Title	中国における大学から企業への知識の流れを理解するための近接アプローチ:イノベーションパフォーマンスのための空間傾向、影響要因および戦略
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Doctoral Dissertation

A proximity approach to understanding the knowledge flow from university to enterprises in China: Spatial trend, influential factors and strategies toward innovation performance

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Abstract

Knowledge has become a strategic resource for economic development in a knowledge-based economy. The globalization, networking, and informational society have accelerated the arrival of the era of open cooperative innovation further. University and enterprises have gradually become the main R&D subjects in the national innovation system and play a crucial role in economic development. However, the imbalance of regional university-industry (U-I) collaboration in China restricts this type of effect. How to shorten the "distance" between university and enterprises enhancing the efficiency knowledge flow from university to enterprises for innovation? A proximity approach gives us a new view to understanding U-I linkages. Therefore, this research aims to explore the spatial trend, different influential factors from proximity perspective on knowledge flow from university to enterprises and proposes two types of strategies through entrepreneurship education and region-industry linkage to foster the U-I knowledge flow drawing on the national innovation system, the new knowledge production mode, and triple helix theory. The thesis is organized as following:

Chapter 1, the research background, research meanings, main research questions and research framework were introduced.

Chapter 2, the literature on U-I collaboration, knowledge flow and proximity were reviewed.

Chapter 3 and chapter 4, to find the rule of spatial trend from university to enterprises, we should understand how the knowledge flow. Therefore, this research construct a framework of knowledge flow on U-I collaboration and explore the flow mechanism on two stages of knowledge outflow and inflow from proximity perspective. Then, the trend of inter-regional U-I knowledge flow with 7,994 co-invent patents by university-industry over the period 2013 to 2018 in China were illustrated.

Chapter 5 and chapter 6, this research will discuss what types of proximity impact on knowledge flow by cross-level perspective with embedding absorptive capacity into outflow and inflow stages to cross regional and organizational boundary. Firstly, we used 484 pairs of patents to test the proximity effects on the regional U-I innovation performance. We further verify the catch-up moderating role of regional internal and external absorptive capacity, focusing on the U-I collaboration from non-local universities to local regions that significantly impact lagging regional U-I collaborative innovation performance.

Following this analysis, paying attention to the organizational boundary, the research tests the mediating role of knowledge embeddedness and moderating role of enterprises absorptive capacity. The findings rich triple helix theory from the subjects side which considers the integrated resource endowments in the triple helix research framework and fosters the knowledge flow activities between university and enterprises.

Finally, in chapter 7, we emerge two types of strategies: one is from entrepreneurship education as a means for fostering U-I knowledge flow and the other is region-industry linkages development pathway. These expand in-depth analysis of the impact of proximity, innovation performance, and regional resource endowments on U-I knowledge flow.

Then, we got the results from the following three aspects:

As for flow "spatial trend", the gaps between regions in China are obvious, showing a spatial pattern of "strong in eastern and weak in the other areas". The inter-regional U-I collaboration makes an increasing trend, however, most of the new co-patents flow into prosperous provinces. There is a ladder shape of imbalances development on U-I collaboration in prosperous and lagging regions.

For "influential factors" of flow form universities to enterprises, (1) The long geographic distance is not a hamper for improving regional and enterprises innovation performance. The economic development level has no significantly different effects on such role. (2) Technological proximity plays a negative role in increasing inter-region U-I innovative performance, eastern region has the most noticeable results. However, it can foster the enterprises innovation performance. (3) The better relationship and social trust of subjects can get more innovation performance in eastern and western, but the central area negatively affects. Simultaneously, social proximity also can improve enterprises innovation performance. (4) The U-I collaboration for innovation performance-enhancing advantages are not equal for all regions but are moderating by specific regional absorptive capacity dimensions. The areas with a higher level of internal human capital can get more catch-up effects, the knowledge embeddedness helps enterprises shape innovation performance.

For fostering U-I collaboration "strategies", entrepreneurship education integrated with professional education contribute to U-I knowledge flow through fostering students' creative thinking and problem-solving capability. The universities and enterprises located in lagging regions should increase entrepreneurship education, as a means for U-I knowledge flow. And then the regions cultivate the innovation atmosphere to absorb talents fostering cross-regional cooperation for catching up. Region-industry linkages promote the clustering growth, then push the U-I collaboration development. The conclusion section highlights the most relevant findings of this paper and formulates a set of recommendations. These findings can provide theoretical and practical guidance for innovation by real-world university–industry collaboration.

Keywords: Knowledge flow; University-Industry(U-I) collaboration; spatial trend; proximity; innovation performance

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Chapter 1 Introduction

1.1 Research Background

1.1.1 The status of University-Industry collaboration

The functions of university have evaluated from teaching at the beginning to be closely penetrate with scientific research and social service. From academic "ivory towers" to complex economic organizations, the relationship between universities and the economy is getting closer (Etzkowitz, 2000a). The function-derived of university merge the boundaries with governments and industry. The innovation process shows a more complex, iterative, non-linear, and multi-agent characteristics (Kline,1985; Lundvall, 1988; Berg & von Hippel, 1987). The interaction, symbiosis, and synergy between innovation subjects, creative elements, and the external environment have become the key factors to promoting innovation value. It has entered the stage of an innovation model characterized by a network model and open innovation (Freeman,1991; Van Aken &Weggeman, 2000; Anderson, et al., 2018). The new knowledge production "mode 2" proposed that application-oriented knowledge production can be jointly created by heterogeneous enterprises and universities (Gibbons,1994). The triple helix innovation paradigm breaks the organizational and authority boundaries between industry-university-government and created an innovative environment conducive to knowledge creation, transformation, and application (Etzkowitz, 2000b). The "third mission" except teaching and researching of university and the emphasis on external resources' availability have made U-I collaboration a major source for knowledge production and new technological innovations (Perkmann & Walsh, 2007; Skute et al., 2019). Scholars interest in proceeding on the knowledge spillovers of U-I collaboration to spur regional development (Lee,2011; Giunta, et al., 2016; Oyelaran-Oyeyinka & Adebowale, 2017). The co-evolution relationship between university, enterprises and regional development become gradually significant. In this context, collaborative innovation between industry and universities and how to interact with regional context have received increasing attentions.

Stanford University, in the United States, first proposed a model of industry-university-research technology alliances through the establishment of the "Stanford Industrial Park," namely the "Silicon Valley Model," which enabled the efficiency of the technological transformation innovation and achievements and greatly promotes regional economic growth. The Silicon Valley model has brought a new direction to the technological innovation and has been highly valued in all countries. China began to organize and implement the "Industry-University-Research Collaborative Development Project" in April 1992. After nearly 20 years practices, this project has played a certain role in promoting technological innovation and transformation. As shown in Figure 1.1, the national financial science and technology expenditure has increased year by year. In 2018, the national financial science and technology expenditure was 9518.2 billion yuan, 1134.6 billion yuan higher than 2017, nearly 13.5% over the previous year. Among the R&D projects in 2018, there were 3,636 collaborative items with universities, an 9% increase over the previous year, and the transaction amount was 3,565.5 million yuan, increasing 12.67% than last year.

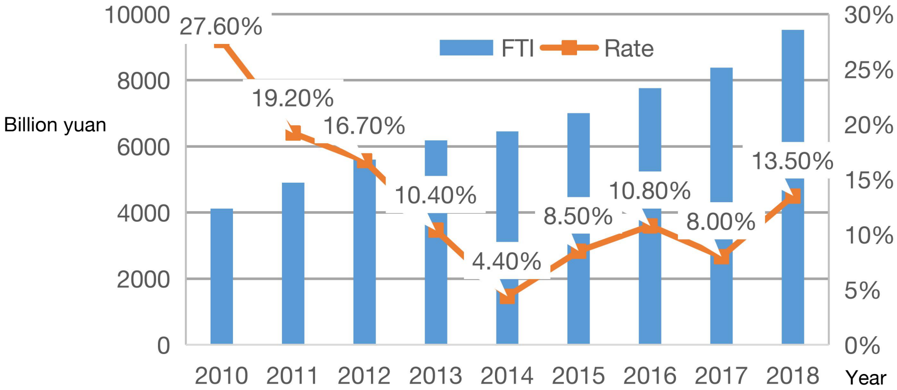


Figure 1.1 Financial Technology investment（FTI）and Rate from 2010-2018
Source: Statistical Bulletin of National Science and Technology Expenditures

To a certain extent, U-I collaboration has promoted the rapidly increase in the output of technological achievements and has certainly improved the country's innovation capabilities. The technology market is developing faster, and the volume of technology contract transactions increased year by year in China. According to the Ministry of Science and Technology data (Figure 1.2), the technological contract turnover rose from 39 million yuan in 2010 to 1.78 trillion yuan in 2018, increasing 356%. In recently, China's industry-university-research cooperative innovation achievements have emerged rapidly. From 2010 to 2018, the cooperative innovation technology achievement awards have shown an upward tendency, from 70 items in 2010 to 186 items in 2018. It gave birth to well-known domestic high-tech enterprises with U-I collaborations, such as Tsinghua Unigroup and Peking University Founder Group Corporation. It can be seen that U-I collaborative innovation has played an important role in promoting technological innovation, transformation and upgrading technological ability of enterprises, and establishing an enterprise-oriented and market-oriented technological innovation system with deep integration of industry and university.

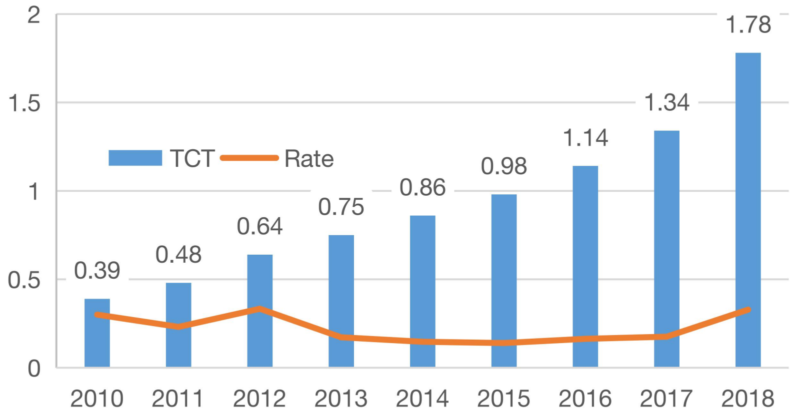


Figure 1.2 Technical contract turnover (TCT) and rate from 2010-2018
Source:Statistical Bulletin of National Science and Technology Expenditures

1.1.2 Existing problems of University-Industry collaboration in China

The U-I collaboration is still in a relative low-level in China. Although the U-I collaboration has made great progress, there are still some problems from the current point of view. The conversion rate of scientific and technological achievements in China's U-I collaboration is less than 30%, far lower than 80% in developed countries. The level of cooperation needs to be further improved. Comparing with the "university-pushed" triple helix in the United States, there is a "government-pulled" triple helix in China. In Figure 1.3, although firms' R&D expenditures for domestic colleges and universities have shown an upward trend, from 5.107 billion yuan in 2009 to 38.72 billion yuan in 2018, however, the proportion of the R&D expenditures of colleges and universities in total expenditures is just 26.6%. Among this total R&D expenditure, the government has always accounted for the largest proportion. The external expenditures of R&D expenditures of enterprises are increasing as a whole, while the proportion decreases, indicating that the cooperation between enterprises and universities is not particularly extensive.

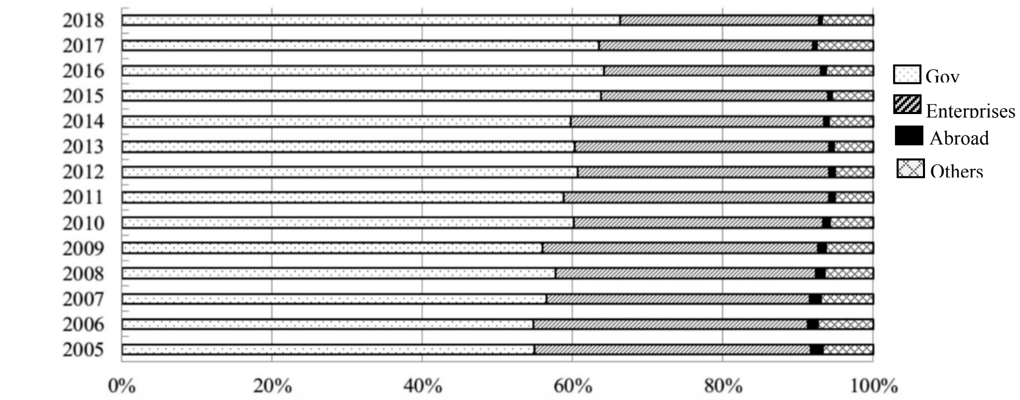


Figure 1.3 Various R&D technology budget expenditure ratios from 2005-2018
Source:China Science and Technology Statistical Yearbook 2005-2018

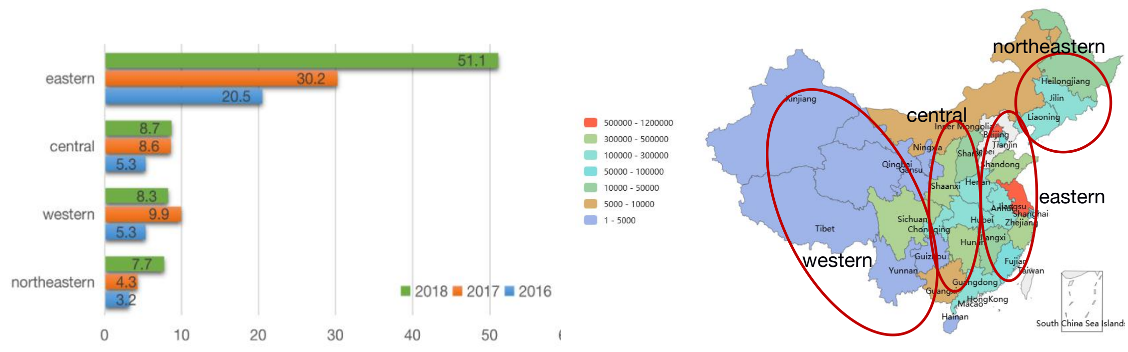
Insufficient role of universities in U-I collaborative system in China. From the perspective of universities, in 2013, the number of R&D projects by colleges and universities was 711,000, where, 158,500 were commissioned by enterprises, accounting for 22.3% of the total number of projects. In 2017, it was 202,692 of 9,966,800 which commissioned by enterprises, only 21.4% of the total number of items. It shows that although the absolute value of the number of R&D resolutions is increasing, the proportion of scientific and technological papers commissioned by enterprises has not increased significantly in recent years, even at a low level. U-I collaboration has not formed a scale yet. Most of the cooperation are still in a point-to-point and single-handed situation. The cooperation is limited to short-term and a single project. There are no long-term, stable, and systematic cooperative environments and relationships, restricting the enterprises from making substantial progress on development's key technical issues.

Imbalanced innovation capabilities among regions. From regional innovation system perspective, the regional economic development is based on local industrial development level which mainly based on technological innovation capabilities of industry. In China, the technological innovation capabilities of various regions show a certain degree of imbalance. Table 1.1 shows the ranking of the regional innovation capability index of China's provinces from 2012 to 2015 in ‘Report on the innovation capability of Chinese cities’. There is a large gap among regions.

Table 1.1 The ranking of regional innovation capacity index (2012-2015)

Province	2015	2014	2013	2012	Province	2015	2014	2013	2012
1 Jiangsu	58.01	1	1	1	17 Henan	25.90	17	16	18
2 Guangdong	52.71	2	2	2	18 Guangxi	23.62	19	21	22
3 Beijing	50.45	3	3	3	19 Jiangxi	23.34	20	20	20
4 Shanghai	45.62	4	4	4	20 Gansu	21.68	18	25	27
5 Zhejiang	42.05	5	5	5	21 Neimenggu	21.44	27	18	17
6 Shandong	37.49	6	6	6	22 Guizhou	21.22	26	24	23
7 Tianjin	36.49	7	7	7	23 Hebei	21.14	24	22	15
8 Chongqing	32.99	8	8	13	24 Helongjiang	20.65	21	19	19
9 Anhui	29.86	9	9	9	25 Shanxi	20.61	22	26	25
10 Fujian	29.25	11	10	16	26 Yunnan	20.30	23	27	28
11 Hunan	29.01	12	13	10	27 Jilin	18.95	25	23	24
12 Hubei	28.59	10	12	11	28 Ningxia	18.52	30	29	31
13 Hainan	28.03	16	17	21	29 Xinjiang	18.04	28	28	26
14 Shanxi	27.14	15	14	14	30 Qinghai	17.71	31	30	29
15 Liaoning	26.88	13	11	8	31 Xizang	17.09	29	31	30
16 Sichuan	26.39	14	15	12					

The ladder shape of U-I collaboration performances in China also shows an "imbalance" problem of spillover effects (Figure1.4). The number of technology transfer commissions between universities and enterprises in Beijing and Jiangsu was 3360 totally in 2017, with only one case in Inner Mongolia, two cases in Ningxia. In 2018, the highest number of contracts for transforming scientific and technological achievements by U-I in the four parts (Appendix Ⅰ) was eastern area, at 51.1 billion yuan, the least is northeastern. The western part got 8.3 billion yuan, a decrease of 20.1% compared with 2017. Using external universities' resources and matching with industrial innovations to promote innovation capabilities in regions, especially in lagging regions, has become a common concern of local governments. Understanding the regional U-I collaborative knowledge flow has great significance.



(a) (b)

Figure1.4 The contract amount for transformation of scientific and technological achievements and distributed in regions

U-I collaborative system should be improved. Universities and research institutions occupy an important position in the national and regional innovation system. Due to the differences among industry, university, and research institutions' value orientations, it is easy to cause conflicts in all subjects. The mainstream form by government-led cooperative system of U-I collaboration is often inefficient. Simultaneously, the policy and supporting environment are still not sufficient enough, which indirectly affects the effectiveness and efficiency of U-I collaboration. At present, the national innovation system is still centered on national key laboratories. Enterprises were not the main body of the national innovation system, not oriented by market. A large amount of research funding is invested in colleges, universities, and research institutions. These units tend to pursuit pure scientific research, and there is still a considerable distance from industrialization. Therefore, universities and research institutions do not play an actual role in supporting enterprises' independent innovation. As the scientific and technological innovation activities of colleges and universities are not well coupled with the market, the technological achievements have caused a relatively low transform rate. Many scientific research results stick in universities and research institutions, causing a great waste of scientific and technological resources. The actual contributions rate to the economic structure's strategic adjustment and economic growth mode transformation is minimal.

Exploring the above problems can be summed up as follows: First, the understanding and research of the collaborative relationship between industry and university are not deep enough, and many information asymmetries make the U-I collaboration unable to connect effectively, and the efficiency of U-I collaboration is low. Second, there is still not sufficient external dynamic mechanisms in China to support U-I knowledge flow. Third, organizational and regional boundary barriers restrict U-I knowledge flow and inhibit the development of innovation capabilities.

U-I collaboration includes organizational, strategic, and knowledge collaboration. Its core of collaboration is knowledge collaboration. Knowledge is the most important resource for innovation (Nonaka & Takeuchi, 1995). The knowledge of the university and research institution side serves the industry technological innovation transforms knowledge innovation's achievements into actual productivity (Wang, et al., 2018). Innovation was uncomplicated if the firms could not be open to knowledge. Effective knowledge management is one way to shape collaborative innovation performance. Therefore, knowledge collaboration is the key link of U-I collaboration which is the starting point of this research. The study of knowledge transfer and flow pathways on U-I collaboration, exploring the laws and motivations of their spatial flow, plays an important role in solving U-I collaboration problems.

1.2 Research questions

The essence of knowledge flow through U-I collaboration is the knowledge flow that crosses organizational boundaries. The driving force behind the generation of knowledge chains is driven by knowledge flow's subjective needs and the potential differences of knowledge. The "distance" between subjects has a certain influence on knowledge flow efficiency and collaborative innovation performance (Anselin et al., 2000; Acs et al., 2002).

The inter-regional knowledge flow causes scholars to focus on U-I collaboration with a spatial proximity perspective, exploring U-I collaborative knowledge spillover's mechanism and shaping innovation performance and regional growth from urban or regional view (Slavtchev, 2013). Space distance plays a vital role in local regional innovativeness as a continuous field of opportunities (Shearmur, 2011). U-I collaboration' knowledge flow should be continuously acquired, developed, decomposed, and stored during the knowledge flowing, making the flow in constant physical changes (Azagra-Caro, 2017). When taking space and region as the knowledge flow carriers, how the university's new knowledge through the organizational and regional boundaries flow into enterprises? It is necessary to realize the development path of "knowledge production and agglomeration to knowledge spillover, and then inflow-region capturing the new knowledge, and finally, inflow-subjects absorbing and transferring knowledge to balance regional development ability." We should embed regional interaction into spatial knowledge flow, shifting from "one-way spillover" to "subject-region" interactive flow shorten the collaborative distance between university and enterprises. Therefore, the main research purpose is :

The thesis aims to understand the coordinated development of regional U-I collaboration in China with apparent institutional arrangements and administrative barriers.

In order to realize the research purpose, the research devotes to answer the following three questions:

Q1: What is the spatial trend of knowledge flow from university to enterprises?

Q2: Which types of proximity enhance or hamper the knowledge flow from *universities to enterprises?*

Q3: How to encourage enterprises, universities, and regions to catch up with U-I collaborative innovation performance?

This research aims to explore effective knowledge flow ways to promote the U-I collaboration, especially for lagging areas in China. Therefore, our research contributes to improving our understanding of knowledge flow from university to enterprises to enhance innovation outputs. Specifically, the research objectives are as following:

- To find the spatial trends of the dynamic U-I knowledge flow network from the two dimensions of time and spatial, then compare the regional differences;
- To explore the relative influence of multidimensional proximity to explain the innovation performance of university-industry collaboration by investigating U-I collaborative innovation activities from regional and enterprising perspectives；
- To shorten the distance between subjects and bring new and non-redundant information to firms through knowledge flow to stimulate new ideas and creativity.

The results clarify the law for cross-boundary knowledge flow from university to industry. It could be better for meeting the subjects' knowledge needs, reducing the cost of knowledge flow, and promoting inter-regional innovation on U-I collaboration. On the other hand, it can also explain the relationships among multidimensional proximity, knowledge flow, and U-I innovation performance. It provides theoretical guidance for innovation by real-world U-I collaboration.

1.3 Significance of this research

Theoretical meaning. Prior research gradually shifted from linear analysis focusing on U-I collaborative models, mechanisms, and talent training to network spatial analysis. As an external mechanism unconsciously produced by human economic activities, knowledge flow has spatial tendency, scale, and interactivity (Bunnell & Coe, 2001). Research on proximity is an essential branch of U-I collaborations spatial studies and has provided a solid foundation for innovation study, organizational cooperation, and regional development (Skute et al.,2017). Scholars proposed the "distance" of the relationship is a prerequisite for interaction between subjects and knowledge spillover (Korotka, 2015; De Fuentes, 2016). This field mainly includes three directions: First, extending geographical proximity to multidimensional proximity, such as cognitive, technological, social, and institutional proximity, etc. (Boschma, 2005; Nooteboom, 2007); Second is introducing proximity factors to the measurement model of U-I knowledge spillover effects (Jaffe, 1993, Acs, 2017); The third is the impacts of diversity proximity mechanism on U-I collaborative performance in different countries (Greunz, 2003; Balconi, 2004; Aldieri, 2011; Marrocu, 2013; Benos, 2015; Arant, 2019; Pan, 2020).

Most works discussed the relationships of proximity on U-I collaboration from individual or organizational levels. Based on the triple helix theory, the existing research on the relationship between enterprises, universities and the government from the perspective of proximity is rare, and lacking analysis on the factors from the "learning area" context. The regional resource endowments of learning area would be objects factors that affect the knowledge flow from university to enterprises. A number of previous studies took the European Union, the US, and Italy etc., as samples, ignoring regional heterogeneity may lead to estimation errors (Giuliani, 2007).

These studied showed a gap in integrating proximity on U-I's spatial interaction processes from an inter-regional and heterogeneity context. Some empirical studies have also verified the influences of some organizational factors on proximity, like firm size (Santoro & Chakrabarti, 2007), organizational absorptive capacity (Cohen,1990; Tether & Tajar, 2008). And they fail to incorporate the knowledge carriers' role of inflow region's absorptive capacity into the research framework, ignoring the availability of regional endowments to capture local proximity.

Therefore, this thesis explores the problems of U-I collaborative innovation from the perspective of knowledge flow, using a two-stage flow of "outflow-inflow" to analyze the spatial differences of knowledge flow from university to enterprises. Universities as exogenous are the primary source of knowledge spillover. They are independent of enterprises and regional endowments. The knowledge under the spatial proximity effect flows from universities to enterprises. The local regional participants are endogenous, absorbing and commercializing the knowledge generated (Lehmann &Menter,2015). The regional absorptive capacity's role is to keep knowledge spillover efficiency and the enterprises' absorptive capacity is to promote the absorption of knowledge (Giuliani & Bell, 2005; Miguélez & Moreno, 2015). Compared with proximity, this "factor endowment" has a more objective existence that affects the enterprises' resources. Therefore, this research tends to take the knowledge flow of non-local universities to local regional firms as research objects and embed inflow regional endowments into proximity factors of U-I knowledge spillover. We explore the influences of diversity proximity on U-I collaboration and analyze whether there is a catch-up effect of absorptive capacity on such a relationship to promote U-I collaborations' coordination.

Practical meaning. In an open innovation environment, facing the increasingly complex market demands, it is difficult for companies to achieve technological innovation only by relying on their own knowledge resources. Network innovation through multi-agent collaboration has become the new economic normal. The mobility of knowledge affects the update of enterprise knowledge reserves and the acquisition of heterogeneous knowledge. Enterprises can realize knowledge integration and creation through the knowledge flow to search, transfer, diffuse, share, and improve their own technological innovation capabilities and innovation performance. However, the knowledge flow among organizations is complicated, and it is not easy to flow successfully from an organization to another. It is even more difficult for knowledge flow between regions. As an important resource for enterprises to gain competitive advantage, knowledge is affected by liquidity factors and network factors (Wang et al., 2014). This research takes knowledge flow from the university to enterprises as the main research object, understanding the spatial trend law of knowledge flow in regional context. On this basis, studying the influencing factors of U-I knowledge flow from the proximity perspective. The results have important practical guiding significance for U-I linkages to identify cooperative opportunities under different spatial scales, effectively improve U-I collaboration performance, and guide both actors to effectively obtain partners' knowledge and resources to improve competitive advantages. Universities and the government jointly create an external environment conducive to improving U-I collaborative innovation and provide policy recommendations for firms.

1.4 Research method

This research studies the spatial trend of knowledge flow in U-I collaboration from knowledge collaboration. It provides targeted suggestions for improving the innovation performance of U-I collaborations. The main research methods of the research are as the following three aspects:

First, exploring the dynamic knowledge flow of U-I collaboration by social network analysis (SNA). In recent years, a complex network relationship has gradually formed between U-I collaboration subjects, reflecting the technical connection and the social network relationship between the issues. Social network analysis is suitable for analyzing relational data as an essential social network analysis tool. The nodes in the network represent the actors, and the connections between nodes represent the connections among actors.

Second, proposing co-patents and questionnaire method to test the proximity effects on knowledge flow of U-I collaboration. In chapter 5, firstly collected the co-patents data in China Patent Data Network. The period was set from 2013.1.1 to 2018.12.31. We obtained 484 pairs of samples covered 30 provinces. Then, the thesis uses cross-sectional data to conduct stepwise and hierarchical regression methods to verify the proximity effect in non-local contexts. In chapter 6, we totally got 100 e-questionnaires with Likert 7 point scale by WJX website within two months from 2019.12 to 2020.1. Following these, we obtain the research data set and analysis the effect of proximity approach.

Finally, the heterogeneity analysis method is used to analyze the differences in regional U-I collaboration development. Based on the different characteristics obtained by social network analysis, regression analysis is used to analyze the main effect characteristics. Based on this method, this research reveals the differences in the features of the regional subjects and the different proximity effects of the eastern, central, and western regions part of China for policymakers to put forward more targeted opinions and suggestions.

1.5 Research framework

To effectively answer these three questions, this research is organized from spatial trend, influential factors, and strategies three aspects (Figure 1.5; Table 1.2) and the chapter lists are as following:

In chapter 1 and Chapter 2, the research background, meanings, questions and research framework will be introduced. The literature on U-I collaboration, knowledge flow and proximity will be reviewed.

In chapter 3 and chapter 4, to find the "spatial trend", this research construct a framework of knowledge flow on U-I collaboration and explore the flow mechanism on two stages of knowledge production inflow and application outflow stage from proximity perspective.

In chapter 5 and chapter 6, the research will discuss what types of proximity factors impact on regional and enterprise innovation performance through knowledge flow from university to enterprises. In chapter 5, the research discuss proximity spillover effects in knowledge innovation outflow stage, and test moderating role of external and internal regional absorptive capacity in knowledge application inflow stage. In chapter 6, in knowledge innovation outflow stage, we focus on proximity effects on local enterprise innovation performance and examine whether the knowledge embeddedness and the enterprise's absorptive capacity affect these relationships when knowledge flow into enterprises.

Finally, we emerge two strategies: one is entrepreneurship education as a means for fostering U-I knowledge flow and the other is the region-industry linkages development pathway facing consumption-driven economy. It expands an in-depth analysis on the impacts of proximity, innovation performance, and regional resource endowments of U-I knowledge flow.

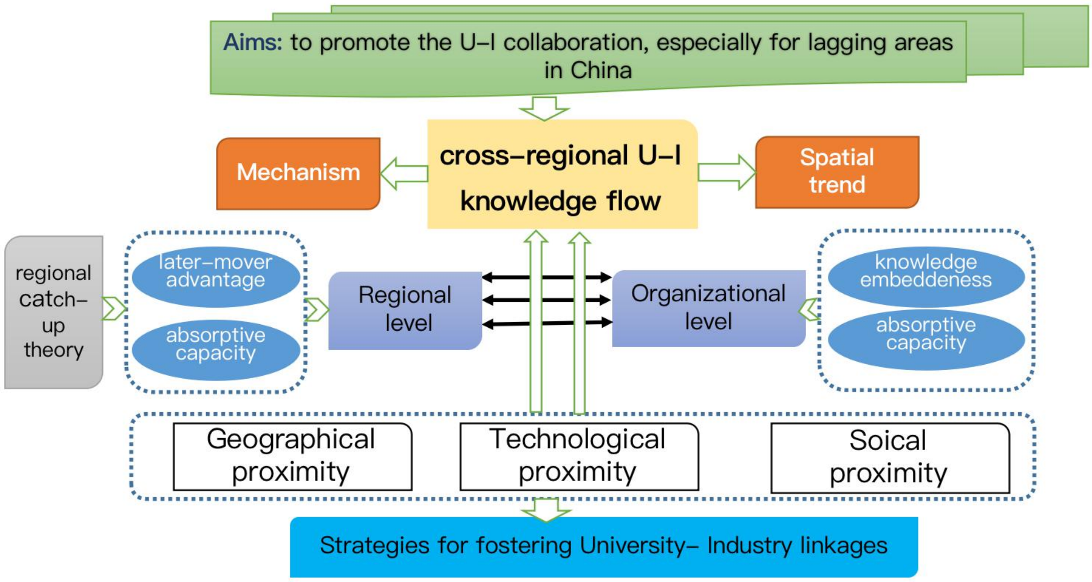
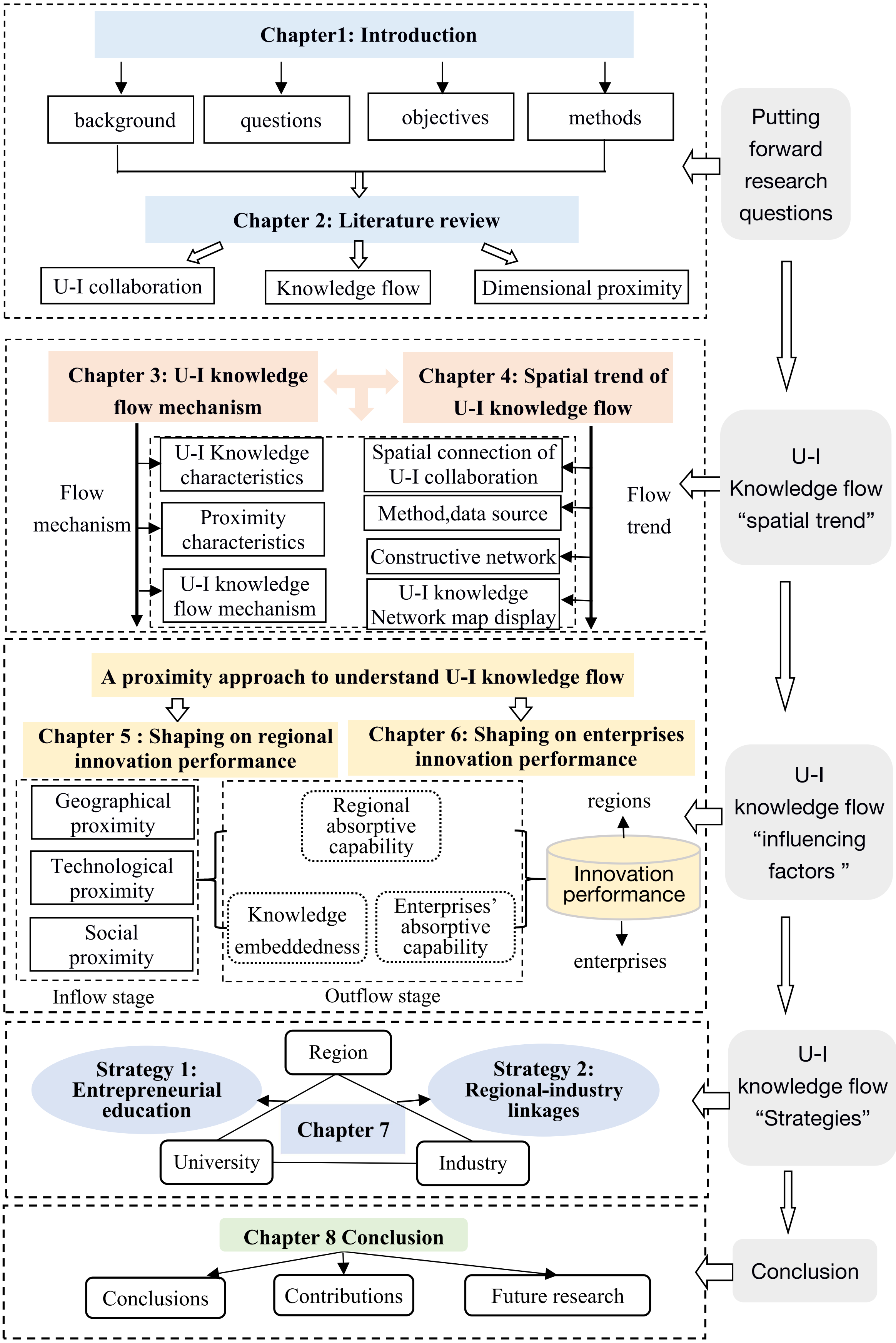


Figure 1.5 The research aim and design

Table 1.2 The research map and framework



Chapter 2 Literature Review

2.1 University-Industry collaboration

As a way of organizing knowledge stock (Cricelli & Grimaldi, 2010), U-I collaboration has a long history (Oliver, 2004). U-I collaboration has gradually become a relatively mature innovation model, which has attracted much attention in various countries, such as the United States (e.g., Lehrer et al., 2009), Japan (e.g., Woolgar, 2007), Singapore (e.g., Lee & Win, 2004), European Union Countries (e.g., Gertner et al., 2011; Marrocu et al.,2013), and China (e.g., Shi et al., 2020). At present, there is no clear definition of the related concepts of U-I collaboration. Borys & Jemison (1989) put forward the definition of university-industry collaboration, which presents a kind of inter-organizational relationship. Compared with the traditional organizational structure, this inter-organizational relationship makes the goals of U-I collaboration more diversified. The uniqueness and hybrid of U-I collaboration can improve the effectiveness of technological innovation. The main aim is to encourage knowledge and technology exchange between any parts of the higher education system and industry (Siegel et al., 2003; Bekkers& Freitas, 2008; Ankrah & Omar, 2015).

Regarding the main subject of U-I collaboration, Cohen and Levinthal (1990) pointed out in his research that "university" mainly refers to public research institutions, including universities and research institutions under the jurisdiction of the government, while "industry" refers to enterprises. U-I collaboration refers to the collaboration of enterprises and public research institutions. Carayannis et al. (2000) proposed that U-I collaboration aims to achieve the greatest degree of knowledge sharing. It requires superb management skills and organizational capabilities to design a flexible cross-organizational knowledge interface. In the process of U-I collaboration, enterprises and universities have complementary advantages and promote an effective combination of various production factors required for technological innovation. In conclusion, although the concepts of U-I collaboration are different, they all supported that U-I collaboration is the knowledge innovation and economic creation activities between enterprises and universities.

2.1.1 Motivations of U-I Collaboration

Enterprises are facing the acceleration of technological change, shortening of product life cycles, intensifying global competition, etc. Because of the continuous emergence of new knowledge, the challenges caused by rising costs and funds problems, universities have increased to seek cooperation with firms to maintain advantages at the leading edge in academic (Hagen, 2002), to get more research and development funds (Mailhot & Mesney, 2007). Enterprises and universities cooperate in complementary resources and often start from their own needs when they seek partners from the perspective of the resources possessed by both industry and university. Geisler and Turchetti (2015) pointed out that universities' advantages mainly lie in basic research, and the advantages of enterprises focus on the application of research and provide better conditions in terms of production technology. The resources owned by enterprises and universities are complementary and dependent, and the main motivation for their cooperation is to seek complementary resources. In addition, in the context of open innovation, U-I collaboration serves as a supplementary choice for traditional internal R&D (Coombs, et al.,2003). It can help organizations use external networks to develop innovation and knowledge (Dess & Shaw, 2001). Shachar and Zuscovitch (1990) pointed out that by collaborating with universities and research institutions, enterprises can use the universities' technology and scientific research capabilities to improve their R&D level, help their development, reduce costs, and enhance their value. Table 2.1 is the motivations of U-I collaborations summarized through meta-analysis by Ankrah and Omar (2015).

Table 2.1 Motivations for universities and industry: a comparison (Ankrah and Omar,2015)

	Universities	**Industry**
Necessity	-Responsiveness to government policy -Strategic institutional policy	-Responsiveness to government initiatives/policy -Strategic Institutional policy
Reciprocity	-Access complementary expertise, state-of-the-art equipment and facilities -Employment opportunities for university graduates	-Access to students for summer internship or hiring -Hiring of faculty members
Efficiency	-Access funding for research (Government grant for research& Industrial funding for research assistance, lab equipment, etc.) -Business opportunity, e.g., exploitation of research capabilities and results or deployment of IPR to obtain patents -Personal financial gain for academics	-Commercialize university-based technologies for financial gain -Benefit financially from serendipitous research results -Cost saving (easier and cheaper than to Obtain a license to exploit foreign technology) -National incentives for developing such relations such as tax exemptions and grants

		-Enhance the technological capacity and economic competitiveness of firms -Shortening product life cycle -Human capital development
Stability	— Shift in knowledge-based economy (growth in new knowledge) — Discover new knowledge/test application of theory —Obtain better insights into curricula development — Expose students and faculty to practical problems/ applied technologies — Publication of papers	— Shift in knowledge-based economy (growth in new knowledge) — Business growth — Access new knowledge, cutting-edge technology, state-of-the art expertise/research facilities and complementary know-how — Multidisciplinary character of leading-edge technologies — Access to research networks or per-cursor to other collaborations — Solutions to specific problems — Subcontract R&D (for example due to lack of in-house R&D) — Risk reduction or sharing
Legitimacy	— Societal pressure — Service to the industrial community/society — Promote innovation (through technology exchange) — Contribute to regional or national economy — Academics' quest for recognition or achieve eminence	— Enhancement of corporate image
Asymmetry	— NA	— Maintain control over proprietary technology

2.1.2 Influential factors of U-I collaboration

Fristsch and Lukas (2001) showed that an enterprise's size affected the formation of U-I collaborations. The larger the enterprise's scale, the more inclined the enterprise is to innovate through U-I collaborations (Santoro & Chakrabarti, 2002). Doloreux (2004) did an empirical study of 53 small and medium enterprises (SMEs) in Canada and showed that SMEs' objects of collaborative innovation relationships are mostly customers or suppliers. Veugelers and Cassiman (2005) focused on 748 manufacturing companies in Belgian and found out that the company's size positively influences the establishment of cooperative scientific research relationships with universities.

The impact of enterprise openness on U-I collaborations attracted some scholars' attention. If a company's innovation results are made public, then the probability of cooperation with universities will be higher (Panagopoulos, 2003). Companies that adopt open search strategies are more inclined to cooperate with universities, and these companies are more likely to benefit from U-I collaboration (Lauresen &Salter, 2004). Fontana and Geuna (2006) conducted a study on 558 innovative companies in the European Union. The results showed that the higher the company's degree of openness, the greater the possibility of U-I collaboration between firms and universities.

The nature of the industry that a company belongs to may also impact the company's tendency to participate in U-I collaboration. Industries such as biology and pharmaceuticals obtain more commercial, scientific research results from universities or scientific research institutions (Cohen et al., 2002). The industry's nature has a positive impact on the establishment of scientific research cooperation between enterprises and universities (Veugelers & Cassiman, 2005). U-I collaboration is the main source of knowledge acquired by enterprises in industries based on analytic knowledge (such as IT, biotechnology, and other high-tech industries) (Asheim & Coenen, 2005; Moodysson & Coenen, 2008). Eom and Lee (2010) also studied the influence of the industry. The industry characteristic index is the intellectual property system. The conclusion showed that the more perfect the industry's intellectual property system, the greater the tendency for U-I collaborations.

There are also some scholars' studies focusing on the role of government support on enterprises' motivations for U-I collaborations. Enterprises with government support are more willing to cooperate with public scientific research institutions for innovation (Capron&Cincera,2003). Many companies that build cooperative relationships with university laboratories have government support (Mohnen & Hoareau, 2003). Government support has a positive impact on establishing cooperative scientific research relationships between them and universities (Veugelers & Cassiman, 2005). The most important factor is the government supporting public scientific research cooperation between companies and universities in Korea (Eom & Lee, 2010).

There is a certain relationship between the university's reputation and U-I collaborations. Mansfield and Lee (1996) surveyed 70 corporate R&D executives from seven industries in the United States and found that the university's reputation positively affects the ratio of corporate to university R&D expenditure. Bruno and Orsenigo (2003) found that university quality significantly affects universities' access to corporate funding in Italy. Therefore, they believe that the low degree of U-I collaboration can be attributed to Italy's low quality. Some scholars also suggested that different forms of knowledge transfer (Arvanitis, 2008) and university intellectual property policies will also affect U-I collaborations' performance (Okamuro & Nishimura, 2013).

Santoro (2003) thought that differences in resources and personnel structure would affect U-I collaboration efficiency. Zhang (2009) researched from the internal perspective of U-I collaboration and proposed that the main factor affecting the efficiency of cooperation is the transaction costs under different collaborative modes. Mediating organizations have provided tremendous help in establishing U-I collaboration, greatly reducing the communication costs between the two subjects and establishing a trust relationship between them. Mora-Valentin et al., (2004) pointed out that a higher degree of trust in cooperation has a positive effect on cooperative projects' success. Norman (2004) discussed that the trust mechanism has a very significant positive impact on cooperative innovation. Shyu and Huang (2017) found that government policies play an important role in U-I collaboration. Goerzen and Beamish (2005) concluded that the heterogeneity between U-I collaboration organizations, including geographic distance, enterprise-scale, capital culture, etc., will affect the performance of cooperative innovation.

2.1.3 Forms of U-I collaboration

Several major forms of U-I collaborations are selected for comparing according to the closeness of the partners, as shown in Table 2.2. Nowadays, universities and enterprises mostly adopt platform-based models such as collaborative innovation centers. The more advanced collaborative innovation forms mainly include enterprise-led or government-pull industrial synergy alliances and university-pushed collaborative innovation centers.

Table 2.2 Comparison of U-I collaboration forms

Collaborative form	Introduction	Degree	Stage
Technology transfer	Both the universities and the enterprises conduct technology transfer or patent authorization on the basis of clearly stipulated contracts to help the disadvantaged party to carry out technological innovation	*	Initial stage

Co-development	On the basis of the contract agreement, the two parties of the school and enterprise will give full play to their respective technological or financial advantages, cooperate in innovation, and share benefits	**	Development stage
Technology Alliance	A deep cooperation model oriented by technology research combining the resource advantages of universities and enterprises fully	**	Development stage
University Science Park	In-depth collaboration around university technology output and industrialization guided by the government and established by universities	***	Mature stage
Joint laboratory	Collaboration on cutting-edge scientific and technological exploration between universities and enterprises based on improving innovation capabilities	***	Mature stage
Collaborative Innovation Center	A large-span integrated innovation model formed by various innovation subjects guided by national strategy	***	Mature stage

PS:The more signal of * , the stronger collaborative degree of universities and industries

2.2 Knowledge flow

The phenomenon of knowledge flow has already existed in human communication and practice for a long time. Because the generation and knowledge flow existed due to the main subjects' activities, the knowledge lacked independence. Simultaneously, knowledge has not become the most important element in social production activities yet, so it got little attention. However, with the advent of the knowledge economy, the value of knowledge is gradually unearthed. The vitality of knowledge flow is prominent, and it plays an irreplaceable role in knowledge sharing and knowledge innovation. Effectively promoting knowledge flow has become the key factor in enhancing their core competitiveness for organizations and individuals.

2.2.1 The basic concepts of knowledge flow

Drucker（1965）has predicted that knowledge would replace land, labor, capital, machinery, and equipment and become the most important production factor. With the development of knowledge management research. The concept of knowledge transfer was proposed for the first time by Teece (1977) during his studying of multinational companies' technology. The concept opened the door to the study of knowledge flow and attracted scholars from all over the world. OECD (Organization for Economic Co-operation and Development, 2000) thought that knowledge flow is the organization-related manifestation of regional innovation systems. Knowledge flow can help knowledge subjects in the region learn and acquire external knowledge and enrich the development within the system in learning. Subjects in the region rely on combining their own knowledge and external knowledge to produce innovations.

Knowledge flow is the transfer of knowledge from the source medium to the end in a certain environment (Szulanski,1996). Boisot (1995) discussed the concept of knowledge flow from the perspective of corporate technology strategy development. He put forward that knowledge flow includes four stages: knowledge diffusion, knowledge absorption, knowledge scanning, and problem-solving. Zhuge (2002) defined knowledge flow as the process of knowledge flow between people or the mechanism of knowledge processing. It contains three important factors: subject, content, and direction. Su et al. (2020) divided knowledge flow into two stages: knowledge innovation flow and knowledge application flow. According to different attributes, knowledge can be divided into explicit and tacit knowledge (Nonaka & Takeuchi, 1995). The feature of explicit knowledge that can be coded enables and can flow in a larger space, while tacit knowledge requires more "face-to-face" communication. Therefore, the tacit knowledge flow will be affected by locality (Zhang, et al., 2014). Knowledge flow also requires the participation of knowledge subjects and objects (Teece, 1977). It came from a high potential to a low potential, and easily affected by factors such as knowledge characteristics, cooperative characteristics, and knowledge receptors for relationship quality. There are various knowledge flow forms, including knowledge diffusion, knowledge exchange, knowledge transfer, knowledge spillover, etc.

2.2.2 Related concepts of knowledge flow

There are many related knowledge flow concepts, such as knowledge spillover, knowledge diffusion, knowledge transfer, and knowledge sharing. We distinguish these related concepts to understand knowledge flow better.

Knowledge diffusion

Knowledge diffusion is an activity or action in which knowledge flows in space and time through a certain carrier (Wang et al., 2014). It is the process of the knowledge subject's initiative and targeted learning, acquiring knowledge, and fusing the learned knowledge with its own knowledge to generate new knowledge (Battisti & Stoneman, 2010). Therefore, new knowledge must be created before it can be called knowledge diffusion. Knowledge diffusion is a purposeful and active knowledge flow. For example, from the perspective of the citation relationship of scientific literature, citing the cited literature is knowledge diffusion and the active form of knowledge flow. The diffusion effect can be used to measure the depth and scope of diffusion through quantitative indicators such as breadth, intensity, and speed (Zhang & Gu, 2014). In addition, knowledge attributes, knowledge subject and object's own factors, and cultural factors have a certain influence on the motivation and effect of knowledge diffusion. The subject of knowledge is the most important factor for knowledge diffusion, and its motivation is the key factor affecting knowledge diffusion (Mcdermott,1999). Knowledge diffusion carriers include researchers, journals, disciplines, patents, etc., as well as network platforms such as social media. The diffusion effect is measured by indicators such as the breadth, intensity, speed of diffusion, journal diffusion factor (Rowlands, 2002), discipline diffusion intensity (Liu & Rousseau, 2010), and the patents (Baruffaldi & Simeth, 2020).

Knowledge dissemination

Knowledge dissemination is a form and way of knowledge diffusion. Knowledge dissemination requires specific media and channels. It is a purposeful dissemination behavior. Knowledge dissemination mainly includes the constituent elements of knowledge dissemination subject, object, dissemination medium, dissemination behavior, environment, purpose, dissemination effect, etc. According to the dissemination scope, knowledge dissemination can be divided into individual, team, and organizational knowledge dissemination. The process of knowledge dissemination is the subject of knowledge dissemination. As for the subject, in the dissemination environment, the knowledge unit is disseminated through one or more dissemination media, and the dissemination effect is achieved.

Knowledge exchange

Knowledge exchange is a two-way communication and dialogue between the subject and the object of knowledge (Barwick et al., 2005, Pérez-Luño et al.,2019). It is a two-way and interactive form of communication centered on the knowledge needs of both parties. The form of knowledge exchange can be divided into formal and informal knowledge exchange. Formal knowledge exchange mainly includes the citation process between papers, journals, and books; there are many informal knowledge exchange methods, including email communication, face-to-face communication, and so on. In the process of knowledge exchange, the subject and the object of knowledge are developed on one or more topics, and the dialogue is constantly adjusted to meet the needs. Due to the differences in knowledge acceptance ability, the two parties can exchange roles during the exchange. Therefore, knowledge exchange has targeted features as direction, openness, and dynamics.

Knowledge transfer

Knowledge transfer emphasizes the one-way output of knowledge producers to knowledge users. It is a form of knowledge diffusion based on knowledge producers (Kang & Kim, 2013). In transferring from the knowledge subject to object, the knowledge subject's will and purpose are the centers. The content and form of the transfer will not be adjusted according to the knowledge object's needs and acceptability. In addition, there will be no role exchange in the process of knowledge transfer, and the knowledge object passively accepts knowledge. They need to interact with the knowledge subject constantly to obtain knowledge that match their own needs. Knowledge transfer has the characteristics of a one-way transfer of subject to object and passive acceptance of the object.

Knowledge spillover

In the context of knowledge exchange, knowledge spillover is an unconscious and directionless form of knowledge flow between different subjects directly or indirectly knowledge exchange (Caniëls & Verspagen, 2001). The spillover effect depends on the attributes of the knowledge unit and the spread of existing knowledge (Maurer et al., 2011). The subject of knowledge creates new knowledge based on its own individual behavior, not on specific situations or knowledge objects' needs. It is a process without certain expected goals. Table 2.3 shows the connotation, characteristics, similarities, and differences of related concepts on knowledge flow.

Table 2.3 Interpretation of concepts related to knowledge flow

Concept	Direction	Purpose	Form	Elements	Characteristic
Knowledge diffusion	Directional or non-directional	The subject of knowledge has activity and purpose	Knowledge unit free and reorganized	Subject, object, medium	The evolution of primary to advanced knowledge, generation of new knowledge
Knowledge dissemination	One-way or two-way	The subject of knowledge has purpose	Individual, team, organizational dissemination	Subject, object, medium, environment, communication purpose and effect	Expecting to achieve the expected effect of the knowledge subject
Knowledge exchange	Two-way	The subject and object of knowledge has activity	Formal and informal exchange	Subject and object	The knowledge exchanged is targeted and dynamic; Interchangeable roles of subject and object of knowledge

Knowledge transfer	One-way	Active transfer of knowledge subjects, Passive acceptance of knowledge objects	From subject to object One-way output	Subject and object	Centered on the will of the subject of knowledge, passive acceptance of the object
Knowledge spillover	non-directional	Knowledge subject unconscious	No specific purpose and contextual overflow	Subject	Unconscious output based on the behavior of the knowledge subject
Knowledge flow	Directional or non-directional	The subject of knowledge has activity and purpose	The flow from high potential to low position	Subject, object, medium	Emphasizing knowledge from high to low direction of diffusion

From the perspective of the connotation and extension of related concepts, knowledge diffusion, knowledge dissemination, and knowledge exchange are the relationship between part and the whole, and the connotation boundaries overlap. Knowledge flow includes knowledge diffusion, knowledge transmission, knowledge transfer, etc. (see Figure 2.1).

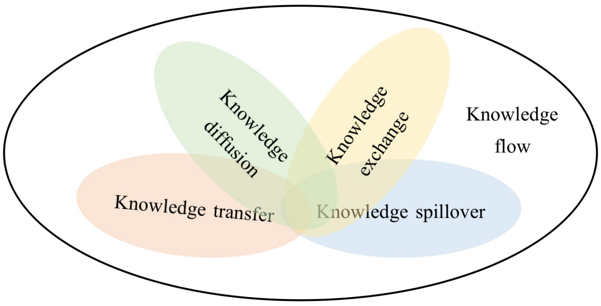


Figure 2.1 The figure of related concepts of knowledge flow

2.2.3 U-I collaboration and knowledge flow

Knowledge flow characteristics of U-I collaborations

Knowledge characteristic. The flow of knowledge depends on the carrier's activities, and it does not have the characteristics of autonomous flow. The basic characteristics of knowledge, such as complexity, embeddedness, and specificity, may even hinder knowledge transfer. Therefore, the characteristics of knowledge (whether it is tacit knowledge, complexity degree, embeddedness degree, etc.) on U-I collaborations will essentially affect the knowledge flow process's smooth progress.

With the deepening of U-I collaborative innovation's relationship, knowledge flow has developed from one level to multilevel. Child and Faulkner (1998) proposed the three-dimensional of the knowledge transfer from innovation activities into technical knowledge transfer, system knowledge transfer, and strategic knowledge transfer. In collaborative innovation between universities and enterprises, this division can also be applied to express the levels of knowledge flow at different stages. Table 2.4 shows the division of knowledge flow.

Table 2.4 The division of knowledge flow in U-I collaborative innovation

Knowledge flow level	**Description**	**Degree of difficulty**
Basic knowledge flow	The technical knowledge transmitted through the carrier is mainly explicit knowledge, which is the easiest to share and transfer	Easy
System knowledge flow	Combining the experience of technical knowledge and the transfer of technical knowledge about product technology, a certain degree of intimacy between universities and enterprises is required to be able to transfer	Common
Strategic knowledge flow	Integrated knowledge transfer, knowledge spillover including way of thinking and management and business philosophy, requires universities and enterprises to have a common language for the transfer	Difficult

Subjects in the knowledge flow process. The main body of knowledge transfer in U-I collaboration including enterprises, universities, and scientific research institutions. The government and related intermediaries are also involved in U-I collaborations, and their impacts on the knowledge flow may be indirect at some time. Universities are the main knowledge providers during the flow process with a fundamental position. Their willingness and ability play a vital role in deciding whether knowledge flow can be carried out effectively. As the knowledge demand side of U-I collaboration, the purpose of enterprises is to obtain the inflow and digestion of required knowledge through interaction and cooperation with universities and research institutions. Factors of enterprises such as the cooperative and interactive ability, the knowledge absorptive capacity, and the knowledge distance with universities and research organizations will affect the knowledge flow. The coordination capacity of government agencies and the intermediary market's development are gradually becoming important factors influencing the smooth transfer of knowledge between universities and enterprises.

Knowledge flow carriers or channels. The smooth knowledge flow between subjects requires suitable channels or media, including publications, patents, consulting, informal meetings, licenses, joint ventures, scientific research contracts, personal exchanges, etc. Different knowledge flow channels or pathways have different characteristics, and they are adapted to the knowledge flow in different environments. Hence, the carriers or channels will have a greater impact on the efficiency of knowledge flow.

Knowledge flow context. The knowledge flow has a complicated external environment, mainly includes system, culture, trust relationship, etc. These factors are combined in different ways to form a "Ba" of knowledge flow in U-I collaborations called knowledge flow context. The context of knowledge flow has always been in different situations, which directly or indirectly affects the knowledge flow, and is an important part of knowledge flow.

U-I knowledge flow based on knowledge classifications

In the innovation system, knowledge has different classifications, and knowledge can be divided into explicit and tacit knowledge. The feature of explicit knowledge that can be coded enables it to flow in a larger space. The knowledge that is easy to communicate and share has the characteristics of easy and clear expression, formal and systematic specifications. However, tacit knowledge is mostly manifested in the specific relationship between personal experience and organization, which is generally dependent on individuals and specific organizations and is difficult to express and share clearly. The flow of tacit knowledge requires more "face-to-face" communication. Jensen et al., (2007) proposed that explicit knowledge is suitable for the science and technology innovation model (STI), and tacit knowledge is suitable for the doing and using innovation model (DUI). OECD has concluded that knowledge has three attributes: ① explicit attributes. ②exclusive attributes. ③existed attributes. By analyzing the three attributes of different knowledge types, a clearer understanding of its characteristics can be formed. Such as, the patent is an existing type of knowledge expressed explicitly and has the right to be protected by law; skilled knowledge is also a type of existing knowledge, which is embedded in the minds of R&D personnel and usually has no legal rights restrictions; the commissioned research and development results are not the existing results, and the expression of other results and the rights provisions vary according to the contract.

University researchers undertake scientific research projects funded by public funds. The progress of the research and development process actually promotes the formation of two types of knowledge: one is the output of explicit knowledge such as patents and papers, which can be cited, transferred, licensed, etc. The second is that people's ability is cultivated in project research and development, and skill-based knowledge is generated and stored in the minds of researchers and development personnel. This type of knowledge cannot be directly measured. The accumulated and stored technical knowledge can be further returned to explicit knowledge through enterprise commissioned R&D or technical services. They can form the R&D results that are suitable for enterprise needs. The collaborative results flow back to the industry to realize university knowledge output contributions to enterprises development and economic society. In addition, skill-based knowledge will spread to society in the form of personnel mobility and training. Due to the different characteristics of knowledge, there are also big differences in the modes of U-I collaboration. Explicit knowledge is often based on transfer, and tacit knowledge is often based on interaction.

It can be seen that different knowledge types have different modes of knowledge flow. Although the existing literature have paid attention to this phenomenon, their research object is the enterprise organization's innovation model. The research lacks innovation mode across organizational boundaries involving U-I collaboration.

U-I collaboration based on knowledge complementary

Many studies have shown that the cooperation between universities and enterprises is often caused by complementary knowledge. The most typical view is from (Partha & David, 1994). They did a comparative analysis of two typical knowledge organizations of universities and enterprises from new scientific economics. The authors pointed out that universities are models of the "Republic of Science" (Merton, 1973), and the enterprises are the representatives of the "Kingdom of Technology." (Nelson, 2004) further developed this idea and discussed it from the perspective of public science and private science. A large number of empirical studies have confirmed that companies cannot produce all new theories, new insights, new technologies, and new skills, but the use of academic knowledge is beneficial to technological change, innovation, and development (Henderson et al.,1998; Zucker et al., 1998; Adams, 2002; Zucker & Darby, 2007). Universities and research institutions are good at producing cutting-edge scientific knowledge, far from enterprises' needs (Motohashi, 2005). The scientific frontier knowledge provided by universities to enterprises is mainly applicable to the early stages of product or process innovation. It has a high degree of uncertainty in technology and the market (Jensen et al.,2003). Universities are considered the most important external sources of knowledge and technology for corporate innovation. Zucker et al. (1998) studied the composition of biotechnology companies. Their analysis showed that the work of American university researchers helped to establish biotechnology companies. Most enterprises' innovation is inseparable from the research results, test equipment, and human resources of universities and public research institutions. The innovation of enterprises highly depends on the development of public science (Cohen et al., 2002). Huang & Chen (2017) based on the data of universities in Taiwan and found that in organizational-level of U-I collaboration system, the universities' innovation performance can get higher with U-I collaboration. Soh & Subramanian (2014) found that U-I cooperation can improve enterprise innovation performance by promoting enterprise product innovation or patent application.

The agglomeration effects formed by cooperation are an important means to drive enterprise growth (Bai & Bian, 2015). In U-I collaboration, companies and universities have heterogeneous knowledge. Universities focus on basic research, and companies pay more attention to applied research. There is a general knowledge gap between the two. These characteristics constitute the background of knowledge flow. The biggest gain of cooperation between enterprises and external organizations is to make full use of the innovative resources brought about by the complementary of knowledge. Enterprises can often cooperate with universities, research institutions, suppliers, customers, and other institutions through resource sharing and complementary advantages innovation.

U-I collaboration based on knowledge interaction

Meyer-Krahmer and Schmoch (1998) demonstrated the mode of U-I interaction from different disciplinary perspectives and scientific and technological fields. Schartinger et al., (2002) also proposed that the knowledge relationship between universities and enterprises is more and more important than traditional knowledge transfer. Antonelli (2008) proposed that the knowledge relationship between universities and enterprises includes knowledge exchange and knowledge interaction. Santoro and Chakrakarti (2002) pointed out that there are usually four basic modes of U-I collaboration, each representing a different degree of interaction between enterprises and universities; Hall and Graham (2004) proved that two enterprises participate motivation for cooperation. One is to obtain complimentary research activities and results, and the other is to obtain important personnel from the university (Table 2.5). Selective cooperation between companies and university research centers can often promote the advancement of knowledge and the production of new technologies. Large enterprises in resource-intensive industrial sectors often use knowledge transfer and research funding to build capabilities in non-core technical fields. In contrast, smaller and flexible high-tech companies focus on solving related problems in core technology fields through technology transfer and cooperative research (Geuna et al., 2003). Some scholars once evaluated U-I relationship as an innovative tool that supports great social change, and it transcends the specific needs of universities and certain specific technical problems of enterprises (Sutz, 2000).

To enhance the U-I linkage and turn it into a true partnership, companies or universities must have a new vision. In the context of globalization, the strategy of changing enterprises has exceeded the capabilities of universities. For universities, the problem is academic planning, and U-I collaboration is generally not taken into consideration. Therefore, the interaction between universities and enterprises will also affect knowledge flow efficiency in U-I linkages.

Table 2.5 Key stakeholders in the transfer of technology from universities to the private sector

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Perspective
University scientist	Discovery of new knowledge	Recognition within the scientific Community-publications, grants(especially if ventured)	Financial gain and a desire to secure additional research funding(mainly for graduate students and lab equipment)	Scientific
Technology transfer office	Works with faculty members and firms/entrepreneurs to structure deals	protect and market the university's intellectual property	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Firm /entrepreneur	Commercializes new technology	financial gain	Maintain control of proprietary technologies	Organic/entrepreneurial

U-I collaboration based on knowledge network

In addition, discussions were conducted around U-I knowledge flow at the technical and regional levels. Matching the geographic location information of patent applicants with provinces and cities, and researchers have established a regional-level U-I patent cooperation network which described the situation of knowledge flow from university to enterprises and identified the differences in the role of each region in the flow of U-I cooperative knowledge. U-I collaboration is rooted in innovation network theory, and the two kind of subjects are the most active organizations in innovation networks. The heterogeneous knowledge flow between enterprises and universities is amplified through the network, effectively increasing innovation output. The current university-industry patent cooperation network research has accumulated rich accumulation. Most of these studies focused on the form, characteristics, and evolution of the joint patent network. These include analyzing specific regions/industry/technical fields or a limited sample of universities and enterprises. Bai (2015) found that U-I collaborations in scientific research and technology was beneficial to the development and promotion of regional economy based on the data of provinces from 1998 to 2012 through spatial measurement methods. Fu et al.,(2013) studied the knowledge supply and demand equilibrium model by U-I co-patent data. Hong (2010) explored the characteristics of the knowledge flow network from 1985 to 2004. Lu et al. (2016) passed the US Patent and Trademark Office's 1986-2014 The data researched the characteristics of China's provincial knowledge flow network center; Zhou et al. (2018) focused on the knowledge flow network of the inter-provincial automobile industry through patent data; Liu (2015) based on Guangxi electronic information industry cooperation patent data from 2001 to 2013, empirically explore the knowledge spillovers and the patios temporal evolution path of the innovation network in the electronics industry; Ma et al. (2016) used the 2014 U-I co-patent data in the Zhejiang ICT industry and found that deepening U-I collaborative innovation must play a role in policy guidance. Cui and Huo (2016) discussed the construction framework of the innovation network of knowledge collaboration and flow in industrial clusters.

Through the analysis of the literature on U-I collaboration and knowledge flow, the research on knowledge flow of U-I collaboration can be divided into basic elements, flow elements, and measurement elements three aspects. Among them, the basic elements are the basis for studying knowledge flow between enterprises and universities (Figure 2.2). The flow element is a process characteristic, and the measurement element is a measure of flow efficiency. We can determine different research objects based on the different combinations of basic elements, flow elements, and measurement elements to solve collaborative problems and improve the performance of U-I collaboration.

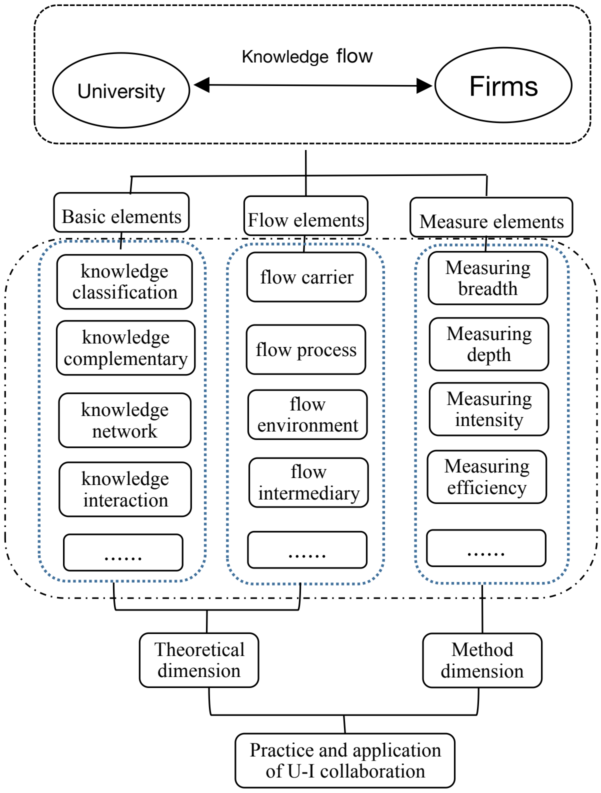
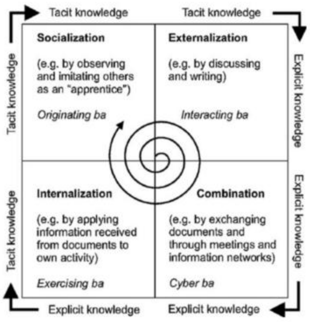
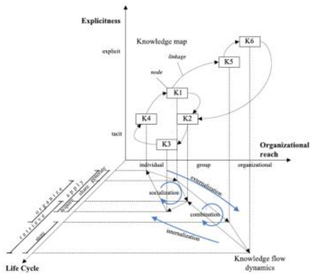
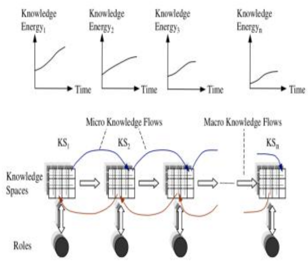
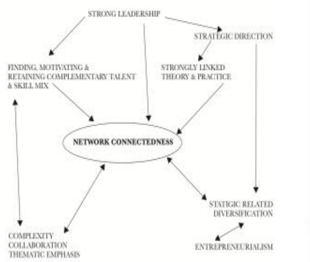
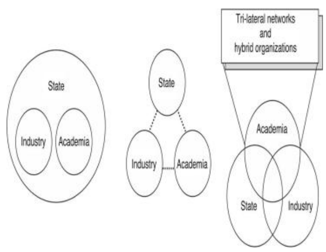


Figure 2.2 Research Framework of University-industry Collaborations

U-I knowledge flow based on theoretical model

The represented theory of knowledge flow is the SECI model proposed by Nonaka (1995). It emphasized the knowledge flow within the organizations. The "Mode-2" knowledge production model of Gibbons et al. (1994) and the national innovation system theory of Nelson (1993) pointed out that the realization of innovation is the result of the nonlinear effect of multiple factors and the joint integration. Etzkowitz et al. (2000a) described a government-industry-university triple helix innovation thought further clarified the interaction mechanism between innovation subjects and the dynamic mechanism of continuous innovation of multiple issues. They proposed applying a knowledge spiral nonlinear interactive model that is conducive to the creation, transformation. This article sorts out the more representative models in different fields, interprets their principles/essences, and summarizes the models' characteristics on this basis, as shown in Table 2.6.

Table 2.6 Theoretical model of U-I knowledge flow

Model	Principle	Schematic	Characteristics
SECI model (Nonaka, 1995, P62)	Explicit and tacit knowledge flow between knowledge subjects at different levels through the four stages of socialization, externalization, combination and internalization, and finally realize a spiral of knowledge.		Focus on explicit and tacit knowledge and the interactive relationship, revealing the beginning and end of creation of knowledge;recognizing the production model category.
Knowledge dynamics-integrated map (Dong. et al.,2018)	Explicit and tacit knowledge complete socialization, externalization, and grouping within synthesis and internalization cycle process from three-dimensional space of the degree of dominance, the scope of the organization and life cycle		Expand the life cycle dimension on the basis of the SECI model, and visualize it in a three-dimensional view to present the dynamic characteristics of knowledge flow.
Knowledge spiral model (Zhuge,2006)	When knowledge flows in the network, it will form a knowledge spiral, that is, knowledge flows between inside and outside nodes.		It can not only show the process of knowledge transfer between members of the organization, but also reflect the process of knowledge creation (abstraction, analogy, synthesis, reasoning, etc.).
Mode-2 (Gibbons,1994 Harvey,2002)	Interdisciplinary knowledge production involving multiple expert fields, establishing and solving problems in an application-based background. Innovation is regarded as the transformation of existing knowledge to new situations.		The realization of innovation is the result of the non-linear effects of multiple factors and joint integration, and the cooperation between subjects can promote the development of innovation.
Triple-Helix model (Etzkowitz, 2000)	The balanced model of Triple Helix "from two opposing perspective:the nationalist model of government controlling university and industry, and a laissez-faire model which industry, university and government are separated with each other and only modestly interact across strong boundaries" .		The Triple Helix model shapes "Innovation in Innovation" that is an enhancement in the conditions that produce knowledge-based innovation

2.3 Multidimensional Proximity

2.3.1 Proximity and its dimensional expansion

Proximity refers to the "proximity" or "similarity" between individuals in specific aspects. The proximity concept covers many aspects (Amin & Wilkinson, 1999; Gilly & Torre, 2000). It includes two types: subjective recognition and proximity, such as social proximity and technological proximity. Emphasizing the individual's subjective feelings based on objective distance is a sense of "distance" proximity (Torre&Rallet, 2005); the other type of proximity in the actual spatial distance like geographic proximity.

Generally speaking, proximity is intuitively referred to as geographic proximity, that is, the innovation subject is very close in space. Regarding the role of geographic proximity in promoting knowledge interactive and collaborative innovation, an easily accepted view is that "knowledge spreads between corridors and streets more easily than across oceans and continents". Scholars generally agree that geographical proximity between innovative actors is an important factor in promoting cooperative innovation (Mansfield & Lee, 1996; Kapetaniou & Lee, 2019; Amidi & Fagheh Majidi, 2020). The convenience of communication and mutual trust brought about by the geographical proximity of innovation subjects makes it easy to establish cooperative innovation relationships, promoting innovation performance better. However, with the globalization of the economy and the development of information and communication technology and modern transportation infrastructure, the cooperation between innovative entities is often cross-regional or even transnational (McKelvey et al., 2003; Mora-Valentin et al., 2004; Ponds et al., 2010).

In today's highly developed network communication, in addition to face-to-face communication between innovative subjects, there are many interactive methods to choose, such as email, video conferencing, and collaborative innovation network platforms. Therefore, in these contexts, whether geographical proximity is still necessary has been repeatedly discussed. Whether geographic proximity is a decisive factor for cooperative innovation or whether other factors can complement geographic proximity has been studied in many kinds of literature (Adams et al., 2005; Broström, 2010; Laursen et al., 2011). Among them, the 'French proximity school' introduced multi-dimensional proximity. It proposed that geographic proximity cannot be used in isolation to explain the formation of partnerships and that proximity in other dimensions has no less effect on promoting interactive learning and innovation than geographic proximity (Torre & Gilly, 2000). Boschma (2005) further elaborated the proximity of various dimensions (geographic proximity, cognitive proximity, institutional proximity, organizational proximity, social proximity) and believed that proximity and geographic proximity could be substituted or complementary. It is neither a sufficient condition nor a necessary condition for cooperation by geographic proximity itself.

However, in a large number of studies, there is no clear boundary between the proximity of different dimensions. For example, organizational proximity is defined as the same relationship space from the perspective of the relationship. It is regarded as having similar customs, customs rulers, and legal rules from the system's perspective. The former is not essentially different from social proximity, while the latter is similar to institutional proximity (Nam, 2015). Similarly, social proximity is considered in the narrow sense as the closeness of social relations between individuals (Coenen et al., 2004), reflecting the basic meaning of social proximity. In a wide sense, it is defined as the similarity of social behavior patterns based on social relations and accompanying regulations, customs, and other social environment factors. This lacks essential differences between institutional proximity and organizational proximity (Miguelez & Moreno, 2014). In addition, although technical proximity and cognitive proximity are different in definition, they are often mixed in research. De Wit-de Vries et al. (2019) found three factors: cognitive differences, differences in goals, and social capital, affecting inter-organizational knowledge transfer. This study is based on three more obvious types: geographic proximity, technological proximity, and social proximity to exploring cross-regional industry-university collaboration. These scholars' research opened up new perspectives for interactive learning and innovation and laid the foundation for empirical research in this field.

Proximity is considered a variable that quantifies the formal space. The individual's spatial dimension is identified and measured by continuous indicators, reflecting the knowing subject's closeness in the geographical space, relational space, and knowledge structure space. Geographical proximity characterizes the degree of embedding of knowledge subjects in geographic space, and social proximity characterizes the degree of embedding of knowledge subjects in relational space. It mainly analyzes individual social factors in knowledge interaction activities (Hubert,

& Lopez, 2013). Technological proximity represents the degree of individual embedding in the technological space, reducing the two interacting parties' cognitive costs (Escribano et al., 2009). The degree of embedding in multiple spaces such as spatial embedding, relational embedding, and individuals' structural embedding helps to solve the flow of knowledge. The uncertainty and legitimacy issues in the process can agglomerate in different spatial dimensions and impact economic development within and outside the region.

2.3.2 Proximity and collaborative innovation

Geographic proximity

Geographic proximity is one of the most frequently studied dimensions in proximity research because the study of geographic proximity has a large amount of knowledge spillover, geographic limitation studies, and industrial cluster research literature as the research basis. And the geographical proximity is not so abstract and relatively easy to be defined and measured as far as the other dimensions' proximity. Regarding the effect of geographical proximity on cooperative innovation, the views are mainly focused on two aspects:

The study of "promotion theory" on geographical proximity. The main argument is that knowledge is divided into explicit knowledge and tacit knowledge. The greater the strength of tacit knowledge in the innovation process, the greater need for face-to-face communication and contact. Face-to-face communication is considered the most basic of geographical proximity. Therefore, geographical proximity is more important. Many literary studies have shown that geographic proximity is an important factor in promoting cooperation and innovation between organizations. This research sorts out the more representative studies (shown in Table 2.6). These studies affirm the positive effect of geographical proximity on cooperative innovation. Katz (1994) researched on public publication data; the findings showed that the frequency of scientific research cooperation between universities decreases exponentially as the distance increased. Mansfield et al. (1996) found that companies are more inclined to cooperate with researchers from local universities within 100 miles of the corporate R&D center. Hoegl and Proserpio (2004) studied the role of team-level geographic proximity. Based on research data on software development teams, they found that geographic proximity between team members significantly affects teamwork quality. Petruzzelli (2011) studied on patent applications jointly by enterprises and universities shows that geographical proximity has a significant impact on industry-university cooperative innovation performance. It can be known from literature research that most studies focus on micro-levels such as enterprises and other research organizations. Still, some scholars also study the role of geographic proximity at the regional level. Ejermo and Karlsson (2006), Maggioni and Uberti (2009) also show that geographic distance significantly impacts regional cooperation and innovation in the European area. Marek et al., (2017) explored the impacts of proximity on knowledge exchange. The results discovered that not only geographical but also other forms of proximity (technological, organizational and institutional) have a significant influence on R&D collaborations. Abramo et al., (2020) found that the geographic distance continues to play a role in the process of knowledge flows. They showed that the effect of geographical proximity was continuous, and there was no cut-back tendency to cooperate with geographically nearby partners.

"Uselessness"opinions on geographical proximity. With the development of information and communication technology and modern transportation infrastructure, highly efficient interactive learning and collaborative innovation can also be carried out between long geographical distance subjects. In view of the importance of geographic proximity to transfer of tacit knowledge, ICT can provide a powerful way to transform tacit knowledge into coded knowledge, thereby increasing the possibility of long-distance cooperation. In addition, there is another view that the partners do not need to be geographically closer all the time during the cooperation process. Temporary geographical proximity such as meetings and short visits can meet the needs of cooperation and exchanges. Short-term face-to-face communication and long-distance cooperation are the norm for many cooperative innovations (Torre & Rallet, 2005). Mora-Valentin et al. (2004) on Spanish industry-university-research cooperation projects, Bercovitz and Feldman (2011) on cooperative innovation teams, and Schwartz et al. (2012) on German cooperative R&D projects, those conclusions are that the performance of geographical proximity on cooperative projects impact is not significant (Table 2.7).

Table 2.7 Positive effect of geographical proximity on U-I collaboration innovation

Author	Data source	Research objects	Dependent	Independent	Conclusion
Katz (1994)	SCI public publication data of universities in the UK, Canada, and Australia	university and university within the country	Number of university collaborations within each country	-geographical proximity	supported
Mansfield,Lee (1996)	A survey of 70 corporate R&D executives from seven industries in the United States	Enterprise and University	The ratio of R&D expenditures of enterprises to universities	-geographical proximity -university quality	supported

Hoegl,Prosepio (2004)	430 team leaders and members of 145 software development teams in Germany	Innovation project team	Quality of team work	-geographical proximity between team members	supported
Singh (2005)	USPTO patent citation data	Innovators who jointly apply for patents	References between patents	-past cooperation belonging to the same region	supported
Ejermo,Karlsson (2006)	EPO database	Cooperation between regions	Attractiveness of regional cooperation	-traffic time -regional population -regional R&D	supported
Gittleman (2007)	112 scientific and technological papers published by American biotechnology companies	Cooperation between enterprises and other organizations	Technological innovation	-geographical proximity -partner reputation	supported
Maggioni,Uberti (2009)	110 FP5 collaborative research network data in NUTS2 regions from five European countries	Cooperation between regions	Participation in the FP5 collaborative research network	-geographic distance -functional distance -industrial distance	supported
Petruzzelli (2011)	Data of 796 patent applications from 33 universities in 12 European countries	Enterprise and University	Cooperative innovation performance	-geographic distance -technology relevance -past contact	supported
Wei Hong (2013)	Patent data from 1985 to 2004 in the database of China Intellectual Property Office	Enterprise and University	Whether there is a cooperative relationship between the enterprise and the university	-geographic distance -organizational proximity -institutional proximity -university reputation	supported
Marek et al., (2017)	Granted research and development (R&D) collaboration projects in German NUTS-3 regions	R&D collaborations	Knowledge exchange of R&D collaborations	-geographic proximity -technological proximity -organizational proximity -institutional proximity	supported
Abramo et al., (2020)	Citations to scientific publications in Italy in the period 2010–2012.	Enterprise and University	Cooperative knowledge flow	-geographic distance -national proximity	supported

Technological proximity

There are relatively more empirical studies on technological proximity because technological proximity methods are more mature, and data are easier to obtain. Mowery et al., (1998) studied the relationship between technological proximity and cooperative tendency. The results showed that the relationship between technological proximity and the cooperative tendency is an inverted U-shaped. Cantner and Meder (2007) studied the relationship between technological proximity and cooperative propensity. The results showed that the closer the technological foundations between enterprises, the more likely they are to establish cooperative relationships. Sampson (2005) and Petruzzelli (2011) are respectively based on the technology relevance measurement method proposed by Jaffe (1986), that is, using the technology classification information in patent data to measure the proximity of the two subjects in the technology space. Branstetter et al. (2002) used the similarity of patent portfolios to measure technological proximity. The results showed that the influence of technological proximity on the output of innovation alliances is positive. Shkolnykova (2020) took German biotechnology SMEs as objects and made a longitudinal dataset covering the period from 1996 to 2016 for the innovative performance of SMEs. The findings showed that the effect of technological (cognitive) proximity could not be confirmed.

Social proximity

The study of social proximity is generally closely linked to the study of social networks. For example, Saxenian (1994) thought that what is important for interactive learning is not simply coexisting geographically but that enterprises actively embedded themselves in the regional network by establishing partnerships with other subjects. Breschi and Lissoni (2003) found that the socially embedded relationship between innovators plays an important role in the process of knowledge spillover. Agrawal et al. (2006) proposed that contacts and connections between companies are often due to their employees working in the same unit in the past. Whittington et al. (2009) used longitudinal data of the US companies in regional clusters to show that companies' centrality in the regional network positively affects their patents.

It is worth noting that a large amount of research literature directly focuses on the impact of previous cooperation experiences on subsequent cooperation between organizations (see Table 2.8). The view that past cooperation experience will significantly increase the possibility of future cooperation has been confirmed by some scholars (Gulati, 1995; Bruneel et al., 2010; Bercovitz & Feldman, 2011). Past studies have shown that companies with previous cooperation experience will form a relationship capability, thereby enhancing their ability to benefit from future cooperation (Anand & Khanna, 2000; Kale et al., 2002).

However, some studies do not support the positive influence of collaorbative experience on subsequent research cooperation. Hoang and Rothaermel (2005) used the cooperative relationship data between large pharmaceutical companies and biotechnology partners to study the influencing factors of cooperative R&D project performance. Dyer and Hatch (2006) researched results on the US cooperative R&D projects also do not support the positive influence of previous cooperation experiences on cooperation results. Schwartz (2012) studied the influence of past cooperation experience on innovation outputs from 417 cooperative R&D projects in Germany. The results showed that past cooperative experience had no significant influence on innovation output. And with the increase of past alliance (cooperation) experience, the probability of successful cooperative projects is reducing instead.

Table 2.8 Prior cooperation experience and collaborative innovation

Author	Data source	Research objects	Dependent	Independent	Conclusion
Gulati (1995)	Data from 166 large companies in the three major industries of the United States, Japan and Europe	Among enterprises	The possibility of forming a cooperative alliance between enterprises	-alliance experience in the past	supported
Kale (2002)	1572 alliance data for 78 companies	Enterprise and University	Alliance performance	-alliance experience in past	supported
Mora-Valentin (2004)	Investigation on Spanish National Industry-University Cooperation Project	Companies and research organizations	The success of R&D cooperation projects	-past experience -geographic distance -organization reputation	supported
Hoang,Rothaermel (2005)	Data on partnerships between large pharmaceutical companies and biotechnology partners	R&D alliance between enterprises	The success of R&D cooperation projects	-cooperation experience with specific objects	Not support
Sampson (2005)	Data of 464 R&D alliances of 487 companies in 34 countries	R&D alliance between enterprises	Innovation performance	-collaborative experience in the past	supported
Singh (2005)	USPTO patent citation data	Innovators who jointly apply for patents	References between patents	-past cooperation belonging to the same region	supported
Dyer (2006)	Investigation of cooperative R&D projects supported by the US ATP project	R&D alliance between enterprises	The success of the cooperative project	-cooperation experience with specific objects -geographic distance	Not support
Kim,Song (2007)	Enterprise alliance data of the pharmaceutical industry in the SDC database	Alliance between companies	Cooperative patent	-alliance experience in the past -technical proximity	supported
Bruneel (2010)	Investigation on the cooperation projects funded by EPSRC in the UK from 1999 to 2006	Enterprise and University	Barriers to cooperation	-collaborative research experience in the past	supported
Petruzzelli (2011)	Data of 796 patent applications from 33 universities in 12 European countries	Enterprise and University	Cooperative innovation performance	-geographic distance -technology relevance -past contact	supported
Schwartz (2012)	Data on 417 funded cooperative R&D projects in Germany from 2000 to 2006	among companies or between companies and universities	Innovative output of cooperative projects	-past cooperation experience -geographical proximity -partner type -project scale	Not support

2.4 Summary

University-industry collaboration has become an important source in the regional innovation system, and the main form of U-I linkage is to shape the innovation performance through knowledge flow. Existing studies have divided the process of U-I knowledge flow into several stages and explored the motivations and influential factors of the cooperation, but most of the studies did not clarify the direction of knowledge flow. The U-I knowledge flow is a two-direction flow. One way is that the university is the source of new knowledge and flows to the enterprise to improve innovation performance. The main purpose is to improve the innovation ability of enterprises and regions. The other way is the flow process taking enterprise as the source of new knowledge, flowing into universities and integrating the production and education. Most of the research proposed the U-I collaborative training model, inviting entrepreneurs to hold lectures or arranging students to get an internship in an enterprise. The main task is to enhance the training quality. This research takes the function derivation of the university as the entry point. Therefore, it focuses on the U-I collaboration where the university is the starting point flow to the enterprises.

On the other hand, from the perspective of research objects, most of the research on the proximity perspective of U-I knowledge flow focuses on the analysis of proximity effects, and less attention to inter-regional U-I collaboration. Guided by the triple helix theory, the regional context is also an important factor affecting U-I knowledge flow. Most works discussed the relationships of proximity on U-I collaborations at the individual or organizational levels, lacking of cross-level analysis from an organizational and regional perspective. At the same time a number of previous studies took the European Union, the US, and Italy etc., as samples, ignoring regional heterogeneity may lead to estimation errors.

Then, this research prefers to discuss the U-I knowledge flow from a proximity perspective by a cross-level analysis, considering the regional endowments and enterprises' role based on knowledge flow direction. The remainder of this thesis comprises six chapters. Chapter 3 and 4 propose the mechanism and spatial trend to understand the U-I knowledge flow. Chapter 5 and Chapter 6 provide the main effect of multidimensional proximity on cross-regional U-I collaboration, the moderating impact of regional and enterprises' absorptive capacity and regional heterogeneity. Chapter 7 illustrates the strategies and provides the policy implications. Finally, Chapter 8 concludes this thesis with future research.

Chapter 3
The knowledge flow mechanism from university to enterprise in regional context

Through the literature analysis in Chapter 2, the research objects of proximity are mainly concentrated on certain industrial areas with the characteristics of regional agglomeration, and insufficient attention has been paid to the role of proximity in inflow regional knowledge and ignoring the inflow subject absorptive capacity. At the same time, some important research issues of U-I collaboration, such as the theoretical compatibility of the different location context of knowledge flow mechanism and the law of change under the network embedding have not been included in the multidimensional proximity research field. The integrated analysis framework of U-I collaborative knowledge flow under the regional context has not yet been formed. Therefore, we embed the regional context into the research framework, and discuss what the proximity effects on U-I knowledge flow would like in different regional context. If the locations of the university and enterprises are in same region, we define it as "local" regional context, otherwise, we name it "non-local" regional context. Specially, this chapter aims to propose an integrated analysis framework for U-I collaboration flow in the context of "local" and "non-local" regional context. It will be helpful to understand the interactive between actors of U-I knowledge flow.

3.1 Proximity characteristics of U-I collaborative knowledge flow

Due to the organizational heterogeneity of universities and enterprises, universities must establish a good cooperative relationship with them for three levels of knowledge flow, and it may be better to conduct knowledge exchanges. Therefore, from the literature analysis in the previous chapters, we can see that geographical, technological, and social proximity have different effects on improving the U-I linkages innovation performance based on the characteristics of knowledge. In the process of knowledge flow in U-I collaboration, knowledge production, as innovative activity, basically occurs at some special "points." In contrast, knowledge spillover, as an external mechanism unconsciously generated by human economic activities, has spatial and interactivity (Bunnell & Coe, 2001). This kind of externality is manifested in the role of a barrier or "lubricant" played by human and natural elements such as culture, system, social relations, and technological foundation on the flow of knowledge. They emphasized a regional innovation model of spillover and anti-spillover, learning and anti-learning formed in the "center" and "periphery" of innovation, making innovation present significant spatial and regional heterogeneity and deriving innovation systems. The arrangement also has a certain scope of application. Therefore, the study of knowledge flow should take space and region as the carriers, and closely focus on the main line of "the agglomeration of knowledge production-knowledge spillover and absorption-regional balanced development," and comprehensively analyze the impact of human factors and economic geography on the innovation system, and the impact of the socio-economic system. Therefore, combining the spatial factors of proximity, the U-I collaborative knowledge flow's multidimensional proximity characteristics are analyzed with basic, system and strategic flow, as shown in Table 3.1.

Table 3.1 Proximity characteristics of knowledge transfer evolution in the process of UIC

Proximity feature	Hierarchical characteristics of knowledge flow	Flow efficiency
Geographical,Technical, Social proximity	Basic knowledge flow	Knowledge spillover and diffusion
	System knowledge flow	Knowledge absorption
	Strategic knowledge flow	Knowledge internalization

3.2 Two-stage division of knowledge flow in U-I collaboration

Knowledge flow is the process of spreading knowledge from the source of innovation to the end of innovation (Sorenson et al.,2006). In the collaborative innovation, knowledge flow is transferred and updated between the innovation subjects, and in the transfer update, the original innovation subject is expanded. Nonaka et al. (2000) proposed the SECI knowledge spiral model, which described the dynamic process of the interaction between tacit and explicit knowledge. That is, by creating an interactive "Ba" and then triggering the transfer and coding of knowledge through dialogue and collective reflection, and then forming organizational knowledge through combination and internalization. It realizes the interactive transfer and creation of knowledge at all levels of individuals, groups, organizations, etc. through SECI model. Gilbert and Cordey-Hayes (1996) proposed a five-stage model of knowledge transfer by analyzing knowledge transfer behavior between organizations, namely knowledge acquisition, knowledge exchange, knowledge application, knowledge acceptance, and knowledge assimilation. The other type is the model after relevant constraints on knowledge. That is, the process of knowledge transfer is discussed at a specific level. Szulanski (2000) put forward the knowledge transfer model, which explored knowledge transfer within an organization and divided the development process of knowledge transfer into four stages: initial, implementation, adjustment, and integration. These research have found the different characteristics during the flow process, however, they ignored the direction when knowledge flow between university and enterprises.

U-I collaboration and innovation is to give full play to the role of enterprises, universities and colleges, effectively combine the advantages of various subjects, carry out different divisions of labor for each subject, conduct joint development and research, and form knowledge complementary between actors to form adequate communication and exchanges between the actors. It is precise because of this labor division that the supply and demand sides of knowledge elements are produced. Universities provide a good knowledge environment for R&D and innovation of enterprises to freely absorb and apply this knowledge. While enterprises need to transform R&D knowledge into products or services, they also need to strengthen the absorption, utilization, and transformation of external knowledge. The knowledge continues to circulate among the innovation subjects and jointly promote the further development of U-I collaboration. Enterprises need to use the knowledge and technological advantages from university through the process of U-I linkage to realize their own economic benefits. This has made the firms become the demand side of knowledge. Universities rely on their own advanced technological knowledge advantages to continuously meet the enterprise's development needs and become the supplier of knowledge. Through this flow of knowledge, both parties establish contracts and develop together.

Based on this analysis, the article divides the knowledge flow of U-I collaboration into two stages. One is the outflow stage of knowledge innovation; the other is the inflow stage of knowledge application. The outflow of knowledge innovation includes the spillover and diffusion of knowledge, the process of socialization and externalization of knowledge, and the inflow of knowledge application includes the absorption and integration of knowledge. It is the process of combining and internalizing knowledge and ultimately obtaining the knowledge or technology required for innovation to realize knowledge complementary and sharing (Figure 3.1).

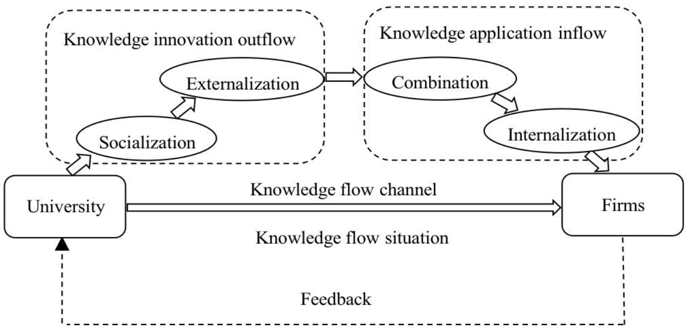


Figure 3.1 Two stages of U-I knowledge flow

3.3 U-I knowledge flow mechanism in "local" regional context

Multidimensional proximity is affected by spatial factors such as regions. If the location of the university and enterprises are in the same region, we define it as "local"regional context, otherwise, we name it "non-local" regional context. We will discuss the mechanism of U-I collaboration's knowledge flow in different context. U-I collaborative innovation is a more complex concept. It specifically refers to giving full play to the comparative advantages of different actors such as enterprises and effectively utilizing the resources at the subjects' hands. With the cooperation of relevant external entities, the universities and the enterprises coordinated development and jointly carried out related technology and innovation activities.

In local regional context, the first step of U-I Knowledge flow is to cross the organizational boundaries and continuously circulates among the innovation subjects, effectively exerting knowledge "externalities" and "spillover effects", increasing knowledge and ultimately forming knowledge advantages. It takes the value chain effect of knowledge spillover as the main point of view to construct the framework of U-I collaborative knowledge flow.

From the innovation value chain perspective, the innovation process can be divided into different stages, and value chain spillover effects exist between each stage. The concept of the innovation value chain was first proposed by (Hansen & Birkinshaw, 2007). They regarded the innovation process as a three-stage process, including creative generation, creative development, and innovation dissemination. Based on the research of Hansen et al. (2007), took into account the differences in innovation subjects, this article divides the knowledge innovation process into two stages: knowledge innovation outflow (I) and knowledge application inflow (A). In the knowledge innovation stage, research is carried out to obtain new knowledge to promote basic science and technology development. The initial input (X_i) forms an intermediate output (Y_a) through the knowledge innovation stage, part of which ($Z_{(i,\ a)}$) is used as the input of knowledge application, and the other part (D) flows directly into the innovation system. The innovation subject at this stage usually is universities. The knowledge application stage introduces new knowledge into the business application field. It inputs (X_i), including intermediate input (F) and part of the intermediate output of the knowledge innovation stage ($Z_{(i,\ a)}$) to form the final output

(Y_a). The subject of innovation at this stage is usually the enterprise. Since knowledge transfer is a process of knowledge flow, this research's knowledge transfer mechanism still works. The process of knowledge feedback from enterprises to universities and research institutions is introduced to form the entire cycle of knowledge flow. In this cycle, if knowledge characteristics are different, its flow also has different path patterns. For example: when the tacit knowledge is transferred, the knowledge conversion will go through socialization ⟶ externalization⟶ combination⟶ internalization. When the transfer is explicit knowledge, knowledge conversion will go through the path of combination ⟶ internalization. However, regardless of the mode of knowledge flow, it ultimately needs to enter the enterprise in an internalized way and complete the entire knowledge transfer process by providing feedback to academic research (see Figure 3.2).

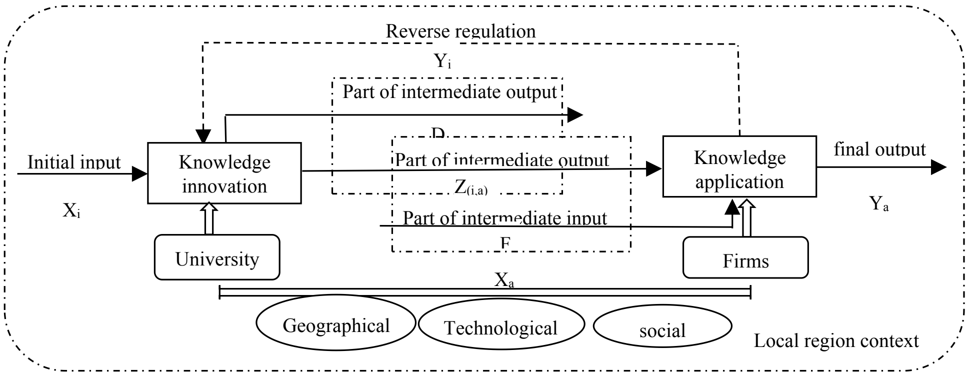


Figure 3.2 "local context" of U-I knowledge flow

In general, within the localized knowledge network, the effect of geographic proximity is significant. The gathering of individuals in a specific geographical space will form a localized social network based on kinship and rural ties and encourage individuals to form a more consistent technical language and technological development trajectory through technical cooperation and knowledge spillover. These gatherings can greatly improve the technology level in the short term. The efficiency of sharing thereby promotes the knowledge flow. And the influence of social proximity and technological proximity will be significantly strengthened. Therefore, the comprehensive effect of multidimensional proximity usually depends on the degree of combination of geographical proximity and social proximity, that is, the localization of the relationship network and the resulting positive effects of trust and regulation in the process of knowledge flow. Simultaneously, technical proximity will adjust the effects of other proximity in different stages and directions (see Figure3. 3). Based on the above analysis, the propositions formed are as follows:

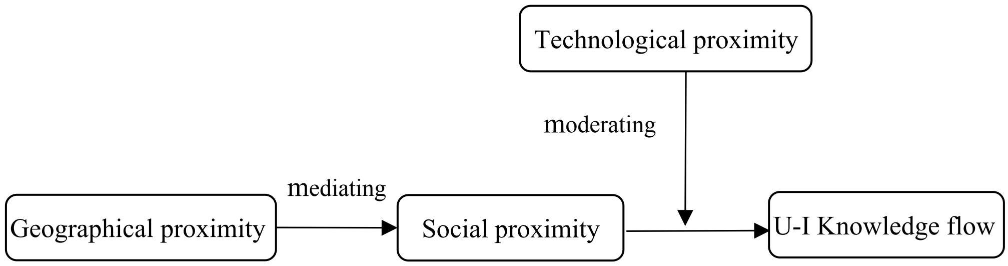


Figure 3.3 The multi-dimensional proximity of U-I collaborations in local context

Proposition 1: Under the local context, geographical proximity play a leading role in the knowledge flow of U-I collaborations,

Proposition 2: Social proximity in the local context play a mediating role in the relationship between geographical proximity and the local university knowledge flow, and

Proposition 3: In the local context, technical proximity dynamically adjust other factors' influence in local knowledge flow.

3.4 U-I knowledge flow mechanism in "non-local" regional context

For cross-regional U-I knowledge flow, after over the organizational barriers, the knowledge innovation also need to cross the regional boundary. Hence, we should consider the proximity spatial effects on these kinds of flow. The flow of innovation elements between regions leads to spatial correlations, and the interaction between regional innovations is called the spatial spillover effect. As shown in figure 3.4, there is a spatial spillover effect between any regional knowledge innovation and the other regional knowledge innovation and knowledge application. There is a value chain spillover effect between the knowledge application in this region. Similarly, there is a spatial spillover effect between regional knowledge and other regional knowledge innovations and applications. There is a value chain spillover effect between knowledge innovation in this region.

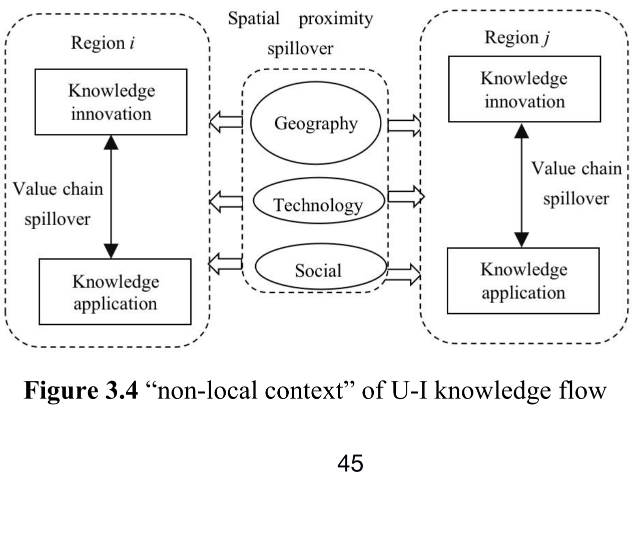


Figure 3.4 "non-local context" of U-I knowledge flow

Knowledge interaction in non-local contexts is usually carried out under relationship or technology orientation. The cultural and technical conditions attached to a specific area are quite different, and the basis of geographical proximity is relatively weakened. Under the guidance of relationships, the long-distance knowledge flow is mainly affected by social proximity based on relationships such as collaboration and cooperation and is regulated by technological proximity. Generally speaking, in the early stage of technical cooperation of running-in, even if the relationship is close, the negative impact of spatial distance will be relatively significant due to the small technical proximity between knowledge subjects. However, once university and enterprise form a mutually understandable technical language in the long-term cooperation, their technical trajectories will get closer and closer, and even short-term frequent contacts (project cooperation, meetings or employee clubs, etc.) will effectively reduce the cost of knowledge exchange and thereby promote the long-distance knowledge flow. Technology-oriented knowledge exchange can occur between closely related knowledge subjects or between individuals with greater technological complementary. In the former case, social proximity will enhance industry-university cooperation in the relationship between technological proximity and knowledge flow. In contrast, geographic proximity will negatively regulate in the short term. In the latter case, due to the lack of a solid foundation of social relations, reducing the cost of knowledge exchange between knowledge subjects mainly depends on the technology-shared language accumulated by both parties over time. Its sustainability depends on the positive effect of technological proximity and the relative magnitude of geographic proximity's negative effects. Once geographic separation plays a leading role in hindering knowledge flow, technology-oriented knowledge flow will become unsustainable due to rising costs (see Figure 3.5).

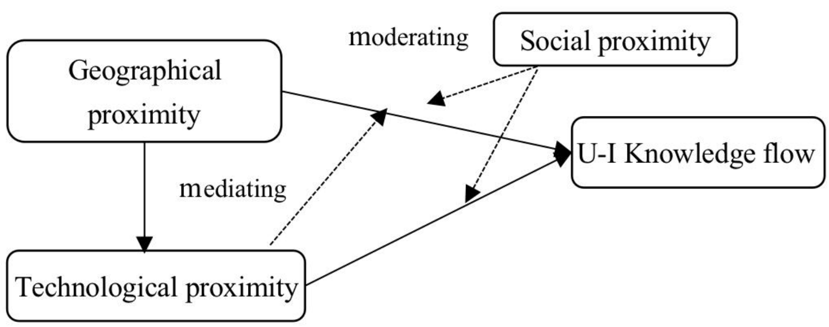


Figure 3.5 The multi-dimensional proximity effects of U-I collaborations in non-local context

Based on the above analysis, the propositions formed are as follows:

Proposition 4: In a non-local context, geographical proximity and technological proximity together play a leading role in the knowledge flow of U-I collaborations;

Proposition 5: Technological proximity in non-local context play a mediating role in the relationship between subjective factors and U-I knowledge flow, and

Proposition 6: Based on non-local situations, social proximity dynamically adjust other factors' influence in the flow of local knowledge.

3.5 The role of absorptive capacity on two effects of U-I knowledge flow

In the "local and non-local" context, we analyzed the local context's value chain effects and the spatial spillover effects in non-local context. We pointed out that multidimensional proximity plays an important role in the knowledge spillover in the stage of knowledge innovation outflow. Multidimensional proximity can take advantage of the knowledge gap between universities and business entities to promote knowledge flow. However, innovation performance is affected by innovation spillovers and the stage of knowledge application. At the knowledge application inflow stage, whether the new knowledge can be applied or not will depend on regional absorptive capacity. Following the regional absorptive stage, new knowledge flow into the absorptive region. Absorptive capacity plays an important role in the efficiency of U-I collaborations. It determines the extent to which a region can transform space spillovers and value chain spillovers into the region's ability to improve innovation efficiency. The effect of absorptive capacity is shown in figure 3.6. In the figure, the knowledge innovation efficiency of region *i* is taken as an example. The knowledge application stage of region *i* produces value chain spillovers to this region's knowledge innovation stage. The effect of spillovers and value chain spillovers on the efficiency of regional *i* knowledge innovation is affected by absorptive capacity. Similarly, the knowledge innovation stage and knowledge application stage of region *j* produce spatial overflows to the knowledge innovation stage of region *i*. The absorptive capacity also plays a crucial role in the spillover effects.

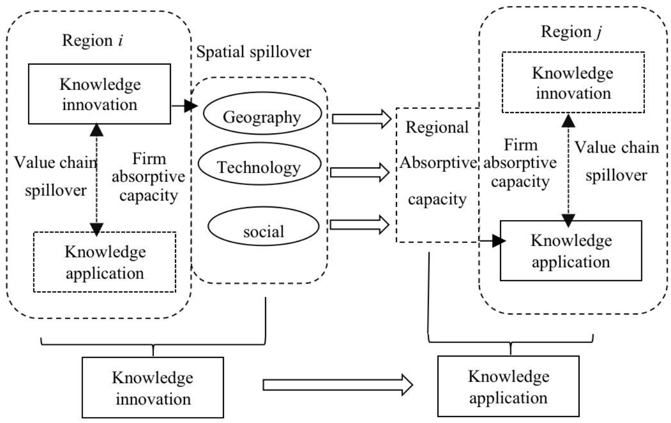


Figure 3.6 The effects of absorptive capacity on UIC knowledge flow

3.6 Summary

In conclusion, the comprehensive effect of multidimensional proximity results from the interaction that evolves with contextual conditions and time stages. With the changes in the evolutionary stage of knowledge networks, local knowledge exchange and cross-regional knowledge interaction are intertwined. The influence of local and non-local contextual factors in the process of enterprise knowledge acquisition will alternately change, leading to changes in the role of proximity. Starting from the overall framework of multidimensional proximity, combined with specific context conditions, we can accurately understand the outflow and inflow mechanism of U-I collaborative activities. The innovation process is not a simple one-time input-output process. It contains multiple stages and multiple elements. Each stage is relatively independent and interrelated, forming a dynamic innovation process. Innovation spillover is manifested in spatial spillover and value chain spillover. Spatial spillover is embodied in different regions, and value chain spillover occurs at different stages of the innovation process. As for the knowledge application inflow stage, the extent of spatial spillover effects and value chain spillover effects are affected by the absorptive capacity of region and enterprises. In regions with different absorptive capacities, the same innovation spillover effects have different impacts on innovation efficiency. Regions and enterprises with stronger absorptive capacity can better achieve innovation efficiency improvements. We will test the multidimensional proximity and the regional resource endowments and enterprise's absorptive capability effects by statistic method.

Chapter 4
The spatial trend of University-Industry knowledge flow

Regional innovation theory has great significance to local economic development, technology promotion, and industrial upgrading. The new regional science school advocates that the role of knowledge and information should be emphasized and knowledge and information flow should be regarded as the main forms of the element exchange within and across regions. The role of knowledge flow in regional innovation has attracted more and more attentions. Similar to traditional elements, the need of subjects for seeking advantage source promotes the flow of innovation factors from regions with lower marginal returns to regions with higher marginal returns, which triggers the dynamic trend of cooperative innovation networks and promotes the coordinated development of the entire network. U-I collaborative innovation generates complex spatial interconnections, especially under increasing transportation facilities and advanced information technology. The cross-regional spatial flow and diffusion of innovation elements will become more active. The results in U-I collaborative innovation space connections will also be more complex and have certain structural features.

4.1 Spatial connection of university-industry collaboration

The spatial connection of U-I collaborative innovation can be positive, such as promoting the diffusion and dissemination of innovative elements between regions (Jaffe,1996; Hicks,2001; Bathelt & Cohendet, 2014), by improving regional innovation performance (Bai & Jiang, 2015), or it may have difficulties when U-I collaboration happened across regions (Owen-Smith, et al., 2002). Therefore, studying the spatial trend of knowledge spillovers and U-I collaboration flows has positive significance for collaborative innovation performance. Using social network analysis to draw a network map can visually show the trend of the collaborative innovation network's spatial structure. The number of patents applied by U-I collaboration is an important aspect of a country or region's ability to realize innovation and industrial transformation and the main basis for research on knowledge flow. From the existing research, few studies focus on inter-provincial and cross-regional mobility. Therefore, this research adopts the social network analysis method and takes the majors of collaborative patents between universities and enterprises in the cities with the largest number of universities in China's four economic regions as the research objects. This chapter's main purpose is to explore the spatial evolution characteristics of knowledge flow between universities and firms from two dimensions by "local and non-local" context. The main creative points of this chapter are as following:

- The time node of the research is divided into six stages. The cross-regional U-I collaborative knowledge flow tendency is studied from the two-dimensional perspective of time and space.
- Taking the U-I collaborative policy as the background, the research comprehensively examines policy superposition effects on the knowledge flow innovation collaborative network.
- By constructing an "inflow-outflow" knowledge flow innovation network map, it is discovered that some characteristics of knowledge flow, such as the scope are expanding, connotative cooperation continues to deepen, and the overall knowledge flow is gradually moving southward, presenting a "core-periphery" structure.

These findings lay a good foundation for the next chapter to study the reasons for knowledge flow.

4.2 Method

Social network analysis is an important analysis method which can studies social phenomena and social structure from the perspective of relationships. It conducts quantitative research on the network formed by actors gathered by a certain relationship, which provides a feasible way to reveal the complex relationship network between actors. Recently, social network analysis methods have broken through sociological research and have gradually extended to other related fields. Social network analysis software includes UCINET, STOCNET, and PAJEK, among them, UCINET is the most commonly used in social network analysis and is developed by Analytic Technologies. The reasons of this research uses Ucinet 6.18 software for social network analysis is the software includes the NetDraw program, which can be used to analyze one-dimensional or two-dimensional data. On the other hand, it integrates the PAJEK program, which can be used to analyze large-scale networks. Software UCINET 6.1.8 built-in social network analysis program is used to generate social network analysis graphs based on importing relational data to obtain social network analysis index values.

4.3 Data source

When analyzing regional U-I collaborative innovation performance, this research chooses invention patents jointly applied by universities and enterprises as a measurement. It embodies technology transfer between industry and universities. Therefore, to accurately find the main U-I collaborations entitles, the sample of this study is available on the China Patent Data Network (http://pss-system.cnipa.gov.cn/ (accessed on March 19, 2021)). The patent search method is to enter the combination of "university," "company," and the city in the column of patent applicants. The applicant will be used as an unified calculation method. Multiple patents of the same combination applicant will only be counted once. When the applicant is in two or more organizations, the first-ranked school or company's place is used to calculate an U-I collaboration. For example, a certain patent application is the following three organizations, an university in Beijing, an university in Shanghai, and an enterprise in Guangdong. It is considered that this patent is counted as a time of U-I collaboration, with Beijing as its place of residence and a time of knowledge outflow. In contrast, Guangdong counts as a time of knowledge inflow. At the same time, the patent application date is limited to six years, 2013.1.1-2018.12.31. The reasons are: first, the background events of the research are traced. This classification method highlights the characteristics of U-I collaborative tendency. It helps us analyze the driving force of social innovation, the response of U-I collaboration to policy releases, and the effect of research policies (see Table 4.1)—secondly, segmentation technology reduces abnormal fluctuations in annual data. Then, we screen a total of 30 provinces co-patents and analysis the whole knowledge flow network. Following, the study selects ten major cities according to the regional creative ability report in 2019 where domestic universities gather: Beijing, Shanghai, Nanjing, Xi'an, Wuhan, Guangzhou, Chongqing, Shenyang, Hangzhou, Harbin for professional data screening, and collate 6 years of patent panel data to form the final sample of this research (Appendix V and VI).

Table 4.1 Important policy and information explanation of U-I collaboration

Year	Important policy	Information explanation
2008	The General Office of the State Council forwards the notice of the Development and Reform Commission and other departments on several policies to promote the industrialization of independent innovation achievements	Encouraging higher education institutions and scientific research institutions to transfer independent innovation achievements to enterprises; Encouraging scientific research personnel to innovate and industrialize their achievements

	"Guiding Opinions on Promoting the Construction of Industrial Technology Innovation Strategic Alliances"	The main task of the alliance is to organize a series of key issues surrounding industrial technology innovation such as enterprises and universities to carry out technical cooperation; Encouraging enterprises, universities and other organizations to explore multiple, long-term and stable production-university-research integration mechanisms.
2012	The Central Committee of the Communist Party of China and the State Council issued the opinions on deepening the reform of the science and technology system and accelerating the construction of the national innovation system	Strengthen overall planning and collaborative innovation to improve the overall effectiveness of the innovation system.
2016	Notice of the State Council on Issuing and Implementing Several Provisions of the "Law of the People's Republic of China on Promoting the Transformation of Scientific and Technological Achievements"	Promoting technology transfer from research and development institutions and universities Creating a good environment for the transfer and transformation of scientific and technological achievements

4.4 Construction of a knowledge flow network for U-I collaboration

There are mainly two types of knowledge inflow and outflow of the U-I collaboration. This research makes statistics on the patent data of U-I collaboration one by one using the network analysis software UCINET 6.1.8. The first row and column in the matrix represent the provinces A, B, C, D... . And, columns represent the direction of knowledge inflow, a_{ij} represents a time of knowledge inflow, and a_{ji} represents one time of knowledge outflow. The value of each patent cooperation mark “1 ”and sum the numbers. The knowledge inflow and outflow among the provinces will eventually form an U-I collaborative relationship matrix across regions. Then, this research inputs the matrices into the software respectively to get the network map. Figure 4.1 shows the constructive process.

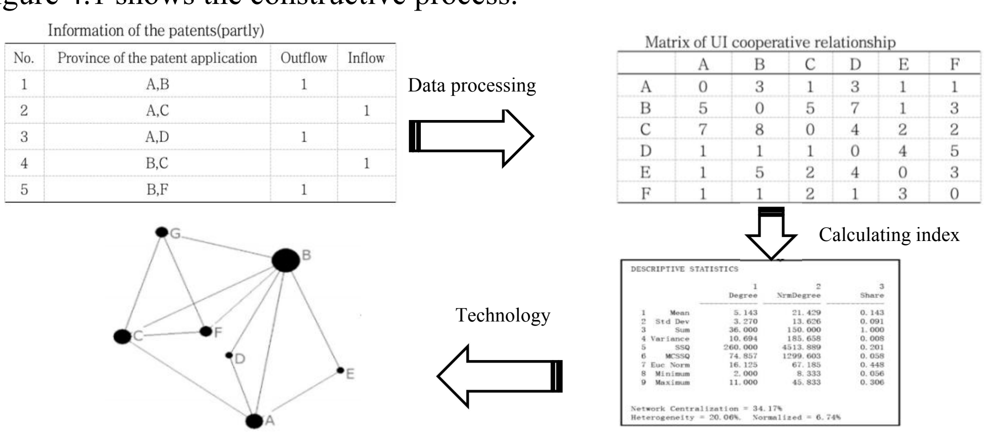


Figure 4.1 The process of the knowledge flow network construction

4.5 U-I collaborative knowledge flow network analysis

4.5.1 Descriptive statistics of patent cooperation

From the perspective of the vertical time dimension, in 2013, the number of university-industry collaborative invention patent applications in China's 30 provinces totaled 9,632, and 16,421 in 2018, an increase of 70.5% in 6 years. This shows that regional U-I collaboration is increasing. The more active, the ability of collaborative innovation has been improved (Figure 4.2).

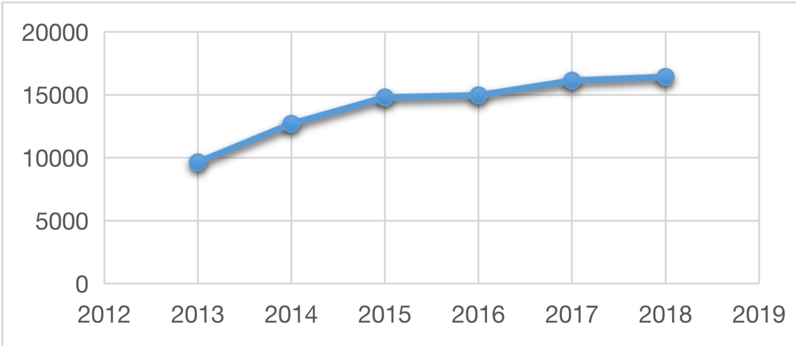


Figure 4.2 The number of U-I collaborative patents from 2013-2018

From the perspective of horizontal spatial dimensions (Figure4.2), Beijing, Shanghai, Zhejiang, Jiangsu, and Shandong rank among the top five, and the total patents in the five provinces are 44,506, accounting for 52.6% of the nation. The total number of patents in the last 10 provinces including Jilin, Hebei, Yunnan, Jiangxi, Gansu and Heilongjiang are less than 7,317, accounting for 8.6% of the nation. It can be seen that the distribution of China's regional U-I collaborative innovation performance is extremely uneven, and the polarization is serious. The above data intuitively reflects the imbalance of China's regional U-I collaborative innovation performance.

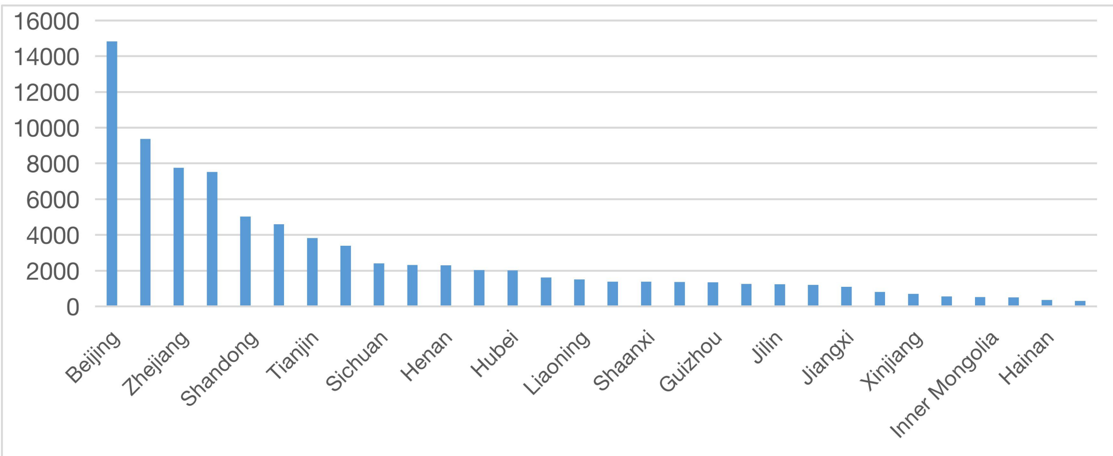
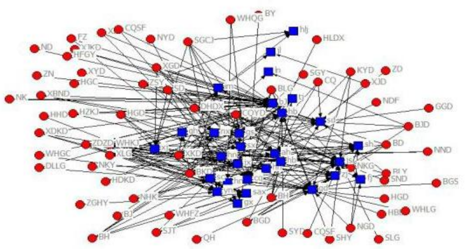


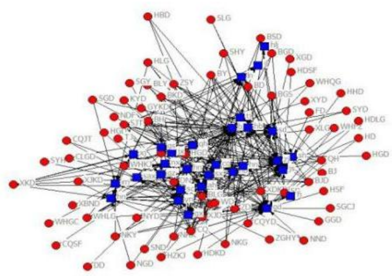
Figure 4.3 The number of U-I collaborative patents in 30 provinces from 2013-2018

4.5.2 Flow trend of University-Industry Collaborative Patents

Figure 4.4 shows the trend of U-I collaborations during 2013-2018 by Ucinet 6.1.8 for inter-regions. The red nodes represent universities, and the blue squares represent the inflow regions. The destiny raised from 0.172 in 2013 to 0.22 in 2018. The number of patent nodes and cooperative lines increased significantly indicating U-I collaborations are increasingly being valued by enterprises and various regions.



2013



2018

Figure 4.4 The trend of cooperative invention patents from 2013 to 2018

4.5.3 Analysis on the Innovation Network of Regional U-I collaborations

Table 4.3 shows the number of relationship connections, the total number of relationships, and the proportion of cross-regional U-I collaborations. Both of them are increasing steadily. More and more regions have established U-I collaborations relationships. The proportion of non-local cooperation patents is gradually increasing. Knowledge spillovers are diversified. Although out-of-region cooperation are rising, most of them flow into economically developed regions, especially in Jiangsu and Zhejiang province (see Table 4.4).

Table 4.3 Statistics of University-Industry Collaboration (2013-2018)

Index	2013	2014	2015	2016	2017	2018
The number of relationship connection	329	367	392	426	451	484
The total number of relationships	912	968	1322	1497	1626	1669
The proportion of cross-regional cooperation (%)	42.2	43.7	45.08	46.56	46.57	49.01

Table 4.4 An analysis of the degree of inflow and outflow of U-I Collaboration（top 3)

Period	Outflow degree (university)		Inflow degree (region)	
2013	Beijing	0.733	Beijing	0.896
	Shanghai	0.690	Guangdong	0.746
	Xian	0.467	Jiangsu	0.552
2018	Wuhan	0.931	Jiangsu	0.959
	Chongqing	0.767	Beijing	0.795
	Beijing	0.533	Zhejiang	0.466

The flow of knowledge and innovation cooperation from outside the region has a trend towards southern cities. It can be seen that, in terms of receiving and transforming external knowledge, the regional internal innovation cooperation core cities have insufficient radiation. Southern cities show more enthusiasm than northern cities. In the future, in resource integration, on the one hand, the radiation of universities to other northern provinces should be further strengthened. On the other hand, more policies should be adopted to reduce barriers across regions and provinces, and promote better knowledge flow across regions.

4.5.4 Regional cluster of U-I collaboration for innovation

To explore regional U-I collaborative innovation performance's spatial evolution characteristics, we divided 30 provinces into 3 ladders with the inflow degree ratio which rank at 5% and 2% of the 30 provinces as the dividing point. The ratio is calculated by the regional U-I collaborative innovation performance to the country's total performance. The results are shown in Table 4.5.

Table 4.5 The spatial trend of regional U-I innovation performance from 2013 to 2018

Year	Region	First echelon	Second echelon	Third echelon
2013	Eastern	Beijing, Shanghai, Jiangsu Zhejiang, Guangdong	Shandong,Tianjin	Fujian,Hebei,Hainan
	Central		Hunan,Henan, Anhui, Guangxi	Shanxi,Hubei,Jiangxi
	Western		Chongqing,Sichuan	Yunnan,Guizhou,Shanxi,Inner Mongolia,Xinjiang Qinghai,Ningxia,Gansu
	Northeastern		Liaoning	Jilin,Heilongjiang
2014	Eastern	Beijing, Shanghai, Jiangsu Zhejiang, Guangdong	Shandong,Tianjin	Hebei,Fujian,Hainan
	Central		Hunan,Hubei,Henan,Guangxi	Anhui,Shanxi,Jiangxi
	Western		Chongqing,Guizhou,Sichuan	Yunnan,Ningxia,Qinghai,Shaanxi,Gansu,Xinjiang, Inner Mongolia
	Northeastern			Jilin,Heilongjiang, Liaoning
2015	Eastern	Beijing, Shanghai, Jiangsu Zhejiang, Shangdong	Guangdong,Tianjin,Hebei	Fujian,Hainan
	Central		Henan,Anhui,Hubei,Hunan	Shanxi,Guangxi,Jiangxi
	Western		Chongqing,Sichuan,Guizhou	Yunnan,Ningxia, Xinjiang,Shaanxi,Gansu,Qinghai,Inner Mongolia
	Northeastern			Liaoning,Jilin, Heilongjiang
2016	Eastern	Beijing, Shanghai, Zhejiang,Jiangsu, Shangdong	Guangdong,Tianjin,	Hebei,Fujian,Hainan
	Central		Henan,Hubei,Hunan,Anhui	Guangxi,Jiangxi,Shanxi

	Western		Chongqing,Sichuan,Shaanxi	Yunnan,Guizhou,Gansu,Xinjiang,Qinghai,Inner Mongolia, Ningxia
	Northeastern			Liaoning,Jilin,Heilongjiang
2017	Eastern	Beijing,Shanghai, Zhejiang,Jiangsu, Shandong	Guangdong,Tianjin,,Hebei	Fujian,Hainan
	Central		Henan,Hubei,Hunan,Anhui	Jiangxi,Guangxi,Shanxi
	Western		Chongqing,Sichuan	Yunnan,Shaanxi,Ningxia,Guizhou,Xinjiang,Gansu,Qinghai,Inner Mongolia,
	Northeastern			Liaoning,Jilin,Heilongjiang
2018	Eastern	Beijing,Zhejiang,Shanghai, Jiangsu, Shandong	Tianjin, Guangdong,Hebei	Fujian,Hainan
	Central		Anhui,Henan,Hubei,Hunan	Shanxi,Guangxi,Jiangxi
	Western		Chongqing,Sichuan,	Shaanxi,Yunnan,Xinjiang,Gansu,Guizhou,Inner Mongolia,Qinghai,Ningxia
	Northeastern			Liaoning,Jilin,Heilongjiang

All provinces in the first echelon come from the eastern region, and Beijing has consistently ranked first. The most obvious change is Zhejiang Province, ranked fourth in 2013, and ranking second in 2018, surpassed Shanghai for the first time. Guangdong and Tianjin follow the first echelon. In 2018, Tianjin surpassed Guangdong and ranked sixth in the country. Hebei Province also squeezed into the second echelon. The coordinated development of Beijing, Tianjin, and Hebei played a certain role. Henan, Hubei, and Hunan, with obvious advantages, have always been the backbone of the central region. Chongqing and Sichuan have always been in the second echelon in the western region, ahead of other western provinces. With the development of the central and western regions, the eastern regions' gap is gradually decreasing. In Northeastern, it has a declining trend. Liaoning has fallen from the original second echelon to the third one. Heilongjiang has been ranked last in the 30 provinces for four years. The Northeastern region overly depends on resource elements and investment-driven, and the motivation for innovation and development is insufficient. The capacity for U-I collaborative innovation needs to be improved. Overall, regional U-I collaborative innovation performance basically shows a pattern of declining "eastern, central, western, northeastern."

Further, we analyze the characteristics of cross-regional knowledge flow through comprehensive factors such as geographical location, corporate research investment, financial and technological support, and high-tech industries. Through the cluster analysis method, the relevant factors are divided into three categories: high, medium and low, combined with the inter-provincial knowledge spillovers in Table 4.6 to analyze the reasons for the dynamic changes of knowledge flow. The data come from the Technical Industry Statistical Yearbook and the Statistical Bulletin of China's Science and Technology Investment.

Table 4.6 U-I knowledge flow in different region endowments

	R&D expenditure	Financial technology expenditure	High-tech enterprise output value	Geographical distance
High-level	Jiangsu,Zhejiang,Beijing, Shanghai,Guangdong, Shandong	Guangdong,Shanghai,Jiangsu,Zhejiang,Beijing	Guangdong,Jiangsu	Xinjiang,Hainan,Yunnan, Ningxia, Guangxi
Mid-level	Liaoning,Hubei,Sichuan, Henan,Shaanxi Hunan,Anhui,Tianjin,Hebei,Fujian	Shangdong,Anhui,Tianjin, Liaoning, Henan,Hubei,Sichuan, Fujian, Hunan	Shanghai, Shandong,Beijing, Zhejiang, Tianjin,Sichuan,Henan, Liaoning	Guizhou,Qinhai,Jiangxi, Inn Mongolia Gansu, Heilongjiang
Low-level	the others	the others	the others	the others

Comparing with the traditional cross-regional natural resource exchange, knowledge flow and diffusion are less affected by geographical factors. The actual geographical distances between Guangdong, Zhejiang, Jiangsu, Shanghai, and Beijing are relatively long, but they are far from Beijing. Knowledge spillovers and innovation cooperation are very close, while some northern regions have relatively little knowledge spillovers. In addition to the differences in economic development between provinces, the most important factor is the impact of technology investment and demand. Guangdong Province ranks among the top two in terms of enterprise R&D investment, financial support, and high-tech output value, especially the output value of high-tech enterprises, far ahead of the other provinces. Knowledge spillovers and innovation cooperation results are also accelerating. This is different from traditional natural resources, infrastructure, and other investments that have reached a certain level but will show a marginal decrease in investment efficiency. The diffusion and flow of knowledge input show a trend of rising marginal efficiency. For the construction of an innovation-driven country, the gradual shift from traditional infrastructure and natural resource construction to knowledge and technology investment should become an important direction in the future. The geographical proximity factor still has a certain influence. The provinces with close input and demand factors and the provinces with relatively short distances still have higher knowledge inflows.

4.6 Summary

As for the outflow stage, regional U-I collaborative innovation performance has greatly improved and shows a rapid growth trend from 2013 to 2018 in China. However, the gap between regions is obvious, showing a spatial pattern of "strong in eastern and weak in the other areas part of China." The inter-regional U-I collaboration makes an increasing trend.

As for inflow stage, most of the new co-patents flow into prosperous provinces. The five provinces of Beijing, Jiangsu, Guangdong, Shanghai, and Zhejiang in the eastern region are far ahead of the other provinces. The number of patents accounts for more than 60% of the nation. As for the western region in China, most provinces are at the bottom of the country. Yunnan, Gansu, Xinjiang, Inner Mongolia, Ningxia, and Qinghai have fewer than one hundred patents. The lagging regions should motivate the U-I collaboration to get more innovation performance.

The social network analysis shows that there is no obvious trend of convergence between regional disequilibrium phenomena, indicating that the performance of regional U-I collaborative innovation will continue to maintain the development trend of "strong constant strength, weak and constant weakness." The coordinated development of U-I collaboration needs to promote the knowledge flow from the "central area(eastern)" to the "peripheral area(the other areas)" in China. The development level of the regional technology market is clearly related to the innovation performance of U-I collaboration in a regional context. Then, the following chapters, the thesis will discuss the multidimensional proximity effects on the knowledge spillover out of university, and then test the absorptive capability of regions and enterprises to capture the inflow knowledge.

Chapter 5
A Proximity approach to understanding cross-regional U-I Knowledge flow for innovation performance

The last chapter analyzed the spatial-temporal trend characteristics of the spatial correlation network of knowledge flow in different part of China. The ladder shape of U-I collaborations performances in China shows an "imbalance" problem of outflow and inflow stage. How to realize the "imbalanced" cross-regional U-I collaborations in China with obvious institutional arrangements and administrative barriers to coordinated development? When taking space and region as the carrier, it is necessary to realize the development path of "knowledge production and agglomeration to knowledge spillover, and then inflow-region capturing the new knowledge, and finally, inflow-subjects absorbing and transferring to balance development." We should embed regional interaction into spatial knowledge flow, shifting from "one-way spillover" to"subject-region"interactive spillover and absorption. Therefore, we devote to answer the following three questions:

- Which types of proximity enhance or hamper the knowledge flow from non-local universities to local enterprises?
- Whether the local regional attributes can capture such knowledge flow?
- How to design policy for regions to encourage firms' local behavior to catch up with U-I collaborations' innovative performance?

Although scholars have studied proximity extensively, there is lacking research on cross-level analysis. Most of works discussed U-I collaborations from organizational or regional level, and less studied consider the knowledge flow direction and ignore the spatial interaction within a regional context. And number of scholars took the European Union, the US, and Italy as samples, ignoring regional context and heterogeneity may lead to estimation errors. In addition, the locking effects of some organizational factors on proximity, like firm size (Santoro & Chakrabarti, 2002), organizational absorptive capacity (Cohen & Levinthal, 1990; Tether & Tajar, 2008) have been verified, but they lack attention on the availability of regional resources to capture local proximity. This chapter tends to embed China regional context into spatial distance factors of U-I knowledge spillover and analyze whether there is a catch-up effect of regional resource endowments on such relationship, constructing a "outflow-inflow" process to promote coordinated development of U-I collaborations.

Then, how proximity and inflow regional endowment are linked together?

Universities as exogenous are the main source of knowledge spillover. They are independent of regional endowments. The knowledge under the spatial proximity effect flows from non-local universities to local enterprises. The local regional participants are endogenous, absorbing and commercializing the knowledge generated (Lehmann & Menter, 2016). Then, the catch-up role of the regional resource endowment is to keep the efficiency of knowledge spillover and promote the absorption of knowledge (Giuliani & Bell, 2005, Miguélez & Moreno, 2015). "Later-mover advantage" and "absorptive capacity" are two main hypothesis of catch-up economy development theory. "Later-mover advantage" makes rapid development efficiency through learning and imitation (Lin & Wang, 2017). "Absorptive capacity" proposed that being backward cannot bring about greater diffusion and catch-up, unless there are specific prerequisites that can absorb advanced ideas and knowledge spillover (Abramovitz,1986; Cohen & Levinthal, 1990). Compared with proximity, this "factor endowment" has a more objective existence that affects the resources the enterprises can obtain. Whether local regions can obtain more collaborative efficiency because of these endowments? Catch up economy develop theory provides a view for integrating proximity with regional resource endowments to measure the regional knowledge capture ability.

This chapter contributes to the existing spatial proximity research context and theoretical analysis framework. First, we introduce regional heterogeneity into the analysis framework, focusing on the U-I collaborations from non-local universities to local regions that significantly impact lagging regions' innovation performance. Second, considering the knowledge flow direction, we integrate the "spatial proximity outflow" with "inflow regional absorptive capacity" and construct a "subject-region" interactive spillover and absorption way in a regional context. Third, according to two central hypotheses: "later-mover advantage" and "absorptive capacity" of catch-up economy theory, we verify the catch-up role from internal (human capital as a proxy variable) and external absorptive capacity (regional technological gap as a proxy variable). This research helps each provincial government, primarily undeveloped areas enhance the introduction, absorption, and effective use of external knowledge based on their actual conditions and influences enterprises' behavior.

5.1 Theory and hypotheses

5.1.1 Geographical proximity and university–industry knowledge flow

Geographic proximity is the spatial starting point for regional innovation research. Scholars generally agree that geographical distance has an obvious negative correlation with innovation activities. It can reduce the cost of diffusion under the influence of knowledge externalization and localized labor markets, facilitates the transfer of tacit knowledge through relatively frequent face-to-face communication (Storper & Venables, 2004), obtains more collaborative benefits (Kabo, Cotton-Nessler, Hwang, Levenstein & Owen-Smith, 2014), and leads to a significant geographical concentration trend of the knowledge flow (Alnuaimi, Opsahl & George, 2012).

With the development of information and communication technology and modern transportation infrastructure, there are many interactive methods to choose, such as email, video conferencing, and collaborative innovation network platforms. The cooperation between innovative entities is often cross-regional or even transnational (McKelvey, Alm & Riccaboni, 2003; Mora-Valentin, Montoro-Sanchez & Guerras-Martin, 2004). Hewitt-Dundas (2013) surveyed 906 businesses in the United Kingdom, finding that 538 (59.4%) cooperate with non-local universities. This means that the nearest university is not a determining factor.

This study considers that the popularization of telematics technology has made cross-regional collaborations unprecedentedly active, and the hindering effect of geographic distance is not obvious sometimes. The "temporary geographical proximity" formed by the movement of people and frequent travel can replace the role of permanent geographical proximity to a certain extent, thus weakening the dependence of knowledge exchange between individuals on geographic spatial distance. The more developed regions in eastern will overcome geographic barriers to seek more cooperation due to the development of transportation and information, and the undeveloped regions in central and western regions will also overcome geographic barriers and inclined to seek better external knowledge outside the region, which also increases the opportunities of cross-regional U-I collaborations. Therefore, geographical distance can increase the motivation for cooperation, thereby improving the collaborative innovation performance. The above-mentioned reasons lead us to propose the following hypothesis:

H1: Geographical distance is positive related to the cross-regional innovation performance of U-I knowledge flow.

H1a: Regional economic differences will affect the role of geographical distance in promoting innovation, there is significant differences between the eastern region and the other regions.

5.1.2 Technological proximity and university–industry knowledge flow

Technical proximity refers to the degree of technical similarity between two subjects. In general, the diffusion of knowledge among innovative entities with similar technologies is more efficiency. It is easy to form a cooperative relationship and collaborative innovation within a region (Xiang, Cai & Pei, 2010) and across regions (Scherngell & Hu, 2011). It helps overcome institutional differences between subjects and promote effective communication inter-organization, enabling firms to efficiently and cost-effectively acquire and absorb resources and spillover knowledge (Callois, 2008). Technological distances is one of the important factors affecting U-I collaborations innovation activities (Knoben & Oerlemans, 2006). Kim and Song (2007) selected innovation survey data based on the characteristics of Belgian U-I collaboration and got the similar conclusions.

Innovation is the integration of heterogeneous and complementary pieces of knowledge. Excessive similarity of based-knowledge between subjects will reduce the learning space for each other, which is not only detrimental to novel creation, but also brings technological path dependence and lock-in. The technological proximity between participants in U-I is too high or too low, which is not conducive to cross-regional R&D cooperation, and they should be an inverted U-shaped relationship (Nooteboom, et al., 2007). As the level of technological proximity increases, cross-regional U-I has increased first and then declined. The imbalance of technological level between regions makes technological proximity also have differences in the performance of U-I collaborations. The existence of an optimal technological proximity level has the strongest effect on promoting cross-regional U-I. Hence, we argue that:

H2: There is an inverted U-shaped relationship between technological proximity with cross-regional innovation performance of U-I knowledge flow.

H2a: Innovative performance related with the develop level in a region, therefore, the eastern region is in the stage of negatively affecting innovation performance, while the central and western regions are in the stage of positively affecting performance.

5.1.3 Social proximity and university–industry knowledge flow

The proximity framework can benefit from the ongoing theoretical developments taking place in various disciplines including sociology, management, and economics (Rivera et al., 2010; Schweitzer et al., 2009). Social proximity is a trust-based, socially embedded relationship between subjects (Boschma, 2005). This refers to the distance between socially embedded relationships and position in the network structure among actors (Granovetter, 1985; Cummings & Teng, 2003). Technological progress has triggered changes in new forms of space, and economic activity has become fundamentally non-localized. A flowing space has replaced the traditional static local space (Boschma, Heimeriks & Balland, 2014). Socially embedded relationships and common experiences between subjects can further enhance mutual trust and long-term sustainable cooperative relationships can promote innovation in UIC (Boschma, 2005; Petruzzelli, 2011). This kind of trust is often better than an anonymous or new relationship (Broekel, 2012). Trust-based social relationships are conducive to the interactive transfer of tacit knowledge, and effective interactive learning requires firm and lasting social relationships (Maskell & Malmberg, 1999). Therefore, social proximity can thus reduce the information acquisition uncertainty and cooperation costs, especially for cross-regional U-I collaborations. Then, we formulate the following hypothesis:

H3: Social proximity is positively related to the cross-regional innovation performance of U-I knowledge flow.

H3a: The higher technological level can gain closer social relationship, then get more innovation performance. So, there are significant differences between the eastern and other regions.

5.1.4 The catch-up effect of regional absorptive capacity

There is a backward advantage hypothesis in the economic development catch-up theory. It pointed out the greater the resource endowment gap between regions, the more underdeveloped regions can use their backward advantages to narrow the productivity gap with leading areas. Kuznets (1973) thought that the so-called backward advantage means that technologically backward countries can borrow new technologies from technologically leading countries to improve production efficiency. Many scholars have proved the effectiveness of the late-mover advantage as a strategy for economic development in the central and western regions in China (e.g. Guo & Gu, 2015; Xue, 2019).

Another hypothesis in catch-up economic development theory is about absorptive capacity. Abramovitz (1986) thought that being backward alone could not bring about greater diffusion and catch-up, unless there were specific preconditions that could absorb advanced ideas and knowledge spillover. These prerequisites are called "social competence" and they include all factors that promote the imitation or utilization of new technologies, such as education and infrastructure. To further explain the transformation of the external possibility of economic catch-up into internal feasibility, Cohen et al. (1990) introduced the absorptive capacity. It was later used to analyze innovation efficiency at the regional or national level. Giuliani and Bell (2005) defined regional knowledge absorptive capacity, that is, the ability of human capital in the region to use the regional knowledge stock to identify, understand, disseminate, and creatively apply new knowledge from within and outside the region. In specific empirical studies, it can be discussed at the national level (e.g. Dahlman & Nelson, 1995), or at the provincial and municipal levels (e.g., Roper & Love, 2006; Kallio, Harmaakorpi & Pihkala, 2010) and has a driving effect on regional innovation (e.g. Inzelt, 2004; Miguélez & Moreno, 2015; Smit, Abreu & de Groot, 2015).

According to the classical production factor endowment theory, differences factor endowments in region lead to different performances in the resources owned by companies that have an impact on firm's behaviors. Thus, we can understand regional absorptive capacity as a broader concept. The backward advantage hypothesis can be understood as the impact of the gap in the endowment of external factors, and we can call it external regional absorptive capacity. The external "backwardness" of resource endowment increases the motivation for cooperation through external resources to promote economic development. It is possible to find more distant partners and increase the numbers of technology introductions and establish cooperative relations with more entities.

The absorptive capacity hypothesis can be understood as the impact of differences in inner resource endowments, and we can name it as internal regional absorptive capacity. It increases the possibility of transforming external resources into internal power, and enhances the opportunity to find better resources, which can achieve longer-distance and more diversified cooperation. In general, it may affect the proximity–cooperative innovation performance relationship to form a catch-up effects. Hence, we propose the following hypotheses:

H4: Internal regional absorptive capacity has a moderating effect that can help regions through geographical (H4a), technological (H4b), and social proximity(H4c) to catch up more innovation performance of U-I collaborations.

H5: External regional absorptive capacity has a moderating effect that can help regions through geographical (H5a), technological (H5b), and social proximity(H5c) to catch up more innovation performance of U-I collaborations.

The research concept model is presented in Figure 5.1, according to the hypothesized relationships among the constructs.

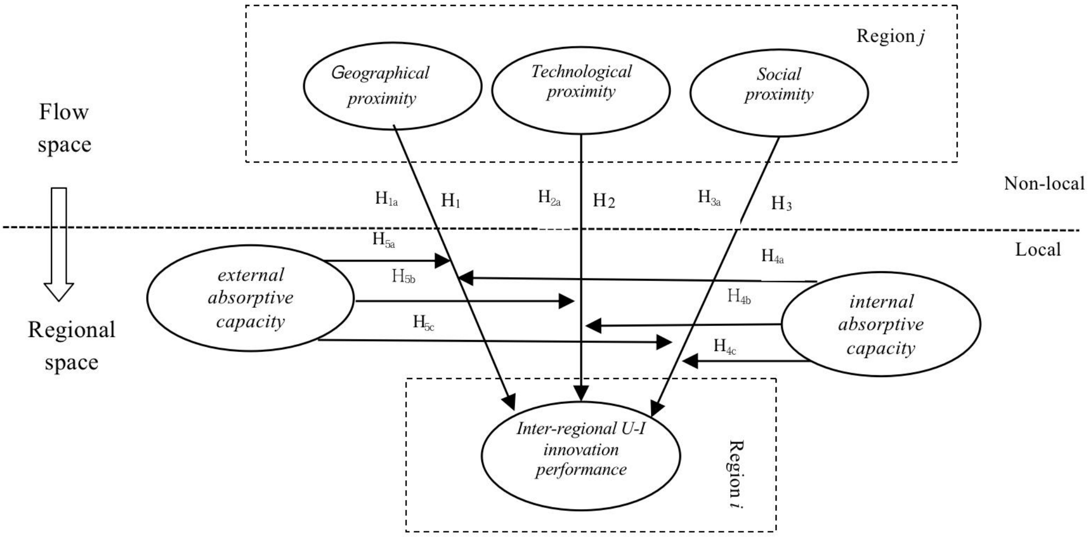


Figure 5.1 Description of the research framework in chapter 5

5.2 Methods

5.2.1 Dependent variable

U-I collaborations are widely regarded as a way to improve economic innovation by promoting the flow and utilization of technology-related knowledge and experience across sectors (Nooteboom et al., 2007; Perkmann, Neely & Walsh, 2011). The contract amount of U-I collaborations more reflects the market value of technology. The use of technical cooperation based on joint invention patents reflects more of an added value, which is conducive to the overflow of tacit knowledge and is more important for promoting regional economic development. Since the research purposes to better understand the performance differences between regions, the innovation performance of the regional U-I collaborations is measured by the number of invention patents applied by the cross-regional U-I collaborations which is recorded as UICP.

5.2.2 Independent variables

Geographical distance

This thesis uses geographical distance as a proxy variable. The greater of the geographic distance, the lower of the geographical proximity. Generally, geographic distance is measured by the physical distance between the cities where the university and the company are located. For research convenience, this study directly uses the straight-line distance between the cities where universities and companies are located to measure geographical distance. The corresponding data can be obtained directly by using the Baidu map (https://map.baidu.com).

Technological proximity

Technological proximity is generally measured as the cognitive distance between subjects and patent indicators (Bercovitz & Feldman, 2011; Basile, Capello & Caragliu, 2012; Cassi & Plunket, 2014). When patents were used to characterize technological proximity, the accuracy depends on the number of patent samples and the division of patent dimensions. Drawing on the practices of Jaffe (1986), Branstetter and Mariko (2002), Benner and Waldfogel (2008), we divide the 120 patent classifications of the original International Patent Classification Standard (IPC) into eight patent departments (A-H). Then, the total number of patents in U-I collaborations of each main body is calculated by counting the proportion of the three-digit IPC subcategories in the patent, and measured by using the industrial structure similarity coefficient. The calculation method of technical proximity is as follows:

$$\text{tec\_prox}_{ij} = \sum_{k=1}^{8} f_{ik} f_{jk} / \sqrt{\sum_{k=1}^{8} f_{ik}^2 \sum_{k=1}^{8} f_{jk}^2} \tag{5-1}$$

Tec_prox represents the technical proximity between the two subjects, and 1–8 represent the eight patent divisions (A-H) of IPC. Further, f_{ik} and f_{jk} represent the total number of invention patents authorized in k patents in subjects *i* and *j* within a certain period of time. The value range is 0–1. The closer the value is to 1, the higher the technical proximity of the two subjects.

Social proximity

There are two methods to measure social proximity: one is whether the two subjects have cooperated before. The cooperative relationship is set as a dummy variable, cooperative experience as "1", otherwise "0". The second is the closeness of the cooperative relationship, that is, the number of existing cooperative relationships. This study selects U-I collaborative entities with experience in cooperation as the sample, so, we use the number of cooperative applications for invention patents in the past to measure social proximity.

5.2.3 Moderating variable

This article draws on the views of Kuznets (1973) and Giuliani and Bell (2005), and measures the internal regional absorptive capacity from the proxy variables of human capital. We use a technology gap to measure the external regional absorptive capacity.

Human capital

Pavitt and Soete (1982) and others thought that most empirical studies ignore innovation variables, leading to the "economic catch-up trap". Fagerberg (1988) introduced R&D factors into the catch-up model. As aims of this chapter is to measure innovation performance, therefore, we also introduced R&D factors in this research. Since colleges and universities focus on basic research, and enterprises focus on applied research, we use the number of R&D in applied research in the region to measure human capital.

Technology gap

This research draws on the practice of Benhabib and Spiegel (1994), using the relative distance from the technology boundary to measure the technology gap, and the calculation formula is:

$$gap_{it} = \frac{maxA_j(t)}{A_i(t)}$$

where gap_{it} is the technology gap, and $A_i(t)$ is the current technology level of area *i*; $maxA_j(t)$ represent the technological boundaries of the country. According to Engelbrecht (1997), if we assume that the ratio of material capital, human resources, and total factor productivity in the production function does not change over time, then gross domestic product (GDP) per capita can be used to measure the level of technology. Therefore, this research assumes $A_i(t)$ that the technological boundary in China is the maximum GDP per capita in all provinces, and it is measured by GDP per capita of region *i*.

5.2.4 Control variables

To make the estimated coefficients in the model more objective, this article needs to control some variables, so as to strip out the influence of unobservant variables on the estimation results as much as possible. Generally, the more demand for innovation activities, the higher the level of innovation in the region. Therefore, this study uses the number of enterprises with R&D activities in the region to measure the demand for innovation activities, and controls it, which is denoted as NTR. In the process of opening to the outside world, each innovation subject in the region can have more information exchanges and communication with the outside world, thereby contributing to the improvement of their own innovation capabilities. Hence, this study controls the level of regional openness measured by the value of imports and exports of high-tech products by region, recorded as OPEN. The amount of research on R&D projects in a region also plays a certain role in promoting the accumulation of knowledge and the creation of innovative activities. For this reason, we also control the number of regional R&D projects by higher education, denoted as NRD.

5.2.5 Data source and sample

One of the main methods of U-I collaborations is joint patent application. It embodies technology transfer between industry and universities. Therefore, to accurately find the main U-I collaborations entitles, the sample of this study is available on the China Patent Data Network (http://pss-system.cnipa.gov.cn//accessed date on March 19, 2021), with the search criteria set as keywords of "university", "company," and "city," and the filter criteria set as invention patents. The cities were selected according to the regional creative ability report in 2019, including Beijing, Shanghai, Chongqing, Xi'an, Nanjing, Shenyang, Wuhan, Hangzhou, Guangzhou, and Harbin. Taking into account the lag of patent authorization, the search period was set from 2013 to 2018, and a total of 7,994 patents were screened. Due to the influential factors of the cross-regional knowledge flow in this study, we excluded the patents for which the enterprise cooperated with universities in same province and the subjects with more than four cooperative entities. For invention patents of over two cooperative subjects, the data were decomposed and processed. For example, a university with two companies was identified as two cooperative patents. However, if they both were within and outside the province among the cooperative entities, only the cooperative patents outside the province will be recognized, and multiple cooperation will be counted once. Finally, we obtained 484 pairs of samples, 73 universities and 427 companies covered 30 provinces (a total of 30 provinces after excluding Tibet, Taiwan, Hong Kong, and Macau). We calculated the multi-proximity based on them(see Appendix Ⅲ). The data for variables are from the China Statistical Yearbook and China Science and Technology Statistical Yearbook (see Table 5.1).

Table 5.1 Description of the variables

Item	Variable Symbol	Variable Description	Data Source
Dependent	UICP	The number of cross-regional UIC patents	China Patent Index Website
Independent variables	Geo	The distance between university and enterprises	Baidu map
	Tec	The coefficient is calculated based on the similarity coefficient of industrial structure	China Patent Index Website
	Soc	The number of invention patents in cooperation between enterprises and universities	China Patent Index Website
Moderating variables	IHC	The number of applied R&D personnel in inflow region	*China Science and Technology Statistical Yearbook*
	ETC	The ratio of the maximum GDP per capita to the regional GDP per capital	*China Statistical Yearbook*
Control variables	NTR	Enterprises having R&D activities (item)	*China Science and Technology Statistical Yearbook*
	OPEN	Imports and exports of high-tech products (M USD)	*China Science and Technology Statistical Yearbook*
	NRD	Regional R&D projects by higher education(item)	*China Science and Technology Statistical Yearbook*

5.2.6 Analysis methods

The error independence assumption in general linear model refers to the fact that there can be no correlation between the errors of each observation in samples. Once the error independence assumption is violated, the probability of false positives will increase. This study contains contextual factors "regions", which can be referred to as a cluster forming a nested data. Therefore, this study uses the method of stepwise and group regression, on the basis of the general linear model, add regional group regression to test the differences among regions. The inverted U-shape of technical proximity is tested by adding technical proximity and the square of technical proximity into the equation respectively. The final model as shown in formula (5-3). Where control represents all control variables in formula (5-2), ε is error term, and i represents the region.

$$UICP_i = \alpha_0 + \mu_1 OPEN_i + \mu_2 NTR + \mu_3 NRD + \varepsilon_i \quad (5\text{-}2)$$

$$UICP_i = \alpha_0 + \alpha_1 Geo\_dist_i + \alpha_2 Tec\_prox_i + \alpha_3 Tec\_prox_i\text{^}2 + \alpha_3 Soc\_prox_i + \mu control_i + \varepsilon_i \quad (5\text{-}3)$$

Hierarchical multiple and group regression were used to test the moderating effect and regional heterogeneity. After centralizing the data, we put the control variables and independent variable in the first and second layer. The second level will input the adjusted variable into the equation, and the third level will introduce the interactive items of independent variables and the adjusted variables. As shown in formulas (5-4) and (5-5). Then, we use group regression to verify regional heterogeneity.

$$UICP_i = \alpha_0 + \alpha_1 X_i + \alpha_2 IHC_i + \alpha_3 X_i * IHC_i + \mu control_i + \varepsilon_i \quad (5\text{-}4)$$

$$UICP_i = \alpha_0 + \alpha_4 X_i + \alpha_5 ETC_i + \alpha_6 X_i * ETC_i + \mu control_i + \varepsilon_i \quad (5\text{-}5)$$

5.3 Data analysis and Results

5.3.1 Proximity effects test

We set the eastern region as dummy variable, as “1”, and other regions as “0”, the model fit of other regions is not well (R^2=0.414), indicating that there is a problem of multi-collinearity between variables. When we performed group regression, the p value in northeastern is null, so the sample in northeast (n=15) are eliminated to compare region heterogeneity. Based on the test results, this article mainly discusses three regions in eastern, central and western.

We adopt a stepwise regression method to introduce geographical, technical, technological square and social proximity into the equations to build Models 1–5, and test the influence of independent variables on dependent variables. In these models, R^2>0.5, and the F value changed significantly, these models fit well (Table 5.2).

Table 5.2 The results of proximity effects

Variable	Total (N=484)					Eastern N=319	Central N=70	Western N=80
	Model 1	Model 2	Model 3	Model 4	Model 5			
Constant	-167.22*** (-13.213)	-177.168*** (-13.892)	-164.142*** (-12.932)	-165.625*** (-12.819)	-172.547*** (-13.252)	-202.846*** (-12.368)	-32.610 (-1.346)	-61.158*** (0.401)
NTR	3.12* (1.682)	4.336** (2.334)	3.084* (1.668)	2.966 (1.595)	4.635** (2.487)	1.529 (0.856)	12.642*** (2.707)	10.855*** (6.425)
OPEN	15.853*** (8.9)	14.357*** (7.976)	15.998*** (9.007)	15.972*** (8.984)	14.448*** (8.075)	17.523*** (9.218)	18.809*** (9.421)	-7.714*** (-5.967)
NRD	26.158*** (6.841)	27.843*** (7.332)	25.833**** (6.775)	26.088*** (6.799)	26.580*** (6.945)	33.498*** (8.187)	-17.447* (-1.945)	15.825*** (6.247)
Geo_dist		0.004*** (3.801)			0.004*** (3.835)	0.003** (2.293)	0.001 (0.904)	-0.0001 (-0.197)
Tec_prox		-4.875* (-1.719)	-6.074** (-2.123)	0.22 (0.021)	1.385 (0.135)	-3.009 (-1.009)	-0.635 (-0.249)	-0.762 (-0.653)
Tec^2				-7.355 (-0.625)	-7.355 (-0.633)			
Soc_prox		0.026** (2.356)			0.026** (2.356)	0.012 (1.307)	-0.026 (-0.776)	0.002 (0.079)
R^2	0.663	0.678	0.665	0.665	0.679	0.666	0.646	0.747
Adj-R^2	0.661	0.674	0.662	0.662	0.674	0.66	0.612	0.727

F	314.415	167.716	237.808	190.082	143.633	103.688	19.137	35.958

*p<0.1 **P<0.05 ***P<0.01

H1 proposed that geographic distance has a significant positive impact on the innovation performance of cross-regional U-I collaborations. According to the results of Models 2 in Table 4, it has a significant positive correlation with collaborative innovation performance ($\beta = 0.004$, $p<0.01$), and thus, H1 is supported. The results show that for the subjects of cross-regional U-I collaborations, the demand side of the enterprise can overcome the obstacle of geographical distance and form more cooperative innovation performance driven by demand and cooperative motivation, and convenient transportation.

H2 proposed that technological proximity has an invert U-shaped impact on the innovation performance of cross-regional U-I collaborations. According to the results of Models 3–4, after adding technical proximity, R^2 did change significantly ($\beta=-6.074$, $p<0.05$), then we input Tec-prox^2 into the model, R^2 did not change significantly ($\beta=-7.355$, $p>0.01$) and H2 is not supported. This result indicates technological proximity is negatively impact innovation performance but did not form an invert U-shaped. This result implies that there is a contradiction between unique and shared in technological proximity. The stronger the technological proximity the subjects have, it will be more unhelpful for them to absorb knowledge beneficial for their own technological improvement and product innovation from their partners. The reason maybe is that cooperative participants are increasingly demanding technological heterogeneity.

H3 posits that social proximity has a significant positive impact on cooperative innovation performance. According to the results of Model 2, we input social proximity into the model, and both R^2 and F have changed significantly. It was found that social proximity and cooperative innovation performance are significantly positively correlated ($\beta=0.026$, $p<0.05$), and H3 is supported. This also verified the theoretical conception of scholars, such as Das (2007), showing that in cross-regional U-I collaborations, higher social proximity will increase mutual trust between subjects that can reduce a series of uncertain risks brought by innovation activities, and save knowledge transactions trial and error costs.

5.3.2 Regional heterogeneity test

From the coefficients of group regression (Table 5.3), in terms of geographic proximity, the impact on U-I collaborations innovation performance has a positive influence in eastern and central, and a negative influence in western (β=0.003; β=0.001; β=-0.0001), there are no significant differences between eastern, central and western (P>0.05). The H1a hypothesis is rejected. Technological proximity negatively affects U-I collaborations innovation performance in all regions (β=-3.009; β=-0.635; β=-0.762). There are significant differences in regions (t = -1.932; t = -4.073, p< 0.05), and the eastern region has a more significant negative effect. H2a hypothesis is established. There are obvious differences between eastern with central and western regions on social proximity (t = -3.028; t = 6.210, p<0.01). There is positive influence in eastern and western regions (β=0.012; β=0.002), and negative impact in central (β=-0.026). The negative impact in the central region is the most significant, and the H3a hypothesis is supported.

Table 5.3 Regression coefficient difference test

Name	Item1	Item2	b1	b2	divergence	*T*-value	*P*-value
Geo_dist	Eastern	Central	0.003	0.001	0.002	0.216	0.829
	Eastern	Western	0.003	-0.0001	0.003	-1.653	0.099
	Central	Western	0.001	-0.0001	0.001	-0.897	0.371
Tec_prox	Eastern	Central	-3.009	-0.635	-2.2374	-1.932	0.057*
	Eastern	Western	-3.009	-0.762	-2.247	-4.073	0.000***
	Central	Western	-0.635	-0.762	0.127	2.160	0.034**
Soc-prox	Eastern	Central	0.012	-0.026	0.039	-3.028	0.003***
	Eastern	Western	0.012	0.002	0.011	6.210	0.000***
	Central	Western	-0.026	0.002	-0.028	-1.301	0.197

*p<0.1 **P<0.05 ***P<0.01

5.3.3 Regional absorptive capacity "catch-up" effect test

First, we centralized the data, and introduced the moderating variables and the independent variables into the equation. We take the logarithm in the calculation because the standard deviation of the IHC variable is too large. Models 6–8 examine the moderating effect of internal absorptive capacity (human capital), and Models 9–11 certify the effect of external absorptive capacity (technological gap). In Table 5.4, the interactive terms of geographic with internal absorptive capacity have a negatively significant moderating effect on the explained variables (β=-0.004, P<0.01). Technological and social proximity with internal absorption capacity has a positively significant adjustment relationship (β=18.146, P<0.01; β=0.037, P<0.1). The above results indicate that H4a, H4b, and H4c are all supported. The "absorptive capacity" hypothesis can shape the performance of U-I collaborations.

The results from table 5.4 show that external absorptive capacity (technological gap) has not significant adjust effects. The hypothesis H5a H5b and 5c are not supported. “Being backward advantage” hypothesis did not work on the U-I collaborations innovative performance.

Table 5.4 Results of moderating effect

Variable	Internal Absorptive Capacity			External Absorptive Capacity		
	Model 6	**Model7**	**Model 8**	**Model 9**	**Model 10**	**Model 11**
Constant	188.885*** (6.095)	185.65*** (5.926)	180.503*** (5.693)	-105.295*** (-6.620)	-102.257*** (-6.375)	-99.309 (-6.191***)
NTR	-20.344*** (-7.97)	-21.173*** (-8.223)	-20.129*** (-7.7)	6.967*** (3.807)	5.511*** (3.013)	5.951*** (3.234)
OPEN	0.5073*** (2.921)	6.982*** (4.051)	6.889* (3.944)	11.227*** (6.222)	13.152*** (7.408)	13.047*** (7.370)
NRD	-21.629*** (-4.192)	-22.163*** (-4.25)	-21.795*** (-4.112)	14.444*** (3.451)	13.017*** (3.074)	12.143*** (2.857)
Geo_dist	0.004*** (4.436)			0.005*** (4.151)		
Tec_prox		-6.132** (-2.455)			-5.030* (-1.819)	
Soc_prox			0.015** (1.185)			0.021 (0.838)
lnIHC	78.925*** (12.527)	76.239*** (12.089)	74.435*** (11.675)			
ETC				-8.498*** (-6.505)	-8.069*** (-6.132)	-8.085*** (-6.029)
Geo*lnIHC	-0.004*** (-2.59)					
Tec*lnIHC		18.146*** (2.972)				
Soc*lnIHC			0.037* (0.727)			
Geo*ETC				-0.001 (-0.413)		
Tec*ETC					0.517 (0.157)	
Soc*ETC						-0.003 (-0.117)
R^2	0.753	0.746	0.740	0.699	0.690	0.691
Adj-R^2	0.750	0.743	0.737	0.695	0.686	0.687
F	242.558	233.148	226.759	184.365	176.589	177.471

*p<0.1 **P<0.05 ***P<0.01

5.3.4 Moderating effect heterogeneity test

Because the moderating effect of external absorptive capacity did not pass the test, this study focuses on the internal absorptive capacity (human capital) to analyze the regional heterogeneity. According to the stratified regression method, the results of the heterogeneity of moderating effect are shown in Table 5.5.

Table 5.5 Moderating effects of internal human capital: Sub-regional analysis

	Eastern			Central			Western		
Constant	615.117*** (10.369)	546.534*** (9.132)	545.367*** (9.126)	-121.874*** (-4.848)	-116.538*** (-4.694)	-117.501*** (-4.746)	45.522*** (3.885)	44.704*** (3.685)	46.835*** (3.834)
Geo_dist	-0.001 (-0.798)			-0.0001 (-0.106)			-0.001*** (-0.746)		
Tec_prox		-0.638 (-0.264)			-1.467 (-0.698)			-0.665 (-0.838)	
Soc_prox			0.012 (1.500)			-0.029 (-0.888)			0.017** (1.252)
lnIHC	171.347*** (14.527)	150.313*** (12.854)	150.455*** (12.925)	-40.426*** (-5.660)	-38.2431*** (-5.566)	-38.051*** (-5.542)	28.2*** (9.671)	28.71*** (9.554)	29.416*** (9.613)
Geo*lnIHC	-0.015*** (-6.282)			0.018 (1.394)			-0.001** (-2.520)		
Tec*lnIHC		10.666 (1.239)			-2.842 (-0.162)			2.209 (1.005)	
Soc*lnIHC			0.045 (0.966)			0.145 (0.453)			0.0001* (0.007)
NTR	-54.075*** (-13.038)	-48.991*** (-11.967)	-48.893*** (-11.992)	13.086*** (3.233)	10.961*** (2.830)	11.733*** (3.021)	2.418 (1.492)	1.665 (1.118)	1.526 0.66)
OPEN	4.977*** (2.927)	7.726*** (4.621)	7.767*** (4.649)	21.723*** (12.462)	21.12*** (12.389)	21.225*** (12.438)	-9.132*** (-10.862)	-9.132*** (-10.531)	-9.914*** (-10.648)
NRD	-79.202*** (-9.006)	-71.875*** (-8.138)	-71.763*** (-8.105)	-0.422 (-0.053)	0.621 (0.078)	0.129 (0.016)	-2.226 (-0.939)	-1.51 (2.444)	-1.495 (-0.615)
R^2	0.803	0.778	0.778	0.763	0.757	0.758	0.896	0.889	0.89
Adj-R^2	0.799	0.774	0.774	0.740	0.734	0.735	0.888	0.88	0.88
F	211.798	182.126	182.750	33.761	32.743	32.94	105.11	97.615	97.975
N		319			70			80	

*p<0.1 **P<0.05 ***P<0.01

The R^2 value shows in Table 5.5 that the rank of the adjustment effects of human capital are western > eastern > central region. In general, the moderating role of regional human resources is most obvious in western region. For moderating effect on geographical proximity varies significantly among regions (P<0.01) (Table 5.6). Due to the increase in human capital, the eastern region has formed a concentration of talents, leading to a decrease in cross-regional cooperation (β=-0.015), while the central region has increased the possibility of cross-regional cooperation (β=0.018). The moderating effects between the eastern region with the central and western regions on technological proximity are obvious differences (β=10.66; β=-2.842; β=2.209, p<0.01). The most obvious technological dependence on eastern region. The adjustment effect on social proximity is positive in all regions (β=0.045; β=0.001; β=0.145, p<0.01). The policy of vigorously introducing talents and attracting more R&D personnel brings the most obvious effect on innovation performance in central. This can help building the trust and cooperative relationship between subjects and then improve the innovation performance.

Table 5.6 Regression coefficient difference test on moderating effects

Name	Item1	Item2	b1	b2	divergence	*T*-value	*P*-value
Geo_dist*IHC	Eastern	Central	-0.015	0.018	-0.033	-113.458	0.000***
	Eastern	Western	-0.015	-0.001	-0.013	-25.576	0.000***
	Central	Western	0.018	-0.001	0.02	111.161	0.000***
Tec_prox*IHC	Eastern	Central	10.666	-2.842	13.508	11.779	0.000***
	Eastern	Western	10.666	2.209	8.458	-19.1	0.000***
	Central	Western	0.0001	2.209	-5.05	-12.342	0.000***
Soc-prox*IHC	Eastern	Central	0.045	0.145	-0.1	-20.431	0.000***
	Eastern	Western	0.045	0.0001	-0.044	-24.201	0.000***
	Central	Western	0.145	0.0001	0.144	21.145	0.000***

*p<0.1 **P<0.05 ***P<0.01

5.4 Summary

The role of multi-dimensional proximity and regional absorptive capacity in regional U-I collaborations for innovation is increasingly recognized. Nevertheless, research lacks empirical engaging in the inter-regional heterogeneity context and integrating spatial proximity with regional resource endowments. Our study's major contribution is using proximity approach to test knowledge spillover effect on the outflow stage from university and the regional absorptive capacity in inflow to the enterprises stage. These investigations yield three central results: (1) Long geographical distance is not a hamper for U-I knowledge spillover, while in innovation-driven development background, technological heterogeneity and social proximity can shape more U-I collaborative innovation performance; (2) The influences of proximity on inter-regional U-I collaboration for innovation performance-enhancing advantages are not equal for all regions. In prosperous areas (eastern), geographical proximity and technological heterogeneity play a more significant role. In the lagging regions (western and central), the social relationship closer to prosperous areas can increase innovation performance. (3)The impacts of proximity on U-I collaborative innovations were fostered by regional ability to absorb non-local knowledge through human capital. The number of R&D personnel help for getting catch-up effects in regions, mainly for lagging areas.

Chapter 6
A proximity approach to understanding U-I collaboration on enterprises' innovation performance

The last chapter analyzed the proximity mechanism of "non-local context" of cross-regional U-I collaboration for innovation performance. Then, the following of this research will explain the proximity mechanism of enterprises' innovation performance to help the knowledge flow cross the inflow organizational boundary. Proximity is considered to be an important factor affecting the formation and evolution of innovation knowledge networks and an important driving force for enterprises' innovation. The primary research question of this chapter is as follows:

- What is the impact of multidimensional proximity on U-I collaboration for innovation purposes of enterprises?

More specifically, is geographical distance an important factor in enterprise innovation? Can multidimensional proximity affect enterprise innovation? Sourcing external knowledge is important for firms' innovation (Nonaka & Takeuchi, 1995). The embeddedness of knowledge provides a knowledge base for U-I collaborative innovation and enhances or weakens its proximity (Prahalad & Hamel, 1994). Knowledge acquisition thus plays a crucial role in leading firms to obtain more effective innovations (Molina-Morales et al., 2014, p.233). Then, the two sub-questions are as follows:

- Does knowledge embeddedness increase or decrease the proximity effects in enterprise innovation?
- Does the knowledge absorptive capacity of enterprises have a moderating effect on the close U-I linkages when mediated by knowledge embeddedness?

To answer these two questions, we take enterprises as the research object and construct a theoretical model of multidimensional proximity spillover effects on the innovation performance of enterprises. This study then analyses the effects of knowledge embeddedness and enterprises' absorptive capacity. The findings can be used to improve the efficiency of U-I collaborative innovation during knowledge flow.

6.1 Theory and hypotheses

6.1.1 Geographical proximity and enterprises innovation performance

Tacit knowledge is difficult to spread because it is an understanding of know-how with empirical, cognitive, and situational characteristics. Geographical proximity can improve the direct interactions between enterprises required to improve innovation performance. Choosing a neighborhood for companies and universities with first-class research greatly promotes local collaborative innovation (Laursen et al., 2011). The most effective way to diffuse knowledge is cross-organizational face-to-face informal contact (Kim et al., 2005). This informal communication has a positive effect on cross-organizational innovation. Some local enterprises, especially ranking top of them, prefer to searching for and absorbing non-local knowledge and make it application. They often play the knowledge keepers role (Owen-Smith & Powell, 2004).

The higher the degree of tacit knowledge, the more difficult it is to encode, express, and transfer, which weakens and restricts the spatial transfer and diffusion of knowledge. Those close to the innovation pole and source require more face-to-face communication and contact. They can smoothly promote their innovation activities, which ultimately leads to the localization of innovation. These reasons lead us to propose the following hypotheses:

H_1: Geographical proximity has a positively effects on the innovation performance of enterprises

6.1.2 Technological proximity and enterprises innovation performance

To communicate, understand, and process this new information and knowledge, companies in different locations need to have broadly similar technological foundations (Wuyts et al., 2005). Every new technology has a minimum knowledge threshold. Below this threshold, subjects have difficulty communicating, understanding, and successfully interacting. New technology contains tacit knowledge, which can be digested and absorbed through communication and learning with a similar knowledge base (Boschma, 2005). Technological proximity helps overcome the institutional differences between universities and industries. It can promote effective communication in organizational cooperation, enabling firms to efficiently and cost-effectively acquire and absorb resources and spill over knowledge (Callois, 2008). Moderating technological proximity complements the knowledge between subjects and stimulates innovation (Nooteboom et al., 2007). The innovation output, efficiency, and capability of the network are higher if actors have similar knowledge, technology, and capabilities (Prabhu et al., 2005). The actors who carry out the cooperative innovation can identify, explain, and explore the acquired new knowledge and carry out effective knowledge transfer. Hence, we argue that

H_2: Technological proximity positively related to the innovation performance of enterprises.

6.1.3 Social proximity and enterprises innovation performance

Social proximity is a trust-based, socially embedded relationship between subjects (Boschma, 2005). The discussion of "space" and "relationship" has promoted innovation networks to gradually become the core research area of collaborative innovation. A "relational space" can largely complement or replace the "point space" of the entity and promote innovation activities in the region. Trust-based social relationships are conducive to the interactive transfer of tacit knowledge, and effective interactive learning requires firm and lasting social relationships (Maskell & Malmberg, 1999). The proximity of social networks can increase the channels of knowledge flow between subjects and provide an effective way for exchanging knowledge. Giuliani et al. (2005), Broekel (2012), and Ter Wal (2014) discussed the positive relationships between social proximity and innovation performance in a Chilean beer cluster, an aviation knowledge network in the Netherlands, and in a German biotechnology industry, respectively. Social proximity can thus reduce information acquisition uncertainty and cooperation costs as well as promote the transmission of factors between universities and industry. Then, we formulate the following hypothesis:

H3: Social proximity is positively related to the innovation performance of enterprises.

6.1.4 The mediating role of knowledge embeddedness

Lundvall and Johnson (1994) proposed that the co-evolutionary logical relationship of collaboration with proximity can be presented by the non-linear processes of interactive learning. U-I collaboration is a dynamic process that can produce creative power for companies and universities through the knowledge flow among collaborative actors. The technological, transaction, and organizational costs of collaborative actors can be reduced by integrating the inflow and outflow of knowledge (Arts & Cassiman, 2016). Therefore, the introduction of mediating factors can affect the inflow and outflow of knowledge and generate momentum potential, which would accelerate or slow the impact on the innovation performance of U-I collaboration.

According to network structure theory, knowledge embeddedness includes the complementarity of different types of knowledge and the relationship based on the trust between innovative subjects. At the same time, it originates from the consideration of the self-interested thinking of creative subjects (Granovetter, 1985; Inkpen & Tsang, 2005; Nielsen, 2005). The core of knowledge embeddedness focuses on how innovative subjects overcome the obstacles of knowledge flow and promote the synergy of knowledge by acquiring complementary knowledge and mutual trust. The knowledge of learners and learning goals can jointly produce qualitative changes through complementary fusion and creation, allowing the performance of the network's knowledge resources to reach the optimal level (Huggins & Johnston, 2009). A higher level of knowledge trust can increase the cooperative flexibility of innovation entities in the network, reduce the cost of innovation activities, and enhance knowledge conversion and potential knowledge learning status (Mortensen, 2012). Knowledge concealment not only forms different knowledge embeddedness structures according to the differences in protection measures and mechanisms, but also reduces the value of embedded knowledge (Nielsen, 2005). The level of knowledge stickiness needs to be reduced to ensure effective knowledge exchange and promote new knowledge in cooperative networks. Knowledge embeddedness can help companies obtain valuable information beyond the barriers of geography, cognition, and social space. Knowledge embeddedness thus plays an important role in improving the synergy of cooperative networks. In general, it affects the proximity–cooperative innovation performance relationship. Hence, we propose the following hypotheses:

H4: Knowledge embeddedness has a positive mediating effect on the relationship between geographical proximity and the innovation performance of enterprises.

H5: Knowledge embeddedness has a positive mediating effect on the relationship between technological proximity and innovation performance of enterprises.

H6: Knowledge embeddedness has a positive mediating effect on the relationship between social proximity and the cross-regional innovation performance of enterprises.

6.1.5 The moderating role of the enterprises' absorptive capacity

An enterprise's absorptive capacity reflects its dynamic learning ability, which is the ability of its members to gradually comprehend and achieve the goal of dynamic "learning to learn" (Volberda et al., 2010). The companies obtain new external ideas and information and can also effectively integrate creative elements from outside the organization to help it overcome internal organizational inertia, functional fixation, and other disadvantages (Ancona & Caldwell, 1992; Fleming & Waguespack, 2007). They enhance the effectiveness and efficiency of the interorganisational knowledge interaction to efficiently introduce external knowledge into the enterprise to promote innovation activities (Rosenkopf & Nerkar, 2001). Absorptive capacity is more prominent for the acquisition and transfer of complex collective and tacit knowledge, which helps enterprises establish relationships with other subjects and maintain dynamic interactions to achieve their organizational goals (Marrone et al., 2007).

The knowledge absorptive capacity determines the benefits of innovation subjects based on the "expected target" of the U-I relationship (Szulanski, 2000). The strength of absorptive capacity directly changes the degree of the acquisition and transformation of the embedded knowledge in the cooperation by innovation subjects, forming a close connection between knowledge embeddedness and collaborative cooperation. The knowledge absorptive capacity may thus affect the interaction strength between knowledge embeddedness and cooperative knowledge synergy. Then, we argue that:

H7: The enterprise's absorptive capacity moderates the relationship between knowledge embeddedness and innovation performance.

Then, we formed the research concept of this chapter (Figure 6.1):

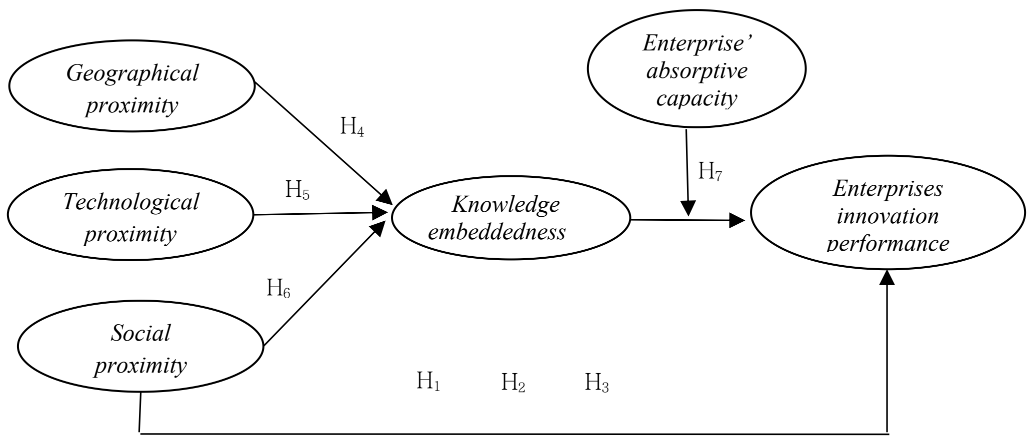


Figure 6.1 The research concept of this chapter

6.2 Methods

6.2.1 Variables

Dependent variable

U-I collaboration is largely regarded as a way to improve economic innovation by promoting the flow and utilization of technology-related knowledge and experience across sectors (Inzelt, 2004; Perkmann et al., 2011). We draw on the scales of Granovetter (1985), Nielsen (2005), and Ankrah and Omar (2015). Innovation performance is divided into its technology-related and management-related aspects. Technology-related performance comprises four items including "the net income of the U-I collaboration reaching or exceeding the expected return and so on." Management-related performance comprises four items including "the number of stakeholders have increased and the technical paradigm of the cooperative network has improved etc.."

Independent variables

Geographical proximity. Following previous measurements (Adams, 2005; Broström, 2010; Laursen et al., 2011), the latent variable of geographical proximity is reflected by "cooperative members are more likely to choose an organization that is closer, the closer the geographical distance to the partner, the better the establishment of a good and stable cooperative relationship, the closer the geographic distance to the partner, the greater the frequency and efficiency of increased knowledge exchange, the closer the geographical distance to the partner, the more face-to-face communication is possible, which is conducive to knowledge sharing and promotes university-industry collaboration."

Technological proximity. Technological proximity is generally measured as the technological distance between subjects and patent indicators (Nooteboom et al., 2007; Basile et al., 2012; Cassi & Plunket, 2014). However, patent-based technological proximity cannot make the subsequent role of proximity more intuitively derived. Technological proximity includes a common language, goals, and a similar technical level and knowledge base between subjects (Li & Wang, 2014). Since this research focuses on the performance of cooperative innovation technology and management performance, it is more appropriate to use a measure of subjective attitude. Therefore, the establishment of cooperation goals, the consistency of knowledge and technical exchange goals, and the similarity of cultural concepts are selected to reflect the potential variables of technological proximity.

Social proximity. Social proximity is usually measured using network structure variables. Bercovitz and Feldman (2011) found that past social connections positively affect later applications for cooperative patents. Breschi and Lenzi (2016) proposed that the mobility of people promotes the establishment of social networks to generate social proximity. According to the organizational form of cooperative innovation, the above measurement indicators are modified to establish the following: "Partners and companies can provide useful information to each other; I rely on my partners and can maintain long and close social relationships with them; partners can help each other to solve each others problems; partners can remind each other of possible problems and changes."

Mediating variable

Knowledge embeddedness is measured using indicators of knowledge trust and knowledge complementary (Granovetter, 1985; Szulanski, 2000; Nielsen, 2005). Knowledge complementary mainly refers to knowledge interaction, compatibility, and cooperation growth. Knowledge trust is measured by contract activity and trust level by improving the scale of Uzzi (1996). Knowledge complementary is measured by three items: knowledge needs, knowledge network connections, and knowledge fusion.

Moderating variable

Absorptive capacity is divided into knowledge acquisition and integration (Zahra & George, 2002; Roberto, 2016). Cohen and Levinthal (1990) used R&D costs as a proxy of absorptive capacity. Schmidt (2010) measured the level of absorptive capacity as the percentage of staff with a university degree. In U-I relationships, agency fees and an organizational academic structure can only represent the absorptive capacity of certain explicit knowledge, whereas tacit knowledge needs to be reflected in practice. This study thus uses the scale compiled by Griffith and Sawyer (2010). Knowledge acquisition is measured using two items: the degree of motivation to acquire learning and the desire for active learning. Knowledge integration is measured using two items: learning practice and knowledge understanding.

Control variables

Firm size may affect the innovation performance of U-I collaborations. When a firm is small, this restricts the absorption and transformation of external knowledge, and the effects of the U-I collaboration cannot be seen. Therefore, we use firm size as a control variable. The different organizational forms of the U-I collaborations may affect its main motivation, which in turn affects its performance; hence, it is also used as a control variable. Whether firms are national or private is also controlled for to obtain more accurate research results. Table 6.1 shows the description of the variables.

Table 6.1 The description of the variables

Variable	Items	Item Source
Geographical proximity (GP)	Cooperative members are more likely to choose an organization that is closer The closer the geographical distance to the partner, the better the establishment of a good and stable cooperative relationship The closer the geographic distance to the partner, the greater the frequency and efficiency of increased knowledge exchange The closer the geographical distance to the partner, the more face-to-face communication is possible, which is conducive to knowledge sharing and promotes university-industry collaboration	Adams (2005), Broström,(2010), Laursen et al.(2011)
Technological proximity (TP)	Desiring to exchange knowledge and technology with partners Understanding the strategy and needs of partners Consistency of goals during knowledge exchange or technical cooperation with partners The degree of cultural or ideological consistency during knowledge exchange or technical cooperation with partners	Li & Wang (2014)
Social proximity (SP)	Partners can provide useful information to each other I rely on my partners and can maintain long and close social relationships with them Partners can help each other to solve each others problems Partners can remind each other of possible problems and changes	Bercovitz and Feldman (2011), Breschi and Lenzi (2016)
Knowledge embeddedness: Knowledge complementary (KC)	The stronger the complementary of knowledge, the better it is for knowledge to be embedded in the collaborative innovation network The higher the degree of complementary of knowledge, the more it can meet the knowledge needs of the subject of innovation The higher the degree of complementary of knowledge, the more it can promote the knowledge connection between the cooperation subjects	Granovetter (1985), Szulanski (2000), Nielsen (2005), Uzzi (1996)
Knowledge embeddedness: Knowledge trust (KT)	The higher the loyalty of the contract content, the more conducive to the flow of knowledge and improve innovation performance The higher the level of trust, the better the knowledge interaction and learning activities in the cooperative network The higher the level of trust, the higher the value of knowledge The higher the level of trust, the less opportunistic behavior of knowledge interaction	Granovetter (1985), Szulanski (2000), Nielsen (2005)
Innovation	Net income in cooperation reaches (exceeds) expected income target	Granovetter

performance: Technological-related (IP-TR)	My products have been improved The number of invention patents for cooperation between partners has improved Collaborative subjects have continuous professional improvement	(1985), Nielsen (2005), and Ankrah and Omar (2015)
Innovation performance: Management-related (IP-MR)	The number of stakeholders in cooperation networks is increased The social reputation of the subject in cooperation is higher Cooperation creates more business (job) opportunities The technical paradigm of cooperative networks has been improved	Granovetter (1985), Nielsen (2005), and Ankrah and Omar (2015)
Enterprises absorptive capacity (EAC)	Regularly discussing market development trends and new product development issues Tending actively to learn and accumulate new knowledge that may be used in the future Communicating frequently with other companies to acquire new knowledge Usually thinking about how to apply knowledge more effectively Ability to quickly analyze and understand changing market needs	Griffith and Sawyer (2010).

6.2.2 Sample

We choose regional cooperative companies from the U-I collaboration patents for database. As a pillar industry in China, the manufacturing industry plays an important role in national innovation and development. Hence, this study selects the manufacturing industry as the main research object, which is reasonable to a certain extent. A total of 107 e-questionnaires were distributed by WJX (www.wjx.com) to 75 large manufacturing enterprises. In total, 100 valid questionnaires were received within two months from 2019.12.1 to 2020.1.31. The regional breakdown were eastern (26%), central (28%), western (19%), and northern (27%). Table 6.2 shows the description of the samples.

Table 6.2 The description of samples

Item	Measurement	Proportion
Size	<100 person	17%
	100-500 person	19%
	500-1000 person	5%
	≧1000 person	59%
Age	<5 years	15%
	5-10 years	11%
	≧10 year	74%
Nature	State-owned	38%
	Private	44%
	Three-capital (foreign-funded)	18%

6.2.3 Analysis techniques

To ensure the validity and reliability of the measurement items, the research selected scales used in relevant studies. A formal questionnaire was modified following the specific content and research purposes (AppendixII). A seven-point Likert scale (1=strongly disagree, 7=strongly agree) was used for the measurement. We used SPSS v. 21.0 to test the reliability and validity. A regression model was used for the main and moderating effect analyses. The mediating effect was studied using the bootstrap sampling test method. The following measurement model was constructed:

$$Y = \alpha + \beta X_i + \mu Z_i + \varepsilon_i \tag{6-1}$$

$$Y = \alpha + \partial I + \delta M + \gamma (I \times M) + \mu Z_i + \varepsilon_i \tag{6-2}$$

Equation (6-1) is a direct effect model and equation (6-2) is a moderating effect model. Y is the innovation performance of UIC and X_i is the independent variable, including geographical, cognitive, and social network proximity. I is the mediating variable, M is the moderating variable (i.e., the boundary-spanning team's absorptive capacity), and Z_i is the control variable.

6.3 Results

6.3.1 Reliability and validity testing

The reliability and validity of the questionnaire data were analyzed by using SPSS 21.0. The overall Cronbach's α is 0.959, which is above the threshold of 0.9, showing that the reliability of this research is of high quality. Data validity is also good according to Bartlett's sphericity test (KMO=0.871>0.70, p=0.000<0.05). This shows that the questionnaire observation index is suitable for factor analysis. Moreover, the factor loading of the 28 variable items of the measurement scale is 0.798–0.950 and the cumulative variance contribution rate is 86.9%>50%, indicating that the scale has high convergence validity.

6.3.2 Confirmatory factor analysis

Table 6.3 shows the results of the confirmatory factor analysis and descriptive statistics of the main research variables. These factors include geographical proximity (GP), technological proximity (TP), social proximity (SP), knowledge embeddedness (measured by knowledge complementary (KC) and knowledge trust (KT)), the enterprise's absorptive capacity (EAC), and the innovation performance of UIC (measured by technical performance (IP-TP) and management performance (IP-MP)). The squared average variance extracted values of all the variables are greater than the correlation coefficients of the variable and other variables, indicating that this data analysis has good convergence validity. The model and hypothesis have certain rationalizes (Table 6.4). Further, the χ^2 /df, CFI, IFI, NFI, GFI, RMSEA, and RMR indicators are in line with or close to the standard, indicating a good fit of this model. We next test the mechanisms among the variables.

For collaborative innovation performance, the correlation coefficients of TP and MP are 0.864, of EAC is 0.852, and of KC and KT are 0.690, which are greater than 0.6. The fit of the nine-factor verification model is good, and collaborative innovation performance, knowledge embeddedness, and the boundary-spanning team's absorptive capacity are high-order variables composed of second-order factors. When the empirical analysis is carried out, the average value of two factors is taken to examine their role in the overall context.

Table 6. 3 Descriptive statistics and correlation analysis

Variable	Mean	S.D.	GP	TP	SP	KC	KT	IP-TR	IP-MR	EAC
GP	5.503	1.258	0.905							
TP	5.346	0.845	0.560**	0.884						
SP	5.313	0.990	0.155	0.586**	0.905					
KC	5.403	1.073	0.169	0.480**	0.621**	0.831				
KT	5.685	0.915	0.179	0.463**	0.543**	0.690**	0.955			
IP-TR	5.252	0.880	0.174	0.590**	0.643**	0.539**	0.630**	0.842		
IP-MR	5.378	0.861	0.202*	0.575**	0.642**	0.661**	0.705**	0.864**	0.865	
EAC	5.521	0.827	0.135	0.551**	0.580**	0.759**	0.768**	0.717**	0.813**	0.908

Table 6.4 Results of the confirmatory factor analysis

Model	χ^2	*df*	χ^2/*df*	*CFI*	*IFI*	*GFI*	*NFI*	*RMR*	*RMSEA*
Result	*557.094*	*304*	*1.833*	*0.920*	*0.922*	*0.749*	*0.843*	*0.048*	*0.091*
Measure	-	-	*<3*	*>0.9*	*>0.9*	*>0.9*	*>0.9*	*<0.05*	*<0.10*
Fit			*Yes*	*Yes*	*Yes*	*Close to*	*Close to*	*Yes*	*Yes*

6.3.3 Main effect tests and analysis

First, in Model 1, the control variables are introduced into the regression equation ($p>0.05$), indicating that control variables such as firm size, property, and form have no significant effect on the innovation performance of UIC. Second, Model 2 incorporates the independent variables of geographical proximity, technological proximity, and social proximity (see Table 6.5). After inputting the independent variable into the model, the explanatory power of the model is 54.1% ($F=15.476$, $p<0.01$), passing the F-test. The variance inflation factor values in the model are all less than 5 and the Durbin–Watson statistic is approximately 2. The model has no collinearity or autocorrelation problems, and the fit of the model data is good. The final analysis shows that the regression coefficients are as follows: geographical proximity β=-0.038 (t=-0.626, p=0.053<0.1), cognitive proximity β=0.326 (t=2.929, p=0.004<0.01), and social network proximity β=0.420 (t=5.327, p=0.000<0.01). This means that geographical proximity does not positively affect innovation performance. Therefore, H1 is not supported. Technological and social proximity have a significant positive impact on innovation performance; hence, H_2 and H_3 are strongly supported. The rank of influence is social proximity>technological proximity>geographical proximity.

Table 6.5 Main and moderating effect results

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	15.095***	3.355***	15.095***	22.755***	23.044***
Size	-1.594	-1.668	-1.336	-0.129	-0.304
Industry	0.692	1.650	1.972	1.336	1.628
Collaborative form	-0.659	-0.499	-0.189	-0.467	-0.648
GP		-0.626*			
TP		2.929***			
SP		5.327***			
KE			9.949***	5.015***	5.443***
EAC				6.240***	6.462***
KE*EAC					2.266**
R^2	0.032	0.541	0.529	0.668	0.685
Adj-R^2	-0.09	0.506	0.504	0.646	0.661
F	0.791	15.476	21.083	31.148	28.620

*p<0.1 **P<0.05***P<0.01

6.3.4 Mediating effect tests and analysis

We separately add the independent variables of geographical proximity, technological proximity, and social network proximity as well as the mediating variable of knowledge embeddedness for the mediation analysis. The study conducts a bootstrap sampling test on the indirect effect value. If the 95% confidence interval (CI) value of the indirect effect value does not include 0, it indicates that it has a mediating effect. Table 6.6 shows the results, indicating that when geographical proximity shapes innovation performance, knowledge embeddedness does not play a mediating role; hence, H4 is not supported. On the contrary, for technological and social proximity, knowledge embeddedness plays a mediating role. H5 and H6 are thus supported.

Table 6.6 Knowledge embeddedness: Mediating analysis

Type	Item	Effect	SE	t	p	LLCI	ULCI
Direct effect	*GP⇒IP*	0.056	0.049	1.131	0.261	-0.041	0.153
	TP⇒IP	0.314	0.077	4.070	0.000	0.163	0.465
	SP⇒IP	0.327	0.071	4.578	0.000	0.187	0.467
Indirect effect	*GP⇒KE*	0.117	0.075	1.556	0.123	-0.030	0.264
	KE⇒IP	0.649	0.067	9.659	0.000	0.517	0.780
	TP⇒KE	0.545	0.097	5.628	0.000	0.355	0.734
	KE⇒IP	0.515	0.071	7.247	0.000	0.376	0.655
	SP⇒KE	0.581	0.073	8.001	0.000	0.439	0.723
	KE⇒IP	0.433	0.078	5.535	0.000	0.280	0.586
Main effect	*GP⇒IP*	0.132	0.069	1.915	0.059	-0.003	0.266
	TP⇒IP	0.595	0.083	7.163	0.000	0.432	0.757
	SP⇒IP	0.578	0.063	9.158	0.000	0.455	0.702

Note: LLCI refers to the lower limit of the 95% CI of the estimated value and ULCI refers to the upper limit

6.3.5 Moderating effect test and analysis

The independent variable knowledge embeddedness (KE) and moderating variable enterprises absorptive capacity (EAC) are centralized for the data. Then, the control variables (Model 1), independent variable (Model 3), moderating variable (Model 4), and mediating variable (Model 5) are introduced into the regression equation in turn. Table 3 shows that the interaction of KE and EAC is significant (t=2.266, p=0.026<0.05). This means that when knowledge embeddedness affects the performance of the innovation, the moderating variable (EAC) is at different levels. The stronger knowledge absorptive capacity, the greater is the impact between knowledge embeddedness and the innovation performance. Then, H7 is supported.

This chapter examines the effect of knowledge embeddedness on the innovation performance at different levels of the team's absorptive capacity based on one standard deviation above and below the mean. The high line is always above the low level, and it is steeper than the low level. In other words, when the team's absorptive capacity is high, the positive impact of knowledge embeddedness on innovation performance rises.

6.4 Summary

The effects of geographical proximity is not sufficiently significant to promote the innovation performance though we original thought that the reason is related with geographical proximity. Although the firms who choose the university located in the same region, considering modern ICT and convenient transportation can promote communication between subjects, and the limitation of geographical proximity is gradually weakening.

Technology proximity plays a role in promoting the innovation performance of enterprises. Such factors as the cooperation experience of subjects and similar goals have laid a good trust foundation for cooperation. Social proximity promotes a significant improvement in the innovation performance as well as facilitates the formation and maintenance of the innovation relationship. When the distance between two regions in the innovation network is relatively close, even if the geographical distance is long or there has been no direct cooperation in the past, it is easier to cooperate to improve the innovation performance. Therefore, the social proximity play a key role for innovation performance in a local context.

Knowledge embeddedness plays an important role as a bridge between proximity and enterprises' innovation performance. Knowledge complementary and trust can increase the potential differences in knowledge flow and improve productive efficiency. Improving cooperative innovation performance has practical significance. The ability of the firms' acquire and integrate knowledge helps knowledge embed into the U-I collaborative process. Frequent discussions and exchanges between partners can raise the quality and efficiency of knowledge transfer and improve innovation performance. We should thus focus on the effect of social networks and technological proximity and expand the search for partners in U-I collaboration. Given the moderating effect of absorptive capacity, the R&D talents are important for U-I collaborations. Such a team proactively relies on business associations and knowledge needs to become more interconnected, thereby shortening the technological gap and social distance between innovative entities.

This chapter contributes in three ways. First, we focus on enterprises innovation performance from a multidimensional proximity perspective. At the same time, the evaluation of innovation performance not only focuses on technical performance but also increases the measurement dimension of management performance. A second contribution is analyzing the mediating role of knowledge embeddedness on the proximity and innovation performance of enterprises and discussing logical paths that deeply affect innovation performance. Third, in contrast to using a traditional single dimension to explore knowledge absorptive capacity, we explain the leverage of different absorptive capacities from a micro perspective.

This chapter still has limitations that are worth investigating in future research. First, the development of U-I collaborative innovation among the main bodies is a dynamic process. Therefore, dynamic growth and relationship variables need to be explored in the future. Second, the size of the sample is limited to the manufacturing industry, which may affect the general ability of this research. Hence, future studies could extend samples to overcome these limitations. Third, environmental factors such as government intervention and market orientation should be considered in the innovation of U-I collaborations. Future research may extend the individual-level factors to include, for example, the psychological and professional levels of the subjects participating in this research.

Chapter 7
Strategies for fostering University- Industry linkages

In knowledge innovation outflow stage, the perceivable proximity effects like social proximity are more conducive to knowledge spillover from universities to enterprises, and this ability mostly dependent on regional and enterprise' collaborative cognition to identify the technological or social proximity. And for the inflow stage, regional and enterprises absorptive capacity can shape knowledge application efficiency. Then the regional endowments and human capital as a bridge connect the external knowledge acquisition and internal knowledge integration (See Figure 7.1).

Human capital has a positive contribution to U-I collaborations. The improvement of education and talent quality is the main way to improve human capital. On the other hand, the fundamental role of consumption in economic growth is effectively playing in China. The contribution rate of China's final consumption expenditure to economic growth in 2018 was 76.2%, which was 43.8 percentage points higher than the total capital formation. In 2019, the total retail sales of consumer goods increased by 8% year-on-year, which was 1.9 percentage points faster than fixed asset investment in the same period. The expansion of consumer demand can provide strong support for industrial structural reforms. Therefore, how to link industrial development with regional consumption structure and formulate effective industrial development policies also play great significance to promote knowledge flow in U-I collaboration. Hence, the strategies proposed based on these research results and focus on the education and the interaction between region and industry facing consumption-driven economic development.

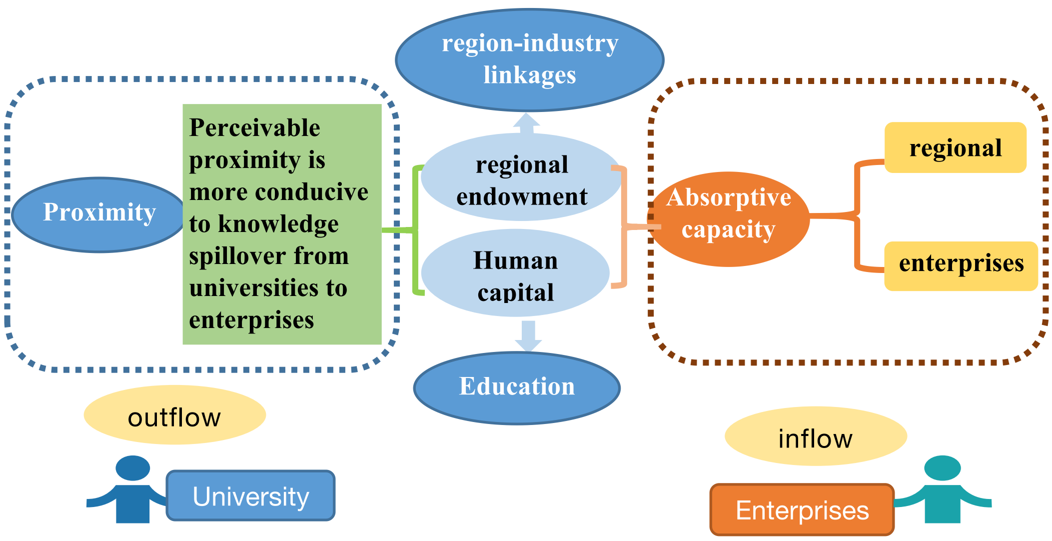


Figure 7.1 Strategy design for fostering U-I knowledge flow

7.1 Strategies 1: Entrepreneurship education as a means for U-I knowledge flow

University-industry linkages and their impact on innovation processes have been widely acknowledged. The triple helix innovation paradigm proposed university has become an innovative organization that is as important as the enterprise and the government. It is pointed out that those universities that pay more attention to technology transfer and the creation of new companies are called "entrepreneurial university" (Etzkowitz, 2009). Universities get two types of role: one is a regional center participant, whose role is knowledge production to improve competitiveness (Goldstein & Drucker, 2006), and as a cultural participant that promotes regional interaction. The rise of the entrepreneurial university is a key driver of transition from an industrial to a knowledge-based society (Etzkowitz, 2014). However, priors research have mostly tested the knowledge flow activities by U-I collaboration from the point of view on the "third mission" (Berbegal-Miraben et al., 2020).

This strategy goes a step further, analyzing U-I knowledge flow processes drowning on the university's teaching function. Being an entrepreneurial university, universities prefer to teach entrepreneurship for cultivating an entrepreneurial attitude in the mindset of their students next to U-I knowledge flow through research. Blankesteijn et al. (2020) makes a better exploitation of the possibilities that science-based entrepreneurship education related with university-industry technological activities. The entrepreneurship education which firmly embedded in a science, technology and R&D environment, both within and outside the university. This kind of entrepreneurship education help for improve the opportunity on U-I technology transfer. Students who experienced entrepreneurship education would contribute to U-I knowledge flow through organizing career events, internships, starting up their own business and similar activities. They foster the new innovative knowledge or skills through the ability that lead new products or service are acceptable by market. Thus, they contribute to U-I knowledge flow in the regional innovation system.

However, there are many difficulties in creating effective U-I knowledge flow, a still remaining question is how U-I knowledge flow can be stimulated by entrepreneurship education. The scientific literature focuses mostly on U-I collaboration to fostering knowledge flow, and not so much in (entrepreuship) education. Many scholars have realized that the research on entrepreneurship education in universities cannot be limited to a single school organization level but should explore the dynamic interaction mechanism between various organizations and elements within universities and between universities and external factors. Entrepreneurship education needs a carrier, and it should be integrated with professional education and regional environment to play the role of entrepreneurship education better. Therefore, the research question of this strategy address is:

How does entrepreneurship education embedded into professional education and regional environment contribute to U-I knowledge flow?

To gain further insight in this question, we need to answer the relationship of entrepreneurship education in the university context, balancing the theory and practice, effecting the entrepreneurship students on regional innovation system. Design education plays a key role in Dalian Polytechnic University. Hence, we take design education as professional education example. Then, the research proposes an embedded framework and related design thinking practices that bridge entrepreneurship education with design education. Entrepreneurship university need the students have high-level thinking, business mindset and the problem-solving capability. The following outcomes of integrated education will be tested from these three aspects

7.1.1 Embeddedness network framework

According to the embeddedness theory, first of all, in the integration network of entrepreneurship education into design education, it is necessary to determine the cooperation relationship between the subjects. Then, it should be to ascertain each subject's position and role, that is, the network node in the network formed by this cooperative relationship. It is also important to consider the factors affecting this status and role. Therefore, the proposal framework answers the following questions:

- *What's the relationship of the subjects in the integrating education system;*
- *What's the entrance point can embed into the process of integrating education;*
- *What factors can affect the relationship of the subjects?*

To more accurately determine the main body of integrated education system and its relationship, we first understood an effective boundary of professional education after integrating entrepreneurship education. The most widely accepted effective boundary of integrated education is, therefore, a new logical structure of the design education process is the following:

- *Effective professional education should be a system;*
- *The learner and the market are part of the system; and*
- *The system is not only affected by internal factors, but also by external factors.*

The integration of entrepreneurship with professional education can produce network activity with two principal effects: learning and coordination effect (Schalk, et al., 2012). Learning effects occur because access to information increases contemporary innovations' awareness (Brass et al., 2004). Coordination effects occur because organizations pool their resources to achieve common policies. Professional education should consider the fact that the clients (or customers), in turn, have in mind a set of users (or customers) for whose benefit the products are being developed. The design process is itself a complex cognitive process (Dym et al., 2005 *P*104). To realize both effects, the main body of the professional education gets another university, teachers, students, and external users and customers. These subjects cooperate and work together to build a platform for collaborative education. The process of knowledge creation and sharing also involves cooperation between organizations and establishing a platform-like partnership. Drawing on Zukin and DiMaggio (1990), cognition, culture, and organization are the distinctive contribution of embeddedness approaches in economic sociology. The embeddedness framework is divided into three dimensions: environmental and organizational embeddedness to produce the coordination effects and design with entrepreneurial-driven bilateral cognitive embeddedness for learning effects—the initial letter of the three parts names this framework (Figure 7.2).

- Environmental embeddedness. It includes two types of embeddedness, structure, and culture. The main task is to identify the structure of integrated education. The network node is the university that connects with teachers, students inside, and social factors outside. University should redesign professional education based on external factors, such as technology, policy, culture, etc. Professional majors should integrate creativity and entrepreneurship into the process of professional skill construction, promote the reform of the teaching system, and guide students to achieve self-improvement and development. The university formulates training objectives, curriculum, and functional systems based on creative and business mindset.
- Organizational embeddedness. The main task is for the subjects to recognize multiple levels of structures to organizational and practical action domains. In

this level network, the main body is teachers who communicate with universities and students. They take the mindset as the guidance and the students as the center to conduct teaching methods. Students establish a market-centered cognitive attitude, form a habit of thinking through the course and practice training, and then impact their own motivations.

- Bilateral cognitive embeddedness. Students as the node the network to transfer their ability to market. The main task is for students from a variety of thinking approaches to apply them to their products. The highest body is the students. Education actors focus on the cultivation of design professional competence and the growth of entrepreneurship ability. Professional talent training with innovation and entrepreneurship education collaboration, the complementary of teaching resources, and the integration of training content would come true during the integration. We can make the following hypothesis:

H1: Environmental embeddedness has a positive correlation with the integrated education goal;

H2: Organizational embeddedness has a positive correlation with the integrated education goal; and

H3: Bilateral cognitive embeddedness has a positive correlation with the integrated education goal.

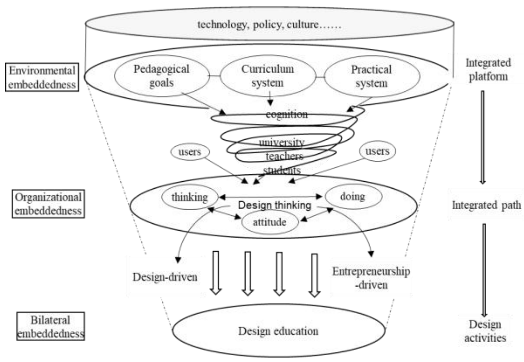


Figure 7.2 “E-O-B” embeddedness network framework for integration

7.1.2 Model test

Method

According to the framework's design, we set the entrepreneurship education performance embedded into design education as the dependent variable, environmental embeddedness, organizational embeddedness, and bilateral cognitive embeddedness as independent variables. First, the research performs a correlation analysis and uses the Person coefficient to determine the correlation between variables and test the impact factors. Then, the linear regression method was used to estimate the fit of the model. If the model makes way for the test, we can design the application path based on this model.

Variable measurement

Dependent variable

To measure the performance of entrepreneurship education integrating into the design education, the first essential thing is to define the goal of integrated education. According to the literature, we collected some talent training goals or understanding some design majors and entrepreneurship education (Table 7.1). From these scholars' ideas, market activities and create awareness or thinking play a significant role in the training goal. Designing products that can satisfy and catch the market opportunity and need are the main purpose. So this research takes the market-related knowledge (business mindset) and creative thinking to measure integrated education performance.

Table 7.1 A variety of training goals on design majors

Major	Training goal	Author
Engineering design	"It is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints."	Dym et al. 2005
Graphic design	"Design as a professional practice has often bridged fields as diverse as engineering, marketing, education, and psychology. Design as an academic study can do no less."	Swanson Gunnar 1994
Art design	"Art and design are about supporting students to find their own way to be an artist or designer. Education places a good deal of emphasis on students becoming increasingly self-reliant in their learning. "	Lau & Lee 2009
Fashion design	"The professionalism, innovation and creativity to develop and realize the design ideas for careers as innovative designers. Designs to contribute innovative ideas to market activities alongside the international design industry."	Choi&Hee 2011
Entrepreneurship	"The primary goal for the majority of the programs was to improve the awareness and understanding of entrepreneurship as a process. The second major goal was to increase students' awareness of entrepreneurship as a career possibility. The programs tried to increase students' awareness of how different management disciplines such as marketing, finance and accounting can be integrated when focusing on promoting innovative ventures."	Liñán &Francisco 2004
Entrepreneurship	"The critical question if entrepreneurship education really contributes to cultivate an entrepreneurial mindset."	Hahn et al. 2017

Independent variables

Environmental embeddedness

Environmental embeddedness refers to the external environment's role in social networks (Eisenhardt et al.,1996). Some educational models determine the way or method when we teach and "educate" while also focusing on the relations between minds and cultures (Bruner & Seymour, 1996.) The heart of the dynamic that binds education to development is culture (Stephens & David, 2007). In the design field, culture is an important factor. Cultural features are considered a unique character to embed into a product to fulfill the individual consumer's experience (Lin, 2005). Cultural values are thought to express entrepreneurial behaviors, such as risk-taking and independent thinking. On the other hand, university education requires long-term, permanent contact with technology. Scientific and technological innovation is the mission of entrepreneurship education. Changes in technology have also caused changes in teaching methods and other aspects during education, such as 3D (Unver, 2006) and VR (Tilhou & Crompton, 2020), MOOC (Mayer, Schmieden, Taheri & Meinel, 2020). There is a much more direct relationship between education and industry which has given birth to various policy initiatives (Ball, 2012). Therefore, environmental embedded variables are measured from culture (CL), technology (TC), and policy (PO) factors to be measured.

Organizational embeddedness

Organizational embeddedness theory prioritizes psychological factors why employees choose to remain in their organizations (Mitchell et al., 2001). It describes the attractiveness of the organization to its employees. Applied it into education, organizational embeddedness can be realized how to organize students' motivation in learning. "Efficacy beliefs influence how people feel, think, motivate themselves, and behave" (Bandura, 1993, p.118). Therefore, an organizational mechanism plays a crucial role in integrated education to improve students' motivation. The mechanism focuses on the practices in terms of the conceptual tools building on environmental embeddedness. Pan (2014) constructed an evaluation index and calculated the weight of each metric for university efficiency including goal setting and planning (20%), expenditure and equipment (17%), teacher capacity (43%), and environmental quality (20%). Crossley et al. (2007) propose that general subjective questions should be used to assess organizational embeddedness. Depending on the position of the integrated framework, the organizational embeddedness of integrated education is measured by teaching resources (TR, 4-item), curriculum setting (CS, 2-item), and teachers' competence (TC, 2-item).

Bilateral cognitive embeddedness

DiMaggio (1990, P.113) thought that "patterns of cognition are deeply implicated in the constitution of social structure." So, the students' cognition is critical in the integrated education context. The bilateral cognitive embeddedness comes from the performance of integrated education. It focuses on how to make students form two kinds of cognition. One is creative thinking, and the other is the business mindset. This cognition can be built into the process of teaching and practice little by little. Therefore, it is calculated by teaching practice (TP,2-item) and teaching methods (TM,2-item). The "E-O-B" framework can be transferred into a research model (See Figure7.3).

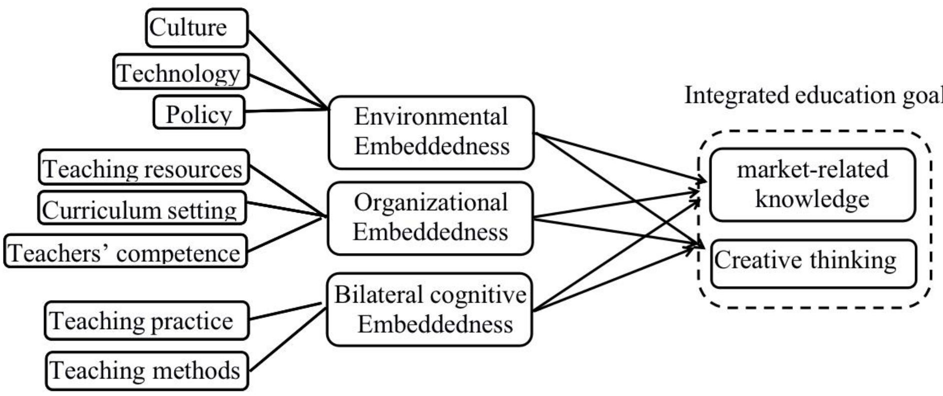


Figure 7.3 Research model of integrating education

Data collection

In check to see the model's validity, a questionnaire survey was conducted on 113 students who have participated in related design majors in entrepreneurship education (Appendix IV). The survey utilized electronic questionnaires. Among them that 52 were male, and 61 were female. Majors included clothing and apparel design, landscape design, digital media design, and lighting design. A questionnaire has 16 questions totally, adopts Likert five-point scales to test which on a scale of 1 (the least satisfaction/agree) to 5 (the most satisfaction/agree).

7.1.3 Results

The questionnaire's overall reliability was Cronbach α = 0.749, and the validity KMO = 0.827, which showed that the questionnaire had satisfactory reliability and validity, and it could verify the model well. We use SPSS software to test the model verification. First, the research performed a correlation analysis and used the Person coefficient to determine the correlation between variables. The results show that the integration of entrepreneurial education and design education by 16 factors such as policy and culture all positively correlate with the level of $p < 0.01$. Simultaneously, the multi-linear regression method was used to estimate the fit of the model. The result is model 1 $R^2=0.584$, after adjustment, is 0.401, ($F=3.187, p=0.003<0.05$), model1 pass the *F* test. Model 2 $R^2=0.785$, after adjustment, is 0.691, ($F=8.289$, $p=0.000<0.05$) (see table 7.2), it passed the F test which the R square is greater than the basic determination standard of 0.5, indicating that the model 1 and model 2 fit well (see Figure 7.4). Hypothesis 1-3 pass the test. That means the more embeddedness well, the better training goal to be achieved.

Table 7. 2 The results of linear regression test

Model Summary					
Model	R	R Square	Adjusted R Square	Std.Error	Durbin-Watson
1	.764a	0.584	0.401	0.485	2.032
a Predictors (Constant), CL, TC, PO, TR, CS, TC, TP, TM					
b Dependent Variable: business mindset					
Model	R	R Square	Adjusted R Square	Std.Error	Durbin-Watson
2	.886a	0.785	0.691	0.327	2.219
a Predictors (Constant), CL, TC, PO, TR, CS, TC, TP, TM					
b Dependent Variable: creative thinking					

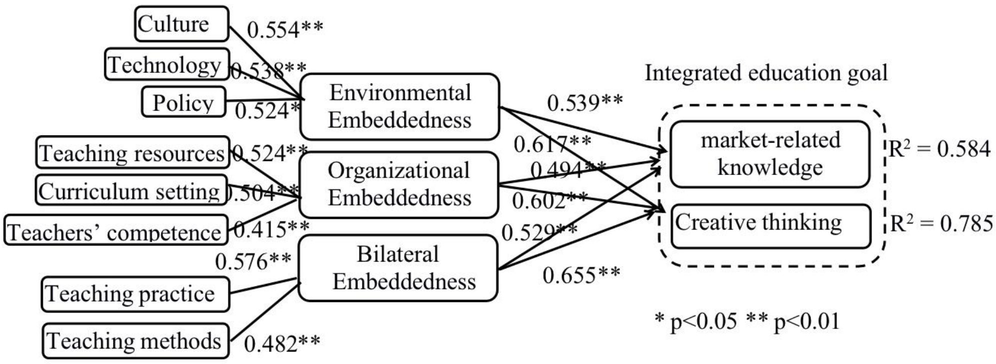


Figure 7.4 The result of the model test

7.1.4 Taking design thinking approach as a bridge for entrepreneurship education embedding design education

How does entrepreneurship education integrate with design education contribute to the design training goal? A cross-curricular integrated into existing subjects is a widespread approach like Bulgaria, Latvia, Poland, including in the subject as 'home economics and technology', 'ethics' or within social sciences. Then, what kind of cross-curricular can be embedded into design courses? The educational process of design is a social process, and similar to the economic activities of the enterprise. It"speaks"several languages with each other (to themselves) (Dym, Agogino, Eris, Frey, & Leifer, 2005, P104). Designers now want to embed incorporate environmental and social elements into their designed system to expand the boundaries of design (Hastings, 2004). In 2004, David Kelley founded the Institute of Design at Stanford, launched a design thinking course and introduced it to education officially. In recent, the core idea behind the design as 'Design Thinking' has gradually entered the perspective of educators and has been widely used. The United States, Australia, Japan, and other countries have introduced design thinking in the field of education, and have implemented some programs such as "Taking design thinking to schools"(Carroll, Goldman, Britos, Koh, Royalty & Hornstein, 2010), "Design Thinking Frameworks as trans-formative cross-disciplinary pedagogy" (Neil, Caroline & Carin, 2014). "Design Thinking for Future Schools" (Takeda, 2013). They attempted to diagnose, analyze and solve problems in education and teaching with the help of design thinking.

Hence, can students benefit from the integration of entrepreneurial skills through design thinking approach? According to the goals of design and entrepreneurship education, this article tries to explore the following three questions:

- *Whether the design thinking approach improve the creative thinking of design students by embedding entrepreneurial education;*
- *Whether the design thinking approach enhance the business mindsets of design students by embedding entrepreneurial education; and*
- *Whether the design thinking approach promote the problem-solving ability of design students by embedding entrepreneurial education.*

In order to effectively answer the above three questions, we divided the students who participated in the design thinking course into two groups. The students who participated in the entrepreneurship course and the students who had not participated the entrepreneurship course were used as the experimental and the control group. The two groups of students were subjected to the same design thinking training course, a comparative analysis of entrepreneurial thinking, business mindset and problem-solving ability is carried out to test whether design thinking can have a significant moderating effect in the process of integrating entrepreneurial education and design education.

Evaluation model construction

Design thinking cultivates high-level thinking capable of future work and life through in-depth reflection and gradual adjustment of cognitive processes and results, including observation and exploration, criticism and solving complex problems, creativity and innovation. Our aim is to explore the moderating effect of design thinking on the integrating education. Therefore, this study constructed a three-dimensional evaluation model to test the effects: “creative thinking,” “business mindset,” and “problem-solving ability” based on the goals of courses (Figure 7.5).

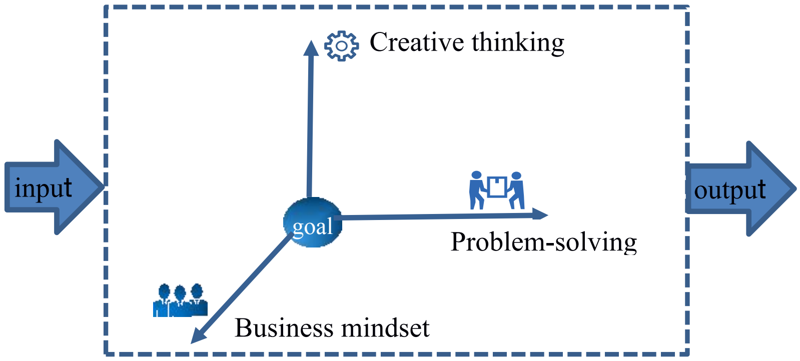


Figure 7.5 Three-dimensional evaluation model.

Considering the dimension of space, we pay attention to the achievement degree of combine courses, whether it impacts creative thinking in terms of horizontal dimension, the article intent to compare problem-solving ability on participants. From a vertical perspective, we will focus on the business mindset to deal with the marketing issues between students who participant the entrepreneurship education and not attend. Therefore, we explore the differences in the contribution design thinking to the performance of design education which include the entrepreneurial elements. We can make the following hypothesis:

H1: Integrated education through design thinking has a positive effect on students' creative thinking;

H2: Integrated education through design thinking has a positive effect on students' business mindset; and

H3:Integrated education through design thinking has a positive effect on students' problem-solving ability.

When teaching with a design thinking method, a reasonable method means that good design thinking can help teaching designers break through the limitations of thinking and find the coincidence between teaching design and society and education. The teacher team systematically designs integrated education based on the five stages of design thinking. The objectives, requirements, and operation of each link are shown in the Table7.3.

Table7.3 Elaboration of Design-thinking workshop

Stage	Objectives	Requirement(tools)	Operation
Discovery	Solving problems encountered in the teaching and daily life; Cultivating students' creative ability	Picking questions from students, defining target needs precisely, and optionally use a commercial canvas	Teachers need to collect survey information about a problem, precisely define the needs of the problem, and form an open, practical, challenging, and interesting question
Interpretation	Gradually backward the knowledge and skills that students may use	A process of reverse analysis, starting from the goal to be achieved, and gradually reversing the subordinate skills that the learner needs to master	Goal-oriented, clearing knowledge and skills that should be possessed at each stage
Ideation	Searching for more possible solutions	Following the principle of deferred comments to encourage students to generate more ideas	Brainstorming, Mind mapping, KJ, enumeration, TRIZ and other innovative methods
Experiment	Selecting several feasible solutions to make a prototype for testing the solution proposed in the previous stage and continuously iterating	Computer, paper, pen, cardboard, Lego bricks, glue, scissors, note paper, etc.	In this process, teachers can guide students in the techniques used in model construction and help students choose how to present prototypes.
Evaluation	Using implemented product prototypes or simulation environments to rigorously test whether problems are resolved, while focusing on the collaborative process	Finding problems in the process and resolve them in a timely manner	Showing your ideas through presentations.Emphasizing teamwork

Participants

According to the elaboration of the course, the purpose of design-thinking workshops is guided up to a point on how to hold successfully tested prototypes and cultivate students' business mindset, to take user need at design start point. Their major was clothing and apparel design. Some of the participants are also registered in the entrepreneurial principles and practice course. There were 22 participants who act the task individually or in teamwork. we got in the evaluation dividing students into two groups:

Group A: students who have finished the credits of entrepreneurship general course;

Group B: students who did not attend entrepreneurship general course.

There were 9 students have attended the general entrepreneurship education. Group A has 9 samples, while 13 in group B. Teachers observed the process of two group students' actions and recorded their behaviors. The performance of the curriculum is measured according to the performance of the integrated education with three aspects: creative thinking, business mindset and problem-solving ability.

Technique

The workshops were carried out in 8 times, 3 hours each time, a totally 24 hours. They consist of three stages: preparing and two main tasks (Table 7.4).

Table 7.4 The workshop processes

Stage	Content	Schedule
Preparing	• Learning some basic knowledge about design and entrepreneurship; • Creative method; • Precautions during the process of the workshop.	2 times
Task1	• **The purpose**: Test prototypes Thinking about what the users' needs from a designer perspective, or even design from their own perspective • **Task:** 1) guided by market demand, finding for a market problem in a design product or work; 2)based on the problems to carry out a design and improvement using the creative method; and 3) discuss marketing and product management issues • **Presentation:** 20 minutes to show the results • **Questions:** How to obtain the feedback of the prototypes from the users?	4 times
Task2	• **The purpose**: Understand business operations and be familiar with the business plan • **Task:** 1) according to the characteristics of the clothing profession, the relevant clothing companies are established, and the service targets are mainly all departments and students of the school; 2)set up a team to determine the division of labor; and 3) a business plan, including finance, marketing, human resource management, risk and so on. • **Evaluation:** 1) group presentation: 20 minutes 2) the quality of the business plan	2 times

Measurements

Creative thinking

The Verbal Torrance Test of Creative Thinking (TTCT-V) has been frequently used to test creative thinking, and which was scored on four scales: fluency, flexibility, originality, and elaboration (Torrance, 1974; Said-Metwaly, Kyndt & Van den Noortgate, 2020). Then, we designed a test (Table 7.5) according to TTCT-V, which was scored on the numbers of creative ideas in their team, and cognitive thinking styles they used, including flexibility and fluency. A topic we set as pre-test were ("asking each group to choose a word of their own such as 'apple' to generate as many business ideas as possible, and report the result"), set as post-test was (Combining the group's projects with AI technology to generate more Internet-based entrepreneurial ideas). To compare groups A and B, the results were scored, and higher points received indicated more creative thinking. In addition, since the participants were seniors, we only focused on their mindset instead of professional ability.

Table 7.5 The evaluation form of creative thinking

Group:	**Members:**	
Elements	**Evaluation description**	**Scores**
Numbers	7-10 There are so many creative ideas; 4-6 There are 3-5 creative ideas; 1-3 There are 1-2 creative ideas.	
Flexibility	7-10 There are so many types of ideas; 4-6 There are 4-5 types of ideas; 1-3 There are just 2-3 types of ideas.	
Fluency	7-10 There are so many ideas coming out and thinking without interruption; 4-6 There are many ideas and 1-2 interruptions in the thinking process; 1-3 There are some ideas and too many times interruptions in the thinking process.	

Business mindset

The second estimation is the business mindset which is mainly evaluated from four aspects: financial knowledge, risk management, legal common sense and marketing. We set some subjective questions on these dimensions after finishing task 2. Questions are "What kind of need could your designed products to satisfy the users?, What the price would you like to ask on your designed products? How to do a market survey for your design product? And what are the difficulties you will face?" The total score is 100(see Table 7.6). Same questions can't test two times. So we just sent these questions in the end of this course. Then, we analyze the distinction between group A and group B.

Table 7.6 Business mindset evaluation form

Index	Questions	Scores
Financial knowledge	What the price would you like to ask on your designed products?	
Risk management	What are the difficulties you will face?	
Legal common sense	How to do a market survey of your designed product?	
Marketing	What kind of need could your designed products to satisfy users?	

Problem-solving ability

Problem solving is the ability of an individual to perform cognitive processing to understand and solve a problem. It is not an immediate, obvious problem situation. It includes the willingness to participate in such situations to realize one's potential as a constructive and reflective citizen (OECD, 2010). Problem-solving ability is more of a cognitive and perceptual ability. Therefore, We design a scale to measure the problem-solving ability. The scale is formulated based on the four dimensions of "sense of ability", "sense of effort", "sense of environment" and "sense of control", including 12 items (Figure 7.6), each of the questions on a scale from 1 (the least satisfaction/agree) to 5 (the most satisfaction/agree). Total scores are 60 points.

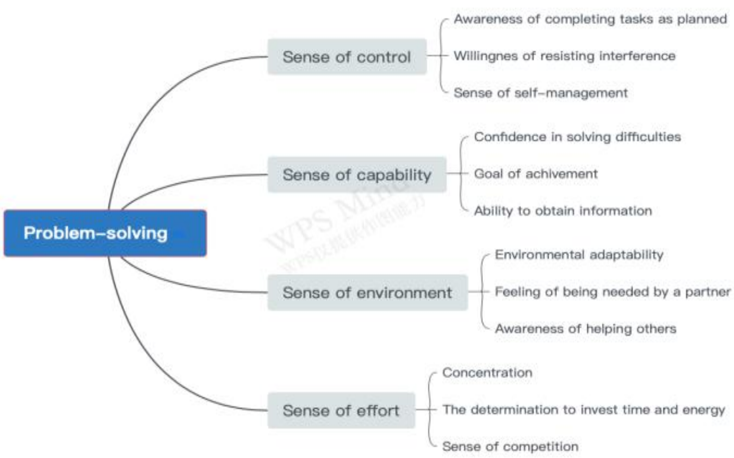


Figure 7.6 The index of problem-solving ability

Results

Creative thinking

First, we compared the differences between each group before and after training using paired sample statistics by bootstrap. As table 7.7 showings, there is no significant difference between the beginning and the end of the training in group A and group B in terms of ideation (P_A=0.347, P_B=0.082>0.05). The results showed that students' progress is not obvious. While on discovery and interpretation, there are significant differences before and after the course in group A and group B (P_A=P_B=0.001<0.05). The students in group A or B all have made obvious progress.

Then, we compared the significant differences between group A and group B on these three aspects. Group A and group B were normally distributed in three factors, and a *T*-test can be carried out. We performed an independent sample *T*-test in group A and group B on discovery, interpretation, and ideation separately. In all of these three aspects, *P*-value was over 0.05. It shows that there are no statistically significant differences in the results of group A and B. However, by comparing the mean values in terms of discovery and interpretation, group A is slightly lower than group B at the beginning of learning. Still, after the course, it is slightly higher than group B. Also, to consider the differences in students' learning levels and professional abilities, design thinking can helped improve their professional abilities through the previous entrepreneurial education. H1 was supported.

Table 7.7 The results of creative thinking

Items	Group A (average±standard deviation)		*t*	*p*	Group B (average±standard deviation)		*t*	*p*
	First(n=9)	After(n=9)			First(n=13)	After(n=13)		
Ideation	5.67± .333	5.89±.423	-1.000	.347	5.62±.290	5.85±.274	-1.897	.082
Interpretation	4.56± .333	6.11±.484	-5.292	.001	5.23± .323	5.92±.760	-2.250	.044
Discovery	5.67±.527	6.78±.494	-5.547	.001	5.85±.373	6.54±.291	-2.920	.013

Business mindset

For the evaluation of this part, we directly use the overall average score for comparison. The average score of Group A is 72. 7 ($Mean_A$=72.7) and Group B is 73.1 ($Mean_B$=73.1). There is no obvious difference from the point of view. We also performed an independent sample T-test in group A and group B on Q1-Q4 separately. In all of these four questions, *P*-value was over 0.05. It shows that there are no statistically significant differences in group A and B. The results showed two types of consequences. One is the students who have finished the entrepreneurship general course cannot improve their business mindset obviously. The other maybe that the design thinking workshop improves students’ business mindset and makes no distinct difference between group A and group B. Hence, H2 cannot be confirmed.

Problem-solving

The results of pre-test

At the beginning, we use the "problem-solving ability scale" to make a pre-test to grasp the current initial level of students. Table 7.8 is the descriptive statistical results of the two groups of pre-test scores, and Figure 7.7 is the distribution diagram of the overall level of the pre-test scores of each item.

Table7.8 The results of pre-test of problem-solving

Items	Average±standard deviation		Mean		Mix.		Max	
	Group A(n=9)	Group B(n=13)	Group A	Group B	Group A	Group B	Group A	Group B
Control ability	3.19± .602	3.13±.563	37.6	37.9	35	33	41	41
Capability	3.04± .536	3.11±.480						
Environment	3.22±.567	3.31±.571						
Effort	3.11±.556	3.10±.475						

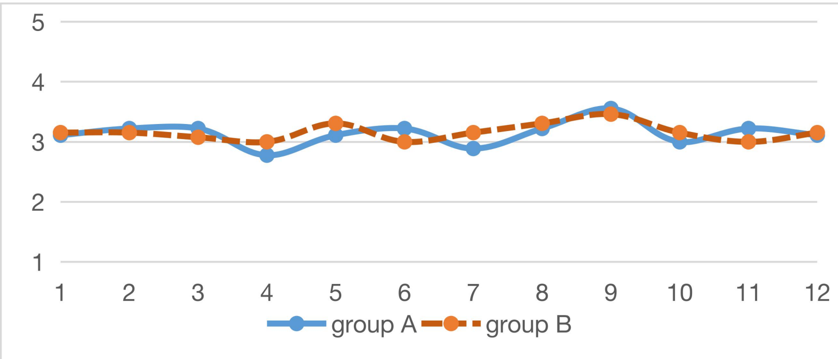


Figure 7.7 Average score distribution of group A and group B in Pre-test

Table 7.8 shows that the average of the total scores of the two groups in the pre-test test is 37.6 and 37.9, and most of the students' scores are between 33-41, indicating that the overall level is not high and needs to be improved. There was no significant differences between the two groups in problem-solving ability methods. Figure 7.6 is the distribution of the average scores of the two groups of each item in the pre-test. Among them, there is the fourth item: confidence in solving difficulties and the sixth item ability to obtain information and the seventh item, the average score of environmental adaptability concentration is at a low point. In summary, students have insufficient confidence in handling problems and low belief in the ability to acquire knowledge from resources; low belief in the ability to purposefully grasp their own behavior, that is, a low sense of self-control and are easily disturbed.

Post-test

We performed a paired sample *T*-test for the pre-test and post-test of the two groups (see Table 7.9) The *P*-value of the two-tailed test of group A and the pre-test is

0.002<0.05, and the test *P*-value is 0.021<0.05 of the two-tailed test of group B, and there is a significant difference between the two groups at the level of 0.05. In summary, the effect of design thinking on problem-solving ability is very significant. At the same time, comparing the coefficient difference between group A and group B, the significance of group A is higher than that of group B, indicating that design thinking is more effective for students with entrepreneurial education background, H3 pass the examination.

Table7.9 The results of post-test of problem-solving

	Mean	SD.	error	95%confidence interval		t	Sig. (two-tail)
				Lower	Higher		
Group A	-0.171	0.352	0.053	-0.278	-0.064	-3.217	0.002
Group B	-0.151	0.417	0.063	-0.277	-0.024	-2.397	0.021

7.1.5 Summary

The main idea of the study was to look for effective ways to explore the entrepreneurship education contribute U-I knowledge flow. From the experimental results, we can see that entrepreneurial education was helpful for improving students' professional abilities to some extent on creative thinking. There was no significant effect on the business mindset's performance when students studied the entrepreneurship general course before. That means, if the university just set a platform course on entrepreneurship and did not embed it into professional education, entrepreneurship education has not enough consequences what it should be. Therefore, making entrepreneurship education embed into professional education is necessary. And the way the push the knowledge flow into region is to enhance the ability of embedded entrepreneurship education into professional education.

7.2 Strategies 2: Regional-industry linkages development strategy

The knowledge spillovers of universities have a positive impact on high-level innovation activities in the region, which will increase the innovation activities of enterprises and promote regional economic development (Feldman, 1999). Route 128 corridor and Silicon Valley, these two areas, rely on the strong scientific research capabilities of the world-class universities in the region to promote the rapid development of science and technology (S&T) and generate many technology spillovers, which greatly promotes regional economic growth. Comparing with the "university-pushed" triple helix in the United States, there is a "government-pulled" triple helix in China. Regional triple helix innovation is also the role of trust between universities, industry, and government, as well as the power of local organization and initiation capabilities. Regional triple helix innovation is also the role of trust between universities, industry, and government, as well as the power of local organization and initiation capabilities (Etzkowitz, 2014, *P*.2). In Chapter 5, we have verified the moderating effect of regional absorptive capacity on U-I collaborations. One of the effective ways to improve absorptive capacity is the linkage between regions and industries, give full play to regional advantages, establish characteristic industries, and attract more talents conducive to the development of regional advantageous industries. Prior research Therefore, this chapter takes Marine industry in Liaoning Province as an example to analyze how the provincial consumption structure and the interaction between marine industries promote industrial innovation.

7.2.1 Status of the Marine Industry

The Chinese Ocean Development Report (2015) issued by the State Oceanic Administration of China states that it is necessary to vigorously develop strategic marine emerging industries and prioritize the role of marine science and technology in the development of marine emerging industries (Research Group of Ocean Development Strategy Research Institute, 2015). Marine industries are strongly characterized by technological dependence, namely, scientific and technological content, high technical level, and environmental friendliness (Xu et al., 2017). Considering the unification of economic, social, and ecological benefits, marine emerging industries are at the high end of the marine industry chain and lead the development of the marine economy (Gao et al., 2018). They have a global, long-term, and shepherding role, and can be divided into marine primary industries characterized by marine aquaculture and marine fishing (Xu et al., 2017); second, marine secondary industries including marine vessels, platforms, and pipelines, among others; and marine tertiary industry including marine transportation, islands, and coastal tourism (Ning *et al*., 2013). Currently, China’s marine industrial structure is not optimal, and the marine emerging industry is still in the early stage of development. Its ocean industrial structure and innovation capacity require further improvements, as shown in Figure7.8. In the context of the innovation era, the development of this industry has shifted from relying on largely constant factors of land and resources to relying on variable factors such as human capital and innovation activities.

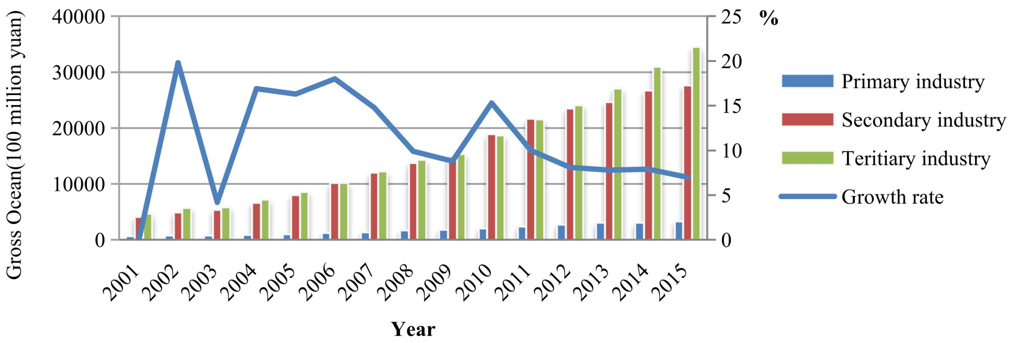


Figure 7.8 The ocean industry structure of China (2001-2015)

Liaoning Province is an important coastal province and city in China. It spans the Yellow Sea and the Bohai Sea, with a mainland coastline of about 2,100 km, accounting for 12% of the national coastline. The climate of Liaoning Province is pleasant, its geographical position is superior, and the marine resources are abundant. The coastal cities are developed, and they have valuable geographical advantages. The total output value of the marine industry in Liaoning Province has increased at a rate of 22% per year, from 20.752 billion yuan in 1996 to 390 billion yuan in 2017, and its share of gross domestic product (GDP) has also increased from 6.57% to 13.56% (Liaoning Statistics Bureau, 2017) However, compared with the developed coastal provinces in China, the marine economic output value of Liaoning Province and its proportion in the national economy are not high. The output value of Guangdong's marine industry has always been in the leading position, while Zhejiang, Fujian, Shandong, and Shanghai follow, with Liaoning Province falling in the third group (Figure 7.9). Thus, the future competitiveness of Liaoning's marine industry will improve with its ability to innovate. This makes building an effective path for innovative development significantly essential. Therefore, improving the innovation capability of the marine industry in Liaoning Province has become an important issue.

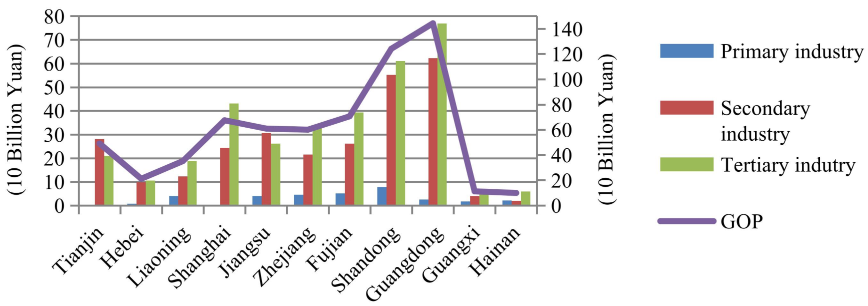


Figure 7.9 The marine industry structure in coastal provinces

Countries globally are now competing for technological superiority in the high-tech marine industry, a critical segment of the emerging industry (Gao et al., 2018). An increasing number of scholars are beginning to pay attention to the strategic choice and innovative development of the marine industry. Research on the marine industry is based on the industrial theory, and largely focuses on innovation. Schumpeter (1912) was the first to propose an "innovation theory," arguing that the advancement of industrial structure relies on constantly breaking the existing equilibrium through innovation. Later, Perroux (1955) proposed the theory of growth poles. This theory holds that growth takes place at different speeds in different regions, and leading industries form a center in this gathering space. This center has economies of scale and grows rapidly, and it has a strong radiation effect on neighboring regions. Herein, development is the spatial concentration of leading industries and innovation-capable industries; it is the external performance of leading industries with agglomeration effects. From the perspective of the driving force of emerging industries, Porter (1990) defined it as a reshaping, or newly established industries being influenced by factors such as technological innovation, new customer needs, relative cost changes, and other social and economic changes. Benito et al. (2003) used Porter's industry and location research framework theory, taking Norway as a typical example. The author noted that a country's protection policy for its domestic marine enterprises, including various subsidies, cannot promote long-term development of the marine industry. Doloreux and Melancon (2008) put forward a regional innovation paradox—in marine industry development, when cooperation and sharing mechanisms between the marine industry and an enterprise are not established, the supply and demand of innovation become unbalanced. It is necessary to challenge the qualitative rationale that the enterprise is responsible for innovation and the government for resource input, and propose a new development rationale for the marine industry. Herein, innovation drive is an important force for marine industry agglomeration and industrial transformation (Xu et al., 2018).

Scholars have studied the development models and mechanisms of marine industries. Ning (2019) claimed that the marine industry, being a leading industry, can promote its economy's sustainable growth and industrial structure upgrades. It is characterized by high-end technology, great market development potential, and high industrial relevance. Xia et al. (2014) believed that the industries of the ocean should reflect the dualities of "strategic" and "emerging." Xiang (2011) proposed that strategic marine industries typify comprehensive use of resources, integration with terrestrial economies, and the national economy's leadership. Wang (2011) analyzed the marine industry models and noted that government-led, home-dominated, or government-driven, and market promotion models are the three main breeding models for strategic emerging industries. Khessina et al. and Lange (1989) proposed three breeding models in industries: grafting, fission, and fusion. Lin (2012) stated that high technology is critical to industrial development. Most enterprises are embarking on the development path to high-tech grafting, fission of traditional industries, and the integration of high-tech and traditional industries.

From the literature analysis perspective, scholars have begun to pay attention to the importance of marine industry innovation and industrial development's technological ability. Currently, most innovation and technological development in this industry are based on the supply, and the Grey industry relation analysis method is used to analyze innovation capability. The consumption structure is interrelated with and interdependent on industrial structure and development. Therefore, this research takes Liaoning Province as its research object because of its rich marine resources to analyze the relationship between consumption and the marine industry structure. It thus explores the development path of U-I innovative capabilities of marine emerging industries.

7.2.2 Methods

The study uses the list of input and output parameters for 42 departments in Liaoning Province released in 2012. The industries mainly include agriculture, forestry, animal husbandry and fishery, industry, construction, transportation, warehousing and postal services, finance, real estate, and other services. In this study, the production influence coefficient is used to measure the correlation spread degree coefficient. The economic analysis value of the influence coefficient is to sort the different industrial sectors according to their size to compare the final demand with the national economy. The coefficient of influence shows that the ratio is the impact of the final product of a sector to the average impact of the final demand of the national economy.

To calculate the impact coefficient of the marine industry in Liaoning Province, this study draws on the input–output table developed by Kedong (2007) (among others) to design the input–output table of the marine industry (Yin et al., 2018) in Liaoning Province. The specific coefficient table is shown in Table7.10.

Table7.10 Marine industry input–output table in Liaoning Province

Input \ Output		Intermediate output				Final output				Total output
		D_1	D_2	D_3	Total	Consumption	Capital formation	Export	Total	
Intermediate input	D_1	X_{11}	X_{12}	X_{13}		C_1	K_1	F_1	Y_1	X_1
	D_2	X_{21}	X_{22}	X_{23}		C_2	K_2	F_2	Y_2	X_2
	D_3	X_{31}	X_{32}	X_{33}		C_3	K_3	F_3	Y_3	X_3
	Total									
Outsourcing resources	E_1	E_{11}	E_{12}	E_{13}						
	E_2	E_{21}	E_{22}	E_{23}						
	E_3	…	…	…						
	E_4	…	…	…						
	E_5	…	…	…						
	E_6	…	…	…						
	E_7	…	…	…						
	E_8	…	…	…						
	Total									
Value Added	G	G_1	G_2	G_3						
	V	V_1	V_2	V_3						
	M	M_1	M_2	M_3						
Total input										

Symbol Description
D_1—Marine primary industry
D_2—Marine secondary industry
D_3—Marine tertiary industry
E_1—Agriculture, forestry, and fishery
E_2—Food manufacturing industry
E_3—Chemical industry
E_4—Power supply industry
E_5—Transportation and warehousing industry
E_6—Education industry
E_7—Real estate industry
E_8—Culture, sports and entertainment industry
G —Depreciation of fixed assets
V — Labor remuneration
M — Social income

The extent to which an industry affects other industries is called the influence of the industry. It is expressed by the influence coefficient. The traditional calculation method is—

$$T_j = \frac{\frac{1}{n}\sum_{i=1}^{n} A_{ij}}{\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} A_{ij}} \text{ (i, j=1,2,…,n),} \quad (7\text{-}1)$$

where A_{ij}—$(I - A)^{-1}$ is the coefficient of the i row and j column.

Since the denominator of the traditional calculation method adopts the equal weighted average method, there are many unreasonable points, and there is no practical economic significance. Thus, it is improved, and the calculation method is improved—

$$M_j = \frac{\frac{1}{n}\sum_{i=1}^{n} A_{ij}}{\sum_{j=1}^{n}\sum_{i=1}^{n} A_{ij} * \alpha_j} \text{ (i, j=1, 2…, n),} \quad (7\text{-}2)$$

$$\alpha_j = \frac{y_j}{y_0} = \frac{y_j}{\sum_{j=1}^{n} y_i}; \ \sum_{j=1}^{n} \alpha_j = 1,$$

where y_i is the j department final product quantity; y_0 is the final product volume of the national economy; and α_j is the proportion of the final product of j department to the total national economy.

7.2.3 Results

The marine economy of Liaoning Province has always maintained a high growth rate. The productivity level and comprehensive economic strength of the coastal areas have been optimal, with significant improvements in the comprehensive economic strength of the ocean. In 2015, the proportion of primary, secondary, and tertiary marine industries in Liaoning Province was 11.4%, 35%, and 53.5% respectively, indicating the dominance of the primary industry, slow growth of the secondary industry, and increasing proportion of the tertiary industry. According to the "2015 China Ocean Report," marine transportation, marine fisheries, and coastal tourism ranked highest in preference in the marine industry of Liaoning Province. These results are consistent with changes in the previously analyzed consumption structure: individualized consumption, such as transportation and tourism, has increased. Then, what is the role of consumption in the changes and development of its industrial structure? How can actors better develop the marine industry in Liaoning Province from the perspective of consumption? To better understand the relationship between Liaoning's consumption structure and the marine industry structure, and to design a more effective innovation capacity improvement path, the relationship between Liaoning's consumption structure and the marine industry is analyzed using the industrial structure and the industrial correlation coefficient.

Industrial structure coefficient measure

According to the basic rules of industrial structure optimization, the industrial structure is used to measure the industrial structure.The specific formula is—

$$\begin{aligned} &\mathit{Industrial\ structure\ similarity\ coefficient\ (SC)} \\ &\quad = \mathit{Secondary\ industry\ value\ added} \\ &\quad + \mathit{Tertiary\ industry\ value\ added\ /GDP} \end{aligned}$$

Therefore, the SC table of Liaoning Marine Industry from 2008 to 2016 is calculated, as shown in Table 7.11. The correlation coefficient between the industrial structure and GDP growth rate is 0.533 using SPSS 24.0. The parameter table is shown in Table 7.12 below.

Table 7.11 Industrial structure coefficient in Liaoning Province (2008–2016)

Year	Gross Ocean Product	MSI Value Added	MTI Value Added	SC	GDP growth rate
2008	4598	2174	2174	0.9458	0.0965
2009	4954	2335	2329	0.9412	0.0940
2010	5958	2808	2830	0.9462	0.1064
2011	7063	3384	3318	0.9489	0.0954
2012	7763	3562	3785	0.9464	0.0786
2013	8419	3861	4105	0.9463	0.0776
2014	9290	4193	4597	0.9462	0.0730
2015	10024	4261	5252	0.9491	0.0690
2016	10929	4416	5960	0.9494	0.0670
2017	12030	4664	6807	0.9536	0.0690

Table 7.12 The Pearson's coefficient of the industrial structure and gross domestic product growth rate

	Unstandardized Coefficients		SD.	*t*
	B	**Std. Error**	**Beta**	
(Constant)	0.957	0.006		167.424
GDP growth rate	-0.122	0.068	0.533	-1.782

The structural coefficient of the marine industry in Liaoning Province has a linear correlation with GDP, which has a positive impact on GDP growth. The industrial structure has led to a certain degree of economic growth. This can be explained by the fact that the isomorphic of the industry has led to fierce market competition, prompting companies to focus more on improving the market competitiveness of products. Enterprises pay more attention to technological progress, production management, and the development of new products, ultimately leading to economic growth.

Estimation of the correlation between consumption structure and marine industry structure in Liaoning Province

The influence coefficient of an industry is greater than 1 or less than 1, indicating that the influence of the industry is above or below the average level of all industries. When T_j>1, the influence of the production of the j product department on other products is higher than the average impact level of the society (i.e., the average value of the impact of each product sector). When T_j=1, the degree of influence of the production of the j product department on other product sectors is equal to the average level of influence of the society. When T_j<1, the influence of the production of the j product department on other products is less than the average level of influence of the society. Evidently, the greater the influence coefficient, the greater the pulling effect of the j product department on other product sectors. The impact coefficient of marine industry in Liaoning Province is shown in Table 7.13.

Table 7.13 Marine industry influence coefficient in Liaoning Province

Department (industry)	Number	Influence Coefficient	Sequence
Agriculture, forestry, and fishery	01	0.89574	5
Food manufacturing industry	06	0.59325	6
Chemical industry	12	1.45044	3
Transportation and warehousing industry	17	1.70045	1
Power supply industry	23	1.48245	2
Real estate industry	33	0.23198	8
Education industry	39	0.57624	7
Culture, sports and entertainment industry	42	1.31928	4

There is a causal relationship between the consumption and the marine industry structure in Liaoning Province. The above analysis shows that the evolution of the consumption structure in Liaoning Province has a good pulling effect on the marine industrial structure, and the correlation is relatively large. Therefore, when adjusting the structure of the marine industry, it is necessary to consider relevant factors such as consumer demand.

The consumption structure of Liaoning Province has a greater impact on the structure of the marine industry in the secondary industry. This is evident from the sequence of the influence coefficient—the marine industry has the largest pulling effects on transportation and warehousing industry, followed by power and chemical industry. This indicates that the marine industry in Liaoning Province has a larger impact on the secondary industry, while real estate and education are relatively smaller. Therefore, we should focus on the development of the secondary industry in when improving the marine industry.

We must pay more attention to the innovation ability of enterprises in marine industrial development. The consumption structure has played an important role in the secondary industry, but in the statistics, the secondary industry in Liaoning Province is marked by slow development. In the development of the secondary industry, the innovation capability of enterprises has become the core factor for gaining competitiveness. Therefore, when developing the marine industry, improving the innovation ability of marine enterprises is critical.

7.2.4 Pathway of improving U-I innovation capability

The resulting new characteristics of the current consumption of Liaoning Province provide opportunities for innovation and development. In previous analyses, technological innovation was noted for playing an important role in the development of the secondary industry. However, the tertiary industry should prioritize market demand. Therefore, based on the external ecosystem supported by the government, concept innovation, and internet technology, a double helix innovation enhance path that is driven by technology and market is designed (Figure 7.10).

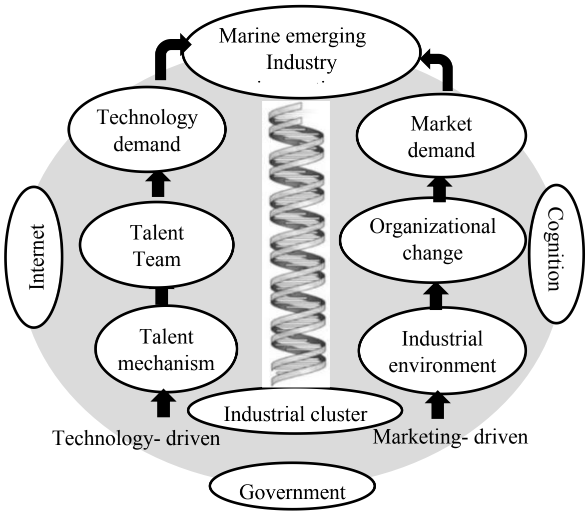


Figure 7.10 Technology and market-drive double helix drive path design

U-I Innovation capability: Technology-driven pathway

Taking "cognition docking" as the entry point, a technology-driven path from talent development to technological innovation is designed, which leads to industrial upgrading. Together, this forms the competitive advantage. Combing the docking "ecological circle" promotes the development of the marine industry toward the high-end industry of the value chain, increases the competitive advantage of enterprises, and improves the innovation capability of marine enterprises.

Perfection of talent introduction mechanism

An important point in the technological drive of the marine industry in Liaoning Province is the introduction and cultivation of innovative talents. Talent loss arising from the recent economic downturn in Northeast part of China is serious. This is particularly detrimental to young and middle-aged technical talents, leading to constraints in the innovation and development of the marine industry. To realize technological innovation, it is necessary to increase talent and formulate reasonable and effective mid-to-high-end talent introduction projects. Enterprises must cooperate with universities and scientific research institutions to develop a talent training model for collaborative education. They can thus attract and cultivate outstanding talents, and provide human resource support for technological innovation.

Building an innovation team

Innovation is an extremely complex matter that requires innovative awareness, approaches, teams, and continuous attempts to overcome risks. Therefore, to promote technological innovation, enterprises must pay attention to complementary technical capabilities of innovative talents, form a stable technical team, and regularly carry out relevant technical training and learning to continually stabilize and improve technical capabilities. Simultaneously, enterprises must create an innovative environment and develop effective compensation performance management methods. This way, innovative teams can effectively cooperate and produce synergies to achieve technological innovation.

Focusing on the improvement of research conditions

Enterprises create conditions to absorb drivers of scientific research into various forms of enterprise innovation. To tackle state-of-the-art technologies, innovative research and application technology must be promoted. Further, independent development and innovation capabilities must be improved. Enterprises should pay attention to investment in science and technology innovation, prioritize research and development, and provide convenient research conditions for science and technology workers.

U-I Innovation Capability: Market-driven pathway

Organization reform

Consumption is not evident in the marine and marine salt industries in Liaoning Province. These two industries have also exhibited a downward trend in recent years. Here, the shipbuilding industry is also crucial to Liaoning, with large state-owned enterprises such as Dalian Shipyard operating out of it. These enterprises are guided by market demand and pay attention to the changes in organizational structure. They accordingly adapt to market economy changes. The design of the organizational structure should thus be oriented toward network development. It must cultivate core competitiveness through four subsystems to realize innovation in organizational capacity: management organization, enterprise governance, production operation, and inter-organizational organization structures.

Promoting the innovation ability of enterprises with industrial clusters

The experience of developed countries and advanced regions shows that a cluster economy is not only conducive to restructuring and extending the industrial chain, but can also effectively promote industrial upgrade. This would significantly reduce logistics costs, and thus improve competitiveness. Currently, there are many small and medium-sized enterprises in Liaoning coastal cities. The marine logistics industry and marine fisheries are relatively developed, but they lack the force of large enterprises and groups. The degree of industrial organization and development are not high. Therefore, it is necessary to speed up the introduction of large-scale enterprises and projects with high relevance and traction. They must take root in coastal areas and promote transformation from a block economy to a cluster economy. Similarly, park development and centralized concentration of related industries should be promoted. Small or underperforming industrial parks must be integrated, expanded, and upgraded.

7.2.5 Summary

Improving the U-I capabilities in regional innovation is inseparable from reforming the marine industrial structure. This industrial restructuring is affected by the consumption structure. Therefore, to efficiently promote better marine industry U-I innovation in Liaoning Province, this study analyzed the relationship of consumption structure with marine industry. In this context, the industrial structure coefficient and the industrial influence coefficient were used to analyze the correlation between consumption structure and marine industry. The change of consumption structure has a greater impact on the secondary industry in the marine industry. And then, the improvement path of the marine industry U-I innovation capability, as driven by technology and market was constructed.

Although this study analyzed the correlation between consumption structure and industry, it does not consider forward association and backward linkage in the analysis process. When formulating the path of innovation capability improvement, it only focused on the secondary industry. However, for the tertiary industry, such as coastal tourism, no specific design proposals have been provided. These areas require be focused in the further research.

Chapter 8 Conclusion

8.1 Conclusion

The knowledge flow from university to enterprises can be affected by geographical, technological, and social proximity, including direct or indirect actions. The moderating effect mechanism of some contextual factors are also included in the discussion. We got the conclusions alongside the research questions.

Research question (1): ***What is the spatial trend of knowledge flow in collaborative innovation?***

In chapter 3, the comprehensive effect of multidimensional proximity results from the interaction that evolves with contextual conditions and time stages. With the changes in the evolutionary stage of knowledge networks, local knowledge exchange and cross-regional knowledge interaction are intertwined. Considering the knowledge flow direction, this research divided the whole knowledge flow process into outflow and inflow stage. As for the outflow stage, the proximity approach can help to understand the knowledge spillover from university. Following the inflow stage, the absorptive capacity would affect the inflow efficiency.

In chapter 4, we collected the co-patents period over 2013 to 2018, using the SNA(social network analysis) to find the development trend of knowledge flow on U-I collaboration. The results proposed that the regional U-I collaborative innovation performance has greatly improved and shown a rapid growth trend from 2013 to 2018 in China. However, there is an obvious imbalance in knowledge flow between industry and university and shapes "strong in eastern and weak in western". The gap between regions still to exist. The inter-regional U-I collaboration makes an increasing trend, however, most of the new co-patents flow into prosperous provinces. The five provinces of Beijing, Jiangsu, Guangdong, Shanghai, and Zhejiang in the eastern region are far ahead of other provinces. The number of patents accounts for more than 60% of the whole country. As for the western region, most provinces are at the bottom of the country. Yunnan, Gansu, Xinjiang, Inner Mongolia, Ningxia, and Qinghai have fewer than one hundred patents. The U-I collaborative innovation capability needs to be improved, especially for lagging areas.

The development level of the regional technology market is clearly related to the innovation performance of U-I collaboration in a regional context. Simultaneously, regions which have appreciate developed in the U-I collaborations network evolution are more inclined to choose inter-region pathway. Therefore, research on U-I collaborations' knowledge flow intra and inter regions plays an important role on promoting U-I linkages' balanced development. The coordinated development of U-I collaboration needs to promote the knowledge flow from the "central area (eastern)" to the "peripheral area (the other areas)" in China.

Research question (2): ***Which types of proximity enhance or hamper the knowledge flow from universities to enterprises?***

The chapter 5 and chapter 6 involve to answer this research question. The investigations yield three central results of this research question based on chapter 5 and chapter 6 are: (1) The influences of proximity on inter-regional U-I collaborations for innovation performance-enhancing advantages are not equal for all regions. In prosperous areas (eastern), geographical proximity and technological heterogeneity play a more significant role. In lagging regions (western and central), the social relationship closer to prosperous areas can increase innovation performance. (2) The impacts of proximity on U-I collaborative innovations were fostered by regional and enterprises ability to absorb non-local knowledge through human capital. The number of R&D personnel help for getting catch-up effects in regions, mainly for lagging areas. (3) As the role of proximity on enterprises innovation performance, the social proximity plays a more important role than technological and geographical proximity.

Specially, long geographical distance between subjects is not a hamper on cross-regional U-I collaborative innovation performance, the same results from the test of enterprises innovation performance, which indicates that companies are more willing to enhance their innovation capabilities ignoring the geographical barriers, especially in eastern with higher development level. There, like in Shearmur (2011) or Hewitt-Dundas (2013), the local university is not the critical factor attracting U-I collaborations. While the result is not fit for a region with a lower development level, like western China, the geographical distance could not shape the innovation performance.

Technological proximity impacts the U-I collaborations can not form an inverted U shape for regional innovation performance unlike Wang's (2019) findings. In 2012, China introduced an innovation-driven national strategy to promote U-I collaborations vigorously. The samples selected in this study are just a year after introducing these policies from 2013 to 2018. According to Zhang (2020), period from 2013 to 2018 is a development stage for industry innovation. This result reflects some extent that China's U-I collaborations innovation has passed the peak of cooperation and began to enter the innovation-driven stage. It is one reason why technological proximity has not formed an inverted U shape but has a negative impact, and regions in the east of China have the most obvious.

The results conflict with the enterprises' innovation performance test which plays a positive role in the knowledge flow in chapter 6. One of the reasons may be the measurement of technological proximity on enterprises innovation performance focus on the basic cooperative conditions, then technological proximity has the emphasis effects. While the measurement of technological proximity on regional U-I collaborative innovation performance, we take the co-patents as the proxy variable, it more related with technological innovation, then it produces the negative role. This kind of result is similar to the inverted U shape hypothesis, in the beginning, the technological proximity pushes the collaboration of university with enterprises, and following the higher-level request of the technological innovation, more proximity maybe lead to lag, then negatively affects the knowledge flow from university to enterprises.

Social proximity based on cooperative numbers can shape innovation performance of cross-regional U-I collaborations. The richer collective experiences are, the more conducive to the improvement of innovation performance. This effect makes the social proximity have regional differences and depends on the core eastern region; in central, proximity is a hindrance factor. This result is different from the positive effect on social proximity with Xia (2017).

As for another important result is the capturing effect of the receiving area’s absorptive capacity. The findings show that higher of the number of applied R&D personnel (human capital) can help enterprises capture non-local U-I collaborative knowledge flow. Our work supports the absorptive capacity hypothesis proposed by Cohen(1990); like in Lucas' endogenous theory, human capital can be transformed with each other, forming increasing returns in production. Inner regional human capital endowments can bring catch-up effects for U-I knowledge flow. For external absorptive capacity, which takes the technological gap as a proxy variable, there is no support for the backward advantages hypothesis from Lin (2019). It shows that the requirement for technology to be "endogenous" is getting higher. A more significant technological gap would make the proximity more challenging to realize, which will reduce innovation performance. External technical differences cannot help the spatial distance between enterprises and universities capture more innovation performance.

Geographical proximity to U-I collaborations in the eastern region has gradually weakened with the higher level of human capital. The concentration of talents reduces the innovation performance brought about by long-distance U-I collaborations. The accumulation of skills will also increase the sense of trust between cooperative subjects, driving cooperation frequently and improving collaborative innovation in western and central regions. There is no significant change in the different areas for the technological gap, which further shows that the backward advantage hypothesis is not valid. The reason may be similar to the viewpoint by Pavitt and Soete (1982), who did not consider the innovation factors or, as endogenous theory pointed out, that technology is "endogenous," not "homogeneity".

Regarding the impact of U-I collaborations on enterprises' innovation performance, the findings show that both technological and social network proximity have a significant positive effect on collaborative innovation performance, whereas geographical proximity does not affect innovation significantly. In addition, proximity drawing on knowledge embeddedness encourages efficient knowledge flow and improves innovation performance. The firm's absorptive capacity affects the level of innovation output when knowledge is embedded in the collaboration.

Research question (3): ***How to encourage firms, universities, and regions to catch up with U-I collaborations' innovative performance?***

Our results on chapter 5 and chapter 6 provide some implications for policymakers. It is necessary to broaden the channels of U-I knowledge flow between regions to fostering knowledge exchanges. The area policy should help for sharing resources and technologies and provide technical support to realize regional economic integration. The regions also need to build a public service platform that can conduce to forming cooperative and innovative relationships and reducing the costs and risks of U-I collaborations. One of our findings is social proximity can improve the innovation performance of cross-regional U-I collaborations. Therefore, constructing a public service platform in regions can improve the cross-regional collaborative innovation and reduce the information asymmetry between industry and universities, the promote the development of inter-regional collaborative innovation networks.

In lagging areas, like central and western, in the knowledge outflow stage, if lagging areas obtain more knowledge spillover under proximity effects, they necessary to establish a good cooperative relationship with the prosperous area. Government departments should vigorously develop transportation network and communication technology, improving the level of geographical proximity between regions, and make it easier to communicate and share resources between inter-regional U-I. The governments can also increase the intensity of talent introduction and education. They consider factors such as talent structure, the construction of regional talent echelons, a talent gathering effect, and improve the level of regional absorptive capacity, such as the "Golden panda" talent plan in Sichuan.

For prosperous areas in the eastern, the region should improve the interaction of multiple organizational forms between long-distance regions, especially non-core regions, strengthen knowledge flow between areas. The areas should pay attention to U-I collaborations' networked development for innovation, forming a "core-periphery" development path. Accelerating international cooperation and expanding cooperation boundaries are also excellent ways to promote coordinated regional development.

Therefore, creating a business environment and a better talent strategy is the primary concern of government makers. Then, the chapter shows that enhancing entrepreneurship education in schools and the face of consumption-driven economic development and promoting industrial development from the perspective of consumption structure and industrial linkage are all conducive to U-I relationships.

8.2 Research contributions

As China's regional development is extremely uneven, economic development different level between regions are not conducive to the innovation and development of the entire country. Therefore, this thesis is more inclined to pay attention to the development of lagging areas, taking cross-regional U-I collaboration as the starting point to explore the impact of spatial proximity effects on the knowledge flow from universities to enterprises.

Academic contribution. The first contribution of this research is using cross-level perspective to understand spatial proximity on U-I collaboration to fill the research gap that lacking integrate region and organization. Most of works on Triple helix theory proposed the non-linear relationship among university, industry and government, the interactions analysis from individual or organizational level were mostly verified, while there is seldom to consider the regional context. Then, the thesis put the three subjects into a regional context to understand the knowledge flow mechanism from university to enterprises.

Secondly, it is the first time that the research attempts to consider the impact of regional resource endowments on the performance of knowledge flow between industry and university. Firstly, we constructed a "subject-region" interactive spillover and inflow two-way analysis framework and introduce regional heterogeneity and absorptive capacity into the analysis framework, focusing on the U-I collaboration from non-local universities to local regions that significantly impact lagging regional U-I collaborative innovation performance. Following this analysis, focusing on the organizational boundary, the research tests the mediating role of knowledge embeddedness and moderating role of enterprises absorptive capacity. The findings rich triple helix theory from the subjects side which considers the integrated resource endowments in the triple helix research framework and fosters the knowledge flow activities between university and enterprises.

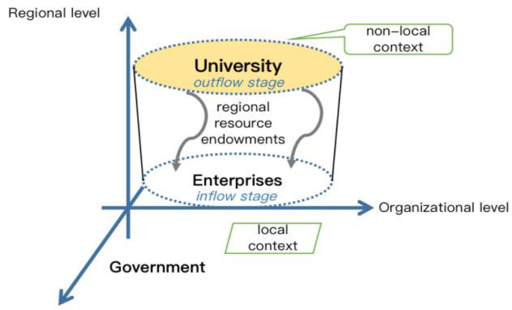


Figure 8.1 One of the academic contribution of this thesis

At the same time, what kind of regional resource endowments help enterprises to capture the inflow knowledge? The thesis focus on pushing the U-I collaboration in lagging area, then, the research contributes to "catch-up theory" from the U-I collaboration perspective. Considering two main "later-mover advantage" and "absorptive capacity" hypothesis of catch-up theory, we added "technology gap" as a new proxy variable to test the regional external absorptive capability. The results help us to understand the status of the non-linear role between different subjects in the process of knowledge flow from non-local university to local enterprises.

Practice contributions. Our study's major contribution is finding the effects of diversity proximity on U-I collaboration from cross-level perspective. For regions, this research helps each provincial government, primarily undeveloped areas enhance the introduction, absorption, and effective use of external knowledge based on their actual conditions and influences enterprises' behavior. For enterprises, this research helps enterprises identify the characteristics of various proximity and explore the effective way to absorb the knowledge flow from university.

The second contribution is to explore the dynamic knowledge flow of U-I collaboration from the two dimensions of time and spatial trend. U-I collaboration is a dynamic process that includes both the characteristics of spatial flow and time flow. Therefore, this study uses two dimensions of time and spatial to study the knowledge flow of U-I collaboration by social network analysis.

Third, discussing the two types of strategies entrepreneurship education and region-industry linkages to fostering U-I collaboration. Previous researches on knowledge flow strategies of U-I collaboration focused on the flow channels, flow mechanisms, etc., while there are few findings considering the education especially entrepreneurship education contribution to U-I collaboration. At the same time, since we have verified the role of regional resource endowment in the U-I knowledge flow, it is also important to link industry with regional endowment factors to discuss the knowledge flow strategy for enhancing U-I innovation capability. The research originally put forward the interaction between Marine industry with consumption structure in Liaoning province for enhancing U-I collaboration.

8.3 Research limitations and further research

This thesis is subject to some limitations. A limitation is we screened the co-invent patents period over 2013-2018; the tendency could not explain several years before 2013, leading to some tests not being supported. Another is considered that the proxy variables we employed are not enough to capture the aspects of regional absorptive capacity, such as policies, investments are not included. Then, a detailed analysis on time lags of patents should also be added into models. Besides, a more accurate method such as cluster analysis can be used to make the regional heterogeneity. In addition, whether the proximity can affect the universities' performance, we don't consider it. We can test more heterogeneity except for regions, like industry fields, life cycles, and different U-I collaborative forms. Finally, we list two types of practices from universities and regions, and the enterprises' development practices should be collected.

In the future, the triple helix structure mentions the interactions among government, enterprises, and universities. Is there a four-helix or other more dimensional forces affecting U-I collaboration, such as knowledge brokers and knowledge platforms? We just collected the data in China, and there are no comparisons with other countries. In the future, cross-country U-I collaborations are another important branch for innovation performance study.

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Innovation is the soul of national progress and an inexhaustible driving force for the prosperity of a country. It is a science but also an art. Innovation is full of philosophy, charm and full of the vision and yearning for the future. I would continue to pursue the research. Let us work together.

References

Abramo, G., D'Angelo, C. A., & Di Costa, F. (2020). The role of geographical proximity in knowledge diffusion, measured by citations to scientific literature. *Journal of Informetrics*, 14(1), 101010.

Abramovitz, M. (1986). Catching up, forging ahead, and falling behind. *Journal of Economic History*, 385-406.

Acs, Z. J., Anselin, L., & Varga, A. (2002). Patents and innovation count as measures of regional production of new knowledge. *Research policy*, *31*(7), 1069-1085.

Acs, Z. J., Audretsch, D. B., Feldman, M. P. (1992). Real effects of Academic research: Comment. *American Economic Review*, 82(1): 363 - 367

Adams, J. D. (2002). Comparative localization of academic and industrial spillovers. *Journal of Economic geography*, 2(3), 253-278.

Agrawal, A., Cockburn, I., & McHale, J. (2006). Gone but not forgotten: knowledge flows, labor mobility, and enduring social relationships. *Journal of Economic Geography*, 6(5), 571-591.

Ahrweiler, P., Pyka, A., & Gilbert, N. (2011). A new model for university - industry links in knowledge - based economies. *Journal of Product Innovation Management*, *28*(2), 218-235.

Aldieri, L. (2011). Technological and geographical proximity effects on knowledge spillovers: Evidence from the US patent citations. *Economics of Innovation and New Technology*, 20(6), 597-607.

Alnuaimi, T., Opsahl, T., & George, G. (2012). Innovating in the periphery: The impact of local and foreign inventor mobility on the value of Indian patents. *Research Policy*,41(9), 1534-1543.

Amidi, S., & Fagheh Majidi, A. (2020). Geographic proximity, trade and economic growth: a spatial econometrics approach. *Annals of GIS*, 26(1), 49-63.

Amin, A., & Wilkinson, F. (1999). Learning, proximity and industrial performance: an introduction. *Cambridge Journal of Economics*, 23(2), 121-125.

Anand, B. N., & Khanna, T. (2000). Do firms learn to create value? The case of alliances. *Strategic management journal*, 21(3), 295-315.

Ancona, D. G., & Caldwell, D. F. (1992). Demography and design: Predictors of new product team performance. *Organization Science*, 3(3), 321-341.

Anderson, R. W., Acur, N., & Corney, J. (2018). How do SMEs use open innovation when developing new business models. *Researching Open Innovation in SMEs*, 179-209.

Ankrah, S., & Omar, A. T. (2015). Universities–industry collaboration: A systematic review. *Scandinavian Journal of Management*, 31(3), 387-408.

Anselin, L., Varga, A., & Acs, Z. (2000). Geographical spillovers and university research: A spatial econometricperspective. *Growth and change*, *31*(4), 501-515.

Antonelli, C. (2008). The new economics of the university: a knowledge governance approach. *The Journal of Technology Transfer*, *33*(1), 1-22.

Arant, W., Fornahl, D., Grashof, N., Hesse, K., & Söllner, C. (2019). University-industry collaborations—The key to radical innovations?. *Review of Regional Research*, 39(2), 119-141.

Arts, S., & Cassiman, B. (2016). Geographic localization of knowledge spillovers from R&D: A reassessment using text mining. In Academy of Management Proceedings (Vol. 2016, No. 1, p. 13703). *Academy of Management*.

Arvanitis, S., Kubli, U., & Woerter, M. (2008). University-industry knowledge and technology transfer in Switzerland: What university scientists think about co-operation with private enterprises. *Research Policy*, 37(10), 1865-1883.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research policy*, 34(8), 1173-1190.

Azagra-Caro, J. M., Archontakis, F., Gutiérrez-Gracia, A., & Fernández-de-Lucio, I. (2006). Faculty support for the objectives of university–industry relations versus degree of R&D cooperation: The importance of regional absorptive capacity. *Research Policy*,35(1), 37-55.

Azagra-Caro, J.M., Barberá-Tomás, D., Edwards-Schachter, M., &Tur, E.M. (2017). Dynamic interactions between university-industry knowledge transfer channels: A case study of the most highly cited academic patent. *Research Policy*, 46(2), 463-474.

Bai, J.H., &Bian, Y.C. (2015). Does Government Support Promote IUR Synergy Innovation? *Statistic Research,*32(11),43-50.

Bai,J.H.,& Jiang, F.X.(2015). Synergy innovation, spatial correlation and regional innovation performance. *Economic Research*, 50(7),174-187.

Balconi, M., Breschi, S., & Lissoni, F. (2004). Networks of inventors and the role of academia: An exploration of Italian patent data. *Research Policy*,33(1), 127-145.

Ball, S. J. (2012). *Politics and policy making in education: Explorations in sociology*. Routledge.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational psychologist*, *28*(2), 117-148.

Baruffaldi, S. H., & Simeth, M. (2020). Patents and knowledge diffusion: The effect of early disclosure. *Research Policy*, *49*(4), 103927.

Barwick, M. A., Boydell, K. M., Stasiulis, E., Ferguson, H. B., Blase, K., & Fixsen, D. (2005). Knowledge transfer and evidence-based practice in children's mental health. *Toronto*, *ON: Children's Mental Health Ontario*.

Basile, R., Capello, R., & Caragliu, A. (2012). Technological interdependence and regional growth in Europe: Proximity and synergy in knowledge spillovers. *Papers in Regional Science*, 91(4), 697-722.

Bathelt, H., & Cohendet, P. (2014). The creation of knowledge: local building, global accessing and economic development—toward an agenda. *Journal of Economic Geography*, *14*(5), 869-882.

Battisti, G., & Stoneman, P. (2010). How innovative are UK firms? Evidence from the fourth UK community innovation survey on synergies between technological and organizational innovations. *British Journal of Management*, 21(1), 187-206.

Bekkers, R., & Freitas, I. M. B. (2008). Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research policy*, *37*(10), 1837-1853.

Benhabib, J., & Spiegel, M. M. (1994). The role of human capital in economic development evidence from aggregate cross-country data. *Journal of Monetary Economics*, 34(2), 143-173.

Benner M., Waldfogel J. (2008). Close to You? Bias and Precision in Patent-Based Measures of Technological Proximity. *Research Policy*, 37(9): 1556-1567

Benos, N., Karagiannis, S., & Karkalakos, S. (2015). Proximity and growth spillovers in European regions: The role of geographical, economic and technological linkages. *Journal of Macroeconomics*,43, 124-139.

Berbegal-Mirabent, J., Gil-Doménech, D., & Ribeiro-Soriano, D. E. (2020). Fostering university-industry collaborations through university teaching. *Knowledge Management Research & Practice*, 18(3), 263-275.

Bercovitz, J., & Feldman, M. (2011). The mechanisms of collaboration in inventive teams: Composition, social networks, and geography. *Research Policy*, 40(1), 81-93.

Berg, O. G., & von Hippel, P. H. (1987). Selection of DNA binding sites by regulatory proteins: Statistical-mechanical theory and application to operators and promoters. *Journal of molecular biology*, *193*(4), 723-743.

Blankesteijn, M., Bossink, B., & van der Sijde, P. (2020). Science-based entrepreneurship education as a means for university-industry technology transfer. *International Entrepreneurship and Management Journal*, 1-30.

Boisot, M. H. (1995). Is your firm a creative destroyer? Competitive learning and knowledge flows in the technological strategies of firms. *Research policy*, 24(4), 489-506.

Borys, B. and Jemison, D.B. (1989) Hybrid Arrangements as Strategic Alliances: Theoretical Issues in Organizational Combinations. *Academy of Management Review,* 14, 234-249.

Boschma, R. (2005). Proximity and innovation: A critical assessment. *Regional Studies,*39(1), 61-74.

Boschma, R., Heimeriks, G., & Balland, P. A. (2014). Scientific knowledge dynamics and relatedness in biotech cities. *Research Policy*, 43(1), 107-114.

Branstetter L. G., Mariko S. (2002). When do research Consortia Work Well and Why? Evidence from Japanese Panel Data. *The American Economic Review*, 92(1): 143-159

Brass, D. J., Galaskiewicz, J., Greve, H. R., & Tsai, W. (2004). Taking stock of networks and organizations: A multilevel perspective. *Academy of management journal*, 47(6), 795-817.

Breschi, S., & Lenzi, C. (2016). Co-invention networks and inventive productivity in US cities. *Journal of Urban Economics*, 92, 66-75.

Breschi, S., & Lissoni, F. (2003). *Mobility and social networks: Localised knowledge spillovers revisited*. Università commerciale Luigi Bocconi.

Broekel, T. (2012). Collaboration intensity and regional innovation efficiency in Germany: A conditional efficiency approach. *Industry and Innovation*, 9(2), 155-179.

Broekel, T., & Boschma, R. (2012). Knowledge networks in the Dutch aviation industry: the proximity paradox. *Journal of economic geography*, *12*(2), 409-433.

Broström, A. (2010). Working with distant researchers—Distance and content in university–industry interaction. *Research Policy*, 39(10), 1311-1320.

Bruneel, J., d'Este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university–industry collaboration. *Research policy*, 39(7), 858-868.

Bruner, J. (1996). *The culture of education*. Harvard University Press.

Bruno, G. S., & Orsenigo, L. (2003). Variables influencing industrial funding of academic research in Italy: an empirical analysis. *International Journal of Technology Management*, 26(2-4), 277-302.

Bunnell, T. G., & Coe, N. M. (2001). Spaces and scales of innovation. *Progress in Human geography*, *25*(4), 569-589.

Callois, J. M. (2008). The two sides of proximity in industrial clusters: The trade-off between process and product innovation. *Journal of Urban Economics*, 63(1), 146-162.

Caniëls, M. C., & Verspagen, B. (2001). Barriers to knowledge spillovers and regional convergence in an evolutionary model. *Journal of evolutionary economics*, 11(3), 307-329.

Cantner, U., & Meder, A. (2007). Technological proximity and the choice of cooperation partner. *Journal of Economic Interaction and Coordination*, 2(1), 45-65.

Capron, H., & Cincera, M. (2004). Industry/University S&T Transfers: What Can We Learn from Belgian CIS-2 Data? *ULB -- Universite Libre de Bruxelles*, 46(3),59-86.

Caragliu, A., & Nijkamp, P. (2016). Space and knowledge spillovers in European regions: the impact of different forms of proximity on spatial knowledge diffusion. Journal of Economic Geography, 16(3), 749-774.

Carayannis, E. G., Alexander, J., & Ioannidis, A. (2000). Leveraging knowledge, learning, and innovation in forming strategic government–university–industry (GUI) R&D partnerships in the US, Germany, and France. *Technovation*, 20(9), 477-488.

Cassi, L., & Plunket, A. (2014). Proximity, network formation and inventive performance: In search of the proximity paradox. *The Annals of Regional Science*, 53(2), 395-422.

Child, J., & Faulkner, D. (1998). *Strategies of cooperation: Managing alliances, networks, and joint ventures*. Oxford University.

Choi, K. H. (2011). A comparative study on fashion design education in Europe and Korea-Focus on the educational cases in the UK, France, Italy and Korea. *Journal of the Korean Society of Clothing and Textiles*, 35(10), 1199-1214.

Coenen, L., Moodysson, J., & Asheim, B. T. (2004). Nodes, networks and proximities: on the knowledge dynamics of the Medicon Valley biotech cluster. *European Planning Studies*, 12(7), 1003-1018.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35, 128-152.

Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2002). Links and impacts: the influence of public research on industrial R&D. *Management science*, 48(1), 1-23.

Coombs, R., Harvey, M., & Tether, B. S. (2003). Analysing distributed processes of provision and innovation. *Industrial and Corporate Change*, *12*(6), 1125-1155.

Cricelli, L., & Grimaldi, M. (2010). Knowledge-based inter-organizational collaborations. *Journal of Knowledge Management*, 14(3), 348-358.

Crossley, C. D., Bennett, R. J., Jex, S. M., & Burnfield, J. L. (2007). Development of a global measure of job embeddedness and integration into a traditional model of voluntary turnover. *Journal of applied Psychology*, *92*(4), 1031.

Cui, R. & Huo,M.K. (2016). Construction of Industrial Clusters Knowledge Collaborative Innovation Network, *Information Science,* 34(1),155-159.

Cummings, J. L., & Teng, B. S. (2003). Transferring R&D knowledge: The key factors affecting knowledge transfer success. *Journal of Engineering and Technology Management*, 20(1-2), 39-68.

Dahlman, C. J., & Nelson, R. (1995). *Social absorption capability, national innovation systems and economic development*. In Social capability and long-term economic growth, (pp. 82-122). Palgrave Macmillan, London.

Das, G. G. (2007). Information age to genetic revolution: Embodied technology transfer and assimilation—A tale of two technologies. *Technological Forecasting and Social Change,* 74(6), 819-842.

De Fuentes, C., & Dutrénit. (2016). Geographic proximity and university–industry interaction: The case of Mexico. *The Journal of Technology Transfer*, 41(2), 329-348.

Dess, G. G., & Shaw, J. D. (2001). Voluntary turnover, social capital, and organizational performance. *Academy of management review*, *26*(3), 446-456.

De Wit-de Vries, E., Dolfsma, W. A., van der Windt, H. J., & Gerkema, M. P. (2019). Knowledge transfer in university–industry research partnerships: a review. *The Journal of Technology Transfer*, *44*(4), 1236-1255.

DiMaggio, P. (1990). *Cultural Aspects of Economic Action and Organization*.In Beyond the Marketplace, edited by R.Fried land and A. F. Robertson. New York: Aldine de Gruyter.

Doloreux, D. (2004). Regional networks of small and medium sized enterprises: evidence from the metropolitan area of Ottawa in Canada. *European planning studies*, 12(2), 173-189.

Doloreux, D. and Melancon, Y. (2008). On the Dynamics of Innovation in Quebec's Coastal Maritime Industry. *Technovation*, 28(4):231-243.

Dong, C., Wang, F., Li, H., Ding, L., & Luo, H. (2018). Knowledge dynamics-integrated map as a blueprint for system development: applications to safety risk management in Wuhan metro project. *Automation in Construction*, 93, 112-122.

Drucker P.F. (1985). *Innovation and Entrepreneurship*, *Harper & Row, Publishers, Inc.*

Dyer, J. H., & Hatch, N. W. (2006). Relation‐specific capabilities and barriers to knowledge transfers: creating advantage through network relationships. *Strategic management journal*, 27(8), 701-719.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of engineering education*, *94*(1), 103-120.

Ejermo, O., & Karlsson, C. (2006). Interregional inventor networks as studied by patent coinventorships. *Research Policy*, 35(3), 412-430.

Eisenhardt, K. M., & Brown, S. L. (1996). Environmental embeddedness and the constancy of corporate strategy. *Advances in Strategic Management*, 13, 187-214.

Engelbrecht, H. J. (1997). International R&D spillovers, human capital and productivity in OECD economies: An empirical investigation. *European Economic Review*, 41(8), 1479-1488.

Eom, B. Y., & Lee, K. (2010). Determinants of industry–academy linkages and, their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization. *Research Policy*, *39*(5), 625-639.

Escribano, A., Fosfuri, A., & Tribó, J. A. (2009). Managing external knowledge flows: The moderating role of absorptive capacity. *Research policy*, 38(1), 96-105.

Etzkowitz, H., & Leydesdorff, L. (2000a). 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., Webster, A., Gebhardt, C., & Terra, B. R. C. (2000b). The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. *Research policy*, 29(2), 313-330.

Etzkowitz, H. (2009). The Triple Helix Model of Entrepreneurial University and Innovation, *Studies in Science of Sciences*, 27(4):481-488.

Etzkowitz, H. (2014). The entrepreneurial university wave: from ivory tower to global economic engine. *Industry and Higher education*, 28(4), 223-232.

Fagerberg, J. (1988). Why growth rates differ. *Technical change and economic theory*, 432-457.

Feldman, M. P. (1999). The new economics of innovation, spillovers and agglomeration: Areview of empirical studies. *Economics of innovation and new technology*, 8(1-2), 5-25.

Fleming, L., & Waguespack, D. M. (2007). Brokerage, boundary spanning, and leadership in open innovation communities. *Organization Science*, 18(2), 165-180.

Fontana, R., Geuna, A., & Matt, M. (2006). Factors affecting university–industry R&D projects: The importance of searching, screening and signalling. *Research policy*, 35(2), 309-323.

Freeman, C. (1991). Networks of innovators: a synthesis of research issues. *Research policy*, 20(5), 499-514.

Fritsch, M., & Lukas, R. (2001). Who cooperates on R&D?. *Research policy*, 30(2), 297-312.

Fu, L.P., Zhou, X.M., & Luo, Y.F., (2013). Knowledge Spillover and Industry-University-Research Cooperative Innovation Research on the Coupling Mechanism of the New Network, *Studies in science of science*,31(10),1541-1547.

Gao, T.Y., Chang, F., and Gao, S.Q. (2018). Research on Transformation and Upgrading of Qingdao Marine Economic Industry Structure—Based on Analysis and Evaluation of Scientific and Technological Innovation Efficiency. *Management Review*, 30(12), 42-48.

Geisler, E., & Turchetti, G. (2015). Commercialization of technological innovations: the effects of internal entrepreneurs and managerial and cultural factors on public–private inter-organizational cooperation. *International Journal of Innovation and Technology Management*, 12(02), 1550009.

Gertner, D., Roberts, J. and Charles, D. (2011). University-industry collaboration: a CoPs approach to KTPs, *Journal of Knowledge Management,15*(4), 625-647.

Geuna, A., Fontana, R., & Matt, M. (2003). Firm size and openness: the driving forces of university-industry collaboration.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. sage.

Gilbert, M., & Cordey-Hayes, M. (1996). Understanding the process of knowledge transfer to achieve successful technological innovation. *Technovation*, 16(6), 301-312.

Gilly, J. P., & Torre, A. (2000). Proximity relations. Elements for an analytical framework. *Industrial networks and proximity*, 1-16.

Giuliani, E. (2007). The selective nature of knowledge networks in clusters: evidence from the wine industry. *Journal of economic geography*, *7*(2), 139-168.

Giuliani, E., & Bell, M. (2005). The micro-determinants of meso-level learning and innovation: Evidence from a Chilean wine cluster. *Research Policy*, 34(1), 47-68.

Giunta, A., Pericoli, F. M., & Pierucci, E. (2016). University–industry collaboration in the biopharmaceuticals: The Italian case. *The Journal of Technology Transfer*, 41(4), 818-840.

Goerzen, A., & Beamish, P. W. (2005). The effect of alliance network diversity on multinational enterprise performance. *Strategic management journal*, 26(4), 333-354.

Goldstein H, Drucker J. (2006). The economic development impacts of universities on regions: do size and distance matter? *Economic Development Quarterly*, 20(1): 22-43.

Granovetter, M. S. (1985). Economic action and social structure: The problem of embeddedness. *American Journal of Sociology*, 91(3), 481-510.

Greunz, L. (2003). Geographically and technologically mediated knowledge spillovers between European regions. *The Annals of Regional Science*, 37(4), 657-680.

Griffith, T. L., & Sawyer, J. E. (2010). Multilevel knowledge and team performance. *Journal of Organizational Behavior*, 31(7), 1003-1031.

Guo, X. B., & Gu, M. F. (2015). The strategic thinking of Hubei's economic development by leaps and bounds under the new normal: Based on the perspective of late-mover advantage, *Hubei Social Sciences*, (08), 55-60.

Hagen, R. (2002). Globalization, university transformation and economic regeneration: A UK case study of public/private sector partnership. *International Journal of Public Sector Management,15(3),204-218.*

Hahn, D., Minola, T., Van Gils, A., & Huybrechts, J. (2017). Entrepreneurial education and learning at universities: exploring multilevel contingencies. *Entrepreneurship & Regional Development*, *29*(9-10), 945-974.

Hall, H., & Graham, D. (2004). Creation and recreation: motivating collaboration to generate knowledge capital in online communities. *International Journal of Information Management*, 24(3), 235-246.

Hansen, M. T., & Birkinshaw, J. (2007). The innovation value chain. *Harvard business review*, *85*(6), 121.

Harvey, J., Pettigrew, A., & Ferlie, E. (2002). The determinants of research group performance: towards mode 2?. *Journal of Management Studies*, 39(6), 747-774.

Henderson, R., Jaffe, A. B., & Trajtenberg, M. (1998). Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988. *Review of Economics and statistics*, 80(1), 119-127.

Hewitt-Dundas, N. (2013). The role of proximity in university-business cooperation for innovation. *The Journal of Technology Transfe*r, 38(2), 93-115.

Hicks, D., Breitzman, T., Olivastro, D., & Hamilton, K. (2001). The changing composition of innovative activity in the US—a portrait based on patent analysis. *Research policy*, *30*(4), 681-703.

Hoang, H., & Rothaermel, F. T. (2005). The effect of general and partner-specific alliance experience on joint R&D project performance. *Academy of Management Journal*, 48(2), 332-345.

Hoegl, M., & Proserpio, L. (2004). Team member proximity and teamwork in innovative projects. *Research policy*, 33(8), 1153-1165.

Hong, W. (2008). Decline of the center: The decentralizing process of knowledge transfer of Chinese universities from 1985 to 2004. *Research policy*, 37(4), 580-595.

Hong, W.(2010). Changes in the innovation model of regional University-industry patent cooperation-based on analysis of social network methods, *Studies in science of science*, 28(1),40-46.

Hong, W., & Su, Y. S. (2013). The effect of institutional proximity in non-local university–industry collaborations: An analysis based on Chinese patent data. *Research Policy*, 42(2), 454-464.

Huang, M. H., & Chen, D. Z. (2017). How can academic innovation performance in university–industry collaboration be improved?. *Technological Forecasting and Social Change,* 123, 210-215.

Hubert, C., & Lopez, B. (2013). Breaking the barriers to knowledge sharing. American Productivity and Quality Center. Available at https://1pdf. net/download/breaking-the-barriers-to-knowledge-sharing-by-cindy-hubert-and-brittany-lopez-or_590915d2f6065dc853a0c395 (accessed 27 August 2017).

Huggins, R., & Johnston, A. (2009). Knowledge networks in an uncompetitive region: SME innovation and growth. *Growth and Change*, 40(2), 227-259.

Inkpen, A. C., & Tsang, E. W. (2005). Social capital, networks, and knowledge transfer. *Academy of Management Review*, 30(1), 146-165.

Inzelt, A. (2004). The evolution of university–industry–government relationships during transition. *Research Policy*, 33, 975-995.

Jaffe A. B.， Henderson T R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics*, 108(3): 577 - 598.

Jaffe, A. B. (1986). *Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value*, (No. w1815). national bureau of economic research.

Jaffe, A. B., & Trajtenberg, M. (1996). Flows of knowledge from universities and federal laboratories: Modeling the flow of patent citations over time and across institutional and geographic boundaries. *proceedings of the National Academy of Sciences*, *93*(23), 12671-12677.

Janssen, M. J., Bogers, M., & Wanzenböck, I. (2020). Do systemic innovation intermediaries broaden horizons? A proximity perspective on R&D partnership formation. *Industry and Innovation*, 27(6), 605-629.

Jensen, M. B., Johnson, B., Lorenz, E., Lundvall, B. Å., & Lundvall, B. A. (2007). Forms of knowledge and modes of innovation. *The learning economy and the economics of hope*, 155.

Kabo, F. W., Cotton-Nessler, N., Hwang, Y., Levenstein, M. C., & Owen-Smith, J. (2014). Proximity effects on the dynamics and outcomes of scientific collaborations. *Research Policy*, 43(9), 1469-1485.

Kale, P., Dyer, J. H., & Singh, H. (2002). Alliance capability, stock market response, and long‐term alliance success: the role of the alliance function. *Strategic management journal*, 23(8), 747-767.

Kallio, A., Harmaakorpi, V., & Pihkala, T.(2010). Absorptive capacity and social capital in regional innovation systems: The case of the Lahti region in Finland. *Urban Studies*,47(2), 303-319.

Kang, M., & Kim, B. (2013). Embedded resources and knowledge transfer among R&D employees. *Journal of Knowledge Management,*17 (5),709-723.

Kapetaniou, C., & Lee, S. H. (2019). Geographical proximity and open innovation of SMEs in Cyprus. *Small Business Economics*, 52(1), 261-276.

Katz, J. (1994). Geographical proximity and scientific collaboration. *Scientometrics*, 31(1), 31-43.

Kim, C., & Song, J. (2007). Creating new technology through alliances: An empirical investigation of joint patents. *Technovation*, 27(8), 461-470.

Kim, J., Lee, S. J., & Marschke, G. (2005). *The influence of university research on industrial innovation* (No. w11447). National Bureau of Economic Research.

Kline, S. J. (1985). Innovation is not a linear process. *Research management*, 28(4), 36-45.

Knoben, J., & Oerlemans, L. A. (2006). Proximity and inter-organizational collaboration: A literature review. *International Journal of management reviews*, 8(2), 71-89.

Korotka, M. A. (2015). Proximity factors influencing academics' decisions to cooperate with industrial organizations. Regional studies, *Regional science*, 2(1), 415-423.

Kuznets, S. (1973). Modern economic growth: Findings and reflections. *The American Economic Review*,63(3), 247-258.

Lau, K. W., Ng, M. C., & Lee, P. Y. (2009). Rethinking the creativity training in design education: A study of creative thinking tools for facilitating creativity development of design students. *Art, Design & Communication in Higher Education*, 8(1), 71-84.

Laursen, K., Reichstein, T., & Salter, A. (2011). Exploring the effect of geographical proximity and university quality on university–industry collaboration in the United Kingdom. *Regional studies*, 45(4), 507-523.

Laursen, K., & Salter, A. (2004). Searching high and low: what types of firms use universities as a source of innovation?. *Research policy*, 33(8), 1201-1215.

Lee, J., & Win, H. N. (2004). Technology transfer between university research centers and industry in Singapore. *Technovation*, *24*(5), 433-442.

Lee, K. J. (2011). From interpersonal networks to inter-organizational alliances for university–industry collaborations in Japan: the case of the Tokyo Institute of Technology. *R&D Management*, 41(2), 190-201.

Lehmann, E.E., Menter, M. (2016). University–industry collaboration and regional wealth. Journal of Technology Transfer, 41, 1284–1307.

Lehrer, M., Nell, P., & Gärber, L. (2009). A national systems view of university entrepreneurialism:Inf erences from comparison of the German and US experience. *Research Policy*, *38*(2), 268-280.

Liaoning Statistics Bureau, 1990–2017. *Liaoning Statistics yearbook*. Shenyang: China Statistics Press.

Liñán, F. (2004). Intention-based models of entrepreneurship education. *Piccolla Impresa/Small Business*, 3(1), 11-35.

Ling, N. and Li, L., (2019). Empirical Study on the Structure and Employment Effect of China's Marine Industry—Based on Dynamic Panel GMM Estimation and Analysis. *Ecological Economy*, 35(01):43-47,78.

Lin, J. Y., & Wang, X. (2017). The facilitating state and economic development: The role of the state in new structural economics. *Man, and the Economy*, 4(2), 1-19.

Li, L., & Wang, X.F. (2014). The impact of geographic and cognitive proximity on innovation performance of high technology district: Based on social network analysis. *Economy Management in Eastern*, 28(11), 32-37.

Lin, R. T. (2005). Creative learning model for cross cultural product. *Art appreciation*, 1(12),

52-59.
Lin, X.J., (2012). Research on the Development and Formation Mode of Strategic Emerging Industries. *China Soft Science*, (02):26-34.
Liu, G.W. (2015). The Time-Space Evolution Model and Empirical Research of I-U-R Cooperative Innovation Network: Based on the Analysis of Cooperative Patent Data in Guangxi from 2000 to 2013, *Science of Science and Management of S.&.T*, (4) ,64-74.
Liu, Y., & Rousseau, R. (2010). Knowledge diffusion through publications and citations: A case study using ESI‐fields as unit of diffusion. *Journal of the American Society for Information Science and Technology*, 61(2), 340-351.
Lu, M.Y., & Wang, D.D. (2016). Research on Inter- regional Knowledge Flows in China Based on the Network of Innovation Cooperation, *Journal of Industrial Technological Economics*, 35(7), 154-160.
Lundvall, B. A. (1988). Innovation as an interactive process: from user-producer interaction to the national system of innovation. *Technical change and economic theory*, 349.
Lundvall, B. Ä., & Johnson, B. (1994). The learning economy. *Journal of Industry Studies,* 1(2), 23-42.
Ma, T.&Guo,J.L.(2016).Hypernetwork Model on Regional-level University-enterprise Cooperation for Applying Patent Based on Weighted Hypergraph: A Case of ICT Industry in Zhejiang. *Technology Economics,*(12) ,76-81,104.
Maggioni, M. A., & Uberti, T. E. (2009). Knowledge networks across Europe: which distance matters? *The Annals of Regional Science*, 43(3), 691-720.
Mansfield, E., & Lee, J. Y. (1996). The modern university: contributor to industrial innovation and recipient of industrial R&D support. *Research policy*, 25(7), 1047-1058.
Marek, P., Titze, M., Fuhrmeister, C., & Blum, U. (2017). R&D collaborations and the role of proximity. *Regional Studies*, 51(12), 1761-1773.
Marrocu, E., Paci, R., & Usai, S. (2013). Proximity, networking and knowledge production in Europe: What lessons for innovation policy? *Technological Forecasting and Social Change*, *80*(8), 1484-1498.
Marrone, J. A., Tesluk, P. E., & Carson, J. B. (2007). A multilevel investigation of antecedents and consequences of team member boundary-spanning behavior. *Academy of Management Journal*, 50(6), 1423-1439.
Maskell, P., & Malmberg, A. (1999). Localised learning and industrial competitiveness. *Cambridge Journal of Economics*, 23(2), 167-185.
Mayer, L., von Schmieden, K., Taheri, M., & Meinel, C. (2020). Designing a Synthesis MOOC: Lessons from Frameworks, Experiments and Learner Paths. *In Design Thinking Research* (pp. 35-47). Springer, Cham.
Maurer, I., Bartsch, V., & Ebers, M. (2011). The value of intra-organizational social capital: How it fosters knowledge transfer, innovation performance, and growth. *Organization Studies*, 32(2), 157-185.
McDermott, R. (1999). Why information technology inspired but cannot deliver knowledge management. *California management review*, 41(4), 103-117.
McKelvey, M., Alm, H., & Riccaboni, M. (2003). Does co-location matter for formal knowledge collaboration in the Swedish biotechnology–pharmaceutical sector?. *Research policy*, 32(3), 483-501.

Merton, R. K. (1973). *The sociology of science: Theoretical and empirical investigations*. University of Chicago press.

Mesny, A., & Mailhot, C. (2007). The difficult search for compromises in a Canadian industry/university research partnership. *The Canadian Journal of Sociology/Cahiers canadiens de sociologie*, 203-226.

Meyer-Krahmer, F., & Schmoch, U. (1998). Science-based technologies: university–industry interactions in four fields. *Research policy*, 27(8), 835-851.

Miguélez, E., & Moreno, R. (2015). Knowledge flows and the absorptive capacity of regions. *Research Policy*, 44(4), 833-848.

Mitchell, T. R., Holtom, B. C., Lee, T. W., Sablynski, C. J., & Erez, M. (2001). Why people stay: Using job embeddedness to predict voluntary turnover. *Academy of Management Journal*, 44(8), 1102– 1121.

Mohnen, P., & Hoareau, C. (2003). What type of enterprise forges close links with universities and government labs? Evidence from CIS 2. *Managerial and decision economics*, 24(2 - 3), 133-145.

Molina-Morales, F. X., García-Villaverde, P. M., & Parra-Requena, G. (2014). Geographical and cognitive proximity effects on innovation performance in SMEs: a way through knowledge acquisition. *International Entrepreneurship and Management Journal*, 10(2), 231-251.

Moodysson, J., Coenen, L., & Asheim, B. (2008). Explaining spatial patterns of innovation: analytical and synthetic modes of knowledge creation in the Medicon Valley life-science cluster. *Environment and planning A*, 40(5), 1040-1056.

Mora-Valentin, E. M., Montoro-Sanchez, A., & Guerras-Martin, L. A. (2004). Determining factors in the success of R&D cooperative agreements between firms and research organizations. *Research policy*, 33(1), 17-40.

Mortensen, M. H. (2012). Understanding attractiveness in business relationships: A complete literature review. *Industrial Marketing Management*, 41(8), 1206-1218.

Motohashi, K. (2005). University–industry collaborations in Japan: The role of new technology-based firms in transforming the National Innovation System. *Research policy,* 34(5), 583-594.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. (1998). Technological overlap and interfirm cooperation: implications for the resource-based view of the firm. *Research policy*, 27(5), 507-523.

Nam, G., Kim, D., Lee, J., Youn, H. Y., & Kim, U. M. (2015). Efficient batch processing of proximity queries with MapReduce. *In Proceedings of the 9th International Conference on Ubiquitous Information Management and Communication*,1-4.

Natalya Smith & Ekaterina Thomas. (2016). Regional conditions and innovation in Russia: the impact of foreign direct investment and absorptive capacity, *Regional Studies*, DOI: 10.1080/00343404.2016.1164307

Nelson, R. R. (2004). The market economy, and the scientific commons. *Research policy*, 33(3), 455-471.

Nielsen, B. B. (2005). The role of knowledge embeddedness in the creation of synergies in strategic alliances. *Journal of Business Research*, 58(9), 1194-1204.

Nonaka, I & Takeuchi, H.(1995).*The knowledge creating company. How Japanese companies create the dynamics of innovation*, Oxford University Press, New York.

Nonaka, I., Toyama, R., & Konno, N. (2000). SECI, Ba and leadership: a unified model of dynamic knowledge creation. *Long range planning*, 33(1), 5-34.

Nooteboom, B. (1999). Innovation, learning and industrial organisation. *Cambridge Journal of Economics*, 23(2), 127-150.

Nooteboom, B., Van Haverbeke, W., Duysters, G., Gilsing, V., & Van den Oord, A. (2007). Optimal cognitive distance and absorptive capacity. *Research Policy*, 36(7), 1016-1034. https://doi.org/10.1016/j.respol.2007.04.003

Norman, P. M. (2004). Knowledge acquisition, knowledge loss, and satisfaction in high technology alliances. *Journal of Business Research*, 57(6), 610-619.

Nsanzumuhire S.U., and Groot W. (2020). Context perspective on University-Industry Collaboration processes: A systematic review of literature, *Journal of Cleaner Production* 258: 120861. DOI: 10.1016/j.jclepro.2020.120861.

Okamuro, H., & Nishimura, J. (2013). Impact of university intellectual property policy on the performance of university-industry research collaboration. *The Journal of Technology Transfer*, 38(3), 273-301.

Oliver, A. L. (2004). On the duality of competition and collaboration: network-based knowledge relations in the biotechnology industry. *Scandinavian Journal of Management*, *20*(1-2), 151-171.

Owen-Smith, J., Riccaboni, M., Pammolli, F., & Powell, W. W. (2002). A comparison of US and European university-industry relations in the life sciences. *Management science*, *48*(1), 24-43.

Oyelaran-Oyeyinka, B., & Adebowale, B. A. (2017). University-industry collaboration as a determinant of innovation in Nigeria. *Institutions and Economies*, 21-46.

Pan, X., Pan, X., Ai, B., & Guo, S. (2020). Structural heterogeneity and proximity mechanism of China's inter-regional innovation cooperation network. *Technology Analysis & Strategic Management*, 32(9), 1066-1081.

Pan, Y. H. (2014). Relationships among teachers' self-efficacy and students' motivation, atmosphere, and satisfaction in physical education. *Journal of Teaching in Physical Education*, 33(1), 68-92.

Panagopoulos, A. (2003). Understanding when universities and firms form RJVs: the importance of intellectual property protection. *International Journal of Industrial Organization*, 21(9), 1411-1433.

Partha, D., & David, P. A. (1994). Toward a new economics of science. *Research policy*, 23(5), 487-521.

Pavitt, K., & Soete, L. (1982). International differences in economic growth and the international location of innovation. Emerging technologies: *The consequences for economic growth, structural change and employment,* 105-133.

Pérez-Luño, A., Alegre, J., & Valle-Cabrera, R. (2019). The role of tacit knowledge in connecting knowledge exchange and combination with innovation. *Technology Analysis & Strategic Management*, 31(2), 186-198.

Perkmann, M., Neely, A., & Walsh, K. (2011). How should firms evaluate success in university–industry alliances? A performance measurement system. *R&D Management*,

41(2), 202-216.
Perkmann, M., & Walsh, K. (2007). University–industry relationships and open innovation: Towards a research agenda. I*nternational journal of management reviews*, 9(4), 259-280.
Petruzzelli, A. M. (2011). The impact of technological relatedness, prior ties, and geographical distance on university–industry collaborations: A joint-patent analysis. *Technovation*, 31(7), 309-319.
Ponds, R., Oort, F. V., & Frenken, K. (2010). Innovation, spillovers and university–industry collaboration: An extended knowledge production function approach. *Journal of Economic Geography*, 10(2), 231–255.
Porter M.E., (1990). *The Competitive Advantage of Nation*. New York: The Free Press.
Prahalad, C. K., & Hamel, G. (1994). Strategy as a field of study: Why search for a new paradigm?. *Strategic management journal*, 15(S2), 5-16.
Prabhu, J. C., Chandy, R. K., & Ellis, M. E. (2005). The impact of acquisitions on innovation: Poison pill, placebo, or tonic? *Journal of Marketing*, 69(1), 114-130.
Research Group of Ocean Development Strategy Research Institute, State Oceanic Administration, (2015). *China Ocean Development Report*. Beijing: Ocean Press, 127-149.
Roberto, G. (2016). Absorptive capacity and knowledge management in small and medium enterprises. *Knowledge Management Research & Practice*, 14(2), 159-168.
Roper, S., & Love, J. H. (2006). Innovation and regional absorptive capacity: The labour market dimension. *The Annals of Regional Science*, 40(2), 437-447.
Rosenkopf, L., & Nerkar, A. (2001). Beyond local search: Boundary‐spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal*, 22(4), 287-306.
Rowlands, I. (2002). *Journal diffusion factors: a new approach to measuring research influence*. In Aslib Proceedings. MCB UP Ltd.
Sampson, R. C. (2005). Experience effects and collaborative returns in R&D alliances. *Strategic Management Journal*, 26(11), 1009-1031.
Santoro, M. D., & Chakrabarti, A. K. (2002). Firm size and technology centrality in industry–university interactions. *Research policy*, 31(7), 1163-1180.
Santoro, M. D., & Saparito, P. A. (2003). The firm's trust in its university partner as a key mediator in advancing knowledge and new technologies. *IEEE Transactions on Engineering Management*, 50(3), 362-373.
Saxenian, A. (1994). *Regional networks: industrial adaptation in Silicon Valley and route 128.*
Schalk. (2012). Two-level effects of inter organizational network collaboration on graduate satisfaction: A comparison of five inter college networks in Dutch higher education.T*he American Review of Public Administration* 42.6: 654-677.
Schartinger, D., Rammer, C., Fisher, M. M., & Fröhlich, J. (2002). Knowledge interactions between universtities and industry in Austria: sectoral patterns and determinants. *Research Policy*, 31, 3.
Scherngell, T., & Hu, Y. (2011). Collaborative knowledge production in China: Regional evidence from a gravity model approach. *Regional Studies*, 45(6), 755-772.
Schmidt, T. (2010). Absorptive capacity—one size fits all? A firm‐level analysis of absorptive capacity for different kinds of knowledge. *Managerial and Decision Economics*, 31(1), 1-18.

Schumpeter, J.A., (1912). *The Theory of Economic Development*, tenth printing 2004, New Jersey: Transaction Publishers, New Brunswick.
Schwartz, M., Peglow, F., Fritsch, M., & Günther, J. (2012). What drives innovation output from subsidized R&D cooperation? Project-level evidence from Germany. *Technovation*, 32(6), 358-369.
Shachar, J., & Zuscovitch, E. (1990). Learning patterns within a technological network. In *Perspectives in industrial organization*,133-150.
Shearmur, R. (2011). Innovation, regions and proximity: from neo-regionalism to spatial analysis. *Regional Studies*, 45(9), 1225-1243.
Shi, X., Wu, Y., & Fu, D. (2020). Does University-Industry collaboration improve innovation efficiency? Evidence from Chinese Firms, *Economic Modelling*, *86*, 39-53.
Shkolnykova, M. (2020). Diffusion of radical innovation for the case of biotechnology SMEs: does proximity matter? *Bremen Papers on Economics & Innovation*.
Shyu, J. Z., & Huang, C. Y. (2017). Configuring the knowledge diffusion policy portfolio of higher education institutes. Eurasia Journal of Mathematics, *Science and Technology Education*, 13(8), 5685-5734.
Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (2003). Commercial knowledge transfers from universities to firms: improving the effectiveness of university–industry collaboration. *The Journal of High Technology Management Research*, 14(1), 111-133.
Skute, I., Zalewska-Kurek, K., Hatak, I.,de Weerd-Nederhof,P. (2019). Mapping the field: a bibliometric analysis of the literature on university–industry collaborations. *Journal of Technology Transfer*, 44, 916–947.
Slavtchev, V. (2013). Proximity and the transfer of academic knowledge: Evidence from the spatial pattern of industry collaborations of East German professors. *Regional Studies*, 47(5), 686-702.
Smit, M. J., Abreu, M. A., & de Groot, H. L. (2015). Micro‐evidence on the determinants of innovation in the Netherlands: The relative importance of absorptive capacity and agglomeration externalities. *Papers in Regional Science*, 94(2), 249-272.
Soh, P. H., & Subramanian, A. M. (2014). When do firms benefit from university–industry R&D collaborations? The implications of firm R&D focus on scientific research and technological recombination. *Journal of Business Venturing*, 29(6), 807-821.
Sorenson, O., Rivkin, J. W., & Fleming, L. (2006). Complexity, networks and knowledge flow. *Research policy*, 35(7), 994-1017.
Stephens, David. (2007). Culture in education and development: principles, practice and policy.*Symposium Books Ltd*.
Storper, M., & Venables, A. J. (2004). Buzz: Face-to-face contact and the urban economy. *Anthony Venables*, 4(4), 351-370.
Su, Y., Lin, Z.Z. & Ou, Z.H. (2020). A research on the impact of knowledge flow on the two stages of regional innovation activities. *Science Research Management,41(7),100-109.*
Sun, Y., & Cao, C.(2015). Intra-and inter-regional research collaboration across organizational boundaries: Evolving patterns in China. Technological Forecasting and Social Change, 96, 215-231.
Sutz, J. (2000). The university–industry–government relations in Latin America. *Research policy*, 29(2), 279-290.

Swanson, G. (1994). Graphic Design Education as a Liberal Art: Design and Knowledge in the University and the" Real World". *Design issues*, 10(1), 53-63.

Szulanski, G. (1996). Exploring internal stickiness: Impediments to the transfer of best practice within the firm. *Strategic management journal*, *17*(S2), 27-43.

Szulanski, G. (2000). The process of knowledge transfer: A diachronic analysis of stickiness. *Organizational behavior and human decision processes*, 82(1), 9-27.

Teece, D. J. (1977). Technology transfer by multinational firms: The resource cost of transferring technological know-how. *The economic journal*, *87*(346), 242-261.

Ter Wal, A. L. (2014). The dynamics of the inventor network in German biotechnology: Geographic proximity versus triadic closure. *Journal of Economic Geography*, 14(3), 589-620.

Tether, B. S., & Tajar, A. (2008). Beyond industry–university links: Sourcing knowledge for innovation from consultants, private research organisations and the public science-base. *Research Policy*, 37(6-7), 1079-1095.

Tilhou, R., Taylor, V., & Crompton, H. (2020). 3D virtual reality in K-12 education: A thematic systematic review. *Emerging technologies and pedagogies in the curriculum,* 169-184.

Torre, A., & Rallet, A. (2005). Proximity and localization. *Regional studies*, 39(1), 47-59.

Unver, E. (2006). Strategies for the transition to CAD based 3D design education. *Computer-Aided Design and Applications*, 3(1-4), 323-330.

Uzzi, B. (1996). The sources and consequences of embeddedness for the economic performance of organizations: The network effect. *American Sociological Review*, 61, 674-698.

Van Aken, J. E., & Weggeman, M. P. (2000). Managing learning in informal innovation networks: overcoming the Daphne-dilemma. *R&d Management*, *30*(2), 139-150.

Veugelers, R., & Cassiman, B. (2005). R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing. *International Journal of Industrial Organization*, 23(5-6), 355-379.

Volberda, H. W., Foss, N. J., & Lyles, M. A. (2010). Perspective—Absorbing the concept of absorptive capacity: How to realize its potential in the organization field. *Organization Science*, 21(4), 931-951.

Wang, C., Rodan, S., Fruin, M., & Xu, X. (2014). Knowledge networks, collaboration networks, and exploratory innovation. *Academy of Management Journal*, 57(2), 484-514.

Wang, H. J., Cheng, J., & Zhou, R. S. (2018). Research on knowledge transfer and coordination mechanism of collaborative innovation in Industry, University and Research Institute. *Scientific Research*, 36(7), 1274-1283.

Wang, H. H.;Wang, M.Y. & Sun, Y.J. (2019). Study on the effect of Multidimensional proximity on regional industry-university cooperative innovation:static and dynamic effects, *Science & Technology Progress and Policy*, 36(2), 44-50.

Wasiluk, A., & Saadatyar, F. S. (2020). Inter-organizational trust as a statement of social proximity. Journal of Entrepreneurship, *Management and Innovation*, 16(3), 77-100.

Wei, H., & Yu, S. S. (2013). The effect of institutional proximity in non-local university–industry collaborations: An analysis based on Chinese patent data. *Research Policy*, 42(2), 454-464.

Whittington, K. B., Owen-Smith, J., & Powell, W. W. (2009). Networks, propinquity, and innovation in knowledge-intensive industries. *Administrative science quarterly*, 54(1), 90-122.

Wuyts, S., Colombo, M. G., Dutta, S., & Nooteboom, B. (2005). Empirical tests of optimal cognitive distance. *Journal of Economic Behavior & Organization*, 58(2), 277-302.

Xia, L. J., Xie, F. J., & Wang, H. H., (2017). The impact of institutional proximity and technological proximity on industry–university collaborative innovation performance: An analysis of joint-patent data. *Studies in Science of Science*, 35(5), 782-791.

Xiang, X. Y., Cai, H., & Pei, Y.L. (2010). Effect of three kinds of proximity in international patent co-application network, *Journal of Management Science*, 23(5), 43-52

Xu, W., Liu, L.N.; Zhang, Q.S. and Wang, X. (2017). A Multi Object Decision-Making Method for Location Model of Manufacturing Industry under Uncertain Environment. *Journal of Interdisciplinary Mathematics*, 20(04):1019-1028.

Xu, W., Liu, L.N. and Zhang, Q.S. (2018). Location Decision-Making of Equipment Manufacturing Enterprise under Dual-Channel Purchase and Sale Mode. *Complexity, Article*. ID 3797131, 16 pages https://doi.org/10.1155/2018/3797131.

Xue, L. A. (2019). Review of late-mover advantage strategies and research on development of western in China. *Economic & Trade Update*, (04), 102-103.

Yin, K.D., Li, J., Zhang, B., and Zhang, Y.G.(2008). Research on Input and Output Model of Marine Economy. *Ocean Development and Management,* (01):83-87.

Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, re conceptualization, and extension. *Academy of Management Review*, 27(2), 185-203.

Zhang, G.F., Wu, G. & Zhou, C. (2014). Tacit Knowledge Transfer Mechanism on the Face-to-face communication Platform: A case Analysis on Cavendish Laboratory. *China Science&Technology Resources Review*, 46(6), 28-37.

Zhang, J. (2009). The performance of university spin-offs: an exploratory analysis using venture capital data. *The Journal of Technology Transfer*, 34(3), 255-285.

Zhang, J.P. & Gu, X. (2014). Knowledge Flow Model and Simulation of Knowledge Network Based on Double-phase Diffusion, *Information Studies:Theory & Application,*(5),74-78.

Zhang, K.; Qian, Q.; Zhao, Y. (2020). Evolution of Guangzhou Biomedical Industry Innovation Network Structure and Its Proximity Mechanism. *Sustainability*, 12, 2456.

Zhuge, H. (2002). A knowledge flow model for peer-to-peer team knowledge sharing and management. *Expert systems with applications*, 23(1), 23-30.

Zhuge, H. (2006). Knowledge flow network planning and simulation. *Decision support systems*, 42(2), 571-592.

Zhou, C, & Wei,H.Q.(2018).Research on the Knowledge Flows of Inter-Provincial Green-car in China Based on Patent Citation Network, *Journal of Information*, 37(7),60-65.

Zucker, L. G., Darby, M. R., & Armstrong, J. (1998). Geographically localized knowledge: spillovers or markets? *Economic Inquiry*, 36(1), 65-86.

Zucker, L. G., Darby, M. R., Furner, J., Liu, R. C., & Ma, H. (2007). Minerva unbound: Knowledge stocks, knowledge flows and new knowledge production. *Research Policy*, 36(6), 850-863.

Zukin, S., DiMaggio, P., & DiMaggio, P. (Eds.). (1990). *Structures of capital: The social organization of the economy*. CUP Archive. Cambridge,MA:Cambridge University Press.

Publications

-Papers published in journals

S.,Yu, S.Zhang, T., Yuizono.(2021). Exploring the influences of innovation climate and resource endowments through two types of University – Industry collaborative activities on regional sustainable development, Sustainability,13(14),7559.

S.,Yu, T., Yuizono.(2021). A proximity approach to understanding university-industry collaborations for innovations in non-local context: Exploring the catch-up role of regional absorptive capacity, Sustainability,13 (6), 3539.

S., Yu, T., Yuizono.(2021). Opening the 'black box' of cooperative learning in face-to-face versus computer-supported learning in the time of COVID-19, Education sciences,11(3), 120.

S., Yu, T., Yuizono.(2019). Improving innovation capability of Marine industries: a perspective of consumption structure change, Journal of Coastal Research,94(SI), 846-850.

S., Yu, T., Yuizono, A framework towards influencing factors of University-Industry knowledge flow based on organizational and regional cross-level perspective, Fudan journal of the humanities and social sciences (2021), 18 pages, under review

-Conference proceedings

S., Yu, T., Yuizono, E.Y. Kim, Integrating entrepreneurship education into design education: toward an embeddedness model based on design thinking, Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019), 118-124, 2019/9/13, University of Strathclyde, Glasgow.

S., Yu, T., Yuizono, L.L., Ma, Analysis of aging population on consumption structure: Creativity in effective industry supply, proceeding of 13 KICSS international conference, 141-146, 2018/11/16, Pattaya, Thailand.

Appendix

AppendixⅠ:The four regions in China

①According to the classification method of China Statistical Yearbook in 2011, the mainland can be divided into four regions: eastern, central, western and northeastern.

Northeastern regions include Liaoning, Jilin, Heilongjiang (GDP per capita: 52,298/yuan, 2018);

Eastern regions include Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Fujian, Zhejiang, Shandong, Guangdong, Hainan (GDP per capita: 96,378/yuan, 2018);

Central regions include Jiangxi, Anhui, Shanxi, Henan, Hubei, Hunan (GDP per capita: 51,684/yuan, 2018);

Western regions include Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang (GDP per capita: 49,914/yuan, 2018).

The prosperous regions in this study refer the eastern provinces and the central, northeast, and western provinces belong to lagging regions.

AppendixⅡ:

The questionnaire of proximity effects on enterprises' innovation performance

Dear friends:

First of all, thank you very much for filling out this questionnaire in your busy schedule. This is a survey on the performance of university-industry collaborative innovation. The information obtained is for academic research only and not for commercial purposes. We will keep the information strictly confidential.Your valuable opinions will be of great contribution and value to this research, thank you again for your help and support!

Completion Instructions:

1. The questionnaires are both single-choice questions and scale questions. Please choose the option you think is most suitable.

2. Please fill in the questionnaire truthfully, and we will keep your personal information and answers confidential.

1. Basic information

(1)Size of your enterprises:

a.100 persons or less b.100-500 persons c.500-1000 persons d.1000 persons or more

(2)The time the enterprise was established:

a.< 5 years b. 5-10 years c. ≧10 years

(3) Enterprise nature

a. State-owned b. Private c. Three-capital (foreign-funded)

(4) The part of your enterprise located:

a. Northeastern (Liaoning, Jilin, Heilongjiang)

b. Eastern (Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Fujian, Zhejiang, Shandong, Guangdong, Hainan)

c. Central (Jiangxi, Anhui, Shanxi, Henan, Hubei, Hunan)

d. Western (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang)

(5) Industry of your company:

a. Manufacturing Information Communication (IT)

b. Service industry

c. Financial industry professional services (such as consulting)

d. Education industry

e. other

(6) Proportion of your institution's master's degree or above

a.≤ 10% b. 11%-20% c. 21%-40% d. 41%-60% e. ≧ 61%

2.**Proximity, knowledge embeddedness and university-industry collaborative innovation performance** (1- strongly disagree 7-strongly agree)

Variable	Items	1 2 3 4 5 6 7
Geographical proximity	Cooperative members are more likely to choose an organization that is closer	
	The closer the geographical distance to the partner, the better the establishment of a good and stable cooperative relationship	
	The closer the geographic distance to the partner, the greater the frequency and efficiency of increased knowledge exchange	
	The closer the geographical distance to the partner, the more face-to-face communication is possible, which is conducive to knowledge sharing and promotes university-industry collaboration	
Technological proximity	Desiring to exchange knowledge and technology with partners	
	Understanding the strategy and needs of partners	
	Consistency of goals during knowledge exchange or technical cooperation with partners	
	The degree of cultural or ideological consistency during knowledge exchange or technical cooperation with partners	
Social proximity	Partners and companies can provide useful information to each other	
	I rely on my partners and can maintain long and close social relationships with them	
	Partners can help each other to solve each others problems	
	Partners can remind each other of possible problems and changes	
Knowledge embeddedness: Knowledge complementary	The stronger the complementary of knowledge, the better it is for knowledge to be embedded in the collaborative innovation network	
	The higher the degree of complementary of knowledge, the more it can meet the knowledge needs of the subject of innovation	
	The higher the degree of complementary of knowledge, the more it can promote the knowledge connection between the cooperation subjects	
Knowledge embeddedness: Knowledge trust	The higher the loyalty of the contract content, the more conducive to the flow of knowledge and improve innovation performance	
	The higher the level of trust, the better the knowledge interaction and learning activities in the cooperative network	
	The higher the level of trust, the higher the value of knowledge	
	The higher the level of trust, the less opportunistic behavior of knowledge interaction	
Collaborative innovation performance: Technological-related	Net income in cooperation reaches (exceeds) expected income target	
	My products have been improved	
	The number of invention patents for cooperation between partners has improved	
	Collaborative subjects have continuous professional improvement	
Collaborative innovation performance: Management-related	The number of stakeholders in cooperation networks is increased	
	The social reputation of the subject in cooperation is higher	
	Cooperation creates more business (job) opportunities	
	The technical paradigm of cooperative networks has been improved	
Knowledge absorptive capacity	Regularly discussing market development trends and new product development issues	
	Tending actively to learn and accumulate new knowledge that may be used in the future	
	Communicating frequently with other companies to acquire new knowledge	
	Usually thinking about how to apply knowledge more effectively	
	Ability to quickly analyze and understand changing market needs	

AppendixⅢ: The data of proximity in non-local context

Geo_dist	Tec_prox	Tec2	Soc_prox	KAS	TAC	ntr	open	nrd	UIC_pat	region
2055.2	0.0012	0.0000	2	0.23	1.6	4.22	5.62	4.90	75	2
270.2	0.0249	0.0006	3	0.4	2.92	3.24	3.50	4.40	21	2
970.8	0.0153	0.0002	3	0.24	2.91	3.65	4.15	4.48	17	3
2010	0.0131	0.0002	6	0.23	1.6	4.22	5.62	4.90	75	2
1018.8	0.1158	0.0134	3	0.15	1.21	4.29	5.37	4.85	70	2
2021.7	0.3552	0.1262	74	0.23	1.6	4.22	5.62	4.90	75	2
2043.4	0.2003	0.0401	17	0.23	1.6	4.22	5.62	4.90	75	2
1314.3	0.0106	0.0001	3	0.17	1.41	4.22	4.46	4.85	34	2
2043.3	0.0266	0.0007	115	0.23	1.6	4.22	5.62	4.90	75	2
2043.3	0.4423	0.1956	4	0.23	1.6	4.22	5.62	4.90	75	2
901.5	0.1006	0.0101	7	0.15	1.21	4.29	5.37	4.85	70	2
1268.1	0.3148	0.0991	14	0.17	1.41	4.22	4.46	4.85	34	2
1178.1	0.0417	0.0017	2	0.17	1.41	4.22	4.46	4.85	34	2
1031.8	0.2457	0.0604	5	0.24	2.91	3.65	4.15	4.48	17	3
682.7	0.0136	0.0002	9	0.24	2.91	3.65	4.15	4.48	17	3
1112.1	0.0752	0.0056	14	0.29	1.03	3.34	5.23	4.75	20	2
1112.1	0.1340	0.0180	26	0.29	1.03	3.34	5.23	4.75	20	2
1929.7	0.0141	0.0002	6	0.23	1.6	4.22	5.62	4.90	75	2
164.6	0.0040	0.0000	6	0.4	2.92	3.24	3.50	4.40	21	2
922.8	0.0017	0.0000	6	0.15	1.21	4.29	5.37	4.85	70	2
705.8	0.0051	0.0000	18	0.15	1.21	4.29	5.37	4.85	70	2
283.7	0.0127	0.0002	3	0.39	3.08	2.65	3.98	4.04	9	3
911.7	0.0014	0.0000	8	0.15	1.21	4.29	5.37	4.85	70	2
552.4	0.0500	0.0025	6	0.27	1.83	3.90	4.47	4.66	30	2
1524.4	0.0066	0.0000	3	0.32	2.85	3.41	4.69	4.73	17	4
261.1	0.0128	0.0002	4	0.4	2.92	3.24	3.50	4.40	21	2
1524.4	0.1910	0.0365	43	0.32	2.85	3.41	4.69	4.73	17	4
681.7	0.0571	0.0033	6	0.28	2.78	3.53	4.71	4.48	18	3
527.7	0.0138	0.0002	3	0.27	1.83	3.90	4.47	4.66	30	2
626.3	0.0138	0.0002	17	0.36	2.41	3.17	4.04	4.54	10	1
1194.2	0.0027	0.0000	8	0.22	2.93	3.55	3.88	4.36	7	3
505.6	0.0003	0.0000	3	0.27	1.83	3.90	4.47	4.66	30	2
1050.8	0.0138	0.0002	5	0.24	2.91	3.65	4.15	4.48	17	3
1054.1	0.0183	0.0003	3	0.34	2.09	3.58	4.25	4.65	11	3
1090.9	0.0080	0.0001	4	0.29	1.03	3.34	5.23	4.75	20	2
904.1	0.0248	0.0006	3	0.15	1.21	4.29	5.37	4.85	70	2
2043.3	0.0057	0.0000	31	0.23	1.6	4.22	5.62	4.90	75	2
1090.9	0.0080	0.0001	12	0.29	1.03	3.34	5.23	4.75	20	2
160.8	0.0080	0.0001	3	0.4	2.92	3.24	3.50	4.40	21	2

183.4	0.0021	0.0000	3	0.4	2.92	3.24	3.50	4.40	21	2
480.4	0.0080	0.0001	3	0.28	2.78	3.53	4.71	4.48	18	3
626.3	0.0119	0.0001	6	0.36	2.41	3.17	4.04	4.54	10	1
901.5	0.0175	0.0003	23	0.15	1.21	4.29	5.37	4.85	70	2
572.8	0.0352	0.0012	15	0.27	1.83	3.90	4.47	4.66	30	2
250.4	0.0018	0.0000	3	0.4	2.92	3.24	3.50	4.40	21	2
1268.1	0.0089	0.0001	7	0.17	1.41	4.22	4.46	4.85	34	2
2287.9	0.0043	0.0000	2	0.43	2.68	1.82	3.23	3.51	5	2
1268.1	0.0161	0.0003	5	0.17	1.41	4.22	4.46	4.85	34	2
610.6	0.0093	0.0001	6	0.27	1.83	3.90	4.47	4.66	30	2
2301.3	0.1504	0.0226	9	0.43	2.68	1.82	3.23	3.51	5	2
444.8	0.0007	0.0000	18	0.27	1.83	3.90	4.47	4.66	30	2
2010	0.1504	0.0226	10	0.23	1.6	4.22	5.62	4.90	75	2
2164	0.0019	0.0000	8	0.56	2.52	2.51	3.38	4.34	4	1
529.5	0.0037	0.0000	18	0.28	2.78	3.53	4.71	4.48	18	3
730.1	0.0007	0.0000	3	0.28	2.78	3.53	4.71	4.48	18	3
251.9	0.1023	0.0105	10	0.4	2.92	3.24	3.50	4.40	21	2
1929.7	0.0349	0.0012	3	0.23	1.6	4.22	5.62	4.90	75	2
516.1	0.0279	0.0008	14	0.39	2.19	3.04	4.48	4.65	8	4
524.1	0.0290	0.0008	6	0.27	1.83	3.90	4.47	4.66	30	2
1268.1	0.9473	0.8974	6	0.17	1.41	4.22	4.46	4.85	34	2
2010	0.0026	0.0000	4	0.23	1.6	4.22	5.62	4.90	75	2
2164	0.0771	0.0059	6	0.43	2.68	1.82	3.23	3.51	5	2
157.1	0.0069	0.0000	3	0.4	2.92	3.24	3.50	4.40	21	2
2010	0.0689	0.0047	15	0.23	1.6	4.22	5.62	4.90	75	2
383.7	0.0007	0.0000	4	0.27	1.83	3.90	4.47	4.66	30	2
1524.4	0.0119	0.0001	28	0.37	2.11	3.36	4.62	4.41	8	4
1524.4	0.7826	0.6125	9	0.32	2.85	3.41	4.69	4.73	17	4
194.6	0.0090	0.0001	8	0.4	2.92	3.24	3.50	4.40	21	2
922.8	0.0396	0.0016	9	0.15	1.21	4.29	5.37	4.85	70	2
371.3	0.0007	0.0000	7	0.27	1.83	3.90	4.47	4.66	30	2
823.3	0.0227	0.0005	3	0.4	2.92	3.24	3.50	4.40	21	2
308	0.0599	0.0036	19	0.27	1.83	3.90	4.47	4.66	30	2
216.6	0.0027	0.0000	7	0.4	2.92	3.24	3.50	4.40	21	2
922.8	0.2095	0.0439	24	0.15	1.21	4.29	5.37	4.85	70	2
1112.1	0.0303	0.0009	19	0.29	1.03	3.34	5.23	4.75	20	2
1476.5	0.2115	0.0447	15	0.37	2.11	3.36	4.62	4.41	8	4
184	0.0028	0.0000	3	0.4	2.92	3.24	3.50	4.40	21	2
2055.2	0.0385	0.0015	16	0.23	1.6	4.22	5.62	4.90	75	2
213.3	0.0104	0.0001	7	0.4	2.92	3.24	3.50	4.40	21	2
2555	0.0161	0.0003	3	0.37	3.76	3.00	3.39	4.21	11	4
1268.1	0.0014	0.0000	41	0.17	1.41	4.22	4.46	4.85	34	2

854.4	0.0104	0.0001	15	0.44	4.45	2.52	2.76	4.04	7	4
1474	0.0495	0.0025	4	0.42	2.04	2.44	2.95	3.96	7	4
1112.1	0.0158	0.0002	4	0.29	1.03	3.34	5.23	4.75	20	2
1112.1	0.3727	0.1389	61	0.29	1.03	3.34	5.23	4.75	20	2
2025.7	0.0092	0.0001	5	0.42	3.37	2.98	3.59	4.19	6	4
283.7	0.0091	0.0001	11	0.39	3.08	2.65	3.98	4.04	9	3
1929.7	0.3768	0.1419	4	0.23	1.6	4.22	5.62	4.90	75	2
440.3	0.0022	0.0000	6	0.27	1.83	3.90	4.47	4.66	30	2
970.8	0.0542	0.0029	3	0.24	2.91	3.65	4.15	4.48	17	3
476.8	0.0013	0.0000	3	0.27	1.83	3.90	4.47	4.66	30	2
1524.4	0.0378	0.0014	25	0.37	2.11	3.36	4.62	4.41	8	4
1778.8	0.0241	0.0006	13	0.28	2.63	3.78	3.76	4.57	7	3
1268.1	0.0151	0.0002	5	0.17	1.41	4.22	4.46	4.85	34	2
1268.1	0.0476	0.0023	10	0.17	1.41	4.22	4.46	4.85	34	2
1054.1	0.0048	0.0000	6	0.34	2.09	3.58	4.25	4.65	11	3
1524.4	0.0201	0.0004	3	0.37	2.11	3.36	4.62	4.41	8	4
1299.3	0.0033	0.0000	2	0.17	1.41	4.22	4.46	4.85	34	2
922.8	0.0025	0.0000	3	0.15	1.21	4.29	5.37	4.85	70	2
2336.1	0.6250	0.3906	15	0.48	3.35	2.69	3.90	4.36	5	4
147.1	0.0147	0.0002	32	0.28	1.16	3.14	4.65	4.36	5	2
1194.2	0.0585	0.0034	58	0.22	2.93	3.55	3.88	4.36	7	3
922.8	0.0072	0.0001	45	0.15	1.21	4.29	5.37	4.85	70	2
2055.2	0.0303	0.0009	3	0.23	1.6	4.22	5.62	4.90	75	2
1268.1	0.0009	0.0000	6	0.17	1.41	4.22	4.46	4.85	34	2
922.8	0.0072	0.0001	45	0.15	1.21	4.29	5.37	4.85	70	2
303.7	0.1604	0.0257	106	0.4	2.92	3.24	3.50	4.40	21	2
1054.1	0.0072	0.0001	9	0.34	2.09	3.58	4.25	4.65	11	3
2043.3	0.1130	0.0128	6	0.23	1.6	4.22	5.62	4.90	75	2
684.3	0.0004	0.0000	4	0.27	1.83	3.90	4.47	4.66	30	2
2326	0.0031	0.0000	4	0.48	3.35	2.69	3.90	4.36	5	4
655	0.0385	0.0015	12	0.27	1.83	3.90	4.47	4.66	30	2
904.1	0.0094	0.0001	66	0.15	1.21	4.29	5.37	4.85	70	2
2043.4	0.0257	0.0007	270	0.23	1.6	4.22	5.62	4.90	75	2
2043.4	0.0004	0.0000	3	0.23	1.6	4.22	5.62	4.90	75	2
922.8	0.0002	0.0000	2	0.15	1.21	4.29	5.37	4.85	70	2
283.7	0.0052	0.0000	3	0.39	3.08	2.65	3.98	4.04	9	3
1054.1	0.0036	0.0000	22	0.34	2.09	3.58	4.25	4.65	11	3
922.8	0.2795	0.0781	8	0.15	1.21	4.29	5.37	4.85	70	2
283.7	0.0090	0.0001	10	0.39	3.08	2.65	3.98	4.04	9	3
922.8	0.0274	0.0008	70	0.15	1.21	4.29	5.37	4.85	70	2
139.5	0.1112	0.0124	23	0.28	1.16	3.14	4.65	4.36	5	2
2055.2	0.1719	0.0295	6	0.23	1.6	4.22	5.62	4.90	75	2

651.6	0.0003	0.0000	6	0.39	2.19	3.04	4.48	4.65	8	4
901.5	0.0124	0.0002	136	0.15	1.21	4.29	5.37	4.85	70	2
1112.1	0.1338	0.0179	68	0.29	1.03	3.34	5.23	4.75	20	2
626.3	0.0405	0.0016	93	0.36	2.41	3.17	4.04	4.54	10	1
904.1	0.0679	0.0046	490	0.15	1.21	4.29	5.37	4.85	70	2
283.7	0.0092	0.0001	6	0.39	3.08	2.65	3.98	4.04	9	3
1031.8	0.0172	0.0003	11	0.24	2.91	3.65	4.15	4.48	17	3
1194.2	0.0124	0.0002	26	0.22	2.93	3.55	3.88	4.36	7	3
1031.8	0.0063	0.0000	9	0.24	2.91	3.65	4.15	4.48	17	3
712.3	0.0444	0.0020	24	0.34	2.57	2.49	2.40	3.66	4	4
1091.2	0.0399	0.0016	642	0.42	1	3.05	4.58	4.98	58	2
506	0.7582	0.5748	46	0.28	2.78	3.53	4.71	4.48	18	3
1512.2	0.1064	0.0113	32	0.37	3.76	3.00	3.39	4.21	11	4
1093.8	0.0551	0.0030	21	0.15	1.21	4.29	5.37	4.85	70	2
1359.4	0.0050	0.0000	9	0.17	1.41	4.22	4.46	4.85	34	2
1300.7	0.0375	0.0014	9	0.17	1.41	4.22	4.46	4.85	34	2
1308.1	0.3718	0.1382	107	0.17	1.41	4.22	4.46	4.85	34	2
1837.8	0.0348	0.0012	18	0.42	2.04	2.44	2.95	3.96	7	4
753.8	0.1212	0.0147	34	0.34	2.09	3.58	4.25	4.65	11	3
1726.4	0.0294	0.0009	2	0.23	1.6	4.22	5.62	4.90	75	2
1728.4	0.1418	0.0201	59	0.23	1.6	4.22	5.62	4.90	75	2
2562.1	0.2266	0.0514	16	0.23	1.6	4.22	5.62	4.90	75	2
1727	0.0285	0.0008	11	0.23	1.6	4.22	5.62	4.90	75	2
714.3	0.1522	0.0232	3	0.32	2.85	3.41	4.69	4.73	17	4
746.7	0.0990	0.0098	9	0.34	2.09	3.58	4.25	4.65	11	3
1300.2	0.0116	0.0001	7	0.17	1.41	4.22	4.46	4.85	34	2
713.5	0.0034	0.0000	10	0.42	2.04	2.44	2.95	3.96	7	4
1310.2	0.0221	0.0005	4	0.15	1.21	4.29	5.37	4.85	70	2
1634.1	0.1872	0.0351	128	0.23	1.6	4.22	5.62	4.90	75	2
865	0.0106	0.0001	3	0.52	2.92	1.78	1.43	3.11	2	4
1298.6	0.0316	0.0010	15	0.17	1.41	4.22	4.46	4.85	34	2
893.1	0.0216	0.0005	15	0.27	1.83	3.90	4.47	4.66	30	2
619.6	0.0162	0.0003	18	0.15	1.21	4.29	5.37	4.85	70	2
1091.6	0.0044	0.0000	6	0.42	1	3.05	4.58	4.98	58	2
1101.5	0.0119	0.0001	6	0.15	1.21	4.29	5.37	4.85	70	2
1151.9	0.0301	0.0009	4	0.28	1.16	3.14	4.65	4.36	5	2
1135.6	0.1064	0.0113	12	0.42	1	3.05	4.58	4.98	58	2
1083.9	0.0204	0.0004	3	0.15	1.21	4.29	5.37	4.85	70	2
1547.7	0.1533	0.0235	18	0.23	1.6	4.22	5.62	4.90	75	2
1087.8	0.0018	0.0000	4	0.15	1.21	4.29	5.37	4.85	70	2
919.5	0.0451	0.0020	12	0.39	3.08	2.65	3.98	4.04	9	3
1772.7	0.2545	0.0648	5	0.36	2.41	3.17	4.04	4.54	10	1

1763.9	0.0210	0.0004	12	0.23	1.6	4.22	5.62	4.90	75	2
1292.9	0.0324	0.0011	3	0.15	1.21	4.29	5.37	4.85	70	2
1793.9	0.0113	0.0001	5	0.36	2.41	3.17	4.04	4.54	10	1
742	0.0371	0.0014	8	0.34	2.09	3.58	4.25	4.65	11	3
964	0.0740	0.0055	3	0.27	1.83	3.90	4.47	4.66	30	2
1116.9	0.2301	0.0530	18	0.28	1.16	3.14	4.65	4.36	5	2
1090.5	0.6101	0.3722	279	0.42	1	3.05	4.58	4.98	58	2
1601.6	0.0008	0.0000	3	0.17	1.41	4.22	4.46	4.85	34	2
365.3	0.0111	0.0001	3	0.28	2.78	3.53	4.71	4.48	18	3
1108.4	0.0555	0.0031	35	0.17	1.41	4.22	4.46	4.85	34	2
714.6	0.0170	0.0003	70	0.34	2.57	2.49	2.40	3.66	4	4
2583	0.0346	0.0012	4	0.44	2.8	2.24	2.67	3.91	5	4
1406.9	0.0144	0.0002	2	0.29	1.03	3.34	5.23	4.75	20	2
815.1	0.0204	0.0004	10	0.39	3.08	2.65	3.98	4.04	9	3
1112	0.1473	0.0217	32	0.15	1.21	4.29	5.37	4.85	70	2
479.5	0.3957	0.1566	122	0.28	2.78	3.53	4.71	4.48	18	3
1091.2	0.0173	0.0003	11	0.42	1	3.05	4.58	4.98	58	2
1630.5	0.2766	0.0765	65	0.23	1.6	4.22	5.62	4.90	75	2
919.3	0.2482	0.0616	43	0.24	2.91	3.65	4.15	4.48	17	3
1309.4	0.0050	0.0000	3	0.17	1.41	4.22	4.46	4.85	34	2
1193.1	0.0142	0.0002	15	0.15	1.21	4.29	5.37	4.85	70	2
537.3	0.3263	0.1065	20	0.28	2.78	3.53	4.71	4.48	18	3
1735.1	0.2393	0.0572	14	0.36	2.41	3.17	4.04	4.54	10	1
1375.8	0.0039	0.0000	4	0.29	1.03	3.34	5.23	4.75	20	2
242.8	0.2194	0.0481	61	0.42	1	3.05	4.58	4.98	58	2
1628.2	0.1902	0.0362	43	0.23	1.6	4.22	5.62	4.90	75	2
1745.4	0.0631	0.0040	7	0.23	1.6	4.22	5.62	4.90	75	2
1107.8	0.0124	0.0002	19	0.42	1	3.05	4.58	4.98	58	2
1634.1	0.1872	0.0351	128	0.23	1.6	4.22	5.62	4.90	75	2
1721	0.7675	0.5891	43	0.23	1.6	4.22	5.62	4.90	75	2
692.8	0.0650	0.0042	4	0.39	3.08	2.65	3.98	4.04	9	3
1081.7	0.2368	0.0561	37	0.42	1	3.05	4.58	4.98	58	2
2544.2	0.0251	0.0006	2	0.44	2.8	2.24	2.67	3.91	5	4
905.3	0.0123	0.0002	26	0.24	2.91	3.65	4.15	4.48	17	3
1119.7	0.0342	0.0012	4	0.42	1	3.05	4.58	4.98	58	2
710.7	0.1336	0.0178	7	0.34	2.57	2.49	2.40	3.66	4	4
1087.1	0.0043	0.0000	4	0.42	1	3.05	4.58	4.98	58	2
501.7	0.0921	0.0085	7	0.28	2.78	3.53	4.71	4.48	18	3
2543.7	0.0603	0.0036	6	0.44	2.8	2.24	2.67	3.91	5	4
1089.8	0.2215	0.0491	3	0.42	1	3.05	4.58	4.98	58	2
1081.6	0.7857	0.6173	9	0.42	1	3.05	4.58	4.98	58	2
707.4	0.0323	0.0010	4	0.27	1.83	3.90	4.47	4.66	30	2

784.6	0.0146	0.0002	8	0.27	1.83	3.90	4.47	4.66	30	2
98	0.1327	0.0176	17	0.32	2.85	3.41	4.69	4.73	17	4
860	0.0535	0.0029	3	0.42	1	3.05	4.58	4.98	58	2
366	0.0137	0.0002	4	0.28	2.78	3.53	4.71	4.48	18	3
643.9	0.1324	0.0175	9	0.44	4.45	2.52	2.76	4.04	7	4
809.9	0.2160	0.0466	109	0.4	2.92	3.24	3.50	4.40	21	2
1267	0.1856	0.0344	6	0.15	1.21	4.29	5.37	4.85	70	2
1113.1	0.0026	0.0000	4	0.15	1.21	4.29	5.37	4.85	70	2
513.1	0.0043	0.0000	3	0.28	2.78	3.53	4.71	4.48	18	3
1349.9	0.0292	0.0009	10	0.29	1.03	3.34	5.23	4.75	20	2
1127.2	0.0492	0.0024	11	0.42	1	3.05	4.58	4.98	58	2
1450.4	0.0035	0.0000	5	0.29	1.03	3.34	5.23	4.75	20	2
1119.1	0.0004	0.0000	3	0.42	1	3.05	4.58	4.98	58	2
1392.6	0.0608	0.0037	18	0.29	1.03	3.34	5.23	4.75	20	2
1767	0.3854	0.1485	21	0.23	1.6	4.22	5.62	4.90	75	2
1364.9	0.6500	0.4225	11	0.29	1.03	3.34	5.23	4.75	20	2
345.9	0.0050	0.0000	15	0.44	4.45	2.52	2.76	4.04	7	4
1118.3	0.0650	0.0042	6	0.42	1	3.05	4.58	4.98	58	2
300.5	0.0329	0.0011	3	0.44	4.45	2.52	2.76	4.04	7	4
246.1	0.0008	0.0000	5	0.15	1.21	4.29	5.37	4.85	70	2
1297.9	0.0005	0.0000	9	0.42	1	3.05	4.58	4.98	58	2
256.2	0.0015	0.0000	2	0.15	1.21	4.29	5.37	4.85	70	2
301.5	0.0035	0.0000	9	0.42	1	3.05	4.58	4.98	58	2
1282.2	0.0899	0.0081	20	0.42	1	3.05	4.58	4.98	58	2
1276.6	0.0088	0.0001	3	0.23	1.6	4.22	5.62	4.90	75	2
682	0.2259	0.0510	150	0.42	1	3.05	4.58	4.98	58	2
682	0.6971	0.4860	7	0.42	1	3.05	4.58	4.98	58	2
674.2	0.0183	0.0003	4	0.4	2.92	3.24	3.50	4.40	21	2
605.1	0.0036	0.0000	6	0.27	1.83	3.90	4.47	4.66	30	2
2460.8	0.1186	0.0141	7	0.32	2.85	3.41	4.69	4.73	17	4
682	0.4342	0.1885	31	0.42	1	3.05	4.58	4.98	58	2
682	0.3284	0.1078	169	0.42	1	3.05	4.58	4.98	58	2
279.4	0.0066	0.0000	3	0.42	2.04	2.44	2.95	3.96	7	4
2413	0.6047	0.3656	7	0.37	2.11	3.36	4.62	4.41	8	4
1257.4	0.3719	0.1383	17	0.17	1.41	4.22	4.46	4.85	34	2
1654.9	0.0088	0.0001	3	0.39	2.19	3.04	4.48	4.65	8	4
1099	0.0885	0.0078	15	0.39	2.19	3.04	4.48	4.65	8	4
1190.6	0.0307	0.0009	3	0.39	2.19	3.04	4.48	4.65	8	4
382	0.0067	0.0000	8	0.15	1.21	4.29	5.37	4.85	70	2
1168.7	0.0167	0.0003	8	0.29	1.03	3.34	5.23	4.75	20	2
1349.5	0.1009	0.0102	11	0.23	1.6	4.22	5.62	4.90	75	2
260	0.0916	0.0084	69	0.17	1.41	4.22	4.46	4.85	34	2

719	0.0015	0.0000	3	0.28	1.53	3.63	4.49	4.55	2	2
1010	0.0943	0.0089	71	0.15	1.21	4.29	5.37	4.85	70	2
1722	0.0650	0.0042	16	0.44	4.45	2.52	2.76	4.04	7	4
1040	0.0717	0.0051	850	0.42	1	3.05	4.58	4.98	58	2
1570	0.0160	0.0003	10	0.36	2.41	3.17	4.04	4.54	10	1
1010	0.0683	0.0047	43	0.15	1.21	4.29	5.37	4.85	70	2
670	0.2680	0.0718	6	0.28	2.78	3.53	4.71	4.48	18	3
303	0.4334	0.1878	12	0.29	1.03	3.34	5.23	4.75	20	2
170	0.3413	0.1165	4	0.24	2.91	3.65	4.15	4.48	17	3
1349.3	0.2567	0.0659	8	0.15	1.21	4.29	5.37	4.9	70	2
1006	0.1599	0.0256	2	0.42	1	3.05	4.58	4.98	58	2
1021	0.6962	0.4846	6	0.42	1	3.05	4.58	4.98	58	2
733	0.1443	0.0208	3	0.28	2.78	3.53	4.71	4.48	18	3
1676	0.1052	0.0111	53	0.32	2.85	3.41	4.69	4.73	17	4
1057	0.0329	0.0011	7	0.42	1	3.05	4.58	4.98	58	2
1372	0.6417	0.4118	9	0.23	1.6	4.22	5.62	4.90	75	2
327	0.0600	0.0036	5	0.29	1.03	3.34	5.23	4.75	20	2
1350	0.2383	0.0568	11	0.23	1.6	4.22	5.62	4.90	75	2
2193	0.1048	0.0110	4	0.32	3.23	2.52	2.81	4.18	1	1
1016	0.7590	0.5761	64	0.42	1	3.05	4.58	4.98	58	2
1036	0.0502	0.0025	4	0.42	1	3.05	4.58	4.98	58	2
1042	0.4824	0.2327	9	0.42	1	3.05	4.58	4.98	58	2
1100	0.0885	0.0078	15	0.39	2.19	3.04	4.48	4.65	8	4
314	0.0346	0.0012	38	0.24	2.91	3.65	4.15	4.48	17	3
2105	0.0319	0.0010	18	0.37	3.76	3.00	3.39	4.21	11	4
742	0.0031	0.0000	4	0.28	1.53	3.63	4.49	4.55	2	2
177	0.7444	0.5541	6	0.24	2.91	3.65	4.15	4.48	17	3
1522	0.0057	0.0000	12	0.42	2.04	2.44	2.95	3.96	7	4
1491	0.0033	0.0000	3	0.32	2.85	3.41	4.69	4.73	17	4
1228	0.0257	0.0007	12	0.23	1.6	4.22	5.62	4.90	75	2
1366	0.0303	0.0009	3	0.23	1.6	4.22	5.62	4.90	75	2
1927	0.0011	0.0000	3	0.43	2.68	1.82	3.23	3.51	5	2
581	0.0170	0.0003	7	0.34	2.09	3.58	4.25	4.65	11	3
279	0.0138	0.0002	4	0.17	1.41	4.22	4.46	4.85	34	2
1014	0.0061	0.0000	4	0.42	1	3.05	4.58	4.98	58	2
1377	0.0078	0.0001	37	0.23	1.6	4.22	5.62	4.90	75	2
1065	0.0754	0.0057	10	0.23	1.6	4.22	5.62	4.90	75	2
680.7	0.0231	0.0005	12	0.15	1.21	4.29	5.37	4.85	70	2
1554	0.1366	0.0187	3	0.37	3.76	3.00	3.39	4.21	11	4
1163	0.0078	0.0001	3	0.42	1	3.05	4.58	4.98	58	2
341	0.3305	0.1092	13	0.28	2.63	3.78	3.76	4.57	7	3
982	0.0010	0.0000	3	0.23	1.6	4.22	5.62	4.90	75	2

1554	0.0324	0.0011	8	0.37	3.76	3.00	3.39	4.21	11	4
1047	0.0196	0.0004	43	0.23	1.6	4.22	5.62	4.90	75	2
559	0.0647	0.0042	7	0.15	1.21	4.29	5.37	4.85	70	2
1065	0.0192	0.0004	9	0.23	1.6	4.22	5.62	4.90	75	2
1194	0.0156	0.0002	33	0.48	3.35	2.69	3.90	4.36	5	4
981	0.2908	0.0846	60	0.23	1.6	4.22	5.62	4.90	75	2
973	0.0534	0.0029	8	0.23	1.6	4.22	5.62	4.90	75	2
973	0.6046	0.3655	66	0.23	1.6	4.22	5.62	4.90	75	2
1588	0.5448	0.2968	19	0.52	2.92	1.78	1.43	3.11	2	4
363	0.0947	0.0090	8	0.15	1.21	4.29	5.37	4.85	70	2
1011	0.0390	0.0015	8	0.23	1.6	4.22	5.62	4.90	75	2
517	0.0536	0.0029	66	0.28	2.78	3.53	4.71	4.48	18	3
850	0.8486	0.7201	51	0.34	2.57	2.49	2.40	3.66	4	4
1451	0.0253	0.0006	6	0.23	1.6	4.22	5.62	4.90	75	2
1057	0.0013	0.0000	13	0.15	1.21	4.29	5.37	4.85	70	2
546	0.1567	0.0246	19	0.15	1.21	4.29	5.37	4.85	70	2
800	0.0118	0.0001	3	0.37	2.11	3.36	4.62	4.41	8	4
873	0.1097	0.0120	54	0.27	1.83	3.90	4.47	4.66	30	2
1157	0.0012	0.0000	6	0.42	1	3.05	4.58	4.98	58	2
1155	0.2575	0.0663	5	0.42	1	3.05	4.58	4.98	58	2
981	0.0106	0.0001	8	0.23	1.6	4.22	5.62	4.90	75	2
1921	0.0064	0.0000	8	0.42	2.04	2.44	2.95	3.96	7	4
385	0.0795	0.0063	9	0.24	2.91	3.65	4.15	4.48	17	3
1152	0.2060	0.0424	12	0.42	1	3.05	4.58	4.98	58	2
1158	0.0016	0.0000	12	0.42	1	3.05	4.58	4.98	58	2
539	0.4972	0.2472	66	0.15	1.21	4.29	5.37	4.85	70	2
1154	0.0402	0.0016	4	0.42	1	3.05	4.58	4.98	58	2
801	0.0556	0.0031	22	0.15	1.21	4.29	5.37	4.85	70	2
717	0.0965	0.0093	3	0.15	1.21	4.29	5.37	4.85	70	2
994	0.0952	0.0091	26	0.23	1.6	4.22	5.62	4.90	75	2
1173	0.0599	0.0036	3	0.42	1	3.05	4.58	4.98	58	2
908	1.0000	1.0000	3	0.4	2.92	3.24	3.50	4.40	21	2
719	0.0096	0.0001	18	0.24	2.91	3.65	4.15	4.48	17	3
1688	0.0130	0.0002	18	0.36	2.41	3.17	4.04	4.54	10	1
796	0.0617	0.0038	7	0.15	1.21	4.29	5.37	4.85	70	2
1202	0.3524	0.1242	14	0.42	1	3.05	4.58	4.98	58	2
725	0.0040	0.0000	4	0.28	2.78	3.53	4.71	4.48	18	3
430	0.0079	0.0001	6	0.28	2.63	3.78	3.76	4.57	7	3
495	0.0082	0.0001	6	0.28	2.63	3.78	3.76	4.57	7	3
854	0.0213	0.0005	3	0.29	1.03	3.34	5.23	4.75	20	2
723	0.0864	0.0075	14	0.15	1.21	4.29	5.37	4.85	70	2
808	0.0868	0.0075	38	0.42	3.37	2.98	3.59	4.19	6	4

847	0.0226	0.0005	5	0.17	1.41	4.22	4.46	4.85	34	2
876	0.0678	0.0046	41	0.4	2.92	3.24	3.50	4.40	21	2
1024	0.0077	0.0001	8	0.23	1.6	4.22	5.62	4.90	75	2
3714	0.0076	0.0001	3	0.44	2.8	2.24	2.67	3.91	5	4
1754	0.0015	0.0000	12	0.43	2.68	1.82	3.23	3.51	5	2
1064	0.0245	0.0006	9	0.23	1.6	4.22	5.62	4.90	75	2
725	0.0506	0.0026	9	0.42	3.37	2.98	3.59	4.19	6	4
1162	0.2027	0.0411	12	0.42	1	3.05	4.58	4.98	58	2
1354	0.1000	0.0100	7	0.44	4.45	2.52	2.76	4.04	7	4
813	0.0129	0.0002	3	0.48	3.35	2.69	3.90	4.36	5	4
751	0.0181	0.0003	6	0.39	2.19	3.04	4.48	4.65	8	4
1198	0.2905	0.0844	8	0.4	2.92	3.24	3.50	4.40	21	2
1096	0.2831	0.0802	3	0.27	1.83	3.90	4.47	4.66	30	2
371	0.0131	0.0002	6	0.28	2.63	3.78	3.76	4.57	7	3
965	0.0340	0.0012	4	0.23	1.6	4.22	5.62	4.90	75	2
196.9	0.0476	0.0023	4	0.15	1.21	4.29	5.37	4.85	70	2
53.8	0.0731	0.0053	139	0.15	1.21	4.29	5.37	4.85	70	2
1418.1	0.0202	0.0004	3	0.23	1.6	4.22	5.62	4.90	75	2
76.5	0.0305	0.0009	16	0.15	1.21	4.29	5.37	4.85	70	2
80	0.0230	0.0005	3	0.39	2.19	3.04	4.48	4.65	8	4
91.8	0.0079	0.0001	4	0.4	2.92	3.24	3.50	4.40	21	2
122.5	0.0086	0.0001	6	0.27	1.83	3.90	4.47	4.66	30	2
1435	0.0141	0.0002	8	0.28	2.63	3.78	3.76	4.57	7	3
67.5	0.0282	0.0008	49	0.23	1.6	4.22	5.62	4.90	75	2
118.2	0.0022	0.0000	7	0.15	1.21	4.29	5.37	4.85	70	2
1228.8	0.0154	0.0002	3	0.28	2.78	3.53	4.71	4.48	18	3
1447.3	0.6786	0.4605	4	0.22	2.93	3.55	3.88	4.36	7	3
1429	0.4211	0.1773	4	0.23	1.6	4.22	5.62	4.90	75	2
793.6	0.3882	0.1507	7	0.23	1.6	4.22	5.62	4.90	75	2
281.8	0.0045	0.0000	3	0.27	1.83	3.90	4.47	4.66	30	2
2616	0.2500	0.0625	4	0.37	3.76	3.00	3.39	4.21	11	4
924.5	0.0455	0.0021	6	0.27	1.83	3.90	4.47	4.66	30	2
691	0.0138	0.0002	6	0.22	2.93	3.55	3.88	4.36	7	3
1354.8	0.0719	0.0052	15	0.39	3.08	2.65	3.98	4.04	9	3
1715.6	0.0038	0.0000	6	0.37	2.11	3.36	4.62	4.41	8	4
322.8	0.7481	0.5596	17	0.15	1.21	4.29	5.37	4.85	70	2
1227.4	0.3917	0.1534	84	0.42	1	3.05	4.58	4.98	58	2
1210.6	0.5677	0.3222	553	0.42	1	3.05	4.58	4.98	58	2
2151.6	0.0114	0.0001	11	0.56	2.52	2.51	3.38	4.34	4	1
172.3	0.4045	0.1636	94	0.17	1.41	4.22	4.46	4.85	34	2
1209.5	0.5692	0.3240	20	0.42	1	3.05	4.58	4.98	58	2
2717.4	0.0064	0.0000	8	0.37	3.76	3.00	3.39	4.21	11	4

1212.6	0.1969	0.0388	6	0.42	1	3.05	4.58	4.98	58	2
1227.9	0.0842	0.0071	106	0.42	1	3.05	4.58	4.98	58	2
1232.6	0.1220	0.0149	14	0.42	1	3.05	4.58	4.98	58	2
1229.4	0.0016	0.0000	4	0.42	1	3.05	4.58	4.98	58	2
162.9	0.0007	0.0000	6	0.17	1.41	4.22	4.46	4.85	34	2
1918.2	0.1197	0.0143	15	0.32	2.85	3.41	4.69	4.73	17	4
228.9	0.1570	0.0246	22	0.15	1.21	4.29	5.37	4.85	70	2
692.9	0.0294	0.0009	8	0.22	2.93	3.55	3.88	4.36	7	3
833.2	0.5898	0.3478	149	0.27	1.83	3.90	4.47	4.66	30	2
908.9	0.0314	0.0010	26	0.27	1.83	3.90	4.47	4.66	30	2
985.3	0.0196	0.0004	9	0.27	1.83	3.90	4.47	4.66	30	2
149.6	0.8345	0.6964	9	0.15	1.21	4.29	5.37	4.85	70	2
368.2	0.0008	0.0000	6	0.17	1.41	4.22	4.46	4.85	34	2
2317.4	0.2812	0.0791	23	0.37	3.76	3.00	3.39	4.21	11	4
300.8	0.4671	0.2181	75	0.15	1.21	4.29	5.37	4.85	70	2
78	0.5171	0.2674	97	0.15	1.21	4.29	5.37	4.85	70	2
397.2	0.0029	0.0000	3	0.17	1.41	4.22	4.46	4.85	34	2
647.2	0.0051	0.0000	2	0.22	2.93	3.55	3.88	4.36	7	3
1726.1	0.0125	0.0002	3	0.23	1.6	4.22	5.62	4.90	75	2
192.4	0.0032	0.0000	4	0.15	1.21	4.29	5.37	4.85	70	2
54.3	0.0777	0.0060	15	0.15	1.21	4.29	5.37	4.85	70	2
845.2	0.0023	0.0000	7	0.27	1.83	3.90	4.47	4.66	30	2
302.1	0.8773	0.7696	13	0.15	1.21	4.29	5.37	4.85	70	2
1232.8	0.2884	0.0831	9	0.42	1	3.05	4.58	4.98	58	2
1421.2	0.2084	0.0434	30	0.23	1.6	4.22	5.62	4.90	75	2
1717.9	0.9177	0.8422	22	0.36	2.41	3.17	4.04	4.54	10	1
1190.4	0.1934	0.0374	4	0.42	1	3.05	4.58	4.98	58	2
117.7	0.0048	0.0000	3	0.15	1.21	4.29	5.37	4.85	70	2
103.3	0.0190	0.0004	6	0.17	1.41	4.22	4.46	4.85	34	2
171.6	0.0140	0.0002	6	0.17	1.41	4.22	4.46	4.85	34	2
1714.4	0.0258	0.0007	21	0.37	2.11	3.36	4.62	4.41	8	4
1421.5	0.0421	0.0018	178	0.23	1.6	4.22	5.62	4.90	75	2
1994.6	0.0180	0.0003	9	0.44	4.45	2.52	2.76	4.04	7	4
1083.2	0.2503	0.0627	17	0.28	1.16	3.14	4.65	4.36	5	2
1334.9	0.0138	0.0002	19	0.23	1.6	4.22	5.62	4.90	75	3
103	0.0216	0.0005	13	0.15	1.21	4.29	5.37	4.85	70	2
131.3	0.0229	0.0005	3	0.17	1.41	4.22	4.46	4.85	34	2
86.3	0.2692	0.0725	4	0.15	1.21	4.29	5.37	4.85	70	2
243.8	0.0135	0.0002	40	0.17	1.41	4.22	4.46	4.85	34	2
1816.5	0.0010	0.0000	3	0.42	3.37	2.98	3.59	4.19	6	4
241.3	0.0077	0.0001	8	0.17	1.41	4.22	4.46	4.85	34	2
890.5	0.1722	0.0297	10	0.34	2.09	3.58	4.25	4.65	11	3

1239	0.0204	0.0004	3	0.24	2.91	3.65	4.15	4.48	17	3
1555	0.0683	0.0047	15	0.15	1.21	4.29	5.37	4.85	70	2
1208.2	0.0628	0.0039	3	0.15	1.21	4.29	5.37	4.85	70	2
326.3	0.2129	0.0453	6	0.32	2.85	3.41	4.69	4.73	17	4
994.2	0.0602	0.0036	51	0.28	2.63	3.78	3.76	4.57	7	3
1577.9	0.7764	0.6028	35	0.17	1.41	4.22	4.46	4.85	34	2
1771.8	0.8364	0.6995	38	0.42	1	3.05	4.58	4.98	58	2
830.5	0.0623	0.0039	19	0.37	3.76	3.00	3.39	4.21	11	4
301	0.0241	0.0006	11	0.42	1	3.05	4.58	4.98	58	2
301	0.1199	0.0144	39	0.32	2.85	3.41	4.69	4.73	17	4
1310.7	0.1143	0.0131	16	0.23	1.6	4.22	5.62	4.90	75	2
1309.4	0.1301	0.0169	18	0.23	1.6	4.22	5.62	4.90	75	2
3015.7	0.0248	0.0006	38	0.44	2.8	2.24	2.67	3.91	5	4
1606.3	0.7391	0.5463	8	0.23	1.6	4.22	5.62	4.90	75	2
1370.6	0.0072	0.0001	9	0.23	1.6	4.22	5.62	4.90	75	2
680.6	0.0033	0.0000	3	0.34	2.09	3.58	4.25	4.65	11	3
698.4	0.0130	0.0002	6	0.42	3.37	2.98	3.59	4.19	6	4
254.8	0.0714	0.0051	6	0.32	2.85	3.41	4.69	4.73	17	4
149.4	0.0155	0.0002	12	0.32	2.85	3.41	4.69	4.73	17	4
830.3	0.0137	0.0002	15	0.37	3.76	3.00	3.39	4.21	11	4
1398.3	0.0019	0.0000	4	0.15	1.21	4.29	5.37	4.85	70	2
301.4	0.2455	0.0603	10	0.32	2.85	3.41	4.69	4.73	17	4
1680.3	0.0095	0.0001	4	0.17	1.41	4.22	4.46	4.85	34	2
2428.7	0.0231	0.0005	5	0.36	2.41	3.17	4.04	4.54	10	1
1159.3	0.1086	0.0118	58	0.28	2.78	3.53	4.71	4.48	18	3
1776	0.0012	0.0000	3	0.42	1	3.05	4.58	4.98	58	2
1436.9	0.0012	0.0000	3	0.23	1.6	4.22	5.62	4.90	75	2
910.5	0.0254	0.0006	4	0.32	2.85	3.41	4.69	4.73	17	4
370.5	0.0825	0.0068	6	0.42	3.37	2.98	3.59	4.19	6	4
845.9	0.0090	0.0001	2	0.37	3.76	3.00	3.39	4.21	11	4
1252	0.0105	0.0001	8	0.23	1.6	4.22	5.62	4.90	75	2
308.5	0.0556	0.0031	2	0.32	2.85	3.41	4.69	4.73	17	4
337.6	0.0352	0.0012	2	0.32	2.85	3.41	4.69	4.73	17	4
1793.9	0.0026	0.0000	6	0.42	1	3.05	4.58	4.98	58	2
1621.5	0.0221	0.0005	10	0.15	1.21	4.29	5.37	4.85	70	2
1412.4	0.6401	0.4098	72	0.23	1.6	4.22	5.62	4.90	75	2
1783.5	0.2360	0.0557	15	0.42	1	3.05	4.58	4.98	58	2
3333.6	0.0036	0.0000	11	0.23	1.6	4.22	5.62	4.90	75	2
259.2	0.1886	0.0356	6	0.56	2.52	2.51	3.38	4.34	4	1
260.1	0.2600	0.0676	7	0.56	2.52	2.51	3.38	4.34	4	1
1364.9	0.0200	0.0004	3	0.4	2.92	3.24	3.50	4.40	21	2
1576.1	0.0097	0.0001	7	0.27	1.83	3.90	4.47	4.66	30	2

3271.4	0.8168	0.6671	2	0.48	3.35	2.69	3.90	4.36	5	4
1896.5	0.1000	0.0100	4	0.28	2.78	3.53	4.71	4.48	18	3
2132.7	0.0011	0.0000	32	0.15	1.21	4.29	5.37	4.85	70	2
3297.4	0.2317	0.0537	9	0.23	1.6	4.22	5.62	4.90	75	2
1455.4	0.0055	0.0000	3	0.27	1.83	3.90	4.47	4.66	30	2
2241.1	0.1096	0.0120	8	0.29	1.03	3.34	5.23	4.75	20	2
1228.3	0.0040	0.0000	8	0.42	1	3.05	4.58	4.98	58	2
1234	0.0481	0.0023	9	0.42	1	3.05	4.58	4.98	58	2
3298.4	0.0036	0.0000	2	0.23	1.6	4.22	5.62	4.90	75	2
1221	0.0224	0.0005	27	0.42	1	3.05	4.58	4.98	58	2
2126.9	0.2165	0.0469	13	0.24	2.91	3.65	4.15	4.48	17	3
2130.6	0.1502	0.0226	10	0.24	2.91	3.65	4.15	4.48	17	3
2138.1	0.3331	0.1109	5	0.15	1.21	4.29	5.37	4.85	70	2
2105.4	0.4004	0.1603	12	0.15	1.21	4.29	5.37	4.85	70	2
1258.2	0.0088	0.0001	12	0.42	1	3.05	4.58	4.98	58	2
2252.5	0.0383	0.0015	16	0.29	1.03	3.34	5.23	4.75	20	2
3334.6	0.0281	0.0008	13	0.23	1.6	4.22	5.62	4.90	75	2
3334	0.4718	0.2226	14	0.23	1.6	4.22	5.62	4.90	75	2
1980.5	0.0118	0.0001	3	0.15	1.21	4.29	5.37	4.85	70	2
3093.5	0.0241	0.0006	8	0.23	1.6	4.22	5.62	4.90	75	2
3290.8	0.0295	0.0009	16	0.23	1.6	4.22	5.62	4.90	75	2
2329.1	0.4042	0.1633	6	0.34	2.09	3.58	4.25	4.65	11	3
1673.4	0.1136	0.0129	6	0.42	2.04	2.44	2.95	3.96	7	4
2102.3	0.3384	0.1145	5	0.15	1.21	4.29	5.37	4.85	70	2
1752.1	0.0085	0.0001	10	0.15	1.21	4.29	5.37	4.85	70	2

AppendixⅣ: Questionnaire on the embeddeness framework of entrepreneurship education

Dear all,

The purpose of this research is to understand the embeddeness framework of entrepreneurial education in universities. The objective and complete information you provide is very important to the research results. This questionnaire adopts an anonymous method. The answers are either good or bad, right or wrong, and are for academic research purposes only. Please express your views and suggestions freely.

1. Basic information

(1) Gender (　　)　　a. Male　b. Female

(2) Age　(　　)　　a. < 18　b. 18-22　c. 23-28 d. 29-35 e. >35

(3) Education background (　　)

a. .Junior college　b. undergraduate　c. master　d. doctoral degree or above

(4) Did you attend entrepreneurship education (　　)

a.Never　　b. attended before 6 months

c. attended before 1 year　d. attended over 1year

2. Embeddedness framework (1- strongly disagree　5-strongly agree)

Variable	Items	1　2　3　4　5
Dependent variable	The market related knowledge (business mindset) has been improved	
	The creative thinking has been improved	
Environmental embeddedness	The culture of university is important for embedding entrepreneurship education into professional education	
	The policy of university is important for embedding entrepreneurship education into professional education	
	The new technology appearance would influence the embedding entrepreneurship education into professional education	
Organizational embeddedness -teaching source	The lecture of business person or staff are very helpful for the embedding entrepreneurship education into professional education	
	The holding creative contests are very helpful for the embedding entrepreneurship education into professional education	
	The establishment of entrepreneurial consulting agencies can help the integration of entrepreneurial education and professional education	
	Increasing professional practice bases can help the integration of entrepreneurial education and professional education	
Organizational embeddedness -curriculum setting	It is important to include entrepreneurial courses in professional education courses	
	Entrepreneurship courses help the understanding of professional courses	
Organizational embeddedness -teachers' competency	The teaching method is very useful for the integration of entrepreneurial education and professional education	
	The practice experiences of teachers are useful for the integration of entrepreneurial education and professional education	
Bilateral cognitive embeddedness -teaching practice	Net income in cooperation reaches (exceeds) expected income target	
	The content of the entrepreneurship education is important for the integration of entrepreneurial education and professional education	
	A practical way is effective for entrepreneurship education integrating into professional education	
Bilateral cognitive embeddedness -teaching method	Collaborative learning re are useful for the integration of entrepreneurial education and professional education	
	Group task are helpful for the integration of entrepreneurial education and professional education	

AppendixⅤ: The social network analysis data in 2018

	bJ	tj	hb	sx	im	ln	jl	hlj	sh	js	zj	ah	fj	jx	sd	hn	hb	hn	gd	gx	hn	cq	sc	gz	yn	sax	gs	qh	nx	xj
BD	0	0	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
BGS	0	0	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BGD	0	0	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BH	0	0	2	0	0	1	0	0	2	2	0	1	0	1	3	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0
BH	0	0	2	0	0	1	1	0	0	1	2	0	0	0	3	3	0	0	1	0	2	0	0	0	0	0	0	0	0	0
BJ	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BJD	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0	1	0	0	0	0	1	0	0	0	0
ZSY	0	0	3	0	0	0	0	0	1	2	0	0	0	0	3	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
BKD	0	0	2	0	1	0	0	0	2	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	1	0	1	0	0	0
BLG	0	0	0	1	0	0	0	0	0	0	1	1	0	0	2	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0
BLY	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
BSD	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
BY	0	0	1	0	0	0	0	0	0	4	1	0	0	1	2	0	1	0	4	1	0	0	0	0	0	0	0	0	0	0
HBD	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
QH	0	1	0	0	0	1	0	0	1	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
KYD	0	0	0	1	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XJD	7	2	0	2	2	3	0	0	2	9	8	1	0	0	2	4	3	0	12	0	0	0	1	0	1	0	0	1	2	1
XKD	5	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2
XGD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XJKD	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
XDKD	2	0	1	0	0	0	0	0	3	2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
XLG	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
XBND	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XYD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ZD	1	0	1	0	0	0	0	0	0	2	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0
HDKD	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
HSF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
DD	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SND	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SYD	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SYH	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SGD	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
GYKD	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GGD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
ZGHY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
FD	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HGD	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DN	1	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
HHD	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ND	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NGD	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NHK	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0
NKG	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

AppendixⅥ: The social network analysis data in 2013

	bJ	tj	hb	sx	im	ln	jl	hlj	sh	js	zj	ah	fj	jx	sd	hn	hb	hn	gd	gx	hn	cq	sc	gz	yn	sax	gs	qh	nx	xj
BD	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
BGS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
BGD	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0
BH	0	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	3	0	0	0	0
BH	0	1	1	0	0	0	0	0	0	1	1	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
BJ	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BJD	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
ZSY	1	0	0	0	0	0	0	1	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
BKD	0	1	3	0	1	0	0	0	1	1	1	1	0	1	4	0	1	0	5	0	0	0	0	0	0	0	0	1	1	0
BLG	0	0	1	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	0
BLY	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
HBD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
QH	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KYD	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
XJD	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XKD	14	1	1	2	1	3	0	0	2	11	8	1	0	0	2	4	3	0	11	0	0	0	1	0	1	0	0	1	2	0
XGD	5	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2
XJKD	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XDKD	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0
XLG	3	1	1	0	0	0	0	0	3	2	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	1	0	0	0
XBND	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
XYD	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZD	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HDKD	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SND	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SYD	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SYH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GGD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZGHY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
HHD	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
ND	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NGD	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
NHK	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
NKG	0	0	0	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
NKY	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
NND	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
NDF	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NYD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
HGD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
HZKJ	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WHFZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
WHGC	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0