universities and local context in supporting the creation of academic spin-offs. *Research Policy* 40: 1113-1127.

Florida, R. (1999). The role of the university: Leveraging talent, not technology. *Issues in Science and Technology* 15(4): 67-73.

Freeman, Chris. (1995). The "National System of Innovation" in historical perspective. *Cambridge Journal of Economics* 19: 5-24.

Friedman, J., and Silberman, J. (2003). University technology transfer: Do incentives, management, and location matter? *Journal of Technology Transfer* 28: 17-30.

Frye, S. et al. (2011). Academic drug Discovery in the U.S.: A survey and analysis. *Nature Reviews Drug Discovery* 10:409-410.

Gao, X. et al. (2014). Technology transferring performance of Chinese universities: Insights from patent licensing data. *Advances in Applied Sociology* 4:289-300.

George, G. (2005). Learning to be capable: Patenting and licensing at the Wisconsin Alumni Research Foundation 1925-2002. *Industrial Land Corporate Change* 14: 119-151.

Gilson, R. J. and Black, B.S. (1998). Venture capital and the structure of capital markets: Banks versus stock markets. *Journal of Financial Economics* 47: 243-277.

Gorga, E., and Halberstam, M. (2007). Knowledge inputs, legal institutions and firm structure: Toward a knowledge-based theory of the firm. *Northwestern University Law Review* 101(3): 1123-1206.

Grimaldi, R., Kenney, M., Siegel, D.S., and Wright, M. (2011). 30 years after Bayh-Dole: Reassessing academic entrepreneurship. *Research Policy* 40: 1045-1057.

Gross, C. M. (2013). The growth of China's technology transfer industry over the next decade: Implications for global markets. *Journal of Technology Transfer* 38:716-747.

Gulbrandsen, M., and Slipersater, S. (2007). The third mission and the entrepreneurial university model. In Andrea Bonaccorsi & Cinzia Daraio (Eds.), *Universities and Strategic Knowledge Creation: Specialization and Performance in Europe* (pp.112-143). Cheltenham, UK: Edward Elgar.

Hamilton, G.G. and Biggart, N.W. (1988). Market, Culture, and Authority: A Comparative Analysis of Management and Organization in the Far East. *American Journal of Sociology* 94: S52-S94.

Haour, G. and Zedtwitz, M. (2016). *Created in China: How China is becoming a global innovator*. London: Bloomsbury Publisher.

Heller, M. A., and Eisenberg, R. S. (1998). Can patents deter innovation? The anticommons in biomedical research. *Science* 280: 698-701.

Henderson, R. et al. (1998). Universities as a source of commercial technology: A detailed analysis of university patenting, 1965-1988. *The Review of Economics and Statistics* 80(1): 119-127.

Hermanlin, B. E. and Katz, M. (1991). Moral hazard and verifiability: The effects of renegotiation in agency. *Econometrica* 59:1735-1753.

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

Hippel, E.V. (1994). “Sticky information” and the locus of problem solving: Implications for innovation. *Management Science* 40:429-439.

Hope, J. (2008). *Biobazaar: The open source revolution and biotechnology*. Cambridge: Harvard University Press.

Howell, J. (1996). Tacit knowledge, innovation and technology transfer. *Technology Analysis & Strategic Management* 8(2): 91-106.

Hong, W. and Su, Y. (2013). The effect of institutional proximity in non-local university-industry collaborations: An analysis based on Chinese patent data. *Research Policy* 42:454-464.

Hu, Z. (2005). Deconstructing State-owned enterprises in socialist China under reform: A scalar examination. *Environment and Planning A: Economy and Space* 37:703-722.

Huggins, R. and Thompson, P. (2015). Entrepreneurship, innovation and regional growth: a network theory. *Small Business Economy* 45:103-128.

Huang, C., et al. (2004). Organization, program and structure: an analysis of the Chinese innovation policy framework. *R&D Management* 34(4): 367-387.

Irish, L.E. et al. (2004). *China's Tax Rules for Not-For-Profit Organizations*. Washington D.C.: World Bank.

Jaff, A. (1986). Technological opportunity and spillovers of R&D: Evidence from firms' patents, profits, and market value. *American Economic Review* 76 (5): 984-1001.

Jain, S., and George, G. (2007). Technology transfer offices as institutional entrepreneurs: the case of Wisconsin Alumni Research Foundation and human embryonic stem cells. *Industrial and Corporate Change* 16(4): 535-567.

Jensen, R., and Thursby, M. (2001). Proofs and prototypes for sale: The licensing of university inventions. *American Economic Review* 91 (1): 240-259.

Johnson, J., Schneider, H.S., and Waldman, M. (2014). Role and growth of new-car leasing: theory and evidence. *Journal of Law and Economics* 57(3): 665-698.

Katz, B. and Wagner J. (2014). The rise of innovation districts: a new geography of innovation in America. Washington D.C.: Brookings Institute.

Kenney, M., and Goe, W. R. (2004). The role of social embeddedness in professional entrepreneurship: a comparison of electrical engineering and computer science at UC Berkeley and Stanford. *Research Policy* 33: 691-707.

Kenney, M., and Patton, D. (2009). Reconsidering the Bayh-Dole Act and the current university invention ownership model. *Research Policy* 38: 1407-1422.

Kesan, J.P. (2009). Transferring innovation. *Fordham Law Review* 2169-2223.

Kitch, E.W. (1977). The nature and function of the patent system. *Journal of Law and Economics* 20: 265-290.

Kneller, R. (2003). University-Industry cooperation and technology transfer in Japan compared with the United States: Another reason for Japan's economic malaise? *University of Pennsylvania Journal of International Economic Law* 24 (2): 329-450.

Kraemer, S. (2006). *Science and technology policy in the United States*. New Brunswick: Rutgers University Press.

Kreeger, D. L. (1974). The control of patent rights resulting from federal research. *Law and Contemporary Problems* 12:714-745.

Kroll, H. and Liefner, I. (2008). Spin-off enterprises as a means of technology commercialization in a transforming economy – Evidence from three universities in China. *Technovation* 28:298-313.

Larena, L.R. (2006). The Price of Progress: Are universities adding to the cost? *Houston Law Review* 43 (5): 1373-1444.

Lee, P. (2009). Interface: The push and pull of patents. *Fordham Law Review* 77: 2225-2235.

Lee, P. (2012). Transcending the tacit dimension: Patents, relationships, and organizational integration in technology transfer. *California Law Review* 100 (6): 1503-1572.

Lee, P. (2013). Patents and the university. *Duke Law Journal* 63(1): 1-88.

Lemley, M.A. (2004). Ex ante versus ex post justification for intellectual property. *The University of Chicago Law Review* 71: 129-150.

Lemley, M.A. (2008). Are universities patent trolls? *Fordham Intellectual Property, Media & Entertainment Law Journal* 18: 611-631.

Lerner, J. (2010). *Boulevard of Broken Dreams: Why Public Efforts to Boost Entrepreneurship and Venture Capital Have Failed – and What to Do About it*. Princeton, New Jersey: Princeton University Press.

Leslie, L. L. (1997). *Academic capitalism: Politics, policies, and the entrepreneurial university*. Baltimore: John Hopkins University Press.

Leyden, D. P. and Link, A.N. (2015). *Public Sector Entrepreneurship: U.S. Technology and Innovation Policy*. Oxford: Oxford University Press.

Litan, R. E., Mitchell, L., and Reedy, E. J. (2008). Commercializing university innovations: Alternative approaches. *Innovation Policy and the Economy* 8: 31-57.

Liu, H. (2015). National university science parks in China and their efficiency – Analysis and implications for future strategies. Ph.D. Dissertation. Tohoku University, Japan.

Liu, H., and Jiang, Y. (2001). Technology transfer from higher education institutions to industry in China: Nature and implications. *Technovation* 21: 175-188.

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

Lopez-Tarruella, A. (2012). *Google and the Law: Empirical approaches to legal aspects of knowledge-economy business models*. The Hague: Springer.

Love, B. J. (2014). Do university patents pay off – Evidence from a survey of university inventors in computer science and electrical engineering. *Yale Journal of Law and Technology* 16: 285-343.

Lowe, C.U. (1982). The triple helix-NIH, industry and the academic world. *The Yale Journal of Biology and Medicine* 55 (3-4): 239-246.

Lu, Ming Q. (2015). *Approaching China's Pharmaceutical Market*. Switzerland: Springer International Publishing.

Luginbuehl, S. and Ganea, P. (2014). *Patent law in greater China*. Cheltenham, UK: Edward Elgar Publisher.

Mansfield, E. (1977). Social and private rates of return from industrial innovations. *The Quarterly Journal of Economics* 91 (2): 312-320.

Mansfield, E. (1995). Academic research underlying industrial innovations: Sources, characteristics, and financing. *The Review of Economics and Statistics* 77(1): 55-65.

Marion, T.J., Dunlap, D., and Friar, J.H. (2015). Northeastern University: A study of technology transfer and the academic entrepreneur. In Albert N. Link, Donald S. Siegel & Mike Wright (Eds.), *The Chicago Handbook of University Technology Transfer and Academic Entrepreneurship* (pp. 245-283). Chicago and London: The University of Chicago Press.

Marshall, R. (1920). *Principles of economics: An introductory volume*. Basingstoke, UK: Macmillan Publisher.

Maurseth, P.B. and Verspagan, B. (2002). Knowledge spillovers in Europe: A patent citations analysis. *The Scandinavian Journal of Economics* 104: 531-546.

Mayer, H. (2013). Entrepreneurship in a hub-and-spoke industrial district: Firm survey evidence from Seattle's technology industry. *Regional Studies* 47 (10): 1715-1733.

Merrill, S.A. and Mazza, A. (2011). *Managing university intellectual property in the public interest*. Washington D.C.: The National Academy Press.

Merton, R. K. (1973). *The Sociology of Science: Theoretical and Empirical Investigations*. Chicago: University of Chicago Press.

McInerney, M. (2011). Tacit knowledge transfer with patent law: Exploring clean technology transfers. *Fordham Intellectual Property, Media & Entertainment Law Journal* 21: 449-493.

Mendi, P. (2007). Contractual implications of international trade in tacit knowledge. *Applied Economics* 39: 1173-1183.

Merges, R. P. (1988). Commercial success and patent standards: Economic perspective on innovation. *California Law Review* 76(4): 803-876.

Merges, R. P., and Nelson, R.R. (1990). On the complex economics of patent scope. *Columbia Law Review* 90(4): 839-916.

Moore, C. G. (2006). Killing the Bayh-Dole Act's Golden Goose. *Tulane Journal of Technology and Intellectual Property* 8:151-172.

Morain, S.R., Joffe S., Campbell, E. G., and Mello, M. M. (2015). Institutional oversight of faculty-industry consulting relationships in U.S. medical schools: a Delphi study. *Journal of Law, Medicine & Ethics* 383-396.

Mowery, D.C., Nelson, R.R., Sampat, B.N., and Ziedonis, AA. (2001). The growth of patenting and licensing by US universities: An assessment of the effects of the Bayh-Dole Act of 1980. *Research Policy* 30(1): 99-119.

Mowery, D. C. (2004). *Ivory tower and industrial innovation: University-industry technology transfer before and after the Bayh-Dole Act in the United States*. Palo Alto: Stanford University Press.

Mowery, D.D. and Sampat, B.N. (2005). The Bayh-Dole Act of 1980 and university-industry technology transfer: A model for other OECD governments? *Journal of Technology Transfer* 30:115.

Muster, P., and Wright, M. (2010). Convergence or path dependency in policies to foster the creation of university spin-off firms? A comparison of France and the United Kingdom. *Journal of Technology Transfer* 35: 42-65.

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

O'Connor, S.M., Graff, G.D., and Winickoff, D. E. (2010). Legal Context of University Intellectual Property and Technology Transfer. In *Managing University Intellectual Property in the Public Interest*. The National Academies of Sciences, Engineering and Medicine.

O'Connor, S. M. (2011). The aftermath of *Stanford v. Roche*: Which law of assignments governs? *Intellectual Property Journal* 24(1): 29-40.

O'Connor, S. M. (2013). The real issue behind *Stanford v. Roche*: Faculty conceptions of university assignment policies stemming from the 1947 Biddle Report. *Michigan Telecommunication & Technology Law Review* 19: 379-422.

Orcutt, J.L. and Shen, H. (2011). *Shaping China's innovation future: University technology transfer in transition*. Cheltenham, UK: Edward Elgar Publisher.

Perkmann, M., and Walsh, Kathryn. (2008). Engaging the scholar: Three types of academic consulting and their impact on universities and industry. *Research Policy* 37: 1884-1891.

Perkmann, M., and Salter, A. (2012). How to Create Productive Partnerships with Universities. *MIT Sloan Management Review* 53 (4): 79-88.

Perkmann, M., et al. (2013). Academic engagement and commercialization: A review of the literature on university-industry relations. *Research Policy* 42: 423-442.

Phan, P. H., Siegel, D. S., and Wright, M. (2005). Science parks and incubators: observations, synthesis and future research. *Journal of Business Venturing* 20: 165-182.

Phanraksa, O. (2005). *Uniformity of the Patent Policy in Technology Transfer in Thailand: To What Extent Can the Bayh-Dole Act Concept be adapted for the Thai Technology Transfer System?* Ph.D. Dissertation. University of Washington.

Pisano, G. (2006). *Science Business: The Promise, the Reality and the Future of Biotech*. Boston, Mass: Harvard University Press.

Polanyi, M. (1958). *Personal knowledge: Towards a post-critical philosophy*. Chicago: University of Chicago Press.

Polanyi, M. (1964). *Science, faith and society*. Chicago: University of Chicago Press.

Polanyi, M. (1967). *The tacit dimension*. Chicago: University of Chicago Press.

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

Qian, H. (2010). *Regional systems of entrepreneurship: The nexus of human capital, knowledge, and entrepreneurial activity*. Ph.D. Dissertation. George Mason University.

Qian, H. and Acs, Z.J. (2013). An absorptive capacity theory of knowledge spillover entrepreneurship. *Small Business Economics* 40 (2): 185-197.

Rai, A. K. (1999). Regulating scientific research: Intellectual property rights and the norms of science. *Northwestern University Law Review* 94 (1): 77-152.

Ranga, M., and Etzkowitz, H. (2013). Triple Helix systems: An analytical framework for innovation policy and practice in the knowledge society. *Industry and Higher Education* 27(4): 237-262.

Robinson, D. and Medlock, N. (2005). Diamond v. Chakrabarty: A retrospective on 25 years of biotech patents. *Intellectual Property and Technology Law Journal* 1-15.

Rock, M. T. and Toman, M. (2015). *China's technological catch-up strategy: Industrial development, energy efficiency and CO2 emissions*. Oxford: Oxford University Press.

Rogers, E.M. (2003). *Diffusion of Innovations*. 5th ed. New York: Free Press.

Romer, P. M. (1986). Increasing Returns and Long-Run Growth. *The Journal of Political Economy* 94(5): 1002-1037.

Rooksby, J. H. (2013). Myriad choices: University patents under the sun. *Journal of Law & Education* 42 (2): 313-326.

Rooksby, J. H. (2013). Innovation and litigation: Tensions between universities and patents and how to fix them. *Yale Journal of Law and Technology* 15: 313-404.

Rooksby, J. H. (2015). *The branding of the American mind: How universities capture, manage and monetize intellectual property and why it matters*. Baltimore: John Hopkins University Press.

Sampat, B.N. (2006). Patenting and US academic research in the 20th century: The world before and after Bayh-Dole. *Research Policy* 35(6): 772-789.

Saxenian, A. (1996). *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Boston, Mass: Harvard University Press.

Scharffs, B. G. (2001). Law as craft. *Vanderbilt Law Review* 54(6): 2243-2348.

Schumpeter, J.A. (1912). *The theory of economic development*. Boston, Mass: Harvard University Press.

Schumpeter, J.A. (1934). *The theory of economic development*. Cambridge: Harvard University Press.

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

Shane, S. (2002). Selling university technology: Patterns from MIT. *Management Science* 48(1): 122-137.

Shane, S. (2004). *Academic Entrepreneurship: University Spinoffs and Wealth Creation*. Cheltenham, UK: Edward Elgar.

Shane, S. (2004). *A general theory of entrepreneurship: The individual-opportunity nexus*. Cheltenham, UK: Edward Elgar.

Shapiro, H.T. (2009). *A Larger Sense of Purpose: Higher Education and Society*. Princeton: Princeton University Press.

Shea, R. P., Allen, T. J., Chevalier, A., and Roche, F. (2005). Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities. *Research Policy* 34: 994-1009.

Siegel, D.S. et al. (2004). Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies. *Journal of England Technology Management* 21:115-142.

Siegel, D.S. et al. (2007). Technology transfer offices and commercialization of university intellectual property: Performance and policy implications. *Oxford Review of Economic Policy* 23 (4): 640-660.

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

Stein, D. (2004). *Buying or Selling Out? The Commercialization of the American Research University*. New Brunswick, New Jersey: Rutgers University Press.

Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Washington D.C.: Brookings Institution Press.

Storr, R.J. (1953). *The beginnings of graduate education in America*. Chicago: University of Chicago Press.

Strandburg, K. (2008). Users as innovators: Implications for patent doctrine. *University of Colorado Law Review* 79: 467-544.

Takenaka, T. (2012). Serious flaw of employee invention ownership under the Bayh-Dole Act in *Stanford v. Roche*: Finding the missing piece of the puzzle in the German Employee Invention Act. *Texas Intellectual Property Law Journal* 20: 281-326.

Tamanaha, B. (2011). The primacy of society and the failures of law and development. *Cornell International Law Journal* 44: 209-247.

Tang, M. (2009). *Technology transfer from university to industry: Insight into university technology transfer in the Chinese national innovation system*. London: Adonis & Abbey.

Tang, X. and Du, J. (2016). The performance of China's biomedical innovation: A scientometric analysis. *Science China* 59: 1074-1082.

Teece, D.J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy* 15 (6): 285-305.

Teitelman, R. (1994). *Profits of Science: the American Marriage of Business and Technology*. New York: Basic Books.

Thursby, J., and Thursby, M. (2007). University licensing. *Oxford Review of Economic Policy* 23 (4): 620-639.

Trani, E.P. and Holsworth, R.D. (2010). *The indispensable university: Higher Education, economic development, and the knowledge economy*. Lanham: Rowman & Littlefield.

Tsai, K.S. (2004). *Back-alley banking: Private entrepreneurs in China*. Ithaca: Cornell University Press.

U.S. Department of Justice. (1947). *Investigation of Government Patent Practices and Policies: Report and Recommendations of the Attorney General to the President*.

Valdivia, W. (2013). *University start-ups: Critical for improving technology transfer*. Washington D.C.: Brookings Institute.

Van Notten, M. M. (1963). Know-how licensing in the common market. *New York University Law Review* 38(3): 525-546.

Villasana, M. (2011). Fostering university-industry interaction under a triple helix model: the case of Nuevo Leon, Mexico. *Science and Public Policy* 38(1): 43-53.

Washburn, J. (2005). *University, Inc.: The Corporate Corruption of American Higher Education*. New York: Basic Books.

Wei, S. et al. (2017). From “made in China” to “improved in China”: Necessity, Prospect, and Challenges. *Journal of Economic Perspectives* 31:49-70.

Winn, J.K. (1994). Relational practices and the marginalization of law: Informal financial practices of small businesses in Taiwan. *Law and Society Review* 28:193-232.

Wu, W. (2010). Managing and incentivizing research commercialization in Chinese universities. *Journal of Technology Transfer* 35: 203-224.

Wu, Y. and Xiong, Y. (2008). Comparison of Bolar exception in China and the United States. *China Patents and Trademarks* 3: 13-23 (2008).

Young, M. (2013). Industry, academia, and government collaboration: A game changer for the U.S. economic future. *Business Horizon Quarterly* 7: 16. Washington D.C.: U.S. Chamber of Commerce Foundation.

Zhou, K. et al. (2017). State ownership and firm innovation in China: An integrated view of institutional and efficiency logics. *Administrative Science Quarterly* 62(2): 375-404.

Zhang, C. et al. (2017). Corruption, marketization and corporate tax management in China: Evidence from listed firms. *Malaysian Journal of Economic Studies* 54(2): 281-299.

Zheng, C. (1998). The TRIPS Agreement and intellectual property protection in China. *Duke Journal of Comparative and International Law* 9: 219-227.

Zhou, Y. (2008). *Inside story of China's high-tech industry: Making Silicon-Valley in Beijing*. Lanham: Rowman & Littlefield.

Zhou, Y. et al. (2016). *China as an innovation nation*. Oxford: Oxford University Press.

Zou, Y. and Zhao, W. (2014). Anatomy of Tsinghua University science park in China: Institutional evolution and assessment. *Journal of Technology Transfer* 39: 663-674.

Ziedonis, A.A. (2001). *The Commercialization of University Technology: Implications for Firm Strategy and Public Policy*. Ph.D. Dissertation, University of California, Berkeley.

CURRICULUM VITAE

Ye Jiang was born in China in 1990. She holds an LL.M. degree in law from Michigan State University and an LL.B. degree in law from Zhejiang University. Her doctoral research interests are in intellectual property, technology innovation, entrepreneurship, and public policy. She was the winner of several academic awards. Her recent research has been published in English in the U.S. law journals. She was a licensed attorney in China and the State of New York.

