University-Industry Collaboration, Innovation and Firms' Performance: The Context of China

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Abstract

The objective of this thesis is to investigate how different patterns of University-Industry Collaboration (UIC) affect firms' innovation outputs and economic performance. Chinese policy-makers have identified innovation as the key to overcoming the middle-income trap and achieving sustainable economic growth. As such, the importance of universities as innovation partners for industrial firms has increasingly been recognised. However, the understanding of how UIC contributes to innovation and firms' performance remains limited, particularly in terms of the informal UIC and the management innovation of firms. Drawing on prior literature, this thesis conceptualises two UIC patterns as the 'Contractual Collaboration' and the 'Relational Collaboration' and explores how these two UIC patterns affect firms' innovation outputs and economic performance. Empirical data employed in this research was gathered from Chinese manufacturing firms. The results reveal that contractual UICs go beyond making the expected impact on firms' technological innovations, as it also promotes firms' organisational changes and new business practices, the latter being mainly achieved through the mediating effects of technological innovation. Neither proximity nor the research quality of universities significantly affect firms' innovation outputs in contractual UICs. The relational UIC, which refers to a variety of informal collaboration methods, positively affects firms' technological and management innovations, with the link being strongest between relational UICs and management innovations. Also, these innovations positively contribute to the economic performance of firms. When engaged in the relational UICs, small and medium sized enterprises (SMEs) and high-tech firms perform better in management innovations.

Findings from this thesis suggest that firms, wherever necessary, should establish formal collaboration networks with universities for better innovation performance. For SMEs who either cannot defray the costs/risks of entering into a formal collaboration or are not capable of absorbing cutting-edge codified knowledge, collaboration with universities via relational channels is an important pathway to better innovation and economic performance. Policy-makers, especially in countries where formal links between science and industries have yet to be fully established, should recognise the importance of the informal innovation network between universities and firms. Also, policy tools should focus on encouraging the lower-ranked regional universities into their local innovation systems rather than solely concentrating on innovation collaborations between elite universities and large firms.

Copyright Statement

Author’s Declaration

This thesis is submitted in fulfilment of the requirements for the degree of Doctor of Philosophy at the Bournemouth University, United Kingdom. I declare that this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that this thesis has not been previously or concurrently submitted, either in whole or in part, for any other qualification at Bournemouth University or other institutions.

I would also like to declare that the chapter 4 and chapter 5 in this thesis are a joint work by myself, Dr. Gelareh Roushan and Professor Davide Parrilli, for which my individual contribution to these two chapters is over 80%.

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List of Contents

List of Tables

List of Figures

Chapter 1 Introduction

1.1 Research Background

Innovation is a torch that guides the progress of human civilisation. From earliest times, the path to our modern society has been marked by illustrious entrepreneurial spirits and revolutionary innovations. From the first bonfire lit by primitive human beings to the vintage light bulb invented by Thomas Edison, and from the Code of Hammurabi carved on a black stone stele to the first computer prototype invented by Alan Turing, it is the bold exploration of the unknown that has brought us where we are today. It is fair to say that innovation in its many forms has laid the foundation of our current way of living, and it also drives the sustainable growth of the economy (Cancino et al. 2018).

Many economists have made noteworthy efforts to explain the role played by innovation in economic activities. For example, in his prestigious work published in 1776, *An Inquiry into the Nature and Causes of the Wealth of Nations*, Adam Smith regarded technological change as an endogenous factor that comes from the division of labour and leads to an increase in productivity (Smith 2010). Decades later, Karl Marx identified knowledge as a productive force, and further argued that the advance of an economic system manifests itself in the levels of endogeneity of technological changes (Bimber 1990). In his paper, *Marx as a Student of Technology,* Rosenberg (1976) summarised Marx's thinking as: (1) the introduction of innovation reduces the price of goods in a market; 2) technological changes increase the extraction of surplus value; and (3) technological changes in capitalism are, in essence, an intentional process of labour substitution. By introducing new production technologies, capitalists are able to reduce the intensity of labour in the production process and, as a consequence, reduce the cost of labour and increase their profits.

Although many renowned economists have made significant contributions to the study of innovation economics, one name nevertheless stands out: that of the Austrian economist, Joseph Schumpeter. In addition to his other important contributions, such as the business cycle (Schumpeter 1939) and democratic theory (Shumpeter 1942), Schumpeter established the 'Schumpeterian growth theory', recognising the importance of institutions and technology to economic growth. Adopting the arguments of Karl Marx, Schumpeter regarded the development of capitalism as an evolutionary process, in which the economic structure constantly evolves through technological progress. Specifically, Schumpeter argues that innovation is a 'creative destruction' that destroys the old economic practices and transforms them into more efficient new ones (Schumpeter 1942a). Five types of innovation were classified by Schumpeter: introducing new products, implementing new production methods, identifying a new source of supplier, opening a new market, and finding new ways to organise business (Schumpeter 1942b). In contrast to Karl Marx, who mainly focused on innovations in the production process, Schumpeter went beyond 'tangible innovation' (e.g., new machinery, new product) to also explore the less tangible nature of innovation, such as new business practices or a new organisational structure. It is the combination of these tangible and intangible innovations that drives sustainable economic growth.

As highlighted by Schumpeter (1982), creative destruction (i.e., innovation) is achieved by re-combining production factors and bringing them together in new forms. Meanwhile, the process of combining these factors is also a social process that integrates talent and knowledge across organisational boundaries (Freeman and Soete 1997). Indeed, innovation in the knowledge economy may not be as it was in the time of Karl Marx or Schumpeter. New technologies and new knowledge are emerging faster than ever, which put firms and nations under pressure to either lead the charge with the use of new technology or settle for playing catch-up. In this regard, an important stream of the innovation literature has focused on innovation collaborations between organisations and has examined how firms and nations can benefit and prosper from such innovation collaborations (for example, see Faems et al. 2005; Chesbrough 2006; Fitjar and Rodríguez-Pose 2013). Scholars in this line of research have emphasised that the generation and usage of technological knowledge should not be viewed as the isolated triumphs of individual organisations; instead, they constitute a systematic process whereby innovation resources flow among heterogeneous groups of learning agents (Freeman 1991; Patel and Pavitt 1994). Building upon this systematic feature of the innovation process, Lundvall et al. (1988) proposed the concept of the 'National Innovation System' (NIS) by arguing that innovation is a result of the complex interactions among firms, governments, and universities/research institutions at national level. Looking into regional specificities, Cooke (1992) proposed the concept of the 'Regional Innovation System' (RIS), which encourages the interactive learning of knowledge at regional level; thus, a localised collaboration network can be formed for the production and diffusion of innovation. The importance of openness in the innovation process was also stressed by Chesbrough (2003), who coined the term 'open innovation' with its connotations that firms can and should utilise both external and internal knowledge to build up their R&D capabilities. In summary, innovation in the knowledge economy is an interactive learning process, and the network of innovation partners matters at both regional and national levels.

In this context, universities serve as important partners in firms' innovation activities. Traditionally, universities were connected to the external world through their core function of training students, equipping them with knowledge and preparing them for their future professional responsibilities. In addition, universities are places where new knowledge is explored, produced, and synthesised. Nowadays, both the quantity and quality of university research are regarded as important indicators of national competitiveness, and higher education institutions (HEIs) are expected to exert an impact on the regional, national, and global contexts (Pinheiro et al. 2015). Scholars argue that universities have a third mission that goes beyond their traditional teaching and researching remits, which is to transfer knowledge that supports industrial innovations and facilitates technological changes (Etzkowitz and

Leydesdorff 1995; Montesinos et al. 2008). This science-market interaction in economic activities is not a new phenomenon since it can be traced back to the 'scientific-technical revolution', when it was recognised by Karl Marx as '*science transferring itself into a production factor which transcends the combination of labour, land, and capital*' (Marx 1953, p.595). However, it was not until the Second World War that the notion of the 'third mission' of universities has been theorised in literature (Nelson 1959; Roy 1972; Lundvall et al. 1988). It has been indicated that nowadays the market is becoming increasingly competitive due to the rapid change in technology, and firms' in-house R&D capabilities may not be sufficient to develop innovations that help them to stand out from the intense competition (Wright et al. 2008). In this line of research, universities are regarded as important players in the innovation system, achieving economic impacts through their networking with partners such as firms and governments. Specifically, Etzkowitz and Leydesdorff (1995) proposed the triple-helix (TH) model, arguing that social and economic development can be promoted by the non-linear interactions between universities, industry, and government. According to the TH model, universities draw on their knowledge and talents to participate in industrial innovation activities; such interactions are also regarded as the 'academic entrepreneurial activities' of universities (Etzkowitz and Zhou 2017).

In this introduction chapter, a brief summary of the current research on University-Industry Collaboration (UIC), as well as the theoretical gaps and practical issues were discussed in Section 2. In Section 3, the research objectives were presented, from which nine research questions were developed to explore the research objectives. The methodology for this research is introduced in Section 4 and the originality and contributions were discussed in Section 5. Lastly, the overall structure and the abstracts of each chapter were presented in Section 6.

1.2 Literature gaps and problem statement

1.2.1 A brief summary of the current research

As the importance of the university has increasingly been recognised, a large amount of theoretical and empirical research has been conducted to explore and investigate the university-industry collaboration (UIC) (for example, see Ponds et al. 2009; Bruneel et al. 2010b; Fernandes and O'Sullivan 2020). In general, the partnership between academia and industry has been argued to be beneficial for both firms and universities, and many researchers have focused on this partnership's influence in different contexts, such as the United States (Ponomariov 2013), the United Kingdom (D'Este and Patel 2007a), Japan (Motohashi and Muramatsu 2012), Norway (Fitjar and Rodríguez-Pose 2013), etc. Despite the apparent variety of research contexts, papers on the UIC can nevertheless be categorised into three groups: (1) the drivers of UIC, (2) patterns of UIC, and (3) the outputs of UIC.

The first stream of literature attempts to understand what factors drive or influence the formation of the UIC. For example, a firm's R&D intensity has been argued to be a critical driver for the UIC (Laursen and Salter 2004; Lopez et al. 2015; Aiello et al. 2019). As university knowledge may be inaccessible and not easily transferred to firms, investing in internal R&D improves the firm's learning ability and increases its capacity for absorbing external knowledge (Cohen and Levinthal 1989). The firm's size and age also impact on its propensity to engage in the UIC (Laursen and Salter 2004; Segarra-Blasco and Arauzo-Carod 2008a). According to the National Bureau of Statistics of China (NBS 2017), firms with less than 1,000 employees are defined as small and medium size-enterprises (SMEs). Compared to SMEs, large firms often have the necessary resources (e.g., talent, funds, information) to establish and maintain a collaborative relationship with universities. Similarly, mature firms are more experienced in external collaborations than young firms. For universities, research quality (Perkmann et al. 2011), research orientation (Arvanitis and Woerter 2009) and their access to public funds (Tseng et al. 2020) are all factors that influence the formation of effective UIC.

The second group of literature focuses on the interaction channels and the collaboration patterns based on these channels. For example, D'Este and Patel (2007a) found that industry-sponsored conferences, joint research projects, contract research, training, and the creation of physical establishments are the most frequently used channels in UIC. Bodas Freitas et al. (2013a) identified two UIC patterns: the institutional pattern and the personal contractual pattern. In the institutional pattern, interactions are mediated by an administrative structure (e.g., transfer offices or relevant departments), whereas in the personal contractual mode, collaboration happens via a direct link between individual academics and firms. Hughes and Kitson (2012) further defined two types of UIC as people-based activities (e.g., personnel exchange, conferences, social networks, training programmes) and problem-solving activities (e.g., joint research, contract research, consulting, informal advice). Fernandez-Esquinas et al. (2016) summarised five types of UIC patterns: the generation and adaptation of knowledge, training and exchanging human resources, creating new establishments, the intellectual property transaction, and the use of university facilities.

The third group mainly focuses on how UICs affect the innovation outputs and economic performance of firms. The current academic debates have reached no firm conclusions about the impacts of UIC on a firm's innovation outputs. While much evidence has pointed to a positive relationship between collaboration and technological innovation (for example, see Kobarg et al. 2018; Hewitt-Dundas et al. 2019a; Tang et al. 2019), there are studies that present contrary findings. For example, Gonzalez-Pernia et al. (2015) found that U-I collaboration itself does not significantly affect a firm's innovation outputs because technological innovations are achieved by combining UIC with other types of collaboration (e.g., collaboration with competitors/customers). For firms with lower absorptive capacity, R&D collaboration with universities does not always transfer university knowledge into new products/processes (Moon et al. 2019). Regarding economic performance, R&D alliances with universities help firms to share the R&D costs and risks (Jones and Corral de Zubielqui 2017), increasing productivity and sales revenue (Garcia-Perez-de-Lema et al. 2017) and helping firms to expand their market shares (Ivascu et al. 2016b).

1.2.2 Gaps in literature

Despite the efforts and progress made in the exploration of the collaborative relationship between universities and industry, at least three knowledge gaps still exist. First, previous studies on collaboration outputs have mainly focused on technological innovation. According to the definition by the Oslo Manual (OECD, 2005), technological innovation at firm level refers to a new or significantly improved product/process. Indeed, these innovations are a direct reflection of firms' innovation capabilities, and studies have also confirmed that new products or new processes are closely linked to the firms' economic performance (for example, see Gunday et al. 2011). However, as indicated by Schumpeter (1942), innovation can also be achieved by identifying new sources of suppliers and markets or finding new ways of organising business practice. These less tangible innovations were designated by the Oslo Manual (2005) as 'non-technological' innovations, which derive from firms' implementations of new or significantly improved organisational practices and marketing strategies. Although Pippel (2014) noted that the impacts of R&D collaboration on non-technological innovations had long been absent from discussions on innovation studies, there remains little clarity about how the UIC affects a firm's non-technological innovation.

Second, previous studies on the interaction patterns of UIC are mostly based on 'formal collaborations', with channels such as contract research, joint research, co-publishing, or patent transactions being extensively examined in the literature (Mirowski and Van Horn 2005; Spithoven et al. 2020). These formal channels can be an effective way for firms to build up and consolidate their internal knowledge base. However, some scholars have argued that it is necessary to explore the 'informal' relationship between universities and firms, and they have also highlighted that informal channels could be essential to understanding how the UIC affects a firm's innovation performance (Ankrah 2013b; Perkmann et al. 2013). Although previous literature did not systematically look into what constitutes these informal channels and what role they can play in UIC, a few recent studies have attempted to build on this line of research (for example, see Olmos-Peñuela et al. 2014; Garcia-Perez-de-Lema et al. 2017; Apa et al. 2020). Despite the contributions made by these studies, more empirical evidence is necessary to understand the marginal effects of the informal UIC on a firm's innovation outputs and how these innovation outputs shape the economic performance of a firm.

Third, previous research has also investigated how contextual nuances affect the outputs of UIC (for example, see Gronum et al. 2012; Mascarenhas et al. 2018). Such context nuances include the firm's size, age, industry, absorptive capacity, the research quality of universities, etc, and these studies generally hold the view that the UIC is beneficial to a certain group of firms (e.g., large firms, those operating in high-tech industries, firms collaborating with elite universities, etc.). However, as mentioned above, these studies are rooted in the 'technological view' of innovation, and their empirical investigation is often focused on formal collaborations. It is worth investigating whether contextual factors moderate collaborative outputs when collaboration happens less formally and how these factors affect the non-technological innovation of firms.

1.2.3 Issues in practice

Issues exist not only in literature but also in practice. A formal R&D collaboration is often associated with high costs, which may impede the engagement of small and medium-sized enterprises (SMEs) in UICs. This is especially the case in emerging economies where SMEs are mostly downstream in the industrial chain and are not capable of making heavy investments in R&D collaborations with universities. Indeed, even in the developed economies, it requires sizeable public investment from the government to encourage R&D collaboration between public and private sectors. For example, the Higher Education Innovation Fund, established by the UK government, has committed to investing £213 million to support interactions between higher education providers and businesses (DBEIS, 2020). In China, it has been observed that university collaborations are mostly established with large firms, particularly the state-owned enterprises, which leaves SMEs less supported in their R&D activities (Liu et al. 2017).

Moreover, the traditional technological view of innovation and the emphasis on formal collaboration channels have limited UICs to the elite universities and the STEM disciplines (science, technology, engineering, and mathematics). In China, universities are classified into the 'first-tier' universities and the 'regional universities'. Generally, the first-tier universities are considered as universities with excellent research quality and they are directly administered by the Ministry of Education, whereas the regional universities are less research-oriented and they are administered by their provincial governments. According to a national survey conducted in 2019 by the Ministry of Education, China (MOE, 2020), each first-tier university was, on average, engaging in 61 industry collaboration programmes, a number that starkly contrasts with the 8 programmes being undertaken by the regional universities. A UK survey conducted by Hughes and Kitson (2012) revealed that STEM subjects and the health sciences together accounted for nearly 50% of the 4,452 collaboration projects reported, followed by around 30% of arts and humanities, and the social sciences participated in around 20% of them. These survey results send a clear signal that although the importance of the elite universities and natural science subjects is recognised, more research should be conducted to understand how lower ranked regional universities and the social sciences can contribute to industrial innovations.

1.3 Research objective and research questions

Responding to the literature gaps and practical issues, this research attempts to further explore the different patterns of the UIC, with the aim of investigating the innovation outputs and economic performances associated with the various patterns. In particular, this research project includes the constructs of informal UICs and non-technological innovations to examine the relationship between the UIC, innovation, and firms' economic performance. Examining the frequently used UIC channels, this research identified two patterns of UIC based on their dominant feature. The first is the 'contractual collaboration', which refers to the R&D collaboration based on a formal contract/agreement. The frequently used channels of contractual UICs include technological consultancy, research grant/scholarship, joint/contract research, patent/licence transaction, use of university facilities, and joint ventures/spin-offs. The other is the 'relational collaboration', which refers to the informal collaboration based on social ties, frequent interactions and a high level of trust. The channels of relational collaboration include social networking activities, forums/conferences, joint PGR supervision, student internship, graduate recruitments, staff secondments, and broad training programmes. Drawing on these two collaboration forms, this research also attempts to examine how different UIC patterns affect firms' innovation outputs and economic performance, and improves understanding of how nuances (e.g., the firm's size, age, industry, university research quality, etc.) influence UIC performance.

In summary, the objective of this research project is to contribute to the current studies by establishing a comprehensive theoretical framework of UIC and using firm-level data to investigate how different forms of UIC affect firms' innovation outputs and economic performance. To carry out this objective, the following research questions are discussed in the thesis:

1. What university-industry collaborations are and what is the current state of scholarly research?
2. What is the contractual collaboration between university and industry?
3. What is the relational collaboration between university and industry?
4. How does the contractual UIC affect firm's technological and management innovation?
5. Do regional proximity and the research quality of universities affect the firm's innovation outputs in contractual UICs?
6. How does the relational UIC affect the firms' technological and management innovation?
7. Do firm's innovation outputs contribute to better economic performance?
8. Do firm's size, age, industry, and absorptive capacity affect the outputs of the relational UICs?
9. How does the institutional environment shape the innovation systems in China?

1.4 Research Methodology

To the best of our knowledge, there is no specific dataset suitable for this research. Relevant data sets such as the Community Innovation Survey and China Enterprise Innovation Survey cannot be adopted in answering our research questions due to the absence of key information (e.g. specific activities of UIC). As such, firm-level data combining UICs and innovation performance is needed to examine the research question 4-8. Therefore, the data employed in this research was gathered through a self-administered questionnaire, which was distributed to randomly selected Chinese manufacturing firms from the following seven provinces/metropolitan regions: Guangdong, Jiangsu, Zhejiang, Shandong, Henan, Beijing, and Shanghai. China has a large geographical territory in which the level of regional development varies greatly. We specifically targeted these seven regions because their institutional environments are similar, enabling the sample selection bias to be better managed (for example, 15,601 and 17,918 USD GDP per capita 2019 in Zhejiang and Jiangsu, respectively). According to the National Bureau of Statistics, they are also the top seven regions in the provincial GDP ranking (NBS 2019). Generally, firms in these regions are more modern, competitive and innovative, compared with firms in other regions. We targeted respondents in management positions, such as general managers, CEOs, and R&D managers, because management has better knowledge of their firms' performance (Garcia-Perez-de-Lema et al. 2017). This means that the data collected for academic research is more accurate and reliable.

For this survey, a questionnaire was developed following an extensive review of the literature and the existing innovation surveys (e.g. Community Innovation Survey by Eurostat). The first section of the questionnaire collects general information from firms, including their geographical location, founding year, main products, performance level in 2018, and the average number of employees over the past three years, etc. The second section uses a five-point Likert scale to ask the respondents to evaluate their use of collaboration channels during the last three years (2016-2018). The third section collects data on firm innovation outputs that have benefited from collaboration with universities. The design of this section echoed Eurostat's Community Innovation Survey 2016 and the National Enterprise Innovation Survey 2019 by the Chinese National Bureau of Statistics, which evaluates the radicalness of technological innovation and the importance of management innovation.

The survey was conducted in different stages. First, the cover letter and questionnaire were translated into Chinese with the help of two Chinese academics in innovation studies. Second, two consecutive rounds of pilot studies were carried out to test the length, reliability, and readability of the questionnaire. The first round of the pilot survey was carried out in China and involved 12 face to face interviews with business managers. We then further tested the questionnaire by enlisting the help of a reputable academic survey company to distribute it to manufacturing firms in our sampled regions. The results of these two rounds of pilot surveys were used to modify and refine our questionnaire items. Lastly, the formal survey was launched in December 2019 and yielded 475 usable questionnaires from the 865 questionnaires returned.

The research questions 4-8 require an empirical investigation into the statistical relationship between UIC, innovation and performance. To address these research questions, this study uses a multivariate analysis method. The structural equation modelling (SEM) is most suitable for this research as it allows researchers to integrate different multiple regression models simultaneously. The LISREL 8.8 was used to execute the analysis process in this study. We also adopted the Partial Least Square modelling technique (SmartPLS) to check the robustness of the research findings. In practice, employing PLS-SEM as a supplement to CB-SEM can act as a tool of methodological triangulation, through which the consistency and reliability of analysis results can be examined (Garcia-Perez-de-Lema et al. 2017).

1.5 Research originality and contributions

Building on the previous literature and academic discussions, this research makes an original contribution to the current literature and practices. First, as informal collaboration is a concept that is more prevalent in inter-firm collaboration studies, this research is one of the few studies to explore the informal collaboration between universities and industries. The concept of informal collaboration in this study was derived from the concept of "Guanxi"— a unique Chinese social philosophy that represents the interpersonal bonds that rely on friendship and the mutual support and trust. In addition, the theoretical basis of the informal collaboration also corresponds to the literature on relational collaboration—a relationship governance mechanism that minimises a firm's transaction costs (Ferguson 2005). Compared to other studies that investigate the informal UIC, (for example, see Olmos-Peñuela et al. 2014; Garcia-Perez-de-Lema et al. 2017; Apa et al. 2020), this research provides a novel understanding of how the informal UIC affects firms' innovation outputs, as well as their economic performance.

Second, this research contributes to the scanty literature on how UIC contribute to management innovation (i.e., organisational and marketing innovation). In the extant literature, researchers tend to uphold the technological view of innovation and they have focused on investigating how universities complement/substitute firms' internal R&D capabilities. As indicated by Pippel (2014), the purely technological view neglects the complexity of innovation; therefore, a more inclusive approach is needed in innovation studies. Using the non-technological innovation defined by Organisation for Economic Co-operation and Development (2005), this study not only extends the current literature by including non-technological innovation in the empirical investigation, it also specifically investigates how collaboration with universities, which has long been held to be a valuable source of technological progress for a firm, contributes to technological and non-technological innovations.

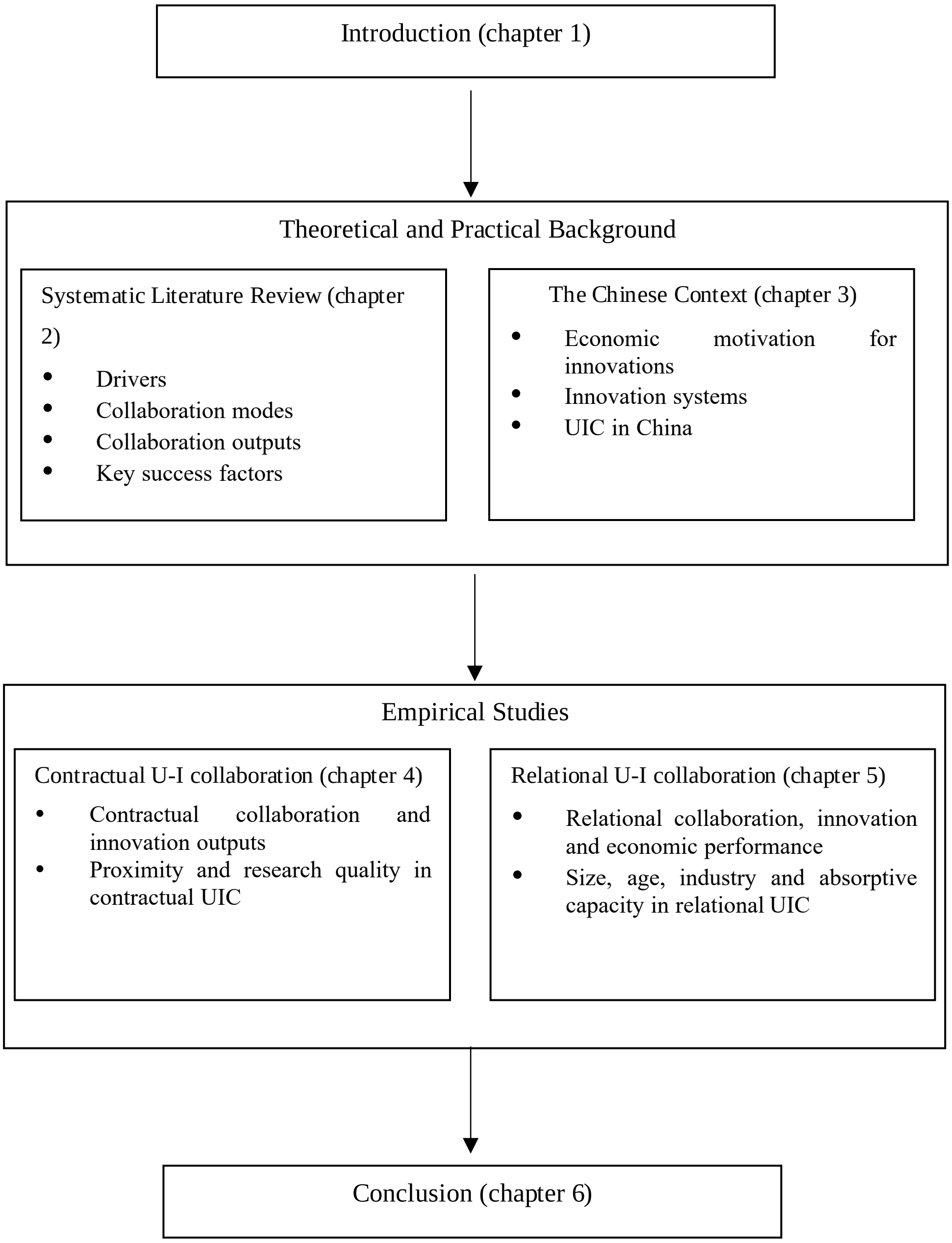
Third, the current literature on firm innovation modes has proposed two approaches. The first is through the application of R&D expenditure and scientific human capital (science and technology-based innovation mode or STI). The other, known as the DUI mode of innovation, relies on learning-by-doing, by-using, and by-interacting (Jensen et al. 2007). In this line of research, universities are considered as valuable partners of firms that are adopting the STI mode of innovation (Chen et al. 2011; Gonzalez-Pernia et al. 2015; Parrilli et al. 2020). Based on the empirical evidence, this research makes the novel argument that universities, like suppliers/competitors/customers, can be an important DUI partner for firms engaged in relational collaboration. Previous literature has examined the role of universities in firm's DUI innovation network, and argued that the DUI firms benefit from UIC mainly through the education and training of students/employees, and it is difficult for universities to participate in the daily innovation process of firms (Benneworth et al. 2009; Isaksen and Karlsen 2010). To the best of our knowledge, this is the first study that revealed how universities directly contribute to the DUI-innovation activities of firms; thus, it makes a novel contribution to the current STI/DUI literature.

This research is also relevant for practice. As discussed, the traditional collaboration method between universities and firms is often based on formal channels, such as patents transactions and contract research. These formal collaborations are associated with higher costs that may create barriers to SMEs. Although it is evident that the process of scientific research can be projected ahead, the outcome is difficult to guarantee. Hence, formal R&D collaborations could be risky endeavours for firms if universities are unable to deliver the desired research outputs. This research proposed relational collaboration as an additional collaboration method and explores how this form of collaboration affects the innovation and economic performance of firms. Also, it highlights the importance of regional (lower ranked) universities in firms' collaborative networks. Although regional universities may not be able to produce excellent academic outputs in basic research, many of them are specialised in applied science, making them valuable partners to support the firm's incremental improvements in their current products and manufacturing processes. Also, collaborating with local SMEs helps regional universities to expand not only the income sources but also to take their social and economic influence to a larger context (Breznitz and Feldman 2012a).

1.6 Structure of the thesis

This thesis follows an integrated-thesis format, in which two empirical papers are complemented by four supplementary chapters. As shown in Figure 1, the content is organised as follows:

Figure 1 The structure of the thesis



Chapter 1 has provided a general introduction to the research. The research background has been justified, followed by a brief discussion of the research gaps and a statement of the problem. The methodology adopted for the research has been introduced, the research's contributions have been explained and their novelty highlighted.

Chapter 2 is a systematic review of the relevant literature. This chapter examines the recent academic contributions by exploring the following questions: (1) what are the factors influencing a firm's propensity to collaborate with universities? (2) what are the frequently used UIC channels and patterns? (3) to what degree can collaboration benefit firms' innovativeness, as well as their financial performance? (4) what are the key variables that influence the success of U-I collaboration? Previous research has examined these four aspects, but the theoretical understanding of UIC still remains fragmented (Al-Tabbaa et al. 2019). This chapter critically integrates the findings from the reviewed literature into a holistic framework, thus providing a more comprehensive understanding of the drivers, interaction patterns, and impacts of the U-I partnership, as well as the key success factors that have managerial implications for businesses and policy-makers. By systematically selecting and reviewing relevant papers published during 2009-2019, we are able to compare and discuss the recent literature and identify the theoretical gaps that are pertinent to the following chapters/papers.

Chapter 3 investigates the institutional environment of China. The literature reviewed in Chapter 2 is mostly rooted in the context of developed economies, in which the allocation of innovation resources is typically a market behaviour (i.e., business R&D). In contrast, China has been recognised as a newly industrialised economy with a top-down governance model, and its innovation activities are influenced more by institutional factors, such as government policies, initiatives, laws, and regional legislation. Therefore, before examining the empirical relationship between U-I collaboration and innovation, this chapter examines the institutional environment for innovation in the Chinese context, with specific regard to the economic motivation for innovation, innovation systems (national and regional), and how UIC works with an example taken from an elite Chinese university (i.e. Tsinghua University).

Chapter 4 is an empirical paper that investigates whether and how contractual U-I collaborations affect firms' innovations. The empirical analysis tests whether this collaboration produces not only the expected technological innovations but also management innovations (i.e. non-technological innovations). Moreover, this paper tests whether the geographical proximity and research quality of the universities (i.e. high ranked Chinese universities) affect firms' innovation outputs. Our findings suggest that universities, in addition to their contributions to firm's technological progress, also promote firms' organisational changes and new business practices. In addition, this paper highlights regional universities as critical innovation partners, which is especially relevant to SMEs.

Chapter 5 is an empirical paper that expands the economic conception of relational collaboration to the realm of the UIC, exploring why and how firms' innovation outputs can benefit from informal collaboration. Furthermore, this paper joins the scholarly debate on whether innovation contributes to the performance of firms. The findings suggest that: (1) relational collaborations with universities positively affect both technological and management innovation; (2) technological and management innovation positively affect the performance of firms, although the effect of technological innovation is stronger; and (3) the positive relationship between relational collaboration and management innovation is stronger for SMEs and high-tech firms. The findings of this paper are not only relevant for firms and SMEs but also for universities and policy-makers.

Chapter 6 synthesises and discusses the research findings of the thesis and highlights its theoretical contribution to the literature. It also discusses the implications for business strategy and policy making. Lastly, the limitations of this research are noted, and future avenues for research are proposed.

Chapter 2 University-Industry Collaboration: A Systematic Literature Review and Synthesis

2.1 Introduction

The interaction that facilitates technology and knowledge exchange between higher education institutions and industries, also referred to as University-Industry Collaboration (UIC) (Perkmann and Walsh 2007b), has long been acknowledged to be an important method of building the knowledge base of a firm. It has been recognised that today's market is becoming increasingly competitive due to rapid changes in technology, and that a firm's in-house R&D capabilities may therefore be insufficient for it to develop innovations that help it rise above the intense competition (Wright et al. 2008). Meanwhile, the higher education sector is also experiencing tremendous changes. The global recession has slowed down most countries' economic development and, as a result, many universities have found that public funding from government has become more and more scarce. The revenue stream from collaboration with the private sector is therefore an attractive funding method for supporting the scientific research activities of universities. According to UniversitiesUK (2016), one-third of the UK universities' income derived from the private sector in 2015, a significant increase on the figure of 25% in 2008. Also, as the demand for new technologies continues to rise, universities must look to industry for insights and knowledge that might inspire research in different subject areas (Hagen 2002); this is particularly relevant to the polytechnic universities. Lastly, there is mounting pressure on higher education institutions to fulfil the 'third mission' of universities by serving as an engine for economic development. From this perspective, U-I collaboration can be a critical element in the innovation networks and contribute to macroeconomic development (Etzkowitz 2003).

However, the complexity of U-I collaboration has hampered policy-makers, practitioners, and researchers seeking to develop effective U-I collaboration networks. For example, given the importance of U-I collaboration, the Chinese government announced the '*Medium and Long-term Scientific and Technological Development Programme 2006-2020'* in which collaborations between universities and industry were explicitly encouraged. Despite this programme, the U-I collaboration network in China is still largely bound to developed city clusters like Shanghai, Beijing, and Nanjing and it has mainly occurred between the high-tech industries and elite universities Fiaz (2013). Given that the 'low-tech' industries make significant contributions to the economy, for example, the food industries alone account for 1.2 trillion euro of the EU's total turnover, according to CIAA (2019), it is relevant to investigate what increases the propensity to collaborate in both high-tech and low-tech industries. Second, collaboration between U-I involves a variety of channels, such as joint research, patenting, conferences, informal contacts, etc. Collaboration channels can be grouped into different modes or patterns. The mode of the U-I interaction depends on factors such as research quality, proximity, absorptive capacity of firms, etc., and the choice of U-I collaboration mode reflects the heterogeneity in organisational resources and institutional environment (Fernandez-Esquinas et al. 2016). Hence, it is important to study the collaboration modes/patterns by investigating the drivers and benefits associated with each mode so that a firm can choose its most appropriate collaboration method and maximise the payoffs from the collaboration. Third, it is worth investigating the outcomes of collaboration in terms of innovation and firm performance. It has been accepted that universities can successfully support the radical technological innovation of firms (Moon et al. 2019), but their role in supporting other types of innovation remains unclear. Compared with radical innovation, incremental innovation can take place simply by improving efficiency in the manufacturing process or by refining the management practices of firms. Universities possess not only cutting-edge technological knowledge; they are also capable of providing managerial knowledge that helps firms improve performance. For example, advice provided by a business school professor can help firms position their product in the marketplace. From this perspective, the potential of universities for supporting incremental and managerial innovation is underestimated. Last, as indicated by Rybnicek and Königsgruber (2018), while numerous studies have examined the success factors of inter-firm relationships, less research has been conducted in the field of U-I collaboration. By synthesising the recent findings on the success factors of U-I collaboration, our research sheds light on the variables that moderate U-I collaboration and business performance. Such factors are also relevant from a managerial perspective as they can help improve understanding of why some U-I collaborations are more successful than others.

This chapter examines the literature, with the aim of achieving the following objectives: (1) To identify the factors influencing a firm's propensity to collaborate with universities. It has been indicated that the formation of a UIC is influenced by a variety of factors, such as the firm's absorptive capacity, size, age, etc. (Lai 2011), but a more comprehensive investigation is needed to understand how the firm's external and internal factors jointly influence the formation of a collaboration. (2) To explore the collaboration modes/patterns of UIC. Interactions between universities and industries take place in different ways, the current understanding of which, as suggested by Ankrah and Al-Tabbaa (2015), remains limited and fragmented. (3) To identify the degree to which collaboration can benefit a firm's innovativeness and its financial performance. Although the positive role played by the university in supporting a firm's innovation performance has been widely accepted, recent studies have also made contrary findings (for example, see Gonzalez-Pernia et al. 2015). As such, it is necessary to reference the most recent literature when examining the relation between UICs and firms' innovation performance. (4) To distinguish the key variables influencing the success of U-I collaboration. In other words, what moderates the relations between collaboration, innovation, and firm performance? We address these research questions by systematically reviewing the most up-to-date literature, discussing the findings, and establishing a theoretical framework that holistically depicts the current knowledge state for the four themes. Although researchers have extensively discussed these four themes, each work has focused on just one of these aspects, which means that the literature lacks a comprehensive understanding of the dynamic process of U-I collaboration. Therefore, the novel contribution of this chapter is to provide a conceptual model that synthesises the fragmented knowledge of U-I collaboration into a single integrated framework. Such a framework not only gives an overview of the state-of-the-art in this research area, it is also enabling a better understanding of the complexity of U-I collaboration.

The remainder of the chapter is organised as follows. The next section introduces the evolving concepts and paradigms in UIC studies; this forms the theoretical background to the reviewed literature. The method that guides our review of literature is introduced in Section 3. In Section 4 we synthesise and discuss the findings in terms of propensity, modes, impacts, and the key success factors of collaboration. The conclusion is presented in Section 5, in which we also discuss the knowledge gaps identified in the reviewed literature and explain how this chapter connects to the rest of the thesis.

2.2 Theoretical Background

The literature regarding the University-Industry collaboration has burgeoned since Etzkowitz and Leydesdorff (2000) highlighted the importance of U-I collaboration in the national innovation system. Previous scholars have investigated the topic of U-I collaboration from different perspectives and with different foci (e.g., drivers, mechanisms, outcomes). Meanwhile, the relevant concepts and paradigms have evolved in both theory and practice. In this section, we briefly introduce the recent shift in the U-I collaboration paradigms, and it is this that forms the theoretical background of our reviewed literature.

2.2.1 Technology Transfer and Knowledge Co-creation

Bozeman (2000) has argued that defining the boundary on 'technology' is difficult, and that the term 'technology transfer' can refer to a variety of study subjects, which differ by discipline and research purpose. In general, technology transfer is a term used to describe the flow of technological knowledge from one organisation to another (Roessner and Wise 1994). In the field of knowledge management studies, the term 'knowledge' is a broad term that includes both tacit and explicit knowledge (Nonaka and Takeuchi 1995b). The technology transfer between U-I is mainly concerned with explicit knowledge, in that it transfers scientific knowledge from industry to university. Nonaka and Takeuchi (1995a) define explicit knowledge as the knowledge that can be codified and transferred formally and systematically (e.g., scientific knowledge). Tacit knowledge, in contrast, is informal, non-verbalizable, and unarticulated (e.g., derived from personal experiences). Because explicit knowledge is more tangible than tacit knowledge, its transfer activities can be achieved through formal contracts such as co-patenting or licensing agreements (Alexander and Martin 2013). In contrast to technology transfer, knowledge transfer also includes activities that transfer an expert's personal experiences and know-how from the university to the firm (de Wit-de Vries et al. 2018). Compared to explicit knowledge transfer, tacit knowledge transfer requires interactions between the partners that are more direct and personal (Daghfous 2004), and the interaction process is often not commercialised (Perkmann and Walsh 2007a). Gopalakrishnan and Santoro (2004) argue that technology transfer in the U-I context refers to a very limited set of activities, and sometimes firms are in fact looking for a direct solution for their technical issues rather than for the radical technology developed by university researchers. Given the differences in knowledge and transfer channels, we define technology transfer in this study as an element of the knowledge transfer activities that take place between universities and firms.

Continuing with this notion of knowledge transfer, it is also important to distinguish the concept of knowledge transfer from that of knowledge co-creation (Powell et al. 1996). In knowledge transfer activities, universities and firms normally specify both their goals and their levels of involvement prior to the collaboration. In contrast, knowledge co-creation activities have a relatively unstructured process in which new knowledge is created during the continued interactions between the parties/actors (Hardy et al. 2003; Ankrah and Al-Tabbaa 2015). The most obvious distinction exists in the orientation of collaboration; transfer activities are often driven by knowledge exploitation whereas co-creation activities represent the knowledge exploration process (March 1991). As argued by Levinthal and March (1993), exploitation activities seek out a commercial use for existing knowledge, and it is the process whereby resources are effectively reallocated among partners/actors. Holsapple and Singh (2001) further add that knowledge transfer between U-I is an exploitation process that involves targeting, producing, and transferring the research output of universities. For example, through the university-owned company Education and Consultancy Service Ltd., the University of Cambridge supports UK manufacturing firms by identifying their technological needs, providing consultancy services, and undertaking contracted research that supports the R&D of its partners. Knowledge exploration within the U-I partnership starts with searching and experimentation, with the eventual aim of co-creating innovation to achieve better performance (March 1991). Joint research, sharing facilities, and co-publication are all common practices in U-I knowledge co-creation.

2.2.2 The Triple Helix model and the Quadruple Helix model

In the Triple Helix model, three core agents are identified: university, government, and industry. Their effective interactions and collaborations facilitate innovation and regional economic prosperity (Etzkowitz and Leydesdorff 1995). For example, universities can sometimes transfer technologies developed in their labs to industries for commercial benefits. The Triple Helix theory expands the function of universities from the promotion of societal education and research to a third mission that supports regional development by producing and disseminating industry-led knowledge across the national innovation system (Etzkowitz 2003). In essence, the Triple Helix model is considered to be an ‘innovation-push’ model, whereby innovation originates within academia and is then developed and utilised by industries (Bercovitz and Feldman 2006). In this model, government fulfils its public function by funding university research and designing the roadmap for regional/national innovation systems through public policies (Lee and Kim 2021).

Carayannis and Campbell (2009) proposed the addition of an extra agent, society-based innovation users, to the Triple Helix model, which they term the Quadruple Helix model. Unlike the Triple Helix model, innovation users are fully integrated into every stage of the innovation process, transferring the ‘innovation push’ of the Triple Helix model to a ‘market-led’ quadruple model that fully captures the evolving trends of U-I collaboration. Furthermore, the Quadruple Helix model proposes that the innovation process is also influenced by the media and not-for-profit organisations, emphasising the social responsibility for innovation. Hence, the traditional triple Helix model has been extended to encourage interactions among all social sectors for the co-creation of new knowledge and innovation (Miller et al. 2018).

2.2.3 Academic commercialisation and engagement

The rational view of U-I collaboration lends support to the commercialisation activities between universities and firms (Ankrah and Al-Tabbaa 2015). According to Transaction Cost theory and Resources Dependency theory, firms are prompted by their limited internal resources and their need to share R&D costs to form strategic alliances with universities (Powell et al. 1996; Tadelis and Williamson 2012). From the university perspective, the commercialisation of university research output demonstrates market acceptance of academic contributions, thus encouraging the formal transfer of technology from universities to industry. The most dominant form of commercialisation is patent licensing provided by universities, which allows academic invention to generate financial rewards (Rothaermel and Alexandre 2009). However, the focus on these formal commercialisation activities has been criticised because it sidelines many other pathways available to a university for exploiting its intellectual property; it also leads to an underestimation of the role of the university in contributing to the regional economy (Breznitz and Feldman 2012b).

Another literature strand endorses a more flexible form of collaboration: academic engagement. Broadly defined as knowledge collaboration between a university and non-academic organizations, academic engagement covers both formal activities (e.g., joint/contracted research) and informal activities (e.g., social networking events, consulting services) (Perkmann et al. 2013). The emphasis on the ‘person to person’ interaction mechanism in academic engagement separates it from commercialisation (Cohen et al. 2002) and diverts the focus away from financial rewards, which are not always the objective of academic engagement. In many cases, academic researchers engage with industries for the benefit of their academic research (e.g., to gain access to data or materials possessed by industries). Notably, it is also argued that academic engagement can sometimes be a catalyst to commercialisation (Perkmann et al. 2013). Working on projects with industrial partners can enlighten researchers about the economic value of their academic insights, which can prompt the introduction and development of follow-up commercialisation activities. For example, the Chinese drone manufacturing company, Dji, originated from a U-I collaboration project aimed at developing drones for agricultural use. Observing the commercial success of the drone, the university developers created Dji and expanded their product line, which has achieved great economic value.

2.3 Research Methodology

The systematic review is used to examine the current state of knowledge in an academic topic (Tranfield et al. 2003). Pioneered by medical studies, the systematic review examines a body of literature on a given research area to identify the consensus and disagreements within that particular topic (Perkmann et al. 2013). The findings of a systematic review not only contribute to academic research but can also identify the implications for relevant stakeholders. Compared to the traditional literature review, the systematic review is more comprehensive and methodological, and the research method is both more transparent and replicable (Siddaway et al. 2019). When the systematic review adopts a statistical approach to synthesise and analyse empirical data from the literature, it is referred to as a meta-analysis (Crowther et al. 2010). In the social sciences, the systematic review has become popular, even though the selection process is followed less strictly than it would be in the natural sciences. Nevertheless, the systematic review is not exempt from limitations. According to Hakala (2011), many systematic review papers exclude book chapters and grey literature from their research scope. Also, the key words used to search literature may not be sufficiently broad for all valuable sources to be identified. Hence, these two limitations may result in important contributions being omitted, despite the suggestion that almost all original scholarly contributions would be first published in academic journals (Pittaway and Cope 2007).

The objective of this systematic review is to draw on recent research contributions to the formation, patterns, outcomes, and success factors of the UIC. As such, this study follows the procedure suggested by Tranfield et al. (2003) for achieving transparency and reliability of research findings; this procedure has guided many systematic review papers in the social sciences (for example, see Ankrah and Al-Tabbaa 2015; Mauricio Sanchez and López Mendoza 2018; Sjöö and Hellström 2019). We started our review by searching for the most recent contributions, i.e., those published between 2009-2019. Our reasoning for this time frame is that the literature relating to university-industry collaboration is abundant, and the research paradigms have changed rapidly over recent years. It is necessary for scholars to keep informed about the latest debates on U-I collaboration. While our timeframe may omit contributions from the older literature, the risks of this will be mitigated by including the recent literature that was developed from the findings of previous studies (Newberg and Dunn 2002; Ankrah 2013a).

We limited our focus to peer-reviewed articles published in English-written academic journals. To fulfil this goal, two distinct electronic databases were used in the search: Science Direct and Web of Science. These two databases were chosen because, as suggested by Al-Tabbaa et al. (2019), most of the good-quality research on U-I collaboration are included in these two databases. In addition to these two databases, we performed a manual search of the important journals in this subject area, such as *Research Policy, Technovation,* and the *Journal of Technology Transfer*; this ensured that our search scope covered all important contributions. Our next step was to search for terms that captured topics related to university-industry collaboration. Three words were used as an umbrella term: University, Industry, and Collaboration, from which Boolean operators were used to develop other similar terms (for the full list of search terms, please see appendix A). For example, one of our search combinations was (universit* OR "higher education") AND (industr* OR firm*) AND (collaborat* OR interact*). The combination of search terms and Boolean operators has been widely used in systematic review articles (see de Wit-de Vries et al. 2018; Mascarenhas et al. 2018; Al-Tabbaa et al. 2019). By searching the title and abstract for all combinations of terms, a total of 553 articles were identified (70 from Science Direct and 483 from Web of Science). After deleting the duplicates, we had 497 papers left for further deliberation.

Our next step was to establish the inclusion and exclusion criteria according to our research scopes and objectives. As stated previously, we regard the university-industry collaboration as a dynamic process that involves the formation, interaction, and impacts of collaboration. We were also interested in examining the factors leading to different innovation and economic performance levels (i.e., the key success factors). Drawing on these four aspects we carefully read the abstracts of all 497 articles to determine whether any one of the four aspects were discussed. When this was the case, the article went through to the next round of analysis. The literature on UIC is abundant but we sought to shed light on firm-level analysis in this thesis, and so we sought out empirical studies that took the perspective of industry. As such, it was essential to draw on literature based on firm-level data rather than macro aggregated data (e.g., country-level statistics). Based on the above considerations, we developed a set of criteria to exclude literature that did not meet our research interest by asking the following questions.

1. Does this study provide empirical analysis to support the main/authors' arguments?
2. Does this study use firm-level data for its empirical analysis?
3. Is the analysis of this study done from the perspective of the firms rather than the university?

After applying the inclusion and exclusion criteria, 97 articles were left for further examination. It is worth noting that, as recommended by Pawson (2006) and Rybnicek and Königsgruber (2018), we retained a wide range of literature for further examination to avoid the risks of omitting important contributions. We then performed an assessment regarding the methodological quality of each articles in terms of its (1) internal validity, (2) descriptive validity, (3) statistical conclusion validity, (4) construct validity, and (5) external validity. An article was excluded if it is less satisfactory in terms of methodological quality. Lastly, as we had read only the abstracts of each article during the inclusion stage, an in-depth analysis of the remaining articles was performed to check if their research questions explicitly related to any of the four research questions of our interests (formation, interaction pattern, outcome, and success factors of UIC). After the screening process was complete, 36 articles were left for our review (see Appendix 3 for the full list of articles).

2.4 Findings and Discussions

In this section we synthesise and discuss the findings drawn from the selected papers. First, we outline the descriptive data from all 36 papers. Second, we organise our findings in line with the three dynamic aspects of university-industry collaboration: collaboration propensity, collaboration modes, and the impacts of collaboration on firms. Finally, the findings regarding the key success factors of U-I collaboration are presented.

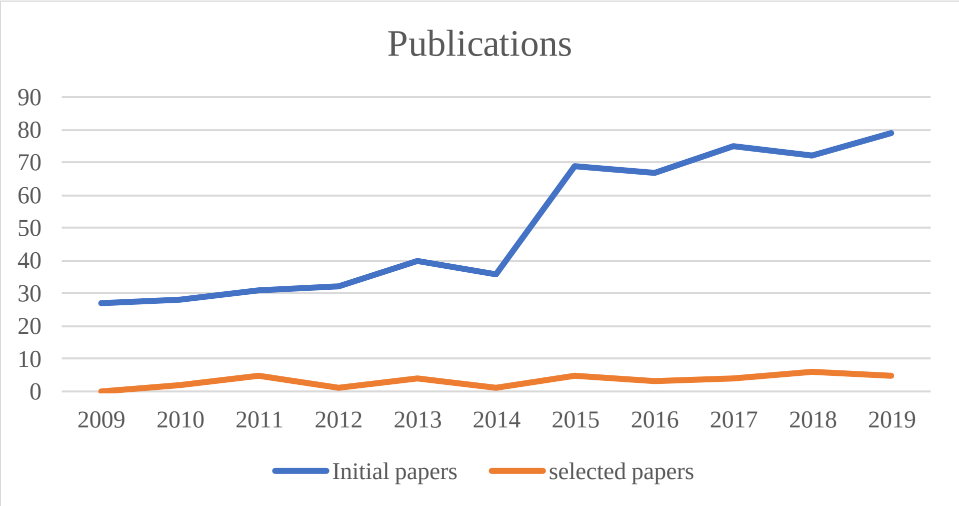
2.4.1 Descriptive data

The analysed 36 papers were published in 17 different peer-reviewed journals. Among these journals, the top five outlets were: (1) Research Policy (5 papers); (2) Technovation (2 papers); (3) Technological Forecasting and Social Change (4 papers); (4) Journal of Business Research (4 papers); and (5) Journal of Technology Transfer (6 papers). The remaining articles came from other important journals such as Regional Studies, Small Business Economics, etc. Comparing the scope of the various journals, we noted that over the past ten years, the topic of university-industry collaboration was a topic of interest for at least three different subject areas (management studies, economics studies, and public policy research).

The investigation into the geographical and sectoral context showed both convergence and divergence. Regarding the geographical context, there were eight selected papers that set their research context in the UK, followed by Spain and Italy (4 papers, respectively). Germany provided the research context for three papers, and China and Mexico each accounted for 2 papers. Notably, the geographical context in some papers was based on a set of countries. There were studies focused on West European countries (Spain, Portugal, and France), East European countries (Czech Republic, Slovakia, and Romania), and North European countries (Netherland and Norway). In contrast, the sectoral context showed a high degree of convergence. Most papers used synthetic data from both the manufacturing and service sectors (25 papers), while four papers focused on the manufacturing sector alone. The research by Hong and Su (2013b), Fiaz (2013), and Belderbos et al. (2016) collected data from firms in high-tech industries, while Maietta (2015a) and Cardamone et al. (2018) focused on the food and beverage industry, which is traditionally regarded as a low-tech industry.

The paper selection showed publication trends over the past ten years (2009-2019). As already noted, the research on UIC has been emerging rapidly over recent years and it is necessary for scholars to keep informed on the latest debates. Although our chosen papers cannot represent all published papers, they still provided useful implications, given the accepted quality of the two source databases (Al-Tabbaa et al. 2019). In general, our sample showed an increasing trend in the publications on university-industry collaborations over these years (Figure 2). Specifically, a rapid growth in publications took place between 2014-2016 (from 36 to 67). The U-I collaboration has attracted more academic attention in the past ten years, which accords with the expectation that universities should play a greater role in the regional innovation system and help firms to create sustainable economic gains (Wang and Shapira 2012; Berbegal-Mirabent et al. 2015; Jones and Corral de Zubielqui 2017).

Figure 2 Publication trends



2.4.2 The determinants for collaboration propensity

Firms can either collaborate vertically (e.g., suppliers, customers) or horizontally (e.g., firms in the same enterprise group, universities) for innovation, and it is necessary to understand the determinants of a firm's choice of different innovation partners (Odei 2018). As argued by Ankrah et al. (2013), the formation of UIC can be examined from the perspectives of industries, universities, and the institutional factors (e.g., public support). In this thesis, we take the firm's perspective and examine how a firm's characteristics and the exogenous factors influence its propensity to collaborate with universities.

2.4.2.1 Firm's characteristics

Our review shows that a firm's **R&D activities** are the main determinant of U-I collaboration (Torres et al. 2011; Fiaz 2013; Fantino et al. 2015; Aiello et al. 2019). Generally, firms conducting R&D and innovation activities are more willing to engage in U-I collaboration since they view universities as an important source of technological knowledge. Firms with higher R&D intensity are more likely to collaborate with universities, as their investment in internal R&D gives them better capacity to absorb external knowledge (Lopez et al. 2015). The positive relation between R&D intensity and the probability of collaboration has also been empirically confirmed by Aiello et al. (2019). Moreover, the technological support provided by university scientists can help firms, especially SMEs, overcome their internal R&D insufficiency, and the costs associated with R&D activities can be shared among partners (Fiaz 2013). Hence, the R&D budget can be optimised for better outputs. Zavale (2018) found that firms engaged in collaboration with universities are mainly driven by the need to obtain short-term production skills for innovation in the manufacturing process (e.g., technological solutions to improve the efficiency in the adoption or use of new machinery), rather than by a search for long-term benefits.

The role of **size** in U-I collaboration has been studied by many scholars (for example, see Tether 2002; Miotti and Sachwald 2003; Mohnen et al. 2003). Our review finds that the effects of firm size on the formation of U-I linkages are diverse and inconclusive. Empirical findings by Aiello et al. (2019) show that size is positively related to engagement with universities, as larger firms can dedicate more resources to establishing and maintaining collaborative links with universities. Lopez et al. (2015) find that firm size is not a significant predictor of U-I collaboration. However, contrary findings have been discovered by Torres et al. (2011) who analyse data from the Mexican manufacturing sector and find a significant negative relationship between size and U-I collaboration. These contradictory findings can be explained by their context; the data of Aiello et al. (2019) were collected from five European developed countries, whereas the research by Torres et al. (2011) is derived from Mexican manufacturing firms. Unlike their European counterparts, large Mexican firms are mostly followers rather than leaders in the technology market. Although they invest in R&D, Mexican firms are more focused on solving technical issues encountered in the manufacturing process rather than on positioning themselves at the technology frontier (Torres et al. 2011). In such a scenario, university knowledge, which is characterised as somewhat radical, is less relevant for large Mexican firms. It has been argued that some European countries (e.g., Bulgaria, Greece, and Romania, among others) are also modest innovators because of their limited technological capabilities, indicating that firms in these regions are more likely to exploit the innovation collaboration with suppliers/competitors/customers than with universities (Parrilli et al. 2020).

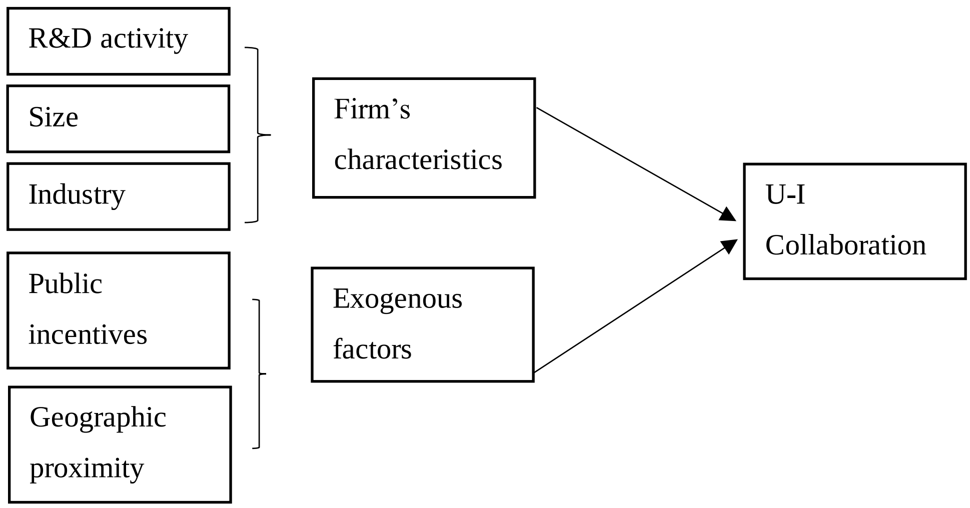
Our sample shows that **industry** is another determinant for the formation of U-I linkage, although industry nuances exist. Traditionally, it has been argued that firms that operate in science-based industries interact more frequently with universities as they are more reliant on scientific progress than other non-scientific firms (Fontana et al. 2006). By collaborating with universities, firms have access to the most advanced technological knowledge, which compensates for deficiencies in their own knowledge base. The empirical analysis by Lopez et al. (2015) shows that industries, in general, do not signicantly affect the collaboration. However, when considering the innovation activities of firms, the authors show that high technology companies pursuing technological innovation are highly motivated to collaborate with universities. Moreover, they argue that the strong relation between science-based firms and universities does not mean that non-science-based firms are less interested in U-I interaction. Low-tech firms that perform both organisational and marketing innovations also tend to be strongly interested in such collaborations. Therefore, a firm's propensity to collaborate with universities can be explained by both the industry and the type of innovation activity. Besides the science-based industries, De Silva and Rossi (2018) find that Knowledge-Intensive Business Service (KIBS, e.g., financial services, insurance, IT and design) firms are also frequently involved in interactions with universities. According to a survey conducted by De Silva and Rossi (2018), 76% of KIBS firms in the UK have collaborated with universities in the past three years (from a sample of 190 companies).

2.4.2.2 Exogenous factors

As defined by Isik et al. (2010), exogenous factors are the variables that are not in the control of organisations but are nevertheless relevant to organisational performance. In this thesis we conclude that **public incentives** and the **geographical proximity** to universities are two key factors influencing a firms' propensity to collaborate with universities. Public incentives, including financial funding, tax reduction, legislation, and policy structuring, have been regarded as an important determinant in the U-I alliance (Guellec et al. 2002). Public funding, which, relatively-speaking, is the most direct and tangible form of support, has played a critical role in regional/national innovation systems (Radosevic et al. 2009). Firms that have received R&D tax allowances and financial subsidies are more interested in collaboration with universities (Aiello et al. 2019). Through the investigation of the case of China, Fiaz (2013) finds that the government's role in promoting R&D is positively correlated with U-I collaboration. By encouraging Chinese firms to collaborate with universities, China is establishing an articulated R&D mechanism for its goal of becoming the 'innovation centre of the world'. However, not all public funding positively affects U-I collaboration. Henry and Odei (2018) examined various sources of public funding and find that funding from central government effectively encourages firms to engage in U-I collaboration, whereas local public funding does not. Firms receiving local funding are more likely to collaborate with other firms located in the same geographical region. This phenomenon can be explained as collaborating with universities requires firms to invest more financial resources, which central public funding is large enough to offer and local authority funding is not. As a consequence, local government tends to provide 'sweetener policies', such as tax reliefs that encourage more firms to engage in regional U-I networks (Henry and Odei 2018).

Geographic proximity is also an important driver in partnership formation. As the interactions in U-I collaborations transfer not only codified knowledge but also tacit knowledge to firms, personal interaction is pivotal in the U-I collaboration (Nonaka and Takeuchi 1995b). However, the literature shows that the spatial effect of collaboration has been largely moderated by the research quality of universities (Laursen et al. 2011; Hewitt-Dundas 2013b; Hong and Su 2013b; Fantino et al. 2015). Specifically, the distance from top universities is the most important determinant of collaboration. The likelihood of collaboration increases if firms are located near elite universities, whereas a shorter spatial distance to a non-elite university does not increase firms' willingness to be involved in U-I interaction (Fantino et al. 2015). Similar findings have been discovered by Hewitt-Dundas (2013b), confirming that firms will cooperate with a local university if that university displays excellent research quality. For example, in Loughborough UK, the local branch of IBM has created a strong connection with the Design School of Loughborough University, leading to various collaboration efforts that include student placements and digital consultancy services. Laursen et al. (2011) discovered a significant but negative relationship between willingness to collaborate and geographic proximity, in that being located near a low-tier university significantly reduces willingness to collaborate. This finding suggests that the mismatch of knowledge leads firms to avoid collaborating with universities when the collaboration outcome is unforeseeable and risky. See Figure 3 for the factors influencing the U-I collaboration propensity.

Figure 3 Factors influencing the collaboration propensity



This review has confirmed previous literature on the role played by the firm's characteristics in U-I collaborations. For example, the positive relation between R&D intensity and U-I collaboration is in line with previous findings (Laursen and Salter 2004; Fontana et al. 2006; Segarra-Blasco and Arauzo-Carod 2008b), suggesting that, for the past decade, universities have been perceived by firms as a ‘technology-transferor’ that can support firms’ innovation projects. Such support can be achieved through joint research, contracted research, licensing, patenting, etc. However, in recent years, U-I collaboration is no longer the sole province of large firms. Our review suggests that more and more SMEs are now striving to reach the technology frontier; thus, sourcing knowledge from universities is becoming a common practice for these companies. Due to the flexible organisational structure and rapid response capability of SMEs, collaborating with universities has incubated many technological enterprises by enabling firms to acquire necessary knowledge. Lastly, our review reveals that industries that depend on intensive knowledge flows are more likely to establish linkages with universities, regardless of the industry’s technical complexity. Although diverse industries bring nuanced findings, the conclusion can be drawn that firms with strong innovation needs (e.g., biotech firms, IT firms) are, in general, more inclined to cooperate with universities due to their greater needs for external knowledge inputs.

The reviewed papers have confirmed previous findings concerning the positive role of exogenous factors in U-I collaboration (Guellec et al. 2002; Mohnen et al. 2003; Fiaz 2013; Henry and Odei 2018; Aiello et al. 2019). To better facilitate the fulfilment of the ‘third mission’ of universities and the U-I linkage, the government is recommended to take a mediating role to support the establishment of U-I partnerships. Although it is argued that the U-I collaboration is often a prerequisite to public R&D subsidies (Czarnitzki et al. 2007), our review suggests that public incentives can also facilitate the formation of U-I collaboration. Since the research by Jaffe (1989), the role of geographical distance in U-I collaboration has been of great interest among academics. Previous literature has indicated that the knowledge spillover effect is stronger when the geographical distance between partners decreases, and weaker when it increases (Anselin et al. 2000; Freel et al. 2002). However, our review of the recent literature suggests that the research quality of universities moderates the geographic constraints of the spillover effects of knowledge. Interestingly, Hong and Su (2013a) suggest that institutional proximity, defined as the subordination to the same administrative unit, is another predictor of U-I collaboration. Given China’s top-down political structure, provincial governments exert a high degree of political influence over their local universities and enterprises. As such, collaborations between local enterprise and universities are likely to be formed by the will of regional governments to boost local economy.

2.4.3 The Collaboration modes

Previous literature has indicated that the interactions between universities and industries do not follow a single pattern; instead, the interaction mechanism is rather complex (Thune 2007). In fact, knowledge transfer activities show a high degree of diversity according to their specific contexts. Bruneel et al. (2010b) conclude that channels and mechanisms differ in their capacity to transfer tacit and codified knowledge. Despite this, as Ankrah and Al-Tabbaa (2015) suggest, our understanding of the interaction ties between university and industry remains limited and fragmented. In this thesis, we attempt to gain an understanding of U-I interactions by investigating the recent theoretical developments on the modes of collaboration (Bruneel et al. 2010a; Freitas et al. 2013a; Fernandez-Esquinas et al. 2016), with special focus on the drivers for engaging in the different modes and the diverse outcomes associated with them.

2.4.3.1 The modes of interaction

Firms collaborate with universities through different channels (e.g., joint research, hiring graduates, informal contacts with university researchers), and researchers define these U-I collaboration modes as a group of channels with similar attributes (Fernandez-Esquinas et al. 2016). Our review of the recent literature shows a flourishing strand that studies the modes of collaboration (see Appendix C for the modes and relevant channels proposed by the literature). Aiming at measuring U-I collaboration in regional innovation systems, Ramos-Vielba et al. (2010) identify four U-I interaction channels: (1) R&D and formal consulting activities, (2) training and transfer of personnel, (3) commercialisation of intellectual property, and (4) other activities (e.g., informal relationship/non-academic knowledge diffusion). Their empirical data indicate that of these four collaboration modes, R&D activities and formal technical consulting services are frequently used by firms in Spain. Similarly, Goel et al. (2017) find that among all collaboration channels, technological consulting activities are the most prevalent in the US. In contrast, research by Zavale (2018) suggests that companies in the African context are more frequently involved in informal ties with universities, and that these ties are characterised by individual-based engagement and the informal exchange of ideas. Differences in the prevalence of the channels can be attributed to the different levels of universities' technological capabilities as well as to the absorptive capacity of firms. Compared to Spain and the United States, African universities possess less of the cutting-edge technology necessary for innovation in industries. Furthermore, firms in Africa may have limited resources for U-I collaboration, especially in terms of R&D personnel. Therefore, establishing collaboration via formal commercial channels is less of a common practice for companies.

Looking beyond the formal/informal modes of U-I collaboration, Bodas Freitas et al. (2013a) studied two interaction modes in Italy, termed institutional modes and personal contractual modes. In the former mode, interactions are mediated by the administrative structure (e.g., transfer offices or relevant departments), whereas collaboration in the personal contractual mode requires a direct link between the individual academic and the firm. This study emphasised the relevance of direct personal contractual collaborations between academics and firms, especially when they are located within the same geographical region. Compared with institutional collaboration, local network links can significantly reduce the transaction cost of a formal contract-based collaboration with individual researchers. In a more comprehensive piece of research, Fernandez-Esquinas et al. (2016) traced the flow of U-I knowledge transfer in Spain, defining U-I collaboration modes as the generation and adaptation of knowledge, training and exchange of human resources, creation of new organisations, intellectual property transactions, and the use of university facilities. All five types of collaboration are in line with the theory of 'knowledge exploration' and 'knowledge exploitation' (March 1991), with the first two focused on discovering useful external knowledge (exploration) and the other three aimed at exploiting external knowledge/resources that are directly beneficial to firms (exploitation). Similar to Zavale (2018) and Freitas et al. (2013a), the study by Fernandez-Esquinas et al. (2016) also gives credit to the importance of informal explorative collaboration activities, as they find that almost 32% of the firms were engaged in this type of interaction, making it the most frequently used channel by their survey samples.

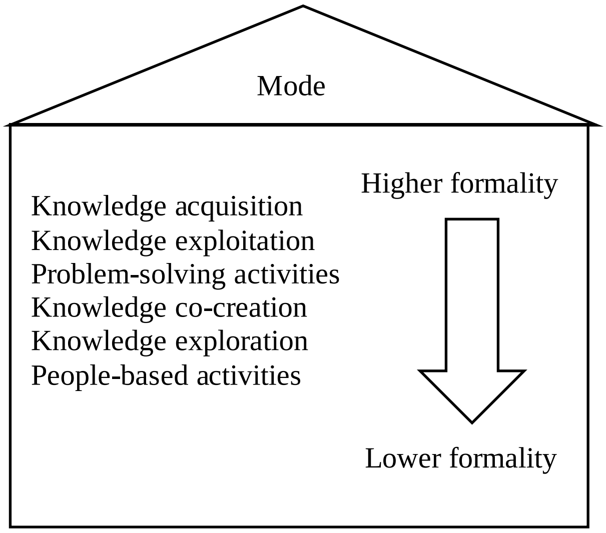
2.4.3.2 Determinants and outcomes of specific modes

Beside the factors influencing the propensity to collaborate, we are also interested in the determinants for engaging in the different collaboration modes. First, as discovered by Goel et al. (2017), joint research, contract research, technology consulting, and licensing are typically initiated by university scientists, whereas employees of a firm are instrumental only in initiating informal contacts. Compared with small firms, large firms are more likely to instigate formal relations with university partners because they normally possess a sufficiently high level of absorptive capacity. Proxied by internal R&D investments, larger firms that possess higher absorptive capacity tend to collaborate through signing formal contracts with universities' technology-transfer offices (TTOs). Small firms that adopt an open innovation strategy are more likely to cooperate with individual researchers on a contractual basis (Freitas et al. 2013b). The positive correlation between size and formality of interaction was also confirmed by Fernandez-Esquinas et al. (2016), as larger firms normally prefer a stable relationship with universities. Such a stable relationship can be achieved by contract-based collaboration, such as through contracted research, patent sales, or the creation of a joint research organisation/project. In contrast, smaller firms with lower absorptive capacity prefer to establish more flexible collaborations. such as through informal contacts, seminars, and joint trips.

Relational capability, which refers to the ability to share knowledge and information in an open and articulate manner, is another determinant of collaboration (De Silva and Rossi 2018). The authors classify relational capability as communication capability, alignment capability, and the capability of devising upfront contractual agreement (structuring capability). By classifying a firm's learning behaviour as knowledge acquisition and knowledge co-creation, they found that the communication capability of firms has a positive influence on both knowledge acquisition and knowledge co-creation. However, this effect is stronger in acquisition activities than in co-creation activities, as the latter are more influenced by the alignment capability of firms (i.e., the ability to adjust norms, routines, and goals). The emphasis placed on the relational capability of firms in U-I collaborations is supported by previous literature (Poppo and Zenger 2002; Zollo et al. 2002) that suggests the capability of firms to manage relationships with universities is essential to knowledge sourcing activities, while the ability to adjust firm's norms and goals is more important when co-creating knowledge with universities.

Prior literature has provided abundant evidence that U-I collaboration is positively associated with an increase in the innovativeness of firms (Etzkowitz 2003; Belderbos et al. 2004; Cassiman et al. 2008), but it is unclear whether differences exist among the various collaboration modes. Recent literature has found that people-based activities (e.g., training programmes/conferences/lectures) have no effect on firm's innovation, whereas problem-solving activities (e.g., joint research/contract research/technology consulting) have a positive effect (Moon et al. 2019). In contrast, Jones and Corral de Zubielqui (2017) find that transfer activities by human resources (i.e., recruitment, training programmes, and cooperation in lecture delivery), have a significant positive effect on firm innovation. Belderbos et al. (2016) studied the direct links and mediated links (collaboration with universities through a third party) and conclude that for firms with higher absorptive capacity, direct links with universities have a stronger influence on innovation performance than indirect links. Vice versa, firms with lower scientific/absorptive capacity may need the assistance of a third party in managing the collaboration with universities, the external agents acting as an information-processing device in such collaborations.

Figure 4 Collaboration modes

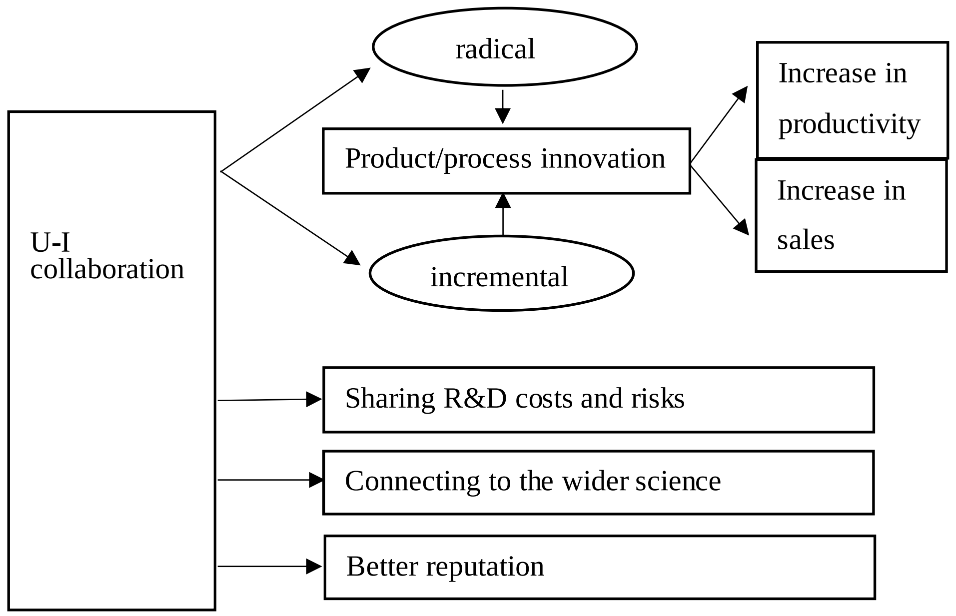


As can be seen from the above figure 4, the modes of collaboration change with the level of formality. Formal collaboration involves channels such as contract research, joint research, patenting, licensing, co-creating organisations, etc. Larger firms have more resources (e.g., financial resources, management skills, and qualified personnel) with which they can establish a formal collaboration with universities and exploit the acquired external knowledge for their innovation activities. To ensure the success of this exploitation process, a higher level of internal absorptive capacity is necessary. Conversely, SMEs have difficulty collaborating in a formal manner due to their lack of resources and absorptive capacity. Where this is the case, informal contacts and interactions with university researchers can help SMEs to acquire external knowledge at a lower cost. Moreover, as suggested by Garcia-Perez-de-Lema et al. (2017), the knowledge transferred through these informal contacts is less codified than that obtained through formal channels, therefore it is easier for this knowledge to be exploited by SMEs in their innovation activities. In general, our review confirms that size and absorptive capacity are positively related to the formality of collaboration modes. Although the relational capability of the firm matters to U-I collaboration in all modes of interaction, it is particularly relevant to an informal collaboration.

2.4.4 The impact of collaboration on innovation and performance

Collaboration with partners can have a profound impact on firms. For example, collaboration with customers can avoid the failures often associated with the introduction of new products to the market (Mansury and Love 2008). When creating radical innovations, firms collaborate with their competitors for constructive intelligence and inspiration (Storer and Hyland 2009). Collaboration with suppliers helps firms to reduce production costs and refine their production systems (Takeishi 2001). Belderbos et al. (2004) and Macpherson et al. (2005) indicate that university-firm collaboration increases the productivity and market growth of firms. There is also substantial evidence that confirms the positive role of universities in collaborations focusing on the innovation output of firms (Motohashi 2005; D'Este and Patel 2007a; Bekkers and Bodas Freitas 2008; Giuliani and Arza 2009; Perkmann et al. 2011). We examined the recent literature that has addressed the topic of how, and to what degree, U-I collaboration benefits the innovation and performance of firms. The impacts of collaboration on firms were summarised in figure 5.

Figure 5 The impacts of collaboration



2.4.4.1 Impacts on the innovativeness of firms

There is a plethora of literature suggesting that U-I collaboration can improve the radicalness of product innovation (Laursen and Salter 2004; Kopel and Löffler 2008). Radical innovations can bring more market opportunities to firms and give a product a relatively longer life cycle; consequently, new-to-market (NTM) product innovation is the pursuit of many firms (Kopel and Löffler 2008). The research by Hewitt-Dundas et al. (2019b) provides empirical evidence that collaboration with universities has a significant positive impact on the NTM innovation of firms and can give firms first-mover advantage in the marketplace. However, it is not always easy to develop NTM innovation because the R&D process is unpredictable and requires cross-functional teamwork and significant financial investment

(Keizer and Halman 2007). Taking the manufacturing and service sectors as a whole, Gonzalez-Pernia et al. (2015) find that collaborating only with universities has no impact on product innovation, but when firms simultaneously cooperate with universities and STI (science and technology innovation) partners, such as consultants and private labs, the likelihood of the firm introducing a product innovation is significantly increased.

Unlike radical innovation, incremental innovation can occur by simply improving the efficiency of the manufacturing process or by refining management practices. From this perspective, it is possible for universities to contribute to incremental improvements in the production process and/or in existing products (Tang et al. 2019). Using data from a large sample of 2,061 German firms (German Community Innovation Survey), Kobarg et al. (2018) empirically confirm that U-I collaboration is positively related to both radical innovation and incremental innovation performance. Maietta (2015a) confirms the existence of a positive collaboration for innovation relations in low-tech industries. Specifically, she finds that informal contacts and direct interactions with local universities (within 150km) are beneficial to incremental innovation in the food and drinks sector in Italy, whereas formal R&D collaboration with universities has a weak effect on radical innovation. This could be attributed to the fact that low-tech sectors such as the food and drinks industry normally use technologies that are developed by other industries (e.g., chemical or biotech companies). Instead of pursuing radical technological advancements, firms in low-tech industries mainly seek out knowledge that can help them to improve their production efficiency and product quality.

2.4.4.2 Impacts on the performance of firms

As shown in Figure 5, collaborating with universities directly improves the R&D capacity of firms. Industrial leaders and R&D managers share their development projects with university researchers and seek out technology collaboration that will enable them to refine their product design and production efficiency. Cutting-edge technology gains can be obtained through assistance from university researchers (Fiaz 2013). In addition, scholars have argued that collaboration is a popular way of sharing R&D costs and risks among partners (Wang and Shapira 2012; Guzzini and Iacobucci 2017; Jones and Corral de Zubielqui 2017). However, promoting R&D capacity and controlling for R&D costs are not the only objectives of collaboration. As Wang and Shapira (2012) suggest, some of the intangible assets possessed by a university can be beneficial for industry. For example, by establishing trustful relationships with university scientists, firms join a wider scientific community and create more opportunities for collaborations. This networking is aligned with the social capital theory proposed by

Portes (1998), which states that the spillover effects can go beyond the traditional view of knowledge diffusion as such networking also connects firms to the social capital of universities (Audretsch and Keilbach 2007). Social capital refers to the resources embedded in the social networks, and the firms who collaborate with universities can get access to the intangible resources held by universities, such as prestigious reputation, alumni network, etc. (Chakrabarti and Santoro 2004). If the collaborative university is prestigious, a 'halo effect' can provide greater opportunities for firms in terms of attracting talent, marketing themselves to customers, and applying for/obtaining public funding.

Whether collaboration with universities does in fact contribute to better financial performance for firms has long been a source of controversy in scholarly debates (Belderbos et al. 2004; Bekkers and Bodas Freitas 2008; Fiaz 2013; Guzzini and Iacobucci 2017; Jones and Corral de Zubielqui 2017). Our review suggests that collaboration with universities does not exert more effect on economic performance than when the collaboration is with other firms (Guzzini and Iacobucci 2017). However, once the mediating effect of innovation outputs is taken into account, U-I collaboration seems to have a positive effect on economic performance. For example, through collaboration with universities, firms may be able to produce more innovative new-to-market products. These give firms a temporary monopolistic advantage that creates considerable economic returns. Jones and Corral de Zubielqui (2017) employed a structural equation model using Australian firm-level data and found that U-I collaboration indirectly leads to better performance of firms. For example, when firms recruit new graduates and provide employees with further training and education, more innovation outcomes are produced. Those innovation outcomes, in turn, lead to an increase in the productivity and sales growth of firms. Similar mediating effects between collaboration, innovation, and performance were also discovered by Garcia-Perez-de-Lema et al. (2017), who suggest that the innovation produced through U-I collaboration could improve the financial performance of firms, and eventually contribute to the macroeconomic growth of a country.

2.4.5 The key success factors for U-I collaboration

Prior literature has investigated the factors that make some partnerships more successful than others (for example, see Parker and Systems 2000; Hoffmann and Schlosser 2001; Kim et al. 2003; Sherer 2003; Blindenbach-Driessen and Van Den Ende 2006). Collaboration between universities and firms can be complicated and problematic because it is normally associated with the 'two-worlds paradox', in which universities and industries have different institutional logics and priorities (Hall 2003). For example, the ultimate goal of industrial R&D is to make profits through innovations, whereas the traditional purpose of university research is to expand the boundaries of current knowledge. To achieve better innovation performance, the U-I collaboration must overcome the barriers caused by these institutional differences (Hewitt-Dundas et al. 2019b). Given the heterogeneity in industries and firms, it is necessary to investigate the success factors that lead to superior U-I collaboration outcomes. To that end, we identify and extract the following key factors from our selected literature: experience, trust, absorptive capacity, and university-related factors (including university quality, technological relatedness, etc.).

Experience plays an important role in U-I collaboration. Although academics are nowadays assessed on their capability to influence business and policy frameworks, publication remains the main pathway to academic success. Firms, in contrast, prioritise economic returns in their operations. A successful U-I collaboration requires firms to establish organisational routines and practices that can cope with any potential issues raised by the clash of different institutional norms and routines. Once established, these practices can guide the subsequent collaborative projects. For example, institutional experiences and routines can help firms with negotiating IP disputes and developing future collaborative agreements (Hertzfeld et al. 2006). Hence, firms' learning behaviour from prior collaborations contributes to better management of the collaboration hazards (e.g., administration bureaucracy, conflicts over IP, different organisational culture) (Bruneel et al. 2010a).

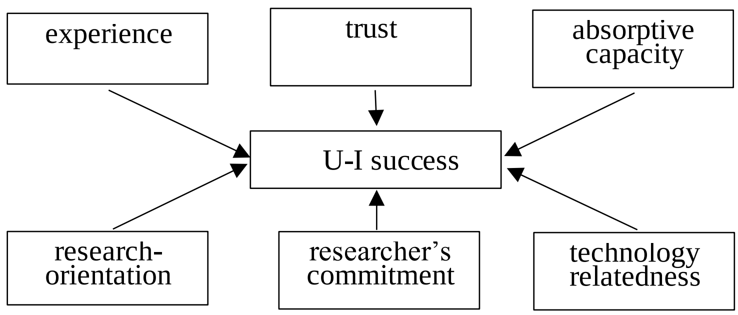
While admitting the relevance of prior collaborations, Hewitt-Dundas et al. (2019b) note that successful U-I performance also depends on firms' experiences from previous innovation activities. Where firms have already conducted R&D activities for radical innovation, they are more likely to have a better awareness of the deficiencies in their internal R&D capacity, as well as of the knowledge needed to compensate for these deficiencies. From this perspective, previous innovation experience enables firms to establish collaborative agreements with clear aims and objectives that maximise the payoffs from the U-I partnership. For international U-I partnerships, Taheri and van Geenhuizen (2019) validate the relevance of the working experiences of the management team, finding that experience accumulated from sales and marketing activities is essential for transforming the cross-cultural collaboration/innovation output into competitive products for the domestic marketplace.

Trust is essential in collaborations as it demonstrates openness to communicating with partners (Hsin-Mei 2006). Trust is based on the expectations of the positive/proactive/collaborative behaviour of another party in any situation (Rousseau et al. 1998). U-I collaborations face a high degree of uncertainty and information asymmetry that can severely hamper business performance. In U-I collaboration, the sharing of commercial secrets and information among partners is often unavoidable , thus a lower level of trust may slow or impede progress and create higher transaction costs (Santoro and Saparito 2003).

Acknowledging the importance of trust, we examined the recent literature to investigate how trust is formed between universities and industries. Bstieler et al. (2017) indicate that reciprocal communication is strongly associated with mutual trust in the U-I partnership. However, the level of trust is not static during the course of the relationship; communication is less important as the relationship grows from the early stage to an intermediate stage, becoming essential again when the relationship moves into the mature stage. Mutual trust can be achieved by constantly evaluating and adjusting behaviours so that these align with the expectations of partners (Bruneel et al. 2010a). Therefore, U-I trust is built on a moving foundation, and the communication strategy must adapt to the different stages of the relationship. University researchers also need to stay in constant communication with industries to keep track of the needs of firms (Hanid et al. 2019). Trust can be developed from prior ties with partners, as repeated collaborations can establish a solid interpersonal relationship among partners that gives each a greater understanding of the other’s advantages and needs (Petruzzelli 2011a). In this sense, the existence of a high level of mutual trust can explain the path-dependent behaviour in the partner-seeking process.

Absorptive capacity, defined as the firm’s ability to recognise, assimilate, and apply external knowledge, is believed to facilitate the collaboration performance of firms (Cohen and Levinthal 1990; Zahra and George 2002). As argued by Moon et al. (2019), mere exploration and exploitation of the knowledge derived from a university cannot guarantee the innovation outcomes of firms, as firms may lack the ability to process this external knowledge. Therefore, firms should also focus on improving their internal learning capability to recognise and exploit the knowledge acquired from external partners. As such, absorptive capacity (AC) represents the firm’s internal learning capability that leads to the effective use of university knowledge. For firms with a low level of AC, collaboration does not translate into any obvious benefit, whereas it significantly increases the innovativeness of firms that possess a higher level of absorptive capacity (Biedenbach et al. 2018). In addition, higher levels of absorptive capacity also positively influence the financial performance of firms by accelerating the transfer speed of external knowledge, enabling firms to introduce new products into the market more quickly (Rothaermel and Alexandre 2009).

Figure 6 The success factors

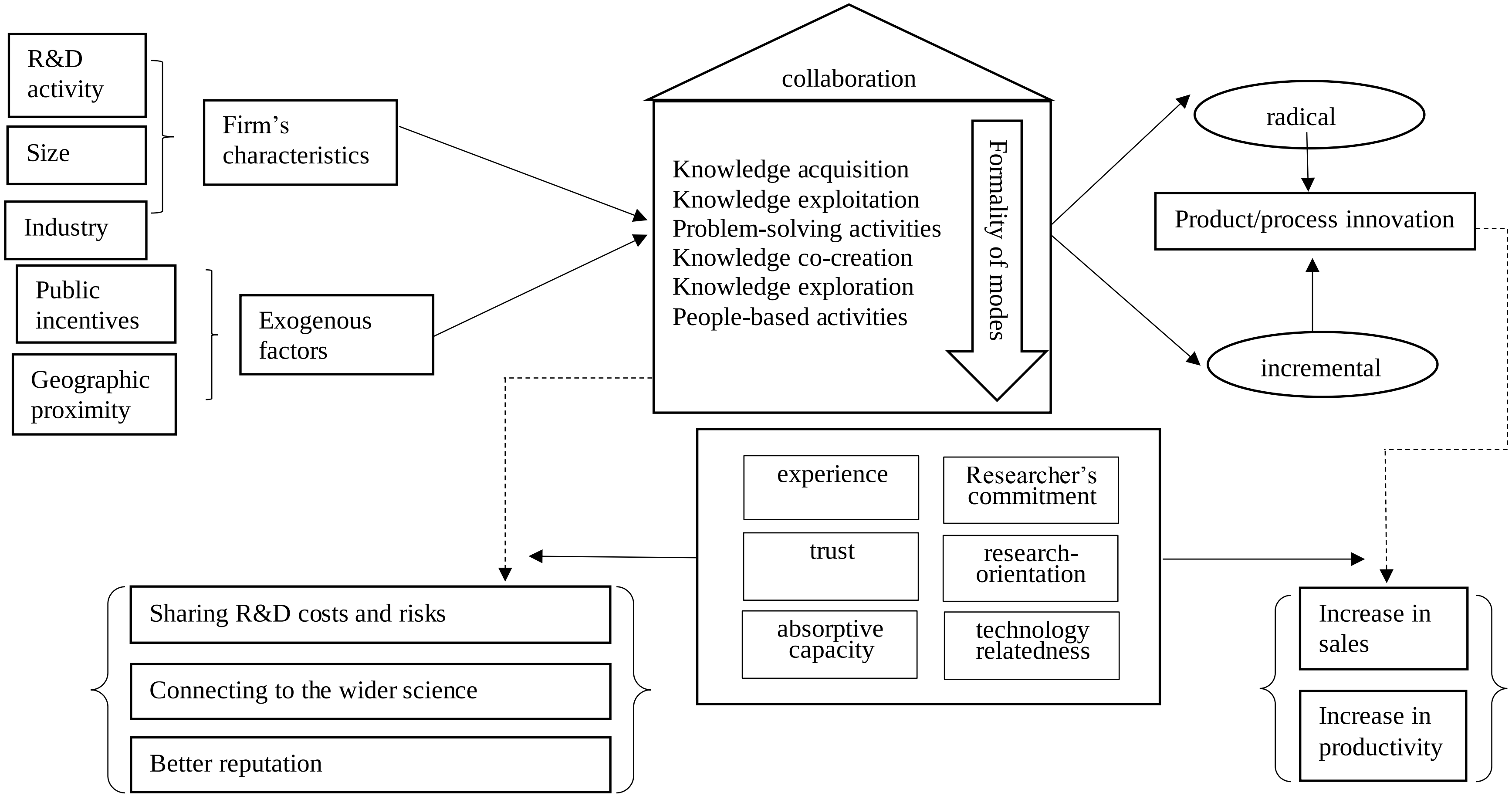


Turning to university-related factors, we identify three factors that may affect the success of a U-I collaboration: the university research-orientation, researcher's level of commitment, and the technology relatedness of universities. Specifically, (1) the **research-orientation** of the university is crucial in U-I collaborations. Applied research is often more relevant than basic research to the creation of commercial value. Therefore, as argued by Berbegal-Mirabent et al. (2015), collaborating with a university that has a stronger focus on applied research (e.g., a polytechnic university) tends to increase the payoffs of a U-I partnership; (2) **researcher's commitment** is vital because it ensures the continuity of the university's support (Hanid et al. 2019). Some collaboration practices can last a long time (e.g., joint research), and these activities may take a while to yield the desired outcomes. As such, researchers involved in such collaborations must fully commit to the collaboration, making continual efforts to reach the desired goals of collaboration; (3) **technology relatedness** refers to the shared knowledge base and technological experiences, and it has been argued to have a complex effect on the collaboration (Petruzzelli 2011a). A high level of technology relatedness is crucial in the matching phase of U-I collaboration, as it brings together partners with similar knowledge bases. However, the development of industrial innovation sometimes requires various types of knowledge and complementary competencies, and a single partner may be unable to provide all of these. Therefore, successful industry innovation requires firms to collaborate with multiple partners, and each partner should be able to contribute one specific component of the innovation process. For example, Coventry University supports the product innovation of the car maker, Jaguar Land Rover, by providing quality testing in their university lab. Meanwhile, the development of electronic control systems was undertaken by the University of Warwick. A brief summary of the success factors is provided in figure 6. Although the above factors cannot be generalised to all types of U-I collaboration, they provide useful implications for scholars and managers wishing to achieve innovation in U-I partnership.

2.5 Conclusion

As the benefits of U-I partnerships have been increasingly recognised, the literature that discusses the different perspectives of U-I collaboration has grown over past decades. However, as Ankrah and Al-Tabbaa (2015, p.388) have indicated, understanding in this area remain fragmented, as '*most studies focused on only one or two aspects of U-I collaboration*' (e.g., antecedents, channels, outputs). This paper critically integrates the key aspects of U-I collaboration into a comprehensive framework (Figure 7), thus providing a more comprehensive theoretical understanding in terms of the drivers, interaction modes, and impact of the U-I partnership, as well as the key success factors that provide managerial implications for businesses and policy-makers. By systematically selecting and reviewing relevant papers published during 2009-2019, we identified the following theoretical gaps that are relevant to our research.

Figure 7 The theoretical framework of U-I collaboration



In our review, four major research gaps were identified. First, the recent literature suggests that U-I partnerships are driven by firms' internal factors and exogenous factors. R&D activity, size, and the industry sector of firms are all important determinants for the formation of a collaboration. However, our review also shows that the role of exogenous factors requires further exploration. For example, Jaffe (1980) argued that close proximity to universities increases the possibility of U-I collaboration, as the knowledge spillover effect of universities attracts firms to establish partnerships with them. We found evidence in our reviewed papers that the research quality of universities impacts on firms' propensity to collaborate with universities (Laursen et al. 2011; Hewitt-Dundas 2012; Fantino et al. 2015). When firms are close to a university with excellent research quality, they are interested in collaborating because it enables them to interact frequently with outstanding researchers. In contrast, being close to a lower-tier university does not increase (Hewitt-Dundas 2013a), and may even reduce (Laursen et al. 2011) the likelihood of collaboration as firms do not expect such universities to contribute to the development of radical product innovations.

However, these arguments could be problematic as they investigate only the roles played by proximity and research quality in the introduction of radical innovations. Although lower-tier regional universities may not be able to assist firms who are striving to introduce products that are new-to-market, they may be able to provide the knowledge and expertise that can help local firms incrementally refine their current manufacturing method (process innovation) and organisational practice (management innovation). As argued by Hall and Andriani (2003), the knowledge required for radical product innovation often originates from long-term basic research, whereas the knowledge required for incremental process and management innovation is rather more tacit in nature and is often practice-based. As such, it is worth investigating whether and how lower-ranked regional universities can provide relevant knowledge to support the technological and management innovations of their local firms.

Second, the studies of U-I collaboration channels lack a clear and comprehensive classification. For example, Fernandez-Esquinas et al. (2016) take 'training and exchange of human resources' as a knowledge exploration behaviour even though the purpose of sending employees on vocational training programmes is to absorb and exploit the knowledge held by universities rather than to co-create knowledge with university researchers. Due to the ambiguities in channel classification, the current literature provides little understanding of the determinants and impacts associated with different collaboration modes. The U-I collaboration modes differ in their capacity to transfer tacit and codified knowledge (Bruneel et al. 2010b). These different kinds of knowledge channels will, respectively, deliver different resources and outcomes to firms. Recent literature has started to pay attention to the formality of interaction modes (Fernandez-Esquinas et al. 2016; Zavale 2018) and it would be interesting to continue with this line of research and establish a typology based on the formality of collaboration modes. This would enable an examination of how different types of knowledge can be delivered through different types of formal collaboration.

Third, the impact of collaboration on firm's innovation outcomes is unclear. While there are abundant contributions that confirm the positive role of U-I collaboration on the radicalness of innovation, the literature that investigates the impact on incremental and non-technological innovations is scanty. As the current literature is mostly focused on product innovation, it is necessary to further expand the measurement of innovation so as to explore the relationship between U-I partnership and incremental innovation in the manufacturing process and in management practices. By so doing, the mediating impact of innovation output on firm's performance can be better examined, given that process innovation and management innovation are proposed to be positively related to the financial performance of firms (Ivanov and Avasilcăi 2014; Ryu 2016; Lee et al. 2019).

Lastly, methodological issues identified in our review provide useful implications for further research. Specifically, we found that most of the research relies on large-scale secondary data (for example, see Lopez et al. 2015; Goel et al. 2017; Henry and Odei 2018; Aiello et al. 2019), thus making it difficult to provide insights into the complexity of the U-I collaboration and its impact on firms. Some secondary data sources (e.g., the Community Innovation Survey) were not designed specifically for the purpose of the U-I partnership study, therefore researchers have to use proxy variables to reflect their study constructs. For instance, due to the limitation of data, researchers use R&D intensity to represent the firm's absorptive capacity. However, absorptive capacity is a dynamic process involving knowledge acquisition, assimilation, transformation, and exploitation (Zahra and George 2002), and R&D intensity can only represent the inputs for innovation activities. Given the disadvantages of secondary data, we recommend that future research conducts a survey that gathers data specific to the research purpose.

This chapter also has implications for managers and policy-makers. For managers, it is important to establish trust when working with university partners. Mutual trust comes from reciprocal communication, but the communication strategy must be adapted as the relationship moves through its different stages to avoid 'information chaos' (Bstieler et al. 2017). In addition, initiating a collaboration with previous partners is a less risky method as both parties are familiar with the demands and advantages of their partner. Repeated collaborations create solid personal relationships among the partners, which further increases the trust level in the partnership. In addition, for firms with higher absorptive capacity, the internal managerial process needs to be simplified when collaborating with universities. Higher absorptive capacity gives firms more potential for introducing radical innovations; however, a complex and bureaucratic internal management process can impede the innovation outcomes developed from U-I partnerships.

Further, as regional funding has a very limited effect on encouraging the formation of local U-I partnership, it would be helpful if the local authority could either increase the size of funding or introduce ‘sweetener policies’, such as tax relief, to stimulate the formation of the regional innovation system. It has been argued that advances in communication technology have diminished the importance of geographical proximity, thus the formation of regional innovation clusters is largely conditioned by the institutional environment (Torre 2008). When financial funding is limited, tax incentives (e.g., tax abatements, temporary or permanent tax exemptions) introduced by local government can tempt innovation actors to set up within certain regions and collaborate with each other.

Through this systematic review, we are able to develop a comprehensive framework that incorporates the formation, patterns, outcomes, and the key success factors of UIC. Meanwhile, knowledge gaps identified in our review lay the foundation for the empirical chapters in this thesis. Specifically, our review establishes the key role played by formality in shaping the collaboration patterns of UIC, and this informs our discussion of contractual collaboration (Chapter 4) and relational collaboration (Chapter 5). Inconsistent findings from previous studies on the impacts of UIC further guide our empirical investigation in Chapter 4 and Chapter 5, in which new evidence can be added for how UIC contributes to the innovation and economic performance of firms. Moreover, the review on the role of proximity, size, and industry has enlightened our investigation into how such factors moderate the performance of UIC in China. Lastly, as this review has found that the use of secondary data for UIC studies leads to methodological issues, our empirical investigation of UIC relies on primary survey data, enabling the reliability and generalisability of research findings to be increased.

Chapter 3 Innovation Systems and the Institutional Environment: The Chinese Context

3.1 Introduction

Recent decades have witnessed the economic success of the People's Republic of China. The economic reform initiated by the former communist party leader Deng Xiaoping in 1978 has brought China onto a fast track of economic development, with 9.5% average growth rate in the gross domestic product (GDP) during the past 40 years (World Bank 2020c). According to data from the World Bank (2020d), in 2019 China was the second-largest economy in the world with USD 14.34 trillion GDP. This compares to the United States' 21.42 trillion (making it the world's largest economy, and Japan's third ranking 5.08 trillion). Today, China is the world's biggest manufacturer and largest source of imports; its thriving manufacturing sector plays an important role in the country's economic structure. In 2019, the value of the Chinese manufacturing sector was 27.17% of GDP, compared to the U.S.'s 11% (World Bank 2020c). Due to its population size, GDP per capita in China was ranked only 79th in the world (11,428 USD), but it nevertheless managed to lift more than 850 million people out of poverty (World Bank 2020e). The recent data also demonstrates the resilience of the Chinese economy. While the economic shock caused by the unprecedented Covid-19 pandemic has badly hit the rest of the world, China, where the outbreak first started, has continued with its economic recovery, experiencing a growth rate of 4.9% growth rate in the third quarter of 2020, making it the only major economy in the world to have seen positive growth during that period (NBS 2020b).

However, the sustainability of the so-called 'China miracle' has been questioned by economists and observers around the world, and China is now at the crossroads of its economic development (Dollar et al. 2020). Looking into the specific drivers of its rapid economic growth, many researchers have used different perspectives to explain China's success story. For example, Lin et al. (2003) indicate that it is the full exploitation of the comparative advantage of labour costs that has enabled China to become a 'world factory', and they note that China has accumulated a large number of foreign exchange reserves. Tracing the financial developments in China from 1970 to 2013, Kandil et al. (2017) find that stable inflation rates and the fast-developing capital market have together contributed greatly to the prosperity of the Chinese economy. Madariaga and Poncet (2007), in an investigation into the impact of foreign direct investment (FDI) on the transition economies, argue that China, as the largest FDI recipient in the world, has not only benefited from local FDI inflows (i.e., FDI into a specific region) but that many Chinese cities have been able to take advantage of the FDI spillover effect from their adjacent cities. No matter what the research perspective may be, there is an apparent consensus that the transition from a centrally-planned to a free market economy has combined with favourable demographics to contribute most to China's current 'economic giant' status (Wei et al. 2017; Dollar et al. 2020). Market-oriented policies have been central to Chinese economic reform, encouraging the price of outputs to be determined by the market mechanism rather than by administrative orders (Lei et al. 2019). These policies have maximised the demographic dividends and created a relatively free market with the world's largest population and lower labour costs.

Nevertheless, this highly effective model of 'economic miracle' creation has been gradually losing its magic, leaving the Chinese economy at a crossroads. The real GDP growth rate in China has started to decline, from 14.2% in 2007 to 6.1% in 2019, which is the lowest in nearly thirty years (World Bank 2020c). Although the communist party leaders describe this slow growth as the 'new normal', it suggests that economic challenges are increasing, both externally and internally. From the perspective of the external environment, the global financial crisis in 2007 led to a sharp decrease in the net FDI inflows to China (from 4.40% in 2007 to 1.08% in 2019) and shrinking international demand has caused exports to decrease from 35.43% to 18.41% of GDP (World Bank 2020b). Also, the ongoing trade war between the U.S and China, characterised by increased tariffs and trade bans, further reduced China's GDP by 1.41% in 2019, and this has caused economists to form a grim assessment of the country's future economic growth (Itakura 2020; Li et al. 2020a). Internally, economists have suggested that the demographic dividends in China are bound to disappear permanently (Cai 2020; Taketoshi 2020). For example, the one-child policy in China has seen the fertility rate fall from 5.8 in 1964 to 1.69 in 2019 (World Bank 2020a), which will inevitably impact negatively on labour supply. Meanwhile, China's increased labour costs are reconstructing the global value chains, as an increased number of manufacturing firms are transferring from mainland China to India and other ASEAN countries, such as Indonesia and the Philippines (Yan and Min 2020). In conclusion, structural changes indicate that China's previous growth, driven by low labour wages and low-end manufacturing/ exports, has largely reached its limit, and a new path to sustainable economic growth must be identified and followed in the decades to come. China is faced with having to find a way of avoiding the so-called 'middle-income trap', in which a country quickly moves from a low-income level to a middle-income level, where it stagnates (Felipe et al. 2012).

Different approaches can be applied to avoid the middle-income trap and to achieve sustainable growth. One approach is to introduce more structural reforms (Wei et al. 2017). According to institutional economists, institutions are the factor that is most critical to driving sustainable economic growth (Daron and Robinson 2012; Jakšić and Jakšić 2018; García-Pérez et al. 2020). Such institutions must tackle issues at both the micro and macro level, incorporating corporate governance, legislation, political stability, corruption, etc. In the past decades, China has been committed to shaping a better institutional environment for economic development. For example, China has largely removed the 'Hukou' system, which was designed to control the free movement of its population between rural areas and city regions. China has also successfully implemented a reform of state-owned enterprises by allowing external capital to acquire shares in such enterprises. However, it is believed that it is impossible for the pace of future institutional reform to be as aggressive as it was, as the '*low-hanging* *fruits of institutional reforms have been picked*' and a certain various interest groups will block further reforms (Wei et al. 2017, p.50).

Another approach, according to the Schumpeterian economists, is through innovation (Alcouffe and Kuhn 2004; Aghion et al. 2015; Yun 2015). The Schumpeterian growth theory was established by the Austrian economist, Joseph Schumpeter, and it departs from the neoclassical growth theory by arguing that technological progress is an independent economic process and is, in fact, the main driver of long-term economic growth (Howitt 2005; Aghion et al. 2015). While acknowledging the importance of institutions, technological progress is argued to be more effective than institutional factors in overcoming the middle-income trap and generating long-term growth (Lee and Kim 2009). Back in the late 1990s, the Chinese government assigned an important role to science and technology in its economic development (Benner et al. 2012). According to data provided by the World Bank (2019a), the research and development (R&D) expenditure of China (as a percentage of GDP) increased from 0.563% in 1996 to 2.186% in 2018. With 553.4 billion dollars invested in 2018, China had the highest R&D expenditure in the world, exceeding even the 511.1 billion dollars invested by the U.S. (World Bank 2019b). It is clear that the importance of innovation is increasingly being recognised by Chinese policy-makers, and that the government is determined to transform its economy from 'made in China' to 'innovated in China' (Tan 2011; Li 2018).

Firms' innovation activities are embedded in different contextual settings. As the importance of innovation has become recognised by Chinese policy-makers, the R&D activities and innovation collaborations of Chinese firms are being affected by institutional factors such as government initiatives, laws, regional regulations, etc. (Zhu et al. 2012; Ahlstrom et al. 2018; Xiong et al. 2019). Chesbrough et al. (2020a) observe that China's unique institutional environment has led to a situation of 'open innovation with Chinese characteristics', and that failing to respond to such factors may pose risks to firms' survival. Thus, before empirically investigating the impacts of universities on firms' innovation outputs, it is necessary to examine how Chinese innovation systems have been shaped by the institutional environment, and to explore how Chinese universities fit into these systems of innovation. For this purpose, Section 2 of this chapter sets out a detailed introduction to the national innovation system (NIS) of China. Also, China's large geographical territory and regional economic disparities has ensured that the innovation system in China is very diverse. As such, Section 3 examines the innovation systems in three different regions. Section 4 uses an example from Tsinghua University to describe how Chinese universities support regional development with their various resources. Finally, Section 5 concludes this chapter.

3.2 The National Innovation System in China

3.2.1 The historical development

The expression of 'National Innovation System' (NIS) was first proposed by Lundvall (1992b) in the book '*National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning'*. Research in this area was started by Freeman (1987), and continued by Lundvall (1992b), Mowery (1992), and Nelson (1993), etc. There is no single definition for the NIS. In general, it refers to an institutional system comprised of different actors that include governments, public institutions, firms, academia, individuals, and other system-based actors. These bodies and individuals interact with each other to promote innovation (Hall et al. 2014). The 1980s witnessed the rapid rise of Japan as an economic superpower and the first empirical use of the NIS was to account for the Japanese experience, for which lessons about the construction of its national innovation capabilities were drawn (Freeman 1987). Since then, NIS research has been extended to other national contexts, such as Denmark (Lundvall et al. 1988) and the U.S. (Mowery 1992).

It is necessary to take a historical view to account for the lessons provided by the Chinese NIS (Lei et al. 2019). When the development trajectory of the Chinese NIS is reviewed, we see that China has gone through different phases and that the policy focus of these phases has greatly varied. This chapter investigates the Chinese NIS by its three different phases: emergence, development, and upgrading.

The Emergence Phase (1949-1985). Established in 1949, the People's Republic of China had largely followed the former Soviet Union model in its political and economic system. This was characterised by a centrally planned structure and minimal involvement of private firms in the country's economic activities. During this phase, S&T missions were assigned only to public research centres and there was little involvement from universities and enterprises. The major S&T projects were focused on military products, such as nuclear weapons and satellites (Xiwei and Xiangdong 2007). In the early 1950s, the Soviet Union assisted China to build up a few heavy industries (e.g., steel, coal mining, and electricity) through technology-transfer and financial loans, but this assistance ended when geopolitical factors caused the deterioration of Sino-Soviet relations. Later on, Chinese S&T activities were mostly suspended due to the disruption caused by the Cultural Revolution. During the 1978 National Science Conference, China initiated the restoration of the damaged national S&T system by acknowledging that S&T was a critical productive force and by reorienting its R&D activity to the needs of industry (Gu 2004). Between 1949 and 1985, the Chinese NIS system gradually emerged, but it was still in its infancy, and the main actor of the NIS was a set of public/military research centres.

The Development Phase (1985-2006). Although in 1978 the Chinese central government explicitly emphasised the importance of S&T in driving forward economic development, it was not until 1985 that China launched its S&T system reform. The Third Plenary Session of the Central Committee of the Communist Party (CCCP) established the 'opening-up and reform' principle as a national strategy, and China started to construct its NIS through the massive introduction of foreign technologies. The 1985 S&T reform established the 'Market for Technology' strategy, hoping that the country's large domestic consumer market would attract foreign technology-transfer (Xiao-hua 2004; Holmes et al. 2015). This strategy was successful and China built its technology market through collaboration with western multinational corporations (Fu 1992). A typical example of these collaborations was the establishment of a car factory in Shanghai by the German Volkswagen Corporation and the Shanghai government. During these times, China's innovation followed an 'Introducing and Imitating western technology' path, and the NIS gradually developed with reducing involvement from public research centres and increasing engagement by enterprises (Xu et al. 1998; Zhou 2006).

The Upgrading Phase (2006 to date). While the 'Introducing and Imitating western technology' strategy greatly contributed to S&T development, it also raised some criticism that China was becoming a 'copycat' nation; indeed, its innovation capabilities fell far behind the pace of the country's overall economic development (Rein 2014). The 2006 National Science and Technology Conference marked the government's determination to turn China's economy from being 'manufacturing-oriented' to 'innovation-oriented'. At this conference, the CCCP and the State Council announced the 'Medium- and Long-Term Plan for the Development of Science and Technology (2006-2020)'. The most significant change sparked by this document was that enterprises, for the first time in the Republic's history, were put at the centre of its innovation system through the establishment of a national strategy called 'Indigenous Innovation' (Gu et al. 2009; Gu et al. 2016). The 'Indigenous Innovation', or '*Zizhu Chuangxin*' in Chinese, is a term used to describe innovations developed through endogenous R&D capacity with little or no involvement by foreign technology. One example of Chinese Indigenous Innovation is the BeiDou Navigation Satellite System (BDS), which came into full operation in 2020 and which represents China's leading position in satellite technology (Li et al. 2020b). During this phase, the NIS has been improved by allowing the market to play a fundamental role in S&T resource allocation and by encouraging innovation collaborations between universities and industry.

3.2.2 Key actors in NIS

As one of the few communist countries in the world, China has a sophisticated bureaucratic system for public policy formulation and implementation (Lieberthal and Oksenberg 1988). On paper, it is the National People's Congress that has the most power and is at the highest legislative level but in reality, it is the **Central Committee of the Communist Party (CCCP)** that, through its standing committee of the political bureau, makes the final decision on all major domestic and foreign affairs. The state council of China, which consists of different ministries and commissions, has responsibility for implementing the strategic decisions made by the CCCP.

The political power of the CCCP is evident in the development of the innovation system in China. Being involved in directly formulating a long-term strategy, the CCCP also established the so-called 'leading groups' (*lingdao xiaozu* in Chinese) for the formulation of the medium-term strategy, and it coordinates works that involve more than one ministry. Meanwhile, ministries of the state council and their sub-institutions are in charge of the formulation and implementation of specific innovation policies, and these ministries and institutions are the key actors in the Chinese NIS. Policy formulation usually involves the Ministry of Science and Technology (MOST), the Ministry of Education (MOE), and the National Development and Reform Commission (NDRC). Policy implementation is primarily within the remit of the Chinese Academy of Science (CAS), public universities/research centres/laboratories, and the private and state-owned enterprises (SOEs), along with other organisations.

With 14 departments and 22 affiliated agencies, the **Ministry of Science and Technology (MOST)** is the main participant and arguably the most important actor in the NIS (Zhang 2008; Liu et al. 2011). The core mission of the MOST is to formulate and facilitate the implementation of S&T policies and plans, as well as to assist other ministries with formulating relevant policies that involve S&T development. The MOST is in charge of organising and evaluating national research projects/programmes and, in collaboration with the NDRC, it also helps to promote the commercialisation of the S&T outputs. The 153 national High-Tech Industrial Development Zones, which are said to be the 'backbone' of the country's high-tech industries, are all administered by the MOST (Zhuang and Ye 2020).

The Ministry of Education (MOE) has a profound influence on the Chinese NIS, derived from its two core responsibilities. First, it is the administrative body of almost every major university in China (including the university-affiliated enterprises and laboratories); therefore, it takes on the function of talent-creation and building the potential for university research in the NIS (Kroll et al. 2008). Second, and perhaps more importantly, it guides the direction of public research by funding the research conducted by universities and their affiliated institutions. As China is assigning more responsibilities to universities so they can create the innovation-driven economy, the role of the MOE is becoming increasingly important in the NIS (Xiwei and Xiangdong 2007; Li et al. 2018; Hong et al. 2019).

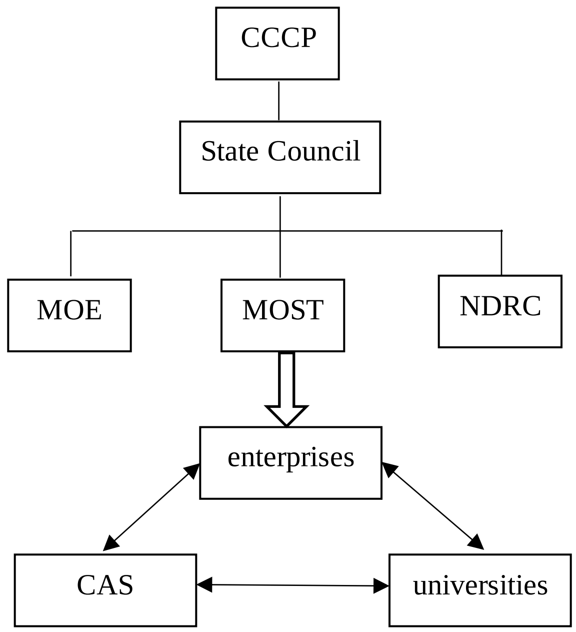
Given its unique responsibilities, **The National Development and Reform Commission (NDRC)** plays a fundamental role in the NIS. Established in 2003, the NDRC succeeded the State Development and Planning Commission (SDPC), which was the main executive body under the centrally planned economic system, in order to implement the economic restructuring strategies. The most significant job of the NDRC is to formulate the industrial innovation policy and to examine and approve the major industrial projects proposed by private and public enterprises (Yang et al. 2016; Zhang et al. 2019). In the current bureaucratic system of China, the NDRC is perhaps the most influential administrative agency within the State Council, making it an indispensable actor in the Chinese NIS (Yeo 2009; Liu et al. 2011).

Established in 1949, **the Chinese Academy of Science (CAS)** is a product of the former Soviet-Union system, and it is both an administrator and a performer of the national R&D programmes (Suttmeier et al. 2006). This was the institution that carried out the Chinese nuclear bomb project and the satellite project in the early 1960s. In 2014, the CAS initiated its reform, which aimed at increasing internal/external collaborations across different disciplines, giving more autonomy to its affiliated research institutes and placing more emphasis on the commercial application of its research outputs (Cao et al. 2015). Today, with 104 research institutes and 56,000 professional researchers, the CAS carries out research in many fields of basic science and technology and it is the highest-ranked scientific agency in China (CAS 2020). The most recent achievements by CAS include a quantum communication technology and a Covid-19 vaccine that is, at time of writing, in the final stage of its clinical trial. Other than its research role, CAS also functions in the Chinese NIS as an innovation intermediary organisation through one of its internal institutions, the Bureau of Science and Technology Development (BSTD). The responsibility of this institution is to transfer the research outputs/intellectual properties produced by CAS to its domestic partners.

The importance of **universities** in the innovation system has been highlighted by many scholars (for example, Leydesdorff and Guoping 2001; Motohashi 2005; Etzkowitz and Zhou 2017). In contrast to the private universities, the public universities in China possess most of the research resources, making them an important performer in the NIS. However, due to political disruption (i.e., the Cultural Revolution of the 1960s and 1970s), the higher education system was all but paralysed and was unable to organise scientific research. It was not until the 1978 National Science Conference that universities were able to resume their research activities and since then, public universities have been assigned an increasingly important role in the national S&T projects (Xue 2006). In 2018, the Chinese public universities have spent more than 145.7 billion RMB (approximately 22.4 billion U.S dollar) in R&D and have generated considerable research outputs for the development of the economy (NBS 2019).

The enterprises, especially the state-owned enterprises (SOEs), are key performers in the Chinese NIS. In the contemporary S&T structure, enterprises are not only the largest end-users of innovation outputs but are also China's biggest R&D investment recipients (Liu et al. 2017). As the government shifts its centrally-planned economic system to one that is more market-centred, the Chinese state-owned enterprises have received strong support from the central government in terms of R&D investments, taxes, land use, etc. (Hu 2014). One example noted by Liu et al. (2017) shows that the electronic display manufacturing firm BOE, a state-owned enterprise, had received 653 million RMB (approximately 93 million USD) of government S&T subsidies in 2013 alone. Besides the SOEs, Chinese private firms are rapidly growing as world-class innovators in the fields of internet technologies, telecommunications, and computers (e.g., Alibaba, Huawei, Lenovo). See figure 8 for the relationships between the key actors in the NIS.

Figure 8 Key actors in NIS



3.2.3 Key innovation policies and programmes

It has been indicated that a successful innovation cannot totally rely on either government or the mechanisms of the market, being rather the product of a balanced labour division between these two players (Mowery et al. 2015). A decentralised market mechanism is essential to resource allocation but, in China, the strong role played by the government is especially important to the country's catch-up of technological progress (Liu et al. 2011).

In 1985, the CCCP released a document entitled 'The **Decisions of the Central Committee of the Communist Party on the Reform of the S&T System**', which marks the beginning of 30 years of S&T reform. This document's core content makes adjustments to the organisational structure of the research institutes, reforms the management system for scientific personnel, reforms scientific research's funding system, and, most importantly, allows scientific researchers to profit from their research outputs (GOV 1985a). Since then, a series of innovation policies and programmes have been introduced by successive administrations of government, including, inter alia, the '863' programme, the '985/211' programme, the 'Medium-and Long-Term Plan for the Development of Science and Technology (2006-2020)'.

Responding to the reform call in 1985, a small group of scientists proposed the **'863' programme**, which was approved by the CCCP in March 1986. As a national R&D programme, the overall goal of the 863 programme was to enable China to catch up with the developed economies in a few high-tech industries. Based on the principle that 'the programme should combine military and civil purposes, but mainly serve for civil use', the expert committee of the programme selected seven areas upon which to concentrate research: biotechnology, space science, information technology, laser technology, automation technology, new energy, and new material (MOST 1986). The majority of public S&T funds and human resources were then mobilised to serve the implementation of the 863 programme. The most distinctive feature of the 863 programme, in contrast to the previous national R&D projects, is that it included projects for civil purpose as well, and placed the economic value at the centre of these projects. Although it was gradually replaced by other programmes in the late 2010s, the 863 programme is still regarded as the 'milestone' of Chinese national innovation policy (Ke 2012).

Having realised the importance of the university to the innovation system, China announced both the **'211' project** and the **'985' project** during the 1990s. Specifically, the '211' project was introduced by the MOE in 1993, and supported 100 universities in their aim to become the 'top universities in the 21st century'. The '985' project was initiated in a 1998 speech from the former president of China, Jiang Zemin, in which he declared that 'China should have a small number of world-class universities'. As such, 39 universities were selected to become the focus of relevant public funding initiatives (Costa and Zha 2020). Although policy nuances exist, these two projects were expected to level up the R&D capacity of key universities in China through the improvement of overall institutional capacity, building key faculties and national laboratories, and allocating more funds to specific universities (Kroll et al. 2008; Hayhoe and Zha 2010). Only a few of these Chinese universities are internationally recognised today, so it is reasonable to conclude that these programmes did not achieve the expected objectives. Nevertheless, the '985' and '211' projects demonstrated the government's commitment to improving national R&D capabilities by increasing support for universities (Zhang et al. 2013).

Despite the achievements of the above policies and programmes, China was still facing severe challenges in building an innovation-driven economy. First, its rapid economic growth was driven not by its high-tech and knowledge-intensive sectors but rather by resource-intensive manufacturing and the relevant exports, which has caused severe environmental issues. Second, future economic growth was inhibited by the low innovative capacity of China's domestic enterprises. Due to the previous emphasis on foreign technology-transfer, the development of the domestic high-tech industry was dominated by multinational companies from developed countries. Third, sanctions had been imposed by other countries, preventing China from importing military products and forcing it to improve its own capacity for developing military technologies (Kroll et al. 2008).

As such, in February 2006, the Chinese State Council issued the **'Medium-and Long-Term Plan for the Development of Science and Technology (2006-2020)'** (MLP). The plan is focused on ten key areas including energy, water and natural resources, environment, agriculture, health and defence industry, etc. The plan ambitiously set out relevant national investment projects for these ten areas and created a set of quantitative objectives. For example, it requires that the total R&D investment should, by 2020, account for over 2.5% of GDP, reliance on foreign technology should go below 30%, and the citation of Chinese scientific papers should be ranked in the top 5 in the world. For the implementation of this strategic plan, relevant policies/incentives have been issued by the MOST, NDRC, MOE and the Ministry of Finance (MOF). According to Gu et al. (2008), the most distinctive feature of the MLP is that, for the first time, it explicitly adopts the perspective of the NIS in the development of its national S&T system. Also, the plan requires that the projects and the relevant S&T policies should give priority to the enterprises, which are therefore placed at front and centre of the NIS.

In recent years, as President Xi Jinping has taken power within CCCP, more ambitious innovation policies have been introduced. Of these, **'Made in China 2025'** has been the focus of research by western observers. This initiative was issued by the Ministry of Industry and Information Technology (MIIT) in 2015, and it is aimed at transforming Chinese manufacturing industry into a world 'technology superpower' (Wübbeke et al. 2016). It is in line with the German concept of 'Industry 4.0' and encourages deep integration between informatisation and industrialisation to further improve the innovation capabilities of Chinese manufacturing firms. The initiative has created a mixture of policies and projects, including 5 major national manufacturing innovation centres and 226 key projects in 'smart manufacturing' (GOV 2015b). Another key innovation policy initiated in 2015 is the '**Mass Entrepreneurship and Innovation'** policy, focused on improving the innovation capabilities of small and medium-sized firms, especially the high-tech start-ups. This policy received additional implementation support in a document promulgated by the State Council in 2017, (GOV 2017). The Mass Entrepreneurship and Innovation policy is the first to focus more on private firms, since the previous preferential innovation policy leant towards the state-owned enterprises (He et al. 2019). See Table 1 for a summary of key policies and projects.

Table 1 Key policies and projects

Policies/Projects	Main features	Year
The Decisions of the Central Committee of the Communist Party on the Reform of the S&T System	Reforms of: 1. the organisational structure of research institutes 2. the management system of scientific personnel 3. the funding system of scientific research 4. scientific researchers are allowed to profit from their research outputs	1985
'863' programme	1. promoting the development of high-tech industries 2. covered also the civil-purpose projects	1986
'211' and '985' projects	1. institutional reform of selected major Chinese universities. 2. build key disciplines and national laboratories and allocate more funds and talent into selected universities	1993 1998
The Medium-and Long-Term Plan for the Development of Science and Technology (2006-2020)	1. explicitly adopts the perspective of the NIS in the development of the national S&T system 2. requires relevant S&T policies and projects to be introduced that give priority to enterprises; therefore, placing enterprises in the centre of the NIS	2006
'Made in China 2025'	1. transform the Chinese manufacturing industry into a world 'technology superpower' 2. construct 5 major national manufacturing innovation centres and 226 key projects in 'smart manufacturing'	2015
'Mass Entrepreneurship and Innovation'	1. improve the innovation capabilities of SMEs, especially the high-tech start-ups 2. the first policy that gives more focus to private firms	2017

Source: Compiled by the author

Through this review of the key actors and policies in the Chinese NIS, it is evident that the Chinese NIS has at least two unique features when compared to its US/European counterparts. First, and perhaps most distinctive feature, is that the NIS is heavily influenced by central government (Oswald and Zhao 2019). The role of government is manifested in the national innovation policies/projects, as well as in the top-down governance structure of innovation. Within this governance structure, the Chinese government is capable of rapidly mobilising innovation resources to its prioritised fields/industries, thus closing the technology gap between China and some of the more developed nations (e.g., US). Second, as indicated by Chen (2010), the interactions within the Chinese NIS are dominated by public research institutions (e.g., CAS) and the state-owned enterprises (SOEs), whereas in developed economies, private enterprises/research institutions play a lead role in the innovation system. Although recent years have witnessed a shift in innovation policies to encourage the engagement of private enterprises, the significance of public research institutions and SOEs is still an important feature of the Chinese NIS (Chen et al. 2015).

3.3 The Regional Innovation Systems of China

The national innovation system is a complex system, from which sub-systems are formed at regional or sectoral level as components of the NIS (Malerba and Orsenigo 2002). Within the sub-systems, interrelated institutions create, diffuse, and exploit innovations (Chung 2002). The concept of the regional innovation system (RIS), which was first used by Cooke (1992) in an examination of the role played by regulation in promoting regional development, provides an important perspective for investigating the innovation capabilities of a specific region. A regional innovation system is a group of adjacent organisations and firms that interact with each other to create and diffuse innovations (e.g., enterprises, universities and research centres, government, business services).

Early economists, for example Alfred Marshall (1890), used the labour division and specialisation theory to explain the formation of industrial districts. Within an industrial district, small firms with similar functions in the industrial production chain, are clustered, and ‘localisation economies’ can be achieved through rapid exchange of information, easier access to skilled labour, and lower transportation costs (Nakamura 2020). Jacobs (1969), on the contrary, has argued that it is the diversity of industries within a specific region rather than the specialisation of an industry that promotes regional innovation and economic growth. This is particularly true if we consider that in today’s knowledge economy, many important innovations have been created via interdisciplinary collaboration and are complementary to industrial knowledge. In this vein, it has been argued that the scientific knowledge alliance has reached beyond geographical boundaries to become increasingly international rather than regional (Niosi and Bas 2003). The globalisation of market and knowledge, in turn, generates both opportunities and threats for local and regional developments (Parrilli et al. 2013).

Nevertheless, the investigation into the regional structure and dynamics of R&D activities is highly relevant as the nation-state has been losing importance in the globalisation era, and the region-state is actually the focus of economic activities (Ōmae and Ohmae 1995). For example, it has been argued that the dense interaction between a regional innovation system and its lead firms (i.e., the firms that produce the final product and coordinate the local supply chain) is crucially important to addressing the threats presented by globalisation (Parrilli 2019).

The regional concentration of R&D and innovation activities is shaped by many factors. Jaffe et al. (1993) and Audretsch and Feldman (1996) indicate that the knowledge spillover from R&D activities is geographically bounded; hence, knowledge-users tend to co-locate with the knowledge-producers so as to benefit from knowledge spillovers. In this case, the specificity of clusters must be taken into consideration, as geographical proximity is especially important for the clusters that rely on tacit or synthetic knowledge (Asheim and Coenen 2005). Meanwhile, the importance of institutional settings in shaping a system of innovation has been highlighted by many scholars (for example, Lundvall 1992a; Cooke et al. 1997; Goel et al. 2005). The generation, diffusion, and application of knowledge are directly influenced by the rules, norms, and established routines in a specific region, and it is the differences in such institutional factors that shape the formation as well as the performance of an RIS (Chung 2014).

As indicated by Jin et al. (2019), a huge number of technological innovations are being introduced by China's manufacturing and high-tech firms, and these firms have agglomerated into certain geographical regions (mostly the developed and coastal regions). With its extraordinary geographic size and regional diversity, China provides a highly relevant context for the study of regional innovation system. It is necessary to take a glance at China's regional inequalities before investigating its RISs. Regional disparities in China imply the success of its economic reform, as many of today's developed regions were in extreme poverty decades ago. However, regional inequality harms the sustainable development of regional and national economies (De Dominicis 2014). Recent research conducted by McCann (2020) adds new evidence to this line of research. Using statistical data from the UK, McCann finds that the UK is one of the most regionally unbalanced of the developed economies and, as a consequence, the future productivity growth of many UK cities is going to be severely limited.

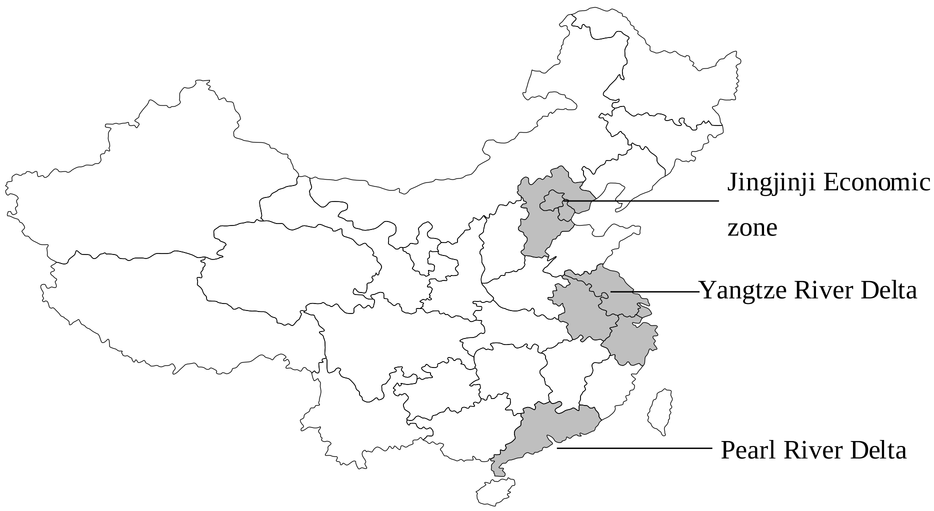
The cause of the regional disparities in China is somewhat complex. First, the eastern regions have historically been more developed than the inland regions. Geographically, the eastern regions enjoy abundant water resources, and in ancient times the rivers/canals provided these regions with transportation advantages over inland areas. The climatic conditions in eastern China are suitable for the development of both traditional agriculture and the sericulture, and the textile industry, as a by-product of these two industries, was also highly developed in eastern regions. In the pre-industrialisation era, these three industries were crucial to the domestic economy. Second, compared to the inland regions where there were frequent political regime changes, the eastern regions remained largely peaceful and were less disrupted by wars. Although some cities in eastern China were impacted by the Second World War, the foundations of the economy (e.g., human capital and the infrastructure) were reasonably well protected. Third, some coastal cities such as Shanghai, Shenzhen, and Xiamen were among the first cities to be 'open-cities' during the economic reform in the 1980s. As such, they have benefitted from heavy foreign direct investment and strong policy support from both central and provincial governments. The spillover effects of FDI in the open-cities also led to technological developments in their neighbouring cities, and together these cities formed highly developed areas (Madariaga and Poncet 2007). Moreover, these coastal regions have enjoyed a high level of fiscal and political autonomy, which has engendered higher economic efficiency, broadening the economic gap between them and the inland regions (Rodríguez-Pose and Ezcurra 2010).

The coastal cities and their clusters are now also the leading innovative regions in China. The distribution of R&D investments at the regional level is similar to the distribution of GDP in China, and this similarity is by no means coincidental. Besides these historical and geographical factors, the Chinese regional innovation systems have been shaped by three institutional factors. First, labour mobility plays a significant role in the RISs in China (Ramirez et al. 2013). The Hukou system, which refers to a national household registration system established in the 1950s, was designed to restrict the free movement of citizens across different regions. Under the Hukou system, Chinese citizens could only get access to public resources (e.g., primary/secondary education, health care, and other public welfare) at their registered place of Hukou. After the economic reform, the system was lifted in many coastal regions, which helped them to attract migrant workers and talent from inland regions. Although the Hukou system has not yet been abolished, local governments have autonomy in determining how the system is enforced. In this regard, coastal cities are commonly found to be more effective at mitigating the limitations imposed by the Hukou system (Xu et al. 2016).

Second, as suggested by Li (2015), the Chinese RISs have also been shaped by variations in the regional intermediate institutions. Such intermediate institutions include legal, financial, technological, and consulting services (which can also be referred to as 'non-manufactured intermediate goods', (Rosenthal and Strange 2001). It has been suggested that such institutional factors help shorten the distance between knowledge-producers and knowledge users, thereby facilitating regional innovation collaboration (Cooke 2001). Rodríguez-Pose and Ezcurra (2010) have noted that political decentralisation is an important vehicle for delivering superior economic efficiency. As a key part of the political reforms in recent years, China's local governments are increasingly being empowered to introduce regional legislation and industrial policies (Wu and Zhang 2018). It has been observed that most of the innovative policies (e.g., R&D policies, land development rights) were first trialled in coastal cities before being formally introduced nationwide, making these regions more competitive innovators than the inland regions (Fan et al. 2011).

Lastly, the innovation capacity of a specific region is also influenced by the institutionalisation of R&D activities (Li 2015). The institutionalisation of R&D activities, or the frequency of R&D activities, indicates how many R&D activities firms conduct in a specific region. In this regard, firms in coastal provinces, such as Guangdong, Jiangsu, and Shanghai, are more engaged in innovation activities such that the total R&D expenditure in the eastern region in 2019 reached 1,512.2 billion RMB (approximately 200 billion in U.S dollars) (NBS 2020c). In summary, the Chinese innovation landscape shows a unique set of regional territorial dynamics (Rodríguez-Pose and Wilkie 2016). Below, we provide a profile of regional innovation systems in the three most developed regions: the Yangtze River Delta, the Pearl River Delta, and the Jingjinji economic zone. See Figure 9 for the geographical location of the three regions.

Figure 9 The geographical location of YRD, PRD and JJJ



3.3.1 The Yangtze River Delta

The Yangtze River Delta (YRD) is among the most important regions in the current economic landscape of China, and the urban agglomeration of the YRD is at the core of China's innovation-driven development strategy (Zou and Zhu 2020). Named after the Yangtze River (*Changjiang* in Chinese), the YRD consists of three provinces (Jiangsu, Zhejiang, and Anhui) and one centrally administrated municipality, Shanghai. With approximately one-seventh of China's population, YRD accounts for about a quarter of China's total GDP and one-fifth of its nationally registered firms (NBS 2020b). The economic structure of the YRD is dominated by a highly developed manufacturing sector but the service sector has also been rapidly developing. Due to its economic structure and geographical attributes, YRD is deeply embedded in international trade. In 2019, the three provinces and Shanghai city together accounted for one-third of China's total volume of foreign trade with 11,300 billion RMB (approximately 1,614 billion USD) (NBS 2020a). The central government has placed great strategic importance on the development of the YRD. In December 2019, the CCCP and the state council of China jointly issued the '*Outline of the Integrated Regional Development of the Yangtze River Delta*', which aims at building the YRD into a 'robust and active pole of national innovative development, and a demonstration area of regional integrated development' (GOV 2020).

Since 1999, the MOST has issued an 'Annual Report of Regional Innovation Capacity', and in every year the YRD areas have been ranked as one of the country's most innovative regions (see MOST, 1999-2019). The YRD has created a well-functioning regional innovation system, in which subsystems can be identified by their unique industrial advantages. According to Cooke (2002), regional innovation subsystems have either the function of knowledge generation/diffusion, or the function of knowledge application/exploitation. The development of the YRD innovation system is also a process of the spatial transition of the regional innovation subsystems. For example, over recent years Shanghai has transferred the majority of its manufacturing industries into Jiangsu and Zhejiang, enabling it to focus on its role of regional R&D centres. Shanghai also has the most developed financial service sector in China, which strongly supports industrial development in other YRD areas. The knowledge diffusion process in the YRD region is shaped by the strong technology spillover from Shanghai as well as by the FDI from Europe, United States, and Japan, which together provide strong support for the development of the advanced manufacturing industries. According to previous literature, universities play a critical role in supporting the RIS (Zhang et al. 2010; Gonzalez-Pernia et al. 2015; Yao et al. 2018). In this regard, YRD areas have 458 universities (colleges), which account for nearly 20% of all universities in China (2,722). The strong regional innovation capacity of the YRD is also associated with its regional R&D intensity (R&D expenditure as a percentage of GDP). In 2019, Shanghai had the second strongest R&D intensity in China (4%), after Beijing (5.64%). It is followed by Jiangsu (2.79%), Zhejiang (2.68%), and Anhui (2.03%) (MOST 2020). See the table below for the R&D intensity of the YRD regions.

Table 2 The R&D intensity of YRD, 2019

Region	R&D expenditure (100 million RMB)	R&D expenditure as a percentage of regional GDP (%)	Ranks of regional R&D intensity (31 regions of China)
Shanghai	1205.21	4.00	2nd
Jiangsu	2260.06	2.63	3rd
Zhejiang	1266.34	2.45	6th
Anhui	564.92	2.05	9th

Source: Annual Report of Regional Innovation Capacity. (MOST 2020)

3.3.2 The Pearl River Delta

Located in south China, the Pearl River Delta (PRD) economic zone covers nine cities, all of which are in Guangdong province. Although its geographic territory is smaller than that of the YRD and the Jingjinji economic zone, it is nevertheless the most developed area in China. The Guangdong province has been ranked as the province that produces the largest GDP since 1989, with approximately 1,538 billion US dollars in 2019 (approximately 11% of China's GDP). The economic development of Guangdong was in stagnation until 1985, when the CCCP determined to establish the Pearl River Delta economic zone, for which it issued a set of relevant preferential policies (GOV 1985b). Since then, the PRD has experienced rapid economic growth from its export-oriented manufacturing economy, which is dominated by electronic products, car manufacturing, and textile industries. One distinctive feature of the PRD is the prosperity of the domestic private sector. In 2019, the private sector contributed 54% of the region's total GDP (NBS 2020b). Some of the most internationally renowned Chinese enterprises are located in the PRD including Huawei, Tencent, and Gree.

According to the Annual Report of Regional Innovation Capacity issued by MOST, the PRD is also the most innovative region in China. However, for a long time, the PRD has relied on processing trade with Hong Kong with a so-called 'shop front, factory back' model. In this model, the PRD enterprises mainly operated in the low-tech end of the industrial value chain, with the high value-added activities remaining in Hong Kong (Schiller 2011). The PRD region is also the largest recipient of FDI from Taiwan and Macau, but these FDIs have not produced a strong technology spillover, being targeted at labour-intensive industries seeking the region's low labour costs. Although this model has brought considerable profits and jobs to the PRD manufacturing industries, it has also reduced the incentive to develop R&D capabilities. Both central and local government have identified this as an issue, most particularly when the export-oriented manufacturing sector was severely hit during the 2008 global financial crisis. Since then, the PRD has been working on upgrade its manufacturing economy by building a robust regional innovation system. In this regard, one important strategy is the establishment of regional R&D centres. For example, Shenzhen, the core city in the PRD, has established more than 100 national key laboratories between 2009-2019; these cover a wide range of fields, such as new materials, information and communication, biotechnology, and intelligent equipment (NBS 2020c). Meanwhile, the central and local governments have introduced effective preferential policies aimed at increasing the intermediate sectors, such as financing and consulting services. In 2019, the CCCP issued the Outline Development Plan for the Guangdong-Hong Kong-Macao Great Bay Area, which aims to fully leverage the comparative advantages of the PRD, Macao, and Hong Kong, deepening the regional collaboration between these regions and finally achieving an 'innovation-led' regional economy (GOV 2019). See the table below for the R&D intensity in PRD.

Table 3 The R&D intensity of PRD, 2019

Region	R&D expenditure (100 million RMB)	R&D expenditure as a percentage of regional GDP (%)	Ranks of regional R&D intensity (31 regions of China)
Guangdong	2343.63	2.61	4th

Source: Annual Report of Regional Innovation Capacity. (MOST 2020)

3.3.3 The Jingjinji economic zone

Geographically, the Jingjinji (JJJ) economic zone refers to the Hebei province, the centrally administered municipality Tianjin, and China's capital city, Beijing. These regions were traditionally at the centre of China's heavy industries, including the steel industry, coal industry, and oil industry. In 2019, JJJ contributed 8.5% of China's national GDP (NBS 2020b). However, due to its economic structure, severe issues have emerged in recent years. First, the regional economic development across these three geographically adjacent regions is largely imbalanced. For example, in 2015, the GDP per capita in Beijing and Tianjin were 17,064 and 16,400 US dollars, in contrast to Hebei's 6,403 dollars (NBS 2016). Hebei's economic reliance on heavy industries has created severe environmental issues (e.g., air pollution) not only to Hebei itself but also to Tianjin and Beijing. Moreover, as a consequence of this regional imbalance and limited public resources, there has been a 'brain drain' phenomenon in Hebei, as talented individuals flow to Beijing and Tianjin for better career opportunities. This phenomenon has also put pressure on these two cities, especially in terms of transportation, housing, health care, and the natural environment.

Responding to the regional imbalance within JJJ, the state council issued the '*Coordinated Development Plan for the Beijing-Tianjin-Hebei Region'* in 2015, which aims to coordinate the region's development by assigning unique functions to each of the three regions. Specifically, the objective is to transform Beijing into the national scientific and technical innovation centre, Tianjin into the national research and development base for advanced manufacturing, and Hebei into both the national base for trade and logistics and a pilot zone for industrial transformation and upgrading (GOV 2015a).

As suggested by Chen and Xie (2018), the core method of achieving these objectives is to promote regional collaborative innovation within the JJJ. To that end, the JJJ has both advantages and limitations to be addressed. The first advantage for JJJ is that it occupies pole position in terms of R&D investments. For example, as Table 4 presents, in 2019 the R&D intensity of the JJJ was 3.09%, compared to the YRD's 2.78% and the PRD's 2.61% (MOST 2020). Second, the JJJ leads the field in basic scientific research, thanks to Beijing's abundant higher education resources. As of 2019, there were 93 higher education institutions located in Beijing, 26 of which were listed in the 985/211 programmes (an indicator for elite universities in China) (MOE 2020a). Third, the technology sectors have been developing rapidly in recent years. For example, Hebei had 139 S&T technology enterprises incubators in 2019, as opposed to 61 in 2015 (NBS 2020c). Therefore, the innovation system in JJJ is characterised by strong knowledge spillover from Beijing and a massive influx of regional R&D expenditure. However, limitations exist in the JJJ's current regional innovation system. For instance, the balance of innovation outputs continues to deteriorate. In 2019, Beijing had 42,851 authorised patents; this is about three times more than Hebei had and twice Tianjin's quota (NBS 2020c).

Table 4 The R&D intensity of JJJ, 2019

Region	R&D expenditure (100 million RMB)	R&D expenditure as a percentage of regional GDP (%)	Ranks of regional R&D intensity (31 regions of China)
Beijing	1579.65	5.64	1st
Tianjin	458.72	2.47	5th
Hebei	452.03	1.26	15th

Source: Annual Report of Regional Innovation Capacity. (MOST 2020)

3.3.4 A comparison of the RISs

In the context of China, it has been concluded by Rodríguez-Pose and Zhang (2020) that it is the eastern regions' better institution quality that makes them more innovative than the other regions. However, there are nuances in the RISs of these regions. Looking into the typology of RIS, Asheim and Isaksen (2002) propose three types of regional innovation system, as follows: the Territorially Embedded Regional Innovation Network, the Regionalised National Innovation System, and the Regional Networked Innovation System. In the Territorially Embedded Regional Innovation Network, innovations mainly result from the localised learning process. These learning processes are based on geographical and social proximity, and there is little engagement with knowledge organisation (e.g., university/research centres). The Regionalised National Innovation System, in contrast, emphasises interactive learning with a partner from outside the regional territory (i.e., national or international). It is clear from these definitions that the development of the PRD has largely followed the Territorially Embedded Regional Innovation Network. The manufacturing economy in PRD can be characterised by clusters of low-end electric industries, and the learning process of the firms relies on informal interactions with localised users, competitors, and suppliers, rather than being driven by the recent public R&D investments (Fu et al. 2013). Meanwhile, as the largest exporting province, the PRD also demonstrates features of the Regionalised National Innovation System. Exporting not only connects local firms to the advanced knowledge held by their internal partners, but the knowledge spillovers significantly increase the innovation capabilities of the other firms in the supply chain (Aghion et al. 2018).

The third type of RIS, the Regional Networked Innovation System, is a more typical model in which firms are geographically surrounded by a variety of supporting infrastructure (e.g., R&D institutions, intermediary organisations, etc.) (Asheim and Isaksen 2002). The YRD and JJJ manifest typical characteristics of RIS because the innovation activities in these regions benefit greatly from the institutional infrastructure within their geographical territory. However, it is worth noting that the YRD may also fit into the Regionalised National Innovation System owing to its highly open economy. As an eastern costal region, YRD (and its leading city Shanghai in particular) is host to the one of the largest amounts of FDI in China. Thus, the knowledge spillover wrought by its international partners further stimulates the local learning activities, making the YRD one of China's most innovative regions.

3.4 University-Industry collaboration in China

3.4.1 Universities in the Chinese innovation system

The role of the university in society goes beyond that of simply providing education, as universities are also the source of talent and new knowledge for economic development. Universities are critical to the innovation system at both regional and national levels. Universities are not only a locus of talent that initiates and facilitates innovation and entrepreneurial behaviour, but the spillover effects of universities' knowledge also directly affects the R&D capabilities of their industrial partners. Finally, as suggested by Yao et al. (2018), the university also contributes to the innovation system by cultivating an entrepreneurial culture by, inter alia, maintaining connections with alumni, professional education programmes, or hosting innovation and entrepreneurship competitions.

Over recent years, Chinese universities have been deeply engaged with the nation's mission to become a 'global scientific powerhouse' (Horta and Shen 2020). As the significance of university knowledge has been placed at the centre of a long-term development strategy, the Chinese government has introduced different legislation and policies to encourage the commercialisation of university research outputs. For example, the *'Law on Promoting the Transformation of Scientific and Technology Achievements'* was promulgated in 1996, but it failed to promote intellectual property moving from the public to the private sector (Ye et al. 2019). To further encourage R&D collaboration, a revision of the law was issued in 2015 that clearly states that universities can keep all the revenues from their intellectual property transactions, and that the researchers concerned can retain a minimum of 50% of the transaction revenue (MOST 2015). This revision is clearly highly significant, being referred to as the Chinese version of the Bayh-Dole Act, and it has greatly fostered university-industry research collaborations (Ge et al. 2020). Another important policy is '*The Action Plan of Promoting University Technology Transfer*', which was issued in 2016 and enables universities to play a full role in supporting industrial innovation activities at regional/national level.

Despite the significant contributions of Chinese universities to economic development, there is much potential remaining to be explored in the future. For example, according to the S&T Statistical Yearbook of Higher Education Institutions issued by the MOE, the total number of university patent applications increased from 40,610 in 2009 to 310,276 in 2019. However, the number of patent contracts, which represent the commercialisation of university intellectual property, only increased from 1,311 to 6,115 during the same time period (MOE 2020b). The slow growth in university patent contracts suggests that although the innovation capabilities of Chinese universities have improved significantly over the last ten years, the transfer rate, which is calculated as the number of IP contracts divided by the number of

IPs, is lagging behind. Furthermore, if we consider engagement in industrial collaborations, there is a severe disparity between the ‘elite’ and regional universities. For example, in 2019, each first-tier university was involved in 61 collaboration programmes, on average, which starkly contrasts with the regional universities’ 8 programmes (MOE 2020b).

Below we offer an example of how a Chinese university has been integrated into the innovation systems. Unlike the market-driven approach adopted in the developed economy, the interactions between university and industry in China are strongly influenced by government policies and public R&D projects (Zhou et al. 2016). However, with recent economic reforms, the engagement of universities in the innovation system is gradually inclining to the market as well, while retaining the influence of government’s strong role. Moreover, apart from directly facilitating technological progress with their R&D resources, the impact of the Chinese universities is also manifest through their non-R&D functions (e.g., technology intermediary). These dynamics of the Chinese UIC can be seen reflected in the five key collaboration platforms of Tsinghua University, which are discussed below.

3.4.2 An example of Tsinghua University

Located in northwest Beijing, Tsinghua University (THU) is one of the oldest and most prestigious universities in China. According to the Times Higher Education Rankings 2021, THU ranked 20th in the world—the highest in China and indeed, the whole of Asia. THU is a comprehensive university that specialises in natural science and engineering subjects, including physics, material science, electrical engineering, etc. With its strong S&T resources, THU has engaged with many key national R&D programmes over the past decades. As well as having a public role, THU is also an active player in supporting industrial innovations. In 2019 alone, the total revenue from collaboration with industries/public institutions reached 1.47 billion RMB (approximately 0.2 billion U.S dollars), which is the highest of all Chinese universities.

The impact of THU on the national/regional innovation system is mainly achieved through five key platforms. The first platform is the range of joint research institutes established by THU and other regional governments (provincial level). These are aimed at using THU’s S&T resources to explore and accelerate the development of regional competitive industries. The core activities of these institutes include R&D programmes, talent training, start-up incubators, technology service and transfer, and financing services. For example, the Yangtze River Delta Institute is a research centre established by THU and the Zhejiang provincial government, with the particular mission of boosting the regional innovation capabilities of the YRD areas. Since its establishment, the institute has launched 19 sub-research centres, each of which is targeted at a specific industry. Overall, the 19 selected industries are closely linked to the strongest disciplinary areas of THU, such as information technology, new energy vehicles, and semiconductor applications.

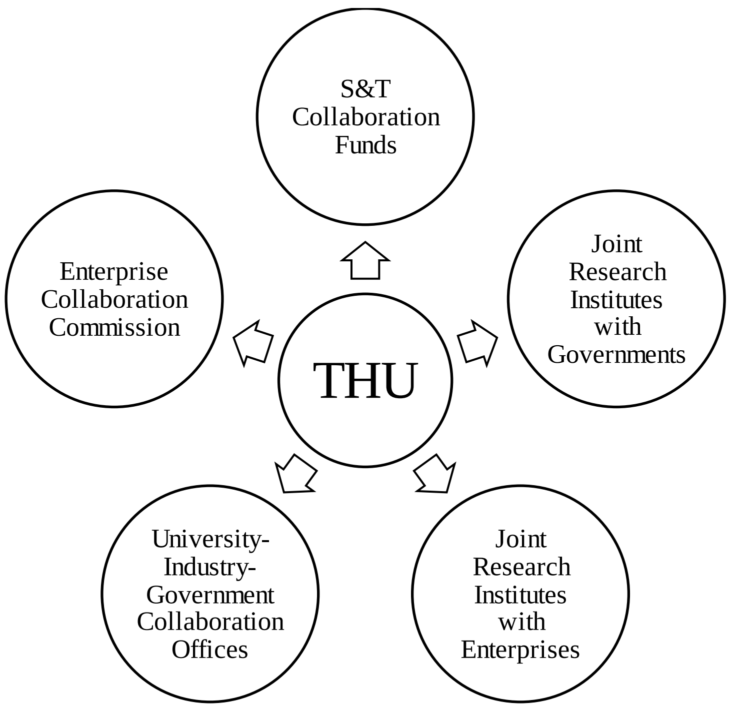
The second platform is similar to the first. It is concerned with the joint research institutes established by THU and the enterprises (domestic and international), and the focus is on the prospective or ongoing R&D programmes of enterprises. These institutes have established their offices within the Tsinghua Beijing Campus, though the enterprises can send employees into the campus to work on joint R&D programmes. Depending on the nature of the R&D subjects and the investment from enterprises, these institutes are further categorised as a university-level institute or a faculty-level institute. After establishing the first enterprise institute with Toyota, THU collaborated with many other partners, including industrial giants such as Microsoft, Bayer AG, and the Chinese internet company, Tencent. It is worth noting that these institutes are often viewed as a strategic investment by firms. For example, over and above the designated projects, Tencent has invested an additional 3 million dollars per year in one or other of the THU research projects that are likely to become a 'technology hotspot' in the next 10-15 years.

The third platform is the 'Industry-University-Government Collaboration Office' ('offices') established by THU with local governments (city-level). There are two features that distinguish these offices from the previously discussed institutes. The first feature is that the offices do not themselves undertake any R&D activities, acting more as a 'technology agent' that provides intermediary services to local cities. Second, unlike the joint research institutes, each of these offices is targeted at a single city rather than at a broader region, making them more focused on the specificities of the individual collaborative cities. In recent years, THU has established offices in cities such as Fuzhou (south eastern), Chungking (western), Maanshan (central China), etc. Administered by THU, the key responsibilities of these offices are (1) to organise trip visits to local firms so that THU experts can assess their current innovation capabilities and provide suggestions for firms' future strategies; (2) to provide intellectual support and consultancy services for local governments' decision-making and planning; and (3) to use THU's rich resources in international collaboration to connect local partners to foreign high-tech enterprises, thus promoting the establishment of local high-tech joint projects.

The fourth platform is a not-for-profit THU organisation established in 1995: the THU Enterprise Collaboration Commission (ECC). The mission of the ECC is to facilitate collaboration between THU and major international/domestic enterprises through a variety of channels, such as information sharing, annual conferences, academic seminars, technology consultancies, etc. Through the ECC, THU also organises student placement activities with partner enterprises. Although the ECC does not conduct research activities itself, it is an important platform that enables R&D collaborations to happen as it brings opportunities for partners to get to know each other and build mutual trust, thereby laying a solid foundation for collaboration. The ECC uses a dynamic mechanism for recruiting members, and many enterprises currently collaborating via joint research institutes were once members of ECC (e.g., BP, Huawei).

The fifth platform, the S&T Collaboration Funds, is another example of a joint project between THU and local governments. The funds are sponsored by local governments and managed by THU, to the extent that government has no right to interfere with how the fund is allocated. When local firms (firms registered with the funding governments) establish R&D collaborations with THU, THU takes the costs/expenses directly from the fund (a maximum of 50% of total contract value, with the rest being paid by firms). In this way, the fund acts as an R&D subsidy for local firms, and because the subsidy goes directly to the firm, the possibility of opportunistic or even fraudulent behaviour is minimised. Meanwhile, all applications are evaluated and determined by the expert committee of THU so that the effectiveness of the funding can be better guaranteed than if the assessment were carried out by government. Several funds have been established between THU and regional governments (e.g., Anshan, Wuxi, Tongling, etc.), and they have improved not only the innovation capabilities of firms but also the effectiveness of public R&D budgets. See Figure 10 for the five main platforms.

Figure 10 The five collaboration platforms of THU



Source: The office of S&T collaboration of Tsinghua University.

3.4.3 A reflection on the collaboration platforms of Tsinghua University

The example of TUH demonstrates how a Chinese elite university can be integrated into the system of innovation in the Chinese context. Freeman (1987) defined the system of innovation as the network of public and private organisations whose activities initiate, modify, and diffuse new technologies. The first two TUH platforms are the joint research institutes, which produce and diffuse technological knowledge in support of economic development. These platforms represent a traditional collaboration pattern, in which the 'third mission' of universities is achieved by utilisation of the rich S&T resources held by universities.

In contrast, the third and fourth platforms are not R&D oriented. As Lundvall (1992a) has noted, actors in the innovations system interact in the production, diffusion, and use of not only technological knowledge, but also of new and economically useful knowledge. Although this knowledge may not directly assist firms' new product/process development, it is relevant to their new business practices and economic performance. With regard to the specific collaboration activities in the third and fourth platforms (e.g., consultancy services, conference/seminars, short visits), the social impact of THU was achieved through such non-R&D collaborations. Instead of gaining specific, sophisticated, technological knowledge, firms engaged in these collaborations can get access to frontier-technology information which they can use to better adjust the direction of their in-house R&D activities. Meanwhile, through face-to-face meetings, firms can get technical/managerial advice from THU researchers, and use such advice to introduce incremental innovations. In addition, compared to the joint research institutes, firms collaborating through these two platforms enjoy a high degree of flexibility that requires less financial investment. For example, the costs of the third platform are covered by local governments, and the fourth platform (ECC) requires no financial investment at all. For THU, such platforms enable its academics to delve further into real-life practices, which is especially relevant to subjects in the applied sciences (e.g., engineering). Although THU may not be able to produce short-term financial returns from these collaborations, they nevertheless represent an important pathway to creating wider impact in the innovation system.

In the innovation system, universities can collaborate with governments by undertaking government-sponsored research, and such collaborations are considered to be an important element in the Triple-Helix model (Etzkowitz and Leydesdorff 1995; Abbas et al. 2019). However, in addition to the economic benefits produced by university research, collaborations between university and government can also produce wider social benefits. For example, the last platform, the S&T collaboration funds, promotes the effective use of public R&D expenditure and further shapes the institutional environment for innovation. Moreover, of the five THU collaboration platforms, three of them are established with government (provincial/city level). This aligns with the viewpoint that, despite the more important role assigned to the market mechanism and public universities by China's recent S&T reforms, governments are still essential and rife to the current Chinese innovation systems (Liu et al. 2017; Lei et al. 2019; Rodríguez-Pose and Zhang 2020).

3.5 Conclusion

Due to its significant progress in innovation capabilities and economic developments, China provides a rich context for the study of innovation and its relevant network/systems. The previous chapter undertook a systematic review of the literature concerning U-I innovation collaboration, and a comprehensive framework was presented with regards to its drivers, channels, outcomes, and key success factors. However, the extant literature mostly focuses on the developed economies, in which the allocation of innovation resources is often a response to market dynamics (Klingebiel and Rammer 2014). China, in contrast, has been recognised as a newly industrialised economy with a top-down governance model, and its innovation activities are more influenced by institutional factors, such as government policies, initiatives, laws, and regional legislation (Li et al. 2020c). Therefore, before investigating the empirical relationship between U-I collaboration and innovation, it is necessary to first review China's relevant institutional environment, and then examine how the U-I collaboration is embedded in the Chinese innovation system.

We began this examination by looking into the rationales for the shift of the long-term economic development strategy from 'made in China' to 'innovated in China'. The deterioration of the external economic environment and the disappearance of China's internal demographic advantages indicate that the traditional economic growth model may not be able to support sustainable growth in the future. Therefore, in line with Schumpeterian theory, the Chinese government expects technological progress to be at the core of its economic development, and the focus of policy is now on creating and improving the national and regional innovation systems to promote technological progress (Gu and Lundvall 2006).

We then examined the national innovation system of China in terms of the historical developments, key actors, and policies/programmes. The Chinese NIS diverges from its US/European counterparts in two ways. First, unlike the interactive approach promoted by Lundvall (1992a), the NIS in China largely follows a top-down structure, in which government plays a fundamental role in the formulation and execution of R&D projects. Second, public research institutions (e.g., CAS) and the state-owned enterprises (SOEs) are key actors in NIS, whereas in the developed economies, private enterprises/research institutions play a crucial role in the innovation system. Although it has been argued that the unique structure of the Chinese NIS may inhibit the growth of private firms (Augier et al. 2016), its contribution to technological progress in some key strategic areas (e.g., renewable resources) cannot be denied.

We also provided an overview of the Chinese regional innovation system by investigating the three most developed regions: Yangtze River Delta, Pearl River Delta and the Jingjinji Economic zone. Although regional economic disparities remain a major issue in China, these three developed regions have successfully established regional innovation systems, which are not only specific to their local industries but are also well-integrated into the national system of innovation. However, as suggested by Rodríguez-Pose and Wilkie (2016), China's coastal agglomerations are pulling innovation resources away from their neighbouring provinces, and they are therefore detrimental to the nation's sustainable developments. Lastly, as a critical part of the system of innovation, the UIC model in China is strongly influenced by government policies and public R&D projects. Indeed, universities can exert impact through formal R&D collaborations as well as through non-R&D collaborations. As such, we reviewed how Chinese universities are integrated into the innovation system with the specific example of Tsinghua University.

Limitations in the innovation systems can be identified through our investigation of the Chinese context. First, as the previous innovation trajectory followed an 'introducing, imitating, and improving' strategy, the importance of indigenous innovation has not received sufficient attention from Chinese firms (Howell 2017). By setting foreign multinationals as their 'innovation benchmark', Chinese firms are highly dependent on foreign technology and they lack the ability to introduce their own ground-breaking innovations (Fu and Gong 2011). Thus, as public investment in the manufacturing industries increases, their marginal productivity is actually decreasing. Another issue caused by low-end manufacturing is the deterioration of the natural environment, as in air pollution and waste of water resources. In this regard, technological innovations, especially those related to new energy and cleaner production, are required for tackling important environmental issues.

Second, the current system lacks an effective mechanism that encourages internal collaboration between key players, such as firm-firm and university-firm collaboration (Attour et al. 2015). The cause of this lack of innovation collaboration can be traced back to the centrally planned system in which each economic department/player has its own assigned role in the system, and these roles are highly compartmentalised. Furthermore, as most Chinese universities have a stable public funding source, the incentives for engaging in industrial collaboration are not as strong as they are for their western counterparts (Wu 2010). Meanwhile, according to Liu et al. (2017), Chinese academics are mainly evaluated and promoted according to their number of publications. Hence, individual researchers also lack the motivation to contribute to industrial innovations. The current U-I interactions are mainly between elite universities and large industrial firms, such that in 2019, each first-tier university has engaged with, on average, 61 collaboration programmes, whereas regional universities only engaged in 8.

Third, previous innovation policies and projects share a common feature, which is a reliance on huge financial investments (e.g., funds, subsidies) and extensive preferential policies (e.g., tax, land, energy). Whilst these policies and projects have accelerated the catch-up stage of China's innovation capabilities, they have also generated a negative impact on future development. Due to the unique bureaucratic system in China, the allocation of public funds and subsidises is often associated with rent-seeking behaviours (Cao et al. 2015). Scientists, firms, and research institutions that have good connections with government are over-funded, while many young scientists see their promising research proposals excluded from public funds. To obtain financial benefits from the government, publication inflation, fraud, and even corrupt behaviours are not rare in the Chinese academic community. This 'bad money drives out good' phenomenon (Gresham's Law) (Rolnick and Weber 1986), results not only in inefficiencies in the use of public R&D resources but also severely impedes the development of R&D capability in Chinese firms. Another issue caused by the reliance on public support can be found in the burgeoning of international trade conflicts (Carbaugh and St Brown 2012; Li 2018). As Chinese firms, especially manufacturing firms, are over-subsidised in the guise of R&D support, such firms acquire an unfair advantage when competing with foreign rivals in the global markets. As such, China's industrial products are increasingly becoming the subject of anti-dumping accusations by western governments. Therefore, while financial support is clearly important for firms, more flexible R&D policy tools should be explored in the future.

By examining the Chinese innovation systems from an institutional perspective, this chapter enables an empirical investigation of U-I relations and their impacts on innovation. China has been recognised as a newly industrialised economy with a top-down governance model, and its innovation activities are mainly led by government rather than the market (Rodríguez-Pose and Zhang 2020). Collaborations between universities and firms, as a key element in the system of innovation, are not exempt from the influence of government. Hence the need to examine in this chapter how institutional factors, such as public policies/projects, have shaped the systems of innovation as a precursor to an empirical investigation of UICs in China. The next two chapters empirically discuss the two forms of U-I collaboration: Contractual Collaboration and Relational Collaboration. Compared to the major developed economies in the world, the innovation collaboration network was formed relatively late in China, but there has been a growing trend in the interactions between Chinese universities and manufacturing enterprises. As a newly industrialised economy, the Chinese context is especially relevant to investigate whether and how firms can benefit from the U-I collaboration in terms of innovation and economic performance. Moreover, implications from the Chinese manufacturing industry would also be relevant to economies that share similar features, such as India and Brazil.

Chapter 4 Contractual Collaboration, Innovation and Firms' Performance

4.1 Introduction

Successful innovation is argued to be a key source of regional development, and the rate of technological change in a specific region is determined by the number and quality of collaborations between the partners involved in the innovation system (Freeman 1987). In this regard, the importance of the University-Industry Collaboration (UIC) has been widely recognised in both theory and practice (Siegel et al. 2003; Ankrah et al. 2013; Stenbacka and Tombak 2020). For firms, getting access to university expertise and facilities can accelerate the speed of new product development. Through a variety of UIC activities, university knowledge enhances a firm’s R&D productivity and innovative capacity, increasing its financial gains (Siegel et al. 2003). UICs are also beneficial to universities. It has been indicated that many publicly-funded universities are now under great financial pressure, as public funding becomes ever more squeezed (Stenbacka and Tombak 2020). Hence, collaborations with industries and communities enable universities to diversify their income sources. Aside from the monetary incentives, researchers’ engagement with industries is motivated by other factors, such as learning from industrial practice and gaining a reputation in industry communities (Ankrah et al. 2013).

However, business collaboration with universities is not an easy task. In practice, the process of the UIC is often associated with high costs, which may stymie the engagement of small and medium-sized enterprises (SME) in UICs. This is especially the case in emerging economies, where SMEs are mostly downstream of the industrial chain and are not capable of making heavy investments in R&D collaboration with universities (Handoko et al. 2014). However, SMEs can sidestep the formal R&D collaboration to benefit from personal contacts with university researchers (Bennat and Sternberg 2020), but such personal contacts can also incur higher transaction costs if they are extra-regional. It is not just SMEs that face difficulties in engaging in UICs. Large firms, too, can be disadvantaged when collaborating with universities. Caraça et al. (2009) indicate that R&D collaboration with universities is characterised by a high level of uncertainty, as it is difficult for the expected outcomes and time length to be projected ahead. Ankrah et al. (2013) further argue that academic research can be too theoretical and somewhat irrelevant to commerce. Large public firms highly prioritise their short-term financial performance (Geyskens et al. 2002), suggesting that they may view R&D collaboration with universities as too risky if it cannot guarantee the delivery of short-term financial benefits.

Despite numerous studies on the UIC, previous literature has failed to resolve at least two issues. First, the role of universities in supporting firms’ innovation activities has been questioned, given the finding that U-I collaboration should be combined with other types of collaboration for technological innovation (Gonzalez-Pernia et al. 2015). Firms’ new product development is a complex process that requires not only cutting-edge research outputs, but also experiential knowledge from other partners (e.g., customers, suppliers, or competitors) to transform a novel product design/prototype into a manufacturable, profitable product. Another issue, as indicated by Pippel (2014), is that studies on the impacts of R&D collaboration are largely focused on technological innovation, whereas studies that offer insights into how non-technological innovation can benefit from U-I collaboration are scarce.

This paper contributes to the current literature in the following ways. First, we examine whether, and how, firms can benefit from a contractual collaboration with universities in terms of technological innovation. Echoing previous studies (Poppo and Zenger 2002; Garcia-Perez-de-Lema et al. 2017), the contractual UIC mode in this study was built by grouping the UIC channels that share similar attributes (higher transaction costs and bonded by a formal agreement). By investigating the relationship between contractual collaboration and technological innovation, we join the debate on whether investing in formal R&D collaboration is beneficial to a firm's technological progress; this issue is relevant to both large firms and SMEs. Second, we examine the impact of contractual collaboration on the management innovation of firms (i.e., a new organisational practice/marketing method), which has been seldom discussed before. This paper reveals how a firm's management innovation can occur as a direct outcome of the UIC and of the technological innovation that comes from university knowledge. For instance, the new product design acquired from a university may cause adjustments in the firm's current manufacturing/marketing methods. Such a mediating effect is especially relevant to understanding the importance of the UIC, as this transforms university knowledge into a firm's technological advantage, enabling the push for innovative organisational practices and better economic performance.

This paper also helps to understand the roles played by geographical proximity and research quality in U-I collaboration. The impact of geographical proximity on interactive learning is a key issue in innovation studies. Previous literature has underlined the importance of geographical proximity in knowledge dissemination (Jaffe et al. 1993; Howells 2002), suggesting that being located close to universities will enable firms to better absorb the tacit knowledge held by university researchers. Spatially concentrated agents benefit most from the knowledge externalities, and short physical distances facilitate the exchange of information. Boschma (2005a), however, questioned the role of geographical proximity in innovation, claiming that 'geographical proximity is neither necessary nor sufficient for innovation collaboration'. As such, this paper examines whether collaborating with local universities has stronger impacts on a firm's innovation outputs, especially in terms of management innovation, which, it has been argued, relies more on tacit knowledge (Hall and Andriani 2003).

Meanwhile, the positive association between the research quality of universities and the innovation performance of their industry partners has been widely recognised (Geldes et al. 2017). However, the research quality of university may not always be a strong predictor of better industrial innovation (Atta-Owusu et al. 2020), and the knowledge from lower-ranked universities can also be an important source of a firm's technological advances. Although lower-ranked universities may not be able to conduct cutting-edge scientific research, most of these universities are applied-science oriented, making them valuable partners for firms that are seeking incremental improvements to their current product/manufacturing process. Using empirical data from China, this paper examines whether significant differences exist in innovation outputs when firms collaborate with higher-ranked universities vis-a-vis lower-ranked universities. This paper's inclusion of variables of proximity and research quality may generate frictions, since the two variables are in the scope of meso economics and are at different analytical levels. However, we address this issue by taking proximity and research quality as binary variables for the group analysis. This can help in addressing the heterogeneity of latent variables and enables comparisons to be made of the effects of explanatory variables in different groups (Kuha and Mills 2020).

The next section introduces the theoretical background and presents the conceptual framework, followed by a description of the research method in Section 3. Section 4 presents the statistical results and discussion. The conclusion is provided in Section 5.

4.2 Theoretical background and hypotheses

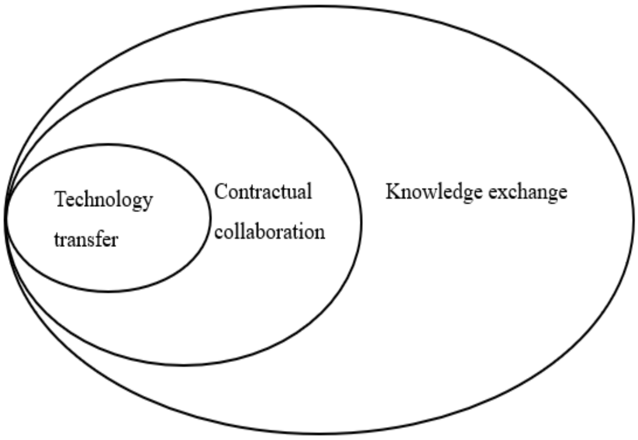
4.2.1 Technology transfer, knowledge exchange and contractual collaboration

Depending on the theory, firms collaborating with external innovation partners are seeking either substitute knowledge or complementary knowledge. The Transaction Cost theory holds the view that, given the high costs associated with R&D, the choice between internal development or external procurement of novel knowledge is motivated by minimising transaction costs. By collaborating with an external partner, firms can share with their partners the costs and risks of R&D (Martino and Polinori 2019). In contrast, the Resource-Based View proposes that firms' collaboration is aimed at gaining complementary knowledge that cannot be developed internally (De Faria et al. 2010). In particular, collaborating with universities and other research institutions provides firms with access to cutting-edge knowledge and advanced scientific facilities, and this serves as an important complement to the firm's in-house R&D (Ponds et al. 2010).

Responding to these two theories, researchers have suggested that firms can collaborate with universities either via technology-transfer channels or by deploying a knowledge-exchange mode of collaboration (Hayter et al. 2020). As the term itself implies, technology transfer is a linear process in which the technology is first developed by university researchers, and then transferred to firms via channels that include contracted research and the licensing/sale of patents, so it can be commercialised in the marketplace by firms. Although the technology-transfer that occurs in a U-I can be a direct source of technological innovation for firms, it has been argued that this pathway fails to capture the complexity of U-I collaboration (Hagen 2008) because it neglects other bidirectional channels of UIC (e.g., joint research). Hence the proposal of recent studies that U-I collaboration be regarded as an interactive system, where technical issues or industrial needs give rise to university research, and universities and firms work jointly to address these issues/needs (Christopherson et al. 2008; Hayter et al. 2020). Unlike technology-transfer, this interactive system of collaboration method is a two-way process, in which the research outputs come from the interactions and exchange of knowledge between firms and universities.

Despite the different theories and collaboration methods, it is evident that U-I collaboration requires investment from firms in the form of human resources, time, and finance. Echoing previous literature, contractual collaboration requires higher levels of financial investment and is often costly to firms (Poppo and Zenger 2002; Garcia-Perez-de-Lema et al. 2017). In essence, contractual collaboration is a transaction behaviour that includes all channels of technology transfer in addition to some specific channels of knowledge-exchange activities (e.g., joint research, sharing university facilities). It is worth noting that while a formal R&D collaboration is a typical form of contractual collaboration, this is not the case for an informal R&D collaboration that takes place without requiring any financial investment (e.g., where it is an informal exchange of ideas between R&D staff). Figure 11 depicts the relationship between technology-transfer, contractual collaboration, and knowledge exchange between the university and firms. As technology transfer involves greater financial investment and the use of formal contracts between university and industry (U-I), it is an element of contractual collaboration. Contractual collaboration is only one aspect of the knowledge exchange activities that occur in collaborations, as knowledge exchange channels can incorporate other non-contractual channels (e.g., informal contacts between staff).

Figure 11 Technology transfer, contractual collaboration and knowledge exchange



4.2.2 Contractual collaboration and innovation

Technological innovation at the firm level refers to a new or significantly improved product/manufacturing process (OECD 2005). March (1991) argues that organisations' learning behaviours can be explained either by the 'knowledge-exploitation' aimed at detecting and utilising ready-to-use external knowledge, or by 'knowledge-exploration' in which firms work with external partners to search out and develop new knowledge. In U-I contractual collaborations, firms can exploit the intellectual properties of the university by purchasing patents or acquiring licences to use the university's knowledge. Alternatively, firms can sponsor academic research that relates to the firm's technological needs or they can arrange a contract for their R&D projects with the universities. This so-called 'sponsored/contract research' has been an important route to product innovations in the developed economies since the 2000s. For example, in 2009 alone, US firms sponsored over 4 billion dollars' worth of academic research (Moon et al. 2019). Further, the contractual collaboration enables universities and firms to engage in problem-solving activities through different channels, such as joint research, formal consultancies, sharing specialised equipment, etc. Such knowledge-exploration activities boost a firm's technological capability by combining and optimising the resources held by both parties, thereby increasing the firm's expertise to solve practical manufacturing issues; knowledge exploration is, therefore, highly relevant to process innovation (Mateos-Garcia and Sapsed 2011).

It is evident that a firm's innovations are not always associated with technological progress. The third version of the Oslo Manual (OECD 2005) has expanded the definition of innovation to incorporate non-technological innovation. Non-technological innovation, also referred to as management innovation, includes both organisational (e.g., organisational structure) and marketing innovation (e.g., new pricing strategy). Compared to technological innovation, the literature on the association between R&D collaboration and management innovation is scarce (Pippel 2014). It has been identified that firms that collaborate with customers, suppliers, and competitors through the Doing-, Using- and Interacting-based (DUI) innovation mode are more likely to introduce non-technological innovations (Apanasovich et al. 2016), but it is unclear whether formal R&D collaboration with universities contributes to such innovations. Damanpour and Aravind (2015) find that acquiring knowledge from external organisations is an important source of management innovation. Although a management innovation may have originally been developed and adopted by one organisation, it can be disseminated to other firms with the involvement of external agents (e.g., spin-offs, consulting firms). For example, some innovative management tools, such as GE's Six Sigma and Toyota's Lean Production System, have been widely disseminated to the world by business schools/consulting agencies. In this regard, the university is an important source of management innovation knowledge. Also, by conducting basic research, universities are capable of providing to firms the cutting-edge knowledge necessary for attaining a more radical type of management innovation. For example, the firms' innovative product promotion strategy can be founded on joint research on consumer psychology and marketing management. Furthermore, the introduction of management innovation requires a combination of knowledge from different subjects (Pippel 2014). To re-organise the administrative structures of firms, managers are expected to be knowledgeable about psychology, organisational management, and even sociology. Universities that conduct research in many different subjects can provide this level of diversified knowledge to firms. Based on the above arguments, we propose that:

H1 Contractual collaboration has a positive impact on firm's technological innovation

H2 Contractual collaboration has a positive impact on firm's management innovation

Management innovation is influenced by determinants other than the UIC. Schmidt and Rammer (2007) conclude that the competitive environment, the firm's characteristics, and labour productivity are the three major determinants that influence a firm's management innovation. An important strand of the literature on innovation studies focuses on the complementarity between technological innovation and management innovation, in which the latter has been argued to be a critical driver of the former (Mol and Birkinshaw 2013). For example, management innovation brings flexible work routines and cultivates creativity in the workforce, which may bolster the introduction of product innovation. However, another strand of literature supports the notion that technological innovation leads to more organisational changes and innovative marketing methods (Khosravi et al. 2019). Drawing on data from Spanish firms, González-Blanco et al. (2019) find that technological innovation positively affects the introduction of marketing innovation, as the updated products often lead to new product offerings and a new pricing strategy. To ensure a newly introduced product's market success, the firm may need to establish a new sales team and create an innovative promotion strategy. Compared to the 'pull effect' of management innovation on a firm's technological progress, technological innovation has a 'push effect' on a firm's new managerial practices. In collaboration with Cranfield University, the UK automobile manufacturer Jaguar Land Rover has successfully developed three types of hybrid electric vehicle, which are now leading a shift in the company's marketing strategy aimed at building a more environmentally friendly public image. In this sense, the technological innovation attained from UIC positively mediates the relationship between contractual collaboration and management innovation. We therefore propose that:

H3 Technological innovation positively mediates the impacts of contractual collaboration on management innovation

4.2.3 The moderating role of proximity

Although university knowledge complements a firm's internal R&D capability, Jaffe (1989) finds that this spillover of knowledge is normally bounded within a certain geographical distance and that the effect will weaken as geographical distance increases. When the knowledge is more a type that is tacit and sticky, the geographic proximity of firms is likely to have a stronger effect on the outcomes of the knowledge exchange (Morgan 2004). This argument finds its roots in the theory of knowledge management, which proposes that the transfer of tacit knowledge requires frequent face-to-face interactions and a high degree of mutual trust (Nonaka and Toyama 2005). Proximity to the university can therefore be more relevant to a firm's management innovation as this relies on practical, experience-based knowledge. Unlike technological knowledge, the source of management-related knowledge is more tacit in nature, and it must be acquired through frequent contacts and a higher degree of trust (Pippel 2014).

However, such face-to-face interactions do not necessarily imply that the co-location of knowledge producer and knowledge user must be permanent. First, the rapid development of information technology has given people a rich choice of platforms for the exchange of video/audio information, which enables them to communicate with their business partners in a face-to-face manner without having to actually be together. Second, evidence is mounting that temporary geographical proximity, which can take the form of short visits, expos, conferences, etc., may be sufficient for effective knowledge exchange (Rychen and Zimmermann 2008; Torre 2008; Torre 2011; Lavoratori et al. 2020).

Akin to the proximity created by information technology, such temporary geographical proximity helps bring organisations together without requiring permanent co-location, and it can act as a substitute for geographical proximity in collaborations that require less face to face interactions (Werker and Ooms 2020).

Further, the impacts of geographical proximity can be hindered in other ways. Geographical proximity does not imply a steady territorial relationship because proximity is a complex concept, in which the organisational, social, institutional and cognitive proximities are all important elements in the collaboration network (Boschma 2005a). Moreover, the formulation of innovation benefits from heterogeneous knowledge, and too much proximity may result in a lack of openness, hobbling the new knowledge-learning behaviour (Boschma 2005a; Boschma and Frenken 2009). As such, geographical proximity is not a sufficient condition for innovation, because innovation significantly benefits from the interactions of different dimensions of proximity (Fitjar et al. 2015). In the context of China, where institution settings play a more significant role in the collaboration network (Chesbrough et al. 2020b), the importance of geographical proximity could be further weakened. We therefore argue that:

H4 The effect of contractual collaboration on management innovation will not differ significantly whether collaborating with local vs non-local universities.

4.2.4 The moderating role of research quality

Academic and financial resources are unevenly distributed among universities with different rankings; consequently, universities demonstrate different levels of research quality. Research quality, reflecting both the quality and quantity of university scientific research, affects not only the academics' willingness to participate in a U-I collaboration, but also the expectation of innovation outcomes from partners (Frey and Rost 2010; Perkmann et al. 2011). Universities with high research quality are generally focused on cutting-edge science and are in a leading position in basic research; this is beneficial to a firm's technological innovation (Tang et al. 2019). For example, pharmaceutical firms strongly rely on the latest discoveries in biochemistry, which are mostly originated in major universities and public research centres. In contrast, universities with a lower research quality possess fewer academic resources and are more specialised in community programmes and teaching activities, making it difficult for them to make similar contributions to a firm's technological innovation activity (Laursen et al. 2011).

That is not to say that research excellence is a must-have condition for the collaboration between university and industry. Atta-Owusu et al. (2020) argue that universities pursuing research excellence may produce a gap between the production of knowledge and the needs of local industries, and the authors' empirical finding suggests that the research quality of universities can even exert a negative impact on UIC. In contrast, lower-ranked universities can be a valuable partner to firms' technological innovations. Ali (1994) dichotomised innovation as 'pioneering' (radical) or 'incremental' and notes that incremental innovation can take the form of a modified version of existing products/process. The Oslo Manual (OECD 2005) further confirms that innovation can include 'new to firm' as well as 'new to market/world'. Although lower-ranked universities may not be able to provide their partner with cutting-edge research outputs, the limited public funding of many such institutions leads them to be practice-oriented and more open to industrial collaboration (Perkmann and Walsh 2007a). In this sense, firms seeking improvements in their existing products/manufacturing process can benefit from the practical knowledge held by researchers in lower-ranked universities. In fact, collaborations with lower-ranked universities represent an important path to industrial innovations in both the developing and developed countries (Guimón 2013; Fitjar and Gjelsvik 2018). As such, we propose that:

H5 In the context of lower ranked universities, the impact of contractual collaboration on technological innovation is likely to be as significant as in the context of higher ranked universities.

4.3 Research method

4.3.1 Data collection and samples

Data employed in this research was gathered through a questionnaire submitted to Chinese manufacturing firms randomly selected from the following seven provinces/metropolitan regions: Guangdong, Jiangsu, Zhejiang, Shandong, Henan, Beijing, and Shanghai. According to the National Bureau of Statistics, these are the top seven regions in the provincial GDP ranking (NBS 2019). China has a large geographical territory in which the regional development level varies greatly. We specifically targeted these seven regions because they have relatively similar institutional environments, enabling sample selection bias to be better managed (for example, 15,601 and 17,918 USD GDP per capita 2019 in Zhejiang and Jiangsu, respectively). The targeted respondents of the questionnaire were people in management positions, including general managers, CEOs, and R&D managers. As management-level staff are more familiar with the performance of firms (Garcia-Perez-de-Lema et al. 2017), the data collected is more accurate and reliable for academic research.

For this survey, a questionnaire was developed following an extensive review of the literature and existing innovation surveys. The first section of the questionnaire collects general information from firms that includes their geographical location, year of establishment, main products, and the average number of employees for the past three years, etc. The second section asks respondents to use a five-point Likert scale to evaluate their use of collaboration channels in the last three years (2016-2018). The third part collects data on firm innovation outcomes that benefited from the collaboration with universities. The design of this section echoes Eurostat's Community Innovation Survey 2016 and the National Enterprise Innovation Survey 2019 by the Chinese National Bureau of Statistics, which evaluate the radicalness of technological innovation and the importance of management innovation.

The survey was conducted in different stages. The first step was to translate the cover letter and questionnaire into Chinese with the help of two Chinese academics from the research field. Second, two consecutive rounds of the pilot study were carried out to test the length, reliability, and readability of the questionnaire. The first round of the pilot survey was carried out in China, for which 12 face-to-face interviews with business managers were conducted. We then further tested the questionnaire by enlisting a reputable academic survey company to distribute it to manufacturing firms in our sampled regions. Results from the two rounds of pilot surveys were used to modify and refine our questionnaire items. Lastly, the formal survey was launched in December 2019, yielding 832 returned questionnaires. After questionnaires with omitted data were discarded, we were left with a final sample of 395 questionnaires.

4.3.2 Measurements

In the realm of inter-organisational collaboration studies, the concept of **contractual collaboration** is used to describe the transactional relationship dominated by the implementation of formal contracts (Poppo and Zenger 2002). With U-I collaboration, not all interactions come under the category of contractual collaboration as some of them may be associated with very small investments from firms and are not bonded with formal contracts (e.g., informal contacts between staff). As stated by Garcia-Perez-de-Lema et al. (2017), a contractual collaboration between U-I has a formal governance structure and it must be aimed at improving the firm's R&D capabilities. Based on their measurement scales for U-I contractual collaboration, we added relevant channels from the U-I technology-transfer and knowledge-exchange activities (Fernandez-Esquinas et al. 2016; Moon et al. 2019) to ensure comprehensiveness of our questionnaire. In the end, six measurement items were established (Table 5), and the scales are based on five-point Likert scales (1, not engaged; 5, frequently engaged).

As innovation at firm-level can take place at both technological and non-technological level, the objective indicators (e.g., number of patents, sales from new products) used in previous studies may not reflect the variety of innovation types. Therefore, this study measures innovation by the self-reported scales recommended by the Oslo Manual (OECD 2005). Specifically, we measured two types of innovation. ***Technological innovation*** refers to new or significantly improved products and processes, while ***management innovation*** includes new or significantly improved organisational practices and marketing methods. Echoing the measurement items employed in CIS 2016, we adopted three items to measure technological innovation and four items to measure management innovation. Five-point Likert scales were adopted to separately measure the radicalness of technological innovation and the importance of management innovation. Similar innovation scales were used by Azar and Ciabuschi (2017). Measurement items can be found in Table 5.

Firm's **proximity** to universities can be measured by the log of the geographical distance, or by scales that are based on geographical distance (Laursen et al. 2011). Following Tang et al. (2019), this study uses a binary variable to investigate whether collaborating with local/non-local universities has influenced collaboration outcomes. Specifically, we asked the respondents to provide the name of their university partner and we checked the university's geographic location against the firm's. We define the university as a 'local' university if it is located in the same province as the firm, otherwise it is referred as a 'non-local' university.

To measure **research quality** of universities, we established a binary variable to distinguish the higher-ranked universities from the lower-ranked universities. The Chinese government launched two funding initiatives in the early 1990s, namely the '985' programme (39 universities) and the '211' programme (116 universities). The universities that were funded under these two programmes were considered to be outstanding in terms of research quality, and they have received extensive support from central government (Chen et al. 2016). In the literature, the '985' and '211' programmes are widely used as indicators of the ranking and research quality of Chinese universities (for example, see Tang et al. 2019). This study refers to collaboration partners that are listed in these two programmes as higher-ranked universities, and all others are referred to as lower-ranked universities.

4.3.3 Statistical technique and exploratory factor analysis

This research uses the structural equation modelling (SEM) to analyse the measurement model and the proposed hypotheses. LISREL 8.80 was used for measurement validation and path analysis. We also adopted SmartPLS 3.2.8 to examine the proposed paths and moderating effects. In addition to LISREL, path analysis performed by PLS can serve as the methodological triangulation, by which the robustness of results can be confirmed (Garcia-Perez-de-Lema et al. 2017).

To validate the questionnaire and measurements, the exploratory factor analysis (EFA) was performed. We assessed the items of each construct with the Cronbach's alpha coefficients. The coefficient values for CC, TI and MI are 0.84, 0.85 and 0.89, all of which are beyond the 0.7 cut-off value for good reliability (Cortina 1993). The Kaiser-Myer-Oklin (KMO) value 0.903 and the Bartlett sphericity test $p<0.001$ suggesting our data is suitable for further analysis. The Harman's single-factor analysis helps us to examine whether common method bias exists in our samples, as data were collected from the same respondents in each firm. Three constructs were extracted with eigen>1 and the main construct accounted for less than 40% of the total variance, confirming the common method bias is not a severe issue in our study (Podsakoff et al. 2003). In addition, all items were loaded on the expected factors without cross-loading, ranging from 0.66 to 0.85. The multicollinearity test shows the variance inflation factor (VIF) of all 16 measurement items ranges from 1.434 to 2.349, suggesting the multicollinearity is less of an issue in our research.

4.4 Results and discussion

4.4.1 Descriptive statistics and measurement validation

Firms in our sample are distributed in seven regions, including: Beijing (n=42), Shanghai (n=57), Guangdong (n=73), Zhejiang (n=47), Jiangsu (n=70), Shandong (n=69) and Henan (n=37). In terms of industries, the electronic communication device takes the most firms in our sample (59), followed by chemicals industry and office machinery (49 and 47, respectively). Other firms located in a wide range of manufacturing industries including rubber and plastic, non-electrical machinery and textile and clothing, etc. Among all the 395 firms, 217 have collaborated with an elite university (i.e. universities listed in 985/211 programme), and 178 have collaborated with universities with lower research quality. According to the National Bureau of Statistics of China (NBS 2017), firms with less than 1,000 employees are defined as SMEs due to the size of Chinese population and economy. In our sample, 165 firms are large firms and 230 are SMEs. For questionnaire respondents, 45% of them are in the top management teams (n=178), whereas 55 % are in the middle management (n=217).

We performed the confirmatory factor analysis (CFA) for constructs employed in this research. To indicate good convergent validity, Fornell and Larcker (1981) recommend the composite reliability (C.R) and the average variance extracted (AVE) to exceed 0.6 and 0.5, respectively. In addition, it is recommended that the AVE square root must be higher than the correlation between constructs to indicate good discriminant validity. In this study, the CR and AVE for each construct are: $CC_{C.R.}$=0.87, CC_{AVE}=0.52; $TI_{C.R.}$=0.85, TI_{AVE}=0.66 and $MI_{C.R.}$=0.90, MI_{AVE}=0.57, showing excellent convergent validity of constructs (Table 5). Table 6 demonstrated that discriminate validity is also confirmed since the square roots of AVE are all higher than the correlation coefficients. Table 6 also confirmed that contractual collaboration is significantly correlated with technological and management innovation, and the correlation can also be found between the two types of innovation. The full structural model incorporating all three constructs was assessed by the model fit statistics. Overall, the fit statistics suggesting a good fit of data as χ^2=170.72, d.f.=101, GFI=0.95, AGFI=0.93, CFI=0.99, NNFI (TLI)=0.99 and RMSEA=0.042.

Table 5 Measurements validation

Constructs & items	**Standardised factor loading**	**t-value**	**Cronbach' alpha**	**CR**	**AVE**
CC			0.835	0.87	0.52
Consultancy service provided by the university	0.657	12.81			
research grant/ scholarship	0.690	13.59			
Joint/contract research	0.727	14.55			
Patent/license transaction	0.765	15.26			
Use of university facilities (e.g. labs, offices, science park)	0.733	13.59			
Joint venture establishment	0.760	16.15			
TI			0.848	0.85	0.66
New product	0.833	19.35			
New method of manufacturing	0.853	19.75			
New supporting activities such as purchasing, logistics, accounting	0.745	15.80			
MI			0.892	0.90	0.57
New business practice	0.782	17.72			
New organisational structure	0.673	14.76			
New external relationship	0.767	16.87			
New packaging	0.752	16.61			
New method of promotion	0.786	17.42			
New sales channel	0.821	17.67			
New pricing strategy	0.694	14.90			

Table 6 Constructs correlation and the square roots of AVE

	Variable	**1**	**2**	**3**
1	CC	1 (0.72)		
2	TI	0.47***	1(0.81)	
3	MI	0.38***	0.55***	1(0.75)

Note: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

4.4.2 Contractual collaboration and innovation

As can be seen from Table 7, the contractual collaboration has a positive effect on the technological innovation of firms (β=0.47, t-value=8.02), thus the first hypothesis was supported. The second hypothesis proposed that contractual collaboration positively affects the management innovation of firms, and it is confirmed as β=0.15, t-value=2.58. Compared with technological innovation, the effects of contractual collaboration on management innovation is much weaker, though significant at $p<0.05$ level. As a prerequisite of the mediating effect of technological innovation (H3), technological innovation should positively influence management innovation of firms. This is confirmed by our results as the path coefficient 0.49 significant at $p<0.001$ level (t-value=7.66). A similar conclusion was drawn by PLS-SEM, suggesting the results of path analysis are consistent with different statistical approaches.

Table 7 Structure model results

Path	Standardised parameter estimates (LISREL)		Path analysis (PLS)	
	Coefficient	T-Statistics	Coefficient	T-Statistics
CC → TI	0.47***	8.02	0.41***	9.29
CC → MI	0.15*	2.58	0.15**	2.76
TI → MI	0.49***	7.66	0.45***	7.01

PLS model fit: R^2_{TI} =0.17, R^2_{MI} = 0.28. Bootstrap with 5,000 subsamples.

P<0.05 *, P<0.01 **, P<0.001 ***

The result of the first hypothesis is in line with prior literature that supports the positive relationship between formal R&D collaboration and the technological innovation of firms (Un et al. 2010; Bodas Freitas et al. 2013b; Moon et al. 2019). It has been argued that universities are gradually devoting more academic resources to applied research, thus supporting the technological development of their industry partners by transferring technology to firms (Perkmann et al. 2011). Firms then incorporate the novel technology in their new product/process development (sometimes with modifications) and achieve commercial success in the marketplace. Besides the technology-transfer between universities and firms, knowledge-exchange activities also contribute to the technological innovation of firms (Hayter et al. 2020). The knowledge-exchange activities bring together different parties, who discuss the technical issues faced by firms and jointly work on finding solutions. It is worth noting that technology-transfer is strongly associated with the radical innovation of firms, as the technologies transferred by the university are often new to the market, whereas the U-I's knowledge-exchange seems to lead to more incremental improvements to a firm's current technology base (Tang et al. 2019; Hayter et al. 2020). Although the R&D collaboration helps firms to introduce technological innovation, it is suggested that the U-I collaboration should be established through a formal contract as this helps to avoid opportunistic behaviour by ensuring the delivery of expected outcomes and the protection of intellectual property (Olander et al. 2010).

Our results also contribute to the scant literature discussing the impacts of U-I collaboration on the management innovation of firms. Pippel (2014) has criticised the current 'technological view' of U-I collaboration, and has confirmed that R&D cooperation with universities positively affects both organisational and marketing innovations. In our analysis, although the path coefficient is relatively small (0.15), it is nevertheless significant at the $p<0.05$ level. We therefore assert that some of the contractual collaboration channels can directly induce organisational change in firms. For example, sharing university facilities creates a platform where the firm's R&D staff can observe and imitate the way university experts organise and conduct their research; furthermore, new organisational routines may be established by firm's staff as a reflection of the observed knowledge. Similar effects can also be exerted by joint research in new product development, in which firms have an opportunity to discuss their commercial concerns about products with university researchers. They thereby deepen their understanding of the new technical attributes of products, which eventually leads to a more accurate market positioning strategy and a more competitive sales channel.

4.4.3 The mediating role of technological innovation

To further test this mediating effect (H3), we followed Baron and Kenny (1986) widely accepted method. Specifically, three regression equations are required to confirm the mediating effect as follows: (1) the independent variable x on the dependent variable y; (2) the independent variable x on the mediator m; and (3) regression of both x and m on y. The mediating effects can be confirmed if all three regressions are statistically significant and the path coefficient from x to y is significantly reduced in the third regression. In our analysis, the first condition was met as $\beta=0.38$, $p<0.001$, as was the second condition ($\beta=0.46$, $p<0.001$). After regressing x and m on y, results show that technological innovation significantly affects management innovation, and the path coefficients from contractual collaboration to management innovation significantly reduced from $\beta=0.38$, $p<0.001$ to $\beta=0.15$, $p<0.01$, confirming the mediating effects of technological innovation. To supplement the Baron and Kenny approach, we also performed the Sobel test and the bootstrap approach. The conclusions drawn by the Baron and Kenny approach and Sobel test can be somewhat conservative as they presume symmetric distribution, hence, it is advised to complement these tests with the bootstrap approach that does not assume normality of distribution (Bollen and Stine 1990). As Table 8 indicates, the mediating effects were confirmed by the Sobel test (significant z value) and bootstrap approach (confidence intervals do not contain 0).

Table 8 The Mediating effect of technological innovation

	Sobel test	**Bootstrap (95% CIs)**	
Dependent variable	Z	CI (percentile)	CI (BC)
Management innovation	5.51***	(0.121, 0.251)	(0.120, 0.249)

BC: Bias Corrected. ***p<0.001

Our result extended the academic discussion on the relationship between technological and management innovation since they show that technological innovation significantly affects management innovation (Table 7). The complementarity between innovation types has been extensively investigated by researchers (Lokshin et al. 2008; Damanpour 2010; Mothe and Thi 2010). With regard to specific innovation types, the impact of technological innovation on organisations is evident. Having new products may require firms to consider a new marketing method so that customers can easily differentiate the new offering from the existing products. Also, a new sales division may be needed to promote the new products, meaning that product innovation may also trigger changes in a firm's organisational structure. Similar effects can also be identified with process innovation, as the increased product quality/production capacity (a result of process innovation) must be accompanied by a new marketing approach to promote the improved product, or new sales channels to exploit the increased capacity.

Our confirmed mediating effects explain previous results that show weak direct impact of contractual collaboration on management innovation. Our findings indicate that management innovation is mainly the result of technological innovation. This extends our understanding of the role played by technological innovation in formal U-I collaboration. Previous studies have highlighted technological innovation as an outcome of U-I collaboration and have also confirmed its mediating effect between collaboration and a firm's financial performance (Garcia-Perez-de-Lema et al. 2017; Rua and França 2017). Our finding suggests that not only can firms benefit from university knowledge in new product/process development, but that these innovations may also lead to the innovative reform of organisational structures and business practices. Take, for example, a firm that purchases a patented manufacturing technology from a university. To commercialise this technology, the firm must first use it to refine its current production equipment (incremental process innovation), or even build a new set of equipment based on that technology (radical process innovation). However, having a new manufacturing method will not automatically generate better production performance unless the firm has staff in its employ who are already trained in the new/refined equipment's use. Otherwise, firms may need to hire a specialised workforce to utilise this new equipment (organisational innovation). From this perspective, the effect of the UIC on management innovation is through the introduction of technological innovation. In the literature, it has been suggested that collaborating with DUI partners (e.g., suppliers, customers, competitors) leads to more incremental improvements of a current product or process (Thomä 2017). Our study indicates that collaborating with universities may bring more holistic and profound changes into organisations, since both technological and management innovations are influenced.

4.4.4 Proximity and research quality

We are also interested in whether the effects of collaboration on innovation will be moderated by firm's proximity to universities and the university research quality, as proposed by hypotheses H4 and H5. As the results revealed (Table 9), there are no significant differences between the groups. In other words, neither the proximity nor research quality moderates the relationship between contractual collaboration and innovation.

Table 9 The moderating effects of proximity and research quality

Path	Comparison	Coeff. difference	p-value (parametric)	p-value (permutation)
CC→TI	Research quality (HR-LR)	-0.104	0.246	0.238
	Proximity (Local-NLocal)	-0.068	0.516	0.540
CC →MI	Research quality (HR-LR)	0.049	0.659	0.664
	Proximity (Local-NLocal)	0.083	0.550	0.567

Note: HR, Higher-Ranked universities; LR, Lower-Ranked universities. Sample size: HR=217, LR=178; Local=293, NLocal=102. $P<0.05$ *, $P<0.01$ **, $P<0.001$ ***

The insignificant results of the group analysis are interesting, as proximity has long been held to be a facilitator in U-I collaboration (Arundel and Geuna 2004). The nature of university knowledge involved in the collaboration can be identified as either tacit or codified, or mixed in some cases. Being geographically proximate enables partners to communicate frequently in a face-to-face manner, which facilitates the exchange of tacit knowledge, and firms may use this knowledge to introduce more management innovations. However, our results show that, in the Chinese context, collaborating with local universities does not have a stronger impact on firms' innovation outputs than if the collaboration were with non-local universities. This finding is aligned with the literature that refutes the positive effect of proximity on U-I collaboration (Petruzzelli 2011b; Hewitt-Dundas 2013b). Although proximity is important in knowledge exchange activities, permanent co-location is not always necessary due to the rapid development of communication technology. Today, partners communicate through a variety of technological tools (e.g., video meetings), and one can expect more revolutionary technology to be introduced with the industrial application of 5G technology (e.g., visual reality). In addition, temporary proximity, defined as short or medium-term visits, may be sufficient for effective knowledge exchange (Torre 2008). Such visits can take place in the form of trade fairs/shows, conferences, etc, which enable face-to-face interactions between partners at reduced cost. Moreover, the absence of the moderating effect of proximity is partially due to the strong relationship between technological and management innovation, as shown in our analysis. Since our result suggests that a firm's management innovation (through U-I collaboration) is mainly influenced by technological innovations, geographical distance becomes less relevant given that technological innovation relies on codified knowledge, the transmission of which is not affected by spatial distance (Boschma 2005b). Therefore, our findings indicate that firms need not prioritise proximity when searching for a university partner, and instead they should focus on better transferring the knowledge obtained from universities into technological innovations. Further, these innovations will act as a catalyst for profound organisational changes.

This paper also provides interesting findings on the impact of research quality. Universities with higher research quality are intuitively more attractive to firms, and collaborations with these universities will strengthen the firm's internal R&D capability, which will in turn foster the introduction of more technological innovations. Cohen et al. (2002) indicate that it is the scarce resources possessed by elite universities (e.g., novel research findings, advanced facilities, talented human resources) that firms are looking for when collaborating with universities. However, our findings suggest that, in the context of China, the calibre of partner university exerts no significant difference on a firm's technological innovation. However, this conclusion may be generalisable with caution beyond the heterogeneity of the Chinese context. Studies that confirm the positive relations between research quality and technological innovation are mostly conducted in the context of the developed economies (Perkmann et al. 2011; Hewitt-Dundas 2013b; Szucs 2018), where there is a well-established link between research outcomes and their industrial application. In China, although the universities own a huge number of patents, the transfer rate is relatively low compared to their western counterparts (WIPO 2019). One example, raised by Sun et al. (2020), shows that of the 400 granted patents held by a major university in China, only ten of these were actually transferred to industrial firms. Given this low efficiency, firms may not be able to benefit as much as western firms from collaborating with higher-ranked universities, which will limit technological innovations.

Meanwhile, regional and lower-ranked universities play an important role in the Chinese innovation system. As suggested by Liu and Jiang (2001), technology transfers from Chinese universities are strongly influenced by government initiatives and policies. In 2013, the central government of China instructed 'regional universities to deepen their collaboration with industries, accelerate the technology transfer activities and contribute more to the development of regional economies' (GOV, 2013). Like all government agencies in the Chinese political system, lower-ranked regional universities can be very sensitive to their upper administrative institutions (central and local government) and they must be proactive in response to government initiatives. Although they may be unable to produce excellent academic outputs in basic research, many of the lower-ranked universities specialise in applied science, making them valuable partners for firms that seek incremental innovation. Therefore, Chinese firms do not necessarily need to collaborate for innovation with research-excellent universities; instead, they should focus on what knowledge they need and can actually acquire when searching for the most appropriate university partner.

4.5 Conclusion

Innovation is the key to achieve sustainable growth in a global market where new technology and new products continuously emerge (Rosenbusch et al. 2011). Based on data collected from the Chinese manufacturing industry, this paper finds that (1) contractual collaboration between university and industry has a strong positive impact on firms' technological innovation; (2) contractual collaboration between university and industry also positively affects the management innovation of firms, although this effect is weaker than for technological innovation; (3) technological innovation positively mediates the impacts of contractual collaboration on management innovation; (4) the proximity and research quality of universities have no impact on firms' innovation outputs.

Our study has interesting implications for the research on U-I collaborations. Although establishing a formal R&D partnership with universities can be expensive and risky, it is worth every penny invested, as our research reveals a strong relationship between contractual UIC and the technological progress of firms. Also, previous studies investigating the impact of UIC have mainly focused on technological innovation, such as innovative products and processes, and it is unclear how collaboration with universities facilitates organisational changes (i.e., innovative business practices and new marketing methods). Our results show that, aside from the direct impact, the contribution of a university to a firm's management innovation is mainly through the mediating effect of technological innovation. As the technological innovation developed from university knowledge has a rather radical nature, firms may need to adapt their existing organisational structure and business practices to commercialise these innovations. Moreover, it has been suggested that technological innovation should be accompanied by the relevant management innovation for better economic returns (Schmidt and Rammer 2007). This paper is not only in line with the literature supporting the complementarity of different innovation types (Damanpour et al. 2009; Mothe and Thi 2010), but it also reveals the mediating role of technological innovation between collaboration and management innovation.

Our findings on the proximity and research quality of universities are especially relevant for managers and policy-makers. Although UIC brings great benefits to firms, searching for the appropriate university partner can be difficult for firms due to asymmetry of information. We compared the innovation performance between firms collaborating with local/non-local universities, as well as with higher-/lower-ranked universities. Our results show that neither of these two factors influences the innovation outcomes of firms. Due to the insignificant role of proximity, business managers should be informed that collaboration with a nearby university does not necessarily have a stronger impact on firms' innovation outcomes. In the meantime, universities with higher research quality may not always be beneficial to firms' technological innovation. We argue that it is more the appropriateness of the knowledge than the quality of the research that shapes the innovation outputs of UIC collaboration. For regional/lower-ranked universities, getting involved in UIC activities enables them to connect their practice-based research to industry experience, which will, in turn improve their academic performance. Also, collaborating with local SMEs helps regional/lower-ranked universities to not only expand their income sources but also to take their social and economic influence to a larger context (Breznitz and Feldman 2012a). Therefore, instead of solely encouraging collaboration between elite universities and industries, policy-makers should recognise the value of practice-led universities to balancing the structure of the national innovation system.

The limitations of this study create avenues for future research on UIC. First, the generalisability of the research findings might be limited as the samples in our study were drawn from China. Due to its unique political structure, researchers have suggested that universities' engagement in UIC in China is strongly influenced by political factors. It is recommended that future research empirically investigate how, and to what degree, the institutional factors influence the firm's innovation benefits from UIC. Second, our data is cross-sectional in nature. Future research based on longitudinal data is needed to better understand the relationship between collaboration and innovation. Lastly, as this paper only investigated the impacts of the UIC on manufacturing firms, future research could also include firms from the services sectors, which would enable more comprehensive insights to be drawn about universities in regional developments.

Chapter 5 Collaborating with Universities for Innovation and Better Performance: A Relational Approach

5.1 Introduction

The Covid-19 pandemic is spreading economic suffering across the globe. It has been suggested that the manufacturing industry is among the most harmed economic sectors because of the direct disruption to the global supply-demand chain (Baldwin and Tomiura 2020). This disruption has even sparked academic discussion on the necessity of shifting the centre of global supply chains from China, where the outbreak first started, to a more steady and balanced structure (Gao and Ren 2020). Although manufactured goods are more susceptible to a rapid drop in demand, economists have predicted that the shortfall in demand is temporary and that manufacturing firms will eventually see a U-shaped recovery (Ozili and Arun 2020). In practice, we have already seen examples of firms prospering during the crisis by successfully creating and leveraging innovations such as remote-working, cloud computing, and intelligent logistics. As suggested by Parrilli and Radicic (2020), to earn their places in the fiercely competitive global market, firms must constantly generate new knowledge and transfer it into innovative products and services. It is, therefore, reasonable to assume that the global market is going to be more competitive than ever in the post-crisis era, and that innovation will be critical to the survival and growth of manufacturing firms.

Limited research and development (R&D) capabilities, the huge costs associated with R&D, and the unpredictable market prospects for innovations are all factors that force firms to open up their organisational boundaries to seek out knowledge sources from external partners (Moon et al. 2019). In this regard, collaborating with higher education institutions is an important option for supporting firms' innovation, and supporting such collaborations has also been a focus of public policy (e.g., the Knowledge Transfer Partnership in the UK). By acquiring unique and hard-to-imitate novel knowledge and leading technologies from universities, firms can establish a competitive advantage in their marketplace. The university-industry collaboration (UIC) that aims at technology-transfer has also attracted academic attention, albeit that this focuses mainly on the formal aspects of collaboration (e.g., technology transfer) (Hoc and Trong 2019). The formal collaboration method implies a linear model, within which collaboration starts as a scientific discovery in universities and ends with the commercialisation of products by firms (Breznitz and Ram 2012).

The disadvantage of this focus is that it overlooks the many other pathways that a university might undertake to exploit its intellectual property, and it also underestimates the role of the university in contributing to the regional economies (Breznitz and Feldman 2012b). The high costs and risks associated with formal R&D activities have hindered many firms, large firms as well as SMEs, from participating in U-I collaboration (Bruneel et al. 2010b). In search of a deeper understanding of U-I collaboration, Ankrah (2013b) highlights the role of informal channels such as researcher secondment, informal meetings and conferences, general training programmes, and networking activities as alternative channels for U-I collaboration. Although current studies have addressed many aspects of the informal U-I collaboration, knowledge gaps exist as we lack a comprehensive understanding of the channels of informal collaboration; specifically, more empirical evidence is required to understand how firms can use informal collaboration to improve their position in a competitive market environment (Schaeffer et al. 2020).

According to the Chinese Enterprise Innovation Survey (NBS 2020), of the total sample of 374,774 manufacturing firms, 52.4% have reported being engaged in innovation activities. However, when it comes to collaborating with external partners for innovation, only 39.3% of the firms chose universities, and these collaborations were mainly through joint research (66.3%). These figures imply that (1) the potential of U-I collaboration for supporting firm-level innovation has not been fully recognised, and (2) the current collaboration landscape is very much centred on formal collaboration, which leaves a window for the exploration of alternative collaboration methods.

To address these gaps, we further develop the definition of informal collaboration from two strands of literature. First, we view informal collaborations in China as an inter-organisational relationship that is deeply embedded in *Guanxi*—a unique Chinese social philosophy originating from Confucianism. Guanxi is a term that describes interpersonal bonds that rely on friendship and mutual support (Shen et al. 2019). Ramasamy et al. (2006) examines the relationship between *Guanxi* and the interfirm knowledge transfer in China and finds that the greater the level of *Guanxi*, the greater the degree of knowledge transfer between firms, which is a consequence of the high level of trust and more effective communication. The second strand of literature to enlighten our exploration of informal collaboration is the transaction cost theory. As transaction behaviours are often associated with additional costs, economists have observed an independent exchange mode in addition to formal contract (Noordewier et al. 1990). Within such an exchange mode, obligations are fulfilled through an informal social process that promotes norms of flexibility, trust, and solidarity, which may involve lower transaction costs than those typical incurred with formal contracts (Dyer and Singh 1998). We therefore use the term ‘relational collaboration’ to represent the informal interaction between universities and firms. This paper contributes to the current literature by investigating how firms can collaborate with universities through informal channels and by exploring how this type of collaboration affects not only technological innovation, but also the management innovation of firms (i.e., new/improved organisational practices and marketing strategy). Moreover, with data from the Chinese manufacturing industries, this paper also adds new evidence to the academic debates about whether and how innovation contributes to firm’s economic performance (for example, see Walker et al. 2011; Slater et al. 2014).

In the next section, we review two strands of literature on knowledge management and innovation modes, which together have shaped our conceptual framework and the research hypotheses set out in Section 3. Section 4 introduces our methodological approach. Analysis and results are provided in Section 5, followed by a discussion in Section 6, and the research implications and limitations are explained in Section 7.

5.2 Theoretical background

5.2.1 Explicit and tacit knowledge

In attempts to explore the nature of knowledge, one important line of literature was established by Polanyi (1966, p.5) who argued that '*We can know more than we can tell*', thereby revealing the existence of 'tacit knowledge'. Nonaka and Takeuchi (1995a) further developed this research strand and defined explicit knowledge as the knowledge that can be codified and transferred formally and systematically. Tacit knowledge, in contrast, is informal, non-verbalizable, and unarticulated. It is the knowledge that comes from previous experiences and it is influenced by personal perceptions and values. Personal points of view, technical skills, and know-how are all forms of tacit knowledge. Explicit knowledge is tangible in nature because it can be encapsulated in manuals, formula, and functions, whereas tacit knowledge is less tangible, being specific to the person or organisation who possesses it, which makes it 'sticky' and difficult to transfer (Nonaka and Takeuchi 1995a). For example, experienced salespeople can quickly identify the buying signs when they are talking to a prospective customer. This ability is generally acquired through accumulated experiences rather than by reading books or learning a formal language, thus it is tacit in nature.

The dissemination of knowledge among organisations occurs in a complex manner as it involves both tacit and explicit knowledge sharing. Sharing explicit knowledge involves the mobilisation of ready-to-use knowledge, which can be available as scientific formula, product properties, texts, and procedures (Doğan and Doğan 2020). Compared to tacit knowledge, explicit knowledge is more easily transferred to individuals, provided of course that high absorptive capacity is in place. The main obstacle to transferring explicit knowledge is that it must be understood and interpreted by the person who is using this knowledge, so a degree of relevant tacit knowledge is required to interpret the explicit knowledge. In contrast, sharing tacit knowledge depends on numerous face-to-face interactions in which individuals demonstrate, observe, and discuss their tacit knowledge (Stevens et al. 2010). Because of the stickiness of tacit knowledge, it can only be acquired by individuals through social interactions or by establishing friendship ties (Leonard and Sensiper 1998).

5.2.2 Modes of innovation: STI and DUI

It has been widely accepted that knowledge plays a crucial role in generating innovations, but the debate on innovation drivers is divergent. One strand of literature emphasises the importance of explicit scientific knowledge, underlining the impact of R&D activities on the innovation performance of firms (Cohen and Levinthal 1990; Mowery and Technology 1998; Roesler and Broekel 2017). In recent years, much research focus has been given to the role of non-R&D activities in innovation studies (e.g., interactions with users, suppliers, and competitors), exploring how these non-R&D factors facilitate the generation of new products and processes by firms (Huang et al. 2010; Moilanen et al. 2014; Lee and Walsh 2016). As stressed by Lundvall (1992a), interfirm interactions, networks, and informal relationships can also contribute to the generation of novel knowledge.

Building on Lundvall (1992a) seminal work, Jensen et al. (2007) informed the scholarly debate on the knowledge drivers of innovation with the identification of two different modes of learning and innovation. The first places emphasis on R&D activities via Science and Technology-based Innovation (STI mode), and the second mode is characterised by learning by Doing, Using, and Interacting (DUI mode). For firms dominated by the STI mode, innovation is a result of continuous investment in R&D and scientific human capital, as well as R&D collaborations with consultancies, universities, and research centres (Cunningham and Link 2015). Firms with STI innovation mode utilise scientific and technical knowledge, which is explicit and codified by nature, and rooted in the formal R&D processes (Aghion et al. 1998). In contrast, the DUI mode is dominated by the informal processes of learning and interaction to generate innovation. Learning by Doing means that by repeating operations, employees' skill level can be strengthened, which improves organisational productivity (Amara et al. 2008). Learning by Using accelerates the innovation process as it enhances the problem-solving ability of employees, helping them to accumulate experiences that enable them to meet innovation targets (Kline and Rosenberg 1986). The knowledge accumulated through Doing and Using is largely based on personal experiences and feedback, hence it is mainly shared through tacit knowledge flows among members within/outside of the organisation (Apanasovich et al. 2016). As a critical method of facilitating these tacit knowledge flows, learning by Interacting underlines the importance of face-to-face communications and the informal relationships among users, suppliers, and competitors (Thomä 2017)

5.3 Conceptual model and hypotheses

5.3.1 Relational collaboration, innovation and firm's performance

As a complement to internal R&D, knowledge exchange between academia and industry increases the knowledge stock, enhancing innovation performance and improving the competitiveness of firms (Huang and Yu 2011). Empirical studies identify various frequently-used transfer channels, such as patenting/licensing, contract/joint research, joint conferences, staff secondment/student placement, training programmes, etc. (Ankrah 2013b). However, not all channels have similar effects on transferring different types of knowledge. The process of innovation, as suggested by Fitjar et al. (2013), is a complex phenomenon that includes the use of tacit knowledge that cannot be captured by a sophisticated formal contract. To develop a more comprehensive taxonomy of U-I collaboration, Alexander and Martin (2013) propose the assessment of channels according to their interaction form, geographic proximity, knowledge transferred, conflict resolution method, and relational embeddedness (i.e., the intensity of any prior relationship). Based on these five criteria, they define relational collaboration as an informal relationship with universities that rely on face-to-face communication channels. These collaborations are not necessarily bounded within a formal contract because it is the interpersonal relationship that plays a pivotal role in maintaining the collaboration. Through relational interaction with universities, the transferee has the opportunity to observe and discuss the tacit knowledge held by the transferor, and the transferor can provide timely feedback that helps improve the transferee's understanding. As suggested by Perkmann and Walsh (2010), tacit knowledge-transfer occurs more effectively in channels that are informal and relational in nature.

Technological innovation, which covers new or significantly improved products or processes (OECD 2005), has been found to be embedded in R&D activities that apply codified, scientific knowledge (Piening and Salge 2015). Relational collaboration with universities can support product and process innovation in at least two ways. First, as indicated by Cavusgil et al. (2003), the greater the extent of tacit knowledge transferred to firms, the more likely it is that the firm's intellectual capital will be unique and effective at producing technological innovations. For example, through frequent interactions with a university researcher, the firm's engineer can accumulate cutting-edge technical information that may guide ongoing improvements in the production process. Second, as knowledge usually exhibits explicit and tacit attributes, the acquisition of the relevant tacit components can enable the explicit components to be better assimilated and interpreted (Hall and Andriani 2003). In the scenario of a U-I patent sale, the licensees will also expect to gain the tacit know-how necessary to be able to apply the purchased technology to new product developments. We therefore outline the following hypotheses:

H1 Relational collaboration with universities positively affects the technological innovation of firms

Business innovation can take place not only by applying newly developed technology into the product or production process, but also by re-organising the firm's business practices, external relationships, and marketing strategies (Pereira and Romero 2013). The Oslo Manual (OECD 2005) has broadened the concept of innovation from technological innovation alone to also cover non-technological innovation (i.e., organisational innovation and marketing innovation). Non-technological innovation (also referred to as management innovation, (Hamel 2006)), requires a higher level of management skills and a profound understanding of customer needs, both of which are less explicit and more experience-based than scientific knowledge. Echoing the work of Pippel (2014), the knowledge relevant to management innovation is somewhat tacit in nature, and it is most likely to be acquired by frequent contacts with both internal and external knowledge sources. Teece (2008) indicates that close and frequent interaction with the external partner allows for prolonged cohabitation of technical and managerial staff, which facilitates the improvement of organisational routines. Through relational channels, universities can not only directly transfer management expertise to firms, but can also transfer tacit knowledge about production processes that facilitates the reformulation of the organisational structure and the product positioning strategy. Besides, Garcia-Perez-de-Lema et al. (2017) point out that relational collaboration prioritises learning through personal bonds, which is a feature of the DUI mode of innovation. As suggested by empirical evidence (see Apanasovich et al. 2016; Parrilli and Heras 2016; Parrilli and Radicic 2020), while product/process innovations are more associated with the STI mode, commercial and organisational innovations rely more on the DUI mode of innovation. Hence, we hypothesise the following:

H2 Relational collaboration with universities positively affects the management innovation of firms

Relational collaboration with universities can also improve the performance of firms. First, the tacit knowledge obtained from external R&D partners can serve as a direct driver for improvements in organisational productivity, which helps firms achieve a better return on assets (Magnier-Watanabe and Benton 2017). The obtained tacit knowledge leads to employees having higher skill levels and also to a refined business process that increases the efficiency of manufacturing (Law and Ngai 2008). Furthermore, the informal interaction network established with universities consolidates the research tie with university staff (Garcia-Perez-de-Lema et al. 2017). A strong tie between academics and firms helps the latter to receive prompt feedback and advice on their in-house innovation projects, thereby improving the success rate of new products and enhancing the financial growth of firms (Asheim and Parrilli 2012; Breznitz and Ram 2012). Hence, we further hypothesize the following relation:

H3 Relational collaboration with universities positively affects the performance of firm

5.3.2 Innovation and firm performance

The endogenous growth theory supports the simultaneity in the relationship between innovation and performance, arguing that the growth of an economy is determined by the impact of technology inputs on the innovation outputs (Aghion et al. 1998). However, in the field of microeconomics, the contribution of innovation to higher firm performance is an ongoing debate among scholars. Past studies have found both positive and negative relationships between innovation and performance. For example, employing a large data sample of 90,000 firms in Europe, Hashi and Stojčić (2013) find a positive impact for innovation activities on firm’s productivity. Bigliardi and Dormio (2009) identify innovation as the main driver for the growth and prosperity of the Italian food machinery enterprises. However, other scholars have found empirical evidence against this positive relationship. Nohria and Gulati (1996) note that engaging in innovation activities is accompanied by increased risks and uncertainty, which could be fatal to the survival of small firms. Moreover, without preliminary market research, innovation may also cause resistance in the marketplace, resulting in a decline in the firm’s sales (Rogers 2010). Given the inconclusive research findings, the relationship between innovation and performance needs to be further investigated with more empirical evidence.

Product innovation refers to a new or significantly improved product, which can include changes in its intended use or characteristics (OECD 2005). With the advancement in technology and the shorter life cycle of products, the impact of product innovation on organisational performance is greater than ever (Slater et al. 2014). From the supply side, innovative products increase product differentiation and reduce possible substitution, thus the profit margin increases accordingly (Belleflamme and Peitz 2015). From the demand side, as innovative products can create new market segments and satisfy the demands of specific customer groups, sales and market shares can increase accordingly (Wang and Wei 2005).

Process innovation means making new or significant changes to the method of production (OECD 2005). These changes are usually oriented at generating faster operations or greater output volumes, or reducing the costs of manufacturing (Kahn 2018). Davenport (1993) finds that process innovation has great potential for improving production quality and flexibility, and reducing process time. From the perspective of the product life cycle, when the design of a certain type of product stabilises, the lower production cost achieved by process innovation helps improve profit margins before the product begins its life cycle in other countries (Adner and Levinthal 2001). In China’s context, Li et al. (2007) find that the R&D capability of Chinese firms is relatively weak, thus cost reductions and energy savings achieved through process innovation are key approaches for enhancing the economic performance of firms. In addition, as the CEO position is often a short-term appointment in China, process innovation is preferred by CEOs as a means of boosting firm performance level as it is easier to achieve and less risky than product innovation (Li et al. 2007). Based on the above arguments, we propose that:

H4 Technological innovation positively affects the performance of firms

Generally speaking, organisational innovation is more about the changes in social systems within the organisation while technological innovation is often the result of persistent R&D efforts. Lam (2004) argued that the ability to renew and reconfigure the organisational structure helps firms to adapt better to the external environment, thus improving their long-term competitive performance. The adoption of innovative organisational practices, such as the Balanced Scorecard or Best Practices, could align the organisation with external demands and increase internal efficiency and effectiveness (Walker et al. 2011). Jiang et al. (2012) find that innovative organisational practises increase the employees' satisfaction, creativity, and administration efficiency, through which better financial returns can be expected. Drawing on data from 1,091 Spanish manufacturing firms, Van Auken et al. (2008) find that management innovation positively improves performance, although this effect is stronger in high-tech firms than in low-tech firms.

Marketing innovation requires new or significant changes in the product's packaging, promotion method, pricing strategy, and sales channels (OECD 2005). Today's market environment is becoming increasingly competitive, and introducing marketing innovation requires additional financial investment as it may require new mobile applications and information technologies in addition to the traditional tools (Vokoun and Píchová 2020). However, it can still contribute to better business performance. Marketing innovation influences sales performance by enabling nuanced interpretation of the buying preferences of customers in the chosen market and the adjustment of R&D projects to satisfy the needs of customers (Otero-Neira et al. 2009). Naidoo (2010) recognises marketing innovation as an important source of competitive advantage in the route to superior business performance. Specifically, it shows that through successful marketing innovation, Chinese manufacturing SMEs earn customer loyalty ahead of their competitors and thereby expand their market shares. Building on these literature, we propose that:

H5 Management innovation positively affects the performance of firms

5.4. Research Method

5.4.1 Survey design and data collection

In this research, data were collected through a questionnaire survey to Chinese manufacturing firms. The first section of the questionnaire gathers general information of firms including age, size, industry, performance level, etc. The second section asked the respondent to provide information regarding the interactive activities with universities. The third part of the questionnaire collects data on firm's innovation outcomes that benefited from the collaboration with universities. This section is based on the Community Innovation Survey 2016 (CIS) and the China National Enterprise Innovation Survey 2018 (CNEIS). The questionnaire of CNEIS is the Chinese equivalent of the CIS questionnaire, with necessary modifications for China's specific context. In our questionnaire, most of the questions were referenced to the last three years (2016-2018), except for the economic performance which is referred to the end of 2018 only. To our knowledge, several of our survey questions—particularly those related to U-I interactions—had not been covered yet by any of the Chinese national surveys. Therefore, this study provides a unique opportunity to investigate the U-I collaborations in China.

Data collection was carried out in several stages. A pilot study of 12 interviews with business managers was conducted to test and adjust the preliminary questionnaire for validity purposes. Then, we distributed the questionnaire between July and August 2019, with the support of a recognised academic survey company in China. This stage yielded 57 responses, based on which further amendments were done to improve the questionnaire quality. The last stage of the survey was done between December 2019 and January 2020, yielding 475 usable answers from 832 returned questionnaires.

Since our data were collected from the one informant (e.g. CEO, CFO) in each firm, the relations between variables could be inflated as a result of the common method variance. To address this issue two approaches were adopted. First, we have taken procedural precautions such as protecting the anonymity, separating measurements by topics, and balancing the question orders. Also, we assessed this potential bias with Harman's single-factor analysis. The data would be problematic if one single factor explains the majority of variances in the variables. Our principal component analysis (PCA) shows four components having eigenvalues >1 with the main factor accounted for less than 50% of the total variances, indicating that the common method bias is not an important issue in our data (Podsakoff et al. 2003).

5.4.2 Samples and the demographic profile

Given the institutional differences of the Chinese provinces, we created our sample from firms in Shanghai (n=64), Beijing (n=42), Guangdong (n=134), Zhejiang (n=47), Shandong (n=76), Henan (n=37), and Jiangsu (n=75). These are China's top seven provinces/regions in GDP ranking and they also have a similar institutional environment (NBS 2019), which enables us to reduce selection bias.

We specifically targeted sample firms in the manufacturing sector for two reasons. First, collaboration with universities is more prevalent in the Chinese manufacturing sector than it is in the service sector (Zhao and Wu 2017). Second, innovation has different manifestations in different sectors. For example, technological innovation is less of a goal for firms in the service sector, as improvements to the performance of services are mainly achieved through management innovations (Aboal and Garda 2015). The respondents to the questionnaire came from management teams, including CEOs, CFOs, and R&D managers, as they are more familiar with the overall performance of firms (Garcia-Perez-de-Lema et al. 2017). The sample distribution of industries is provided in Table 10.

Table 10 Sample distribution

Industry	Number of firms	Percentage
Computer	36	7.6
Office machinery	52	10.9
Electronic communication	66	13.9
Pharmaceuticals	39	8.2
Medical equipment and measuring equipment	30	6.3
Chemicals	58	12.3
Paper and printing	13	2.7
Textile and clothing	31	6.5
Food and beverage	22	4.6
Wood products	21	4.5
Rubber and plastic	49	10.3
Motor vehicle	9	1.9
Non-electrical machinery	36	7.6
Others	13	2.7
Total	475	100.0

5.4.3 Measurements

Relational Collaboration Echoing previous assessments of collaboration channels (D'Este and Patel 2007b; Bruneel et al. 2010a; Alexander and Martin 2013), we asked respondents whether, over the past three years, their firm has been engaged in: (1) networking activities; (2) forums/conferences held by universities; (3) joint PG supervision; (4) student internship; (5) graduates recruitment; (6) staff secondment; and (7) training programme with university/universities. A 5-point Likert scale was adopted to measure the frequency of such activities (1, not engaged; 5, high engagement). A similar scale has been used in previous literature for the measurement of U-I interaction frequency (Garcia-Perez-de-Lema et al. 2017).

Innovation This study measures innovation with self-reported scales. Specifically, innovation was measured by four types of outcome: product, process, organisational, and marketing innovations. We established two constructs in accordance with the Oslo Manual (OECD 2005), namely (a) Technological innovation: product and process innovation; and (b) Management innovation: organisational and marketing innovation. These two constructs reflect both the technical core of firm innovation and the innovative organisational changes. We asked the respondents to indicate the radicalness of the technological innovation (3 items) and the importance of management innovation (7 items). The 5-point Likert scale for innovation measurement in this study was modified from the CIS 2016.

Performance We adopted the performance measurement scale developed by Garcia-Perez-de-Lema et al. (2017), which asked the respondents to rate performance regarding productivity, profitability, and market share according to a 5-point Likert scale. We added a further item – sales revenue – to examine the impacts of innovation on the overall sales performance. It has also been suggested that lag effects may exist between innovation and performance (Rosenbusch et al. 2011), hence we asked the respondents to rate their performance based on the year of 2018 only.

Moderating variables Previous literature suggests that the relationship between collaboration, innovation, and performance may be moderated by the size, age, sector, and absorptive capacity of firms (Hult et al. 2004; Bekkers and Bodas Freitas 2008; Moon et al. 2019). To test the possible moderating effects, we divided our samples by age (young and mature), size (SME and large), sector (high-tech/others), and absorptive capacity (high AC and others). Firms aged below 15 years are classified as young (Ismail et al. 2010) and those with fewer than 1,000 employees are SMEs, according to the National Bureau of Statistics of China (NBS 2017). We identify the high-tech firms by examining whether their industry is recognised by the '*High-Tech Industry Classification, 2017'*, an official document issued by NBS (2017). Absorptive capacity measurement was assessed according to the seminal work of Zahra and George (2002), and further divided for comparison into two groups by the arithmetic mean of scores.

5.4.4 Statistical technique

This study uses a multivariate analysis method to test the relationship between university-industry collaboration, innovation, and firm performance. Structural equation modelling (SEM) is the most suitable technique for this research as it allows researchers to simultaneously integrate different multiple regression models. LISREL 8.8 was used to execute the analysis process in this study. We also adopted the Partial Least Square modelling technique (SmartPLS) to check the robustness of the research findings. Suggested by previous literature, employing PLS-SEM as a supplement to CB-SEM acts as a tool of methodological triangulation, through which the consistency and reliability of analysis results can be examined (Garcia-Perez-de-Lema et al. 2017).

5.5 Results and analysis

5.5.1 Measurements validation

To validate the measurement scales and structural model, both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were performed (Table 11). For the EFA, the Kaiser-Meyer-Olkin (KMO) index is 0.938 and Bartlett's sphericity test is significant at 0.000 level. Furthermore, Cronbach's Alpha for each construct ranging from 0.74 to 0.94, and factor loading for each construct ranging from 0.61 to 0.89, confirming the reliability of the measurement scales (Price and Mueller 1986).

Table 11 Confirmatory factor analysis

Constructs/Items	**Factor loading >0.6**	**t-value >1.96**	**CR >0.6**	**AVE >0.5**
RC (7items)			**0.94**	**0.68**
Social activities with university staff	0.84	22.22		
University forums/conferences	0.85	22.83		
Joint PGR supervision	0.78	19.89		
Students internship	0.85	22.58		
Graduates recruitments	0.81	21.07		
Staff secondments	0.79	20.50		
Training programmes	0.85	22.90		
TI (3 items)			**0.87**	**0.70**
New products	0.87	22.75		
New method of manufacturing	0.89	23.27		
New supporting activities (purchasing/logistics, accounting, etc.)	0.74	18.10		
MI (7 items)			**0.94**	**0.70**
New business practices	0.87	23.61		
New organisational structure	0.80	20.83		
New external relationship	0.84	22.19		
New packaging	0.83	22.07		
New method of promotion	0.85	22.76		
New sales channel	0.87	23.62		
New pricing strategy	0.80	20.87		
Performance (4 items)			**0.74**	**0.42**
Sales revenue	0.70	14.25		
profitability	0.66	13.92		
Market share	0.61	11.97		
productivity	0.62	12.14		

Proposed by Fornell and Larcker (1981), the average variance extracted (AVE) and the composite reliability (C.R.) of a construct should exceed 0.5 and 0.6 for good convergent validity. As shown in Table 11, the $RC_{C.R.}$=0.94, RC_{AVE}=0.68; $TI_{R.C.}$=0.87, TI_{AVE}=0.70; $MI_{R.C.}$=0.94, MI_{AVE}=0.70; and the $PM_{R.C.}$=0.74, PM_{AVE}=0.42 suggesting that the convergent validity in our research is excellent, except the AVE of PM is lower than the threshold. However, the AVE between 0.4 and 0.5 is still acceptable if the C.R. of that construct exceeds 0.6 (Lam 2012). As the C.R. of PM is 0.74, the convergent validity of PM is acceptable in our study. To examine the discriminant validity of constructs, Fornell and Larcker (1981) proposed to compare the square root of AVE with the correlation coefficients. If the square root of AVE is greater than the correlation coefficients with other constructs, it shows good discriminant validity of that construct. In our case, the square root of AVE is larger than the correlation values for each construct, confirming that all measurements for constructs are validated (Table 12).

Table 12 Correlation between constructs

	RC	**TI**	**MI**	**PM**
RC	**1**			
TI	0.49***	**1**		
MI	0.53***	0.47***	**1**	
PM	0.48***	0.48***	0.43***	**1**

Notes: P<0.05 *, P<0.01 **, P<0.001 ***. The square roots of AVE: RC=0.82, TI=0.84, MI=0.84, PM=0.65

5.5.2 Structural model results

The correlation matrix provided in Table 12 confirmed that relational collaboration is significantly correlated with the innovation of both types, and it is also correlated with the performance of firms. We calculated the Variance Inflation Factors (VIF) to check if the multicollinearity issue exists in our analysis. The result shows that in our research the VIF of indicators ranges from 1.896 to 3.501. Ringle et al. (2015) recommended 5 as the threshold value, which suggests our VIF values are acceptable confirming that multicollinearity is not a concern in our analysis.

Table 13 Path analysis

Path	Standardised parameter estimates (LISREL)		Path analysis (SmartPLS)	
	Coefficient	T-Statistics	Coefficient	T-Statistics
RC → TI	0.50***	10.18	0.45***	11.48
RC → MI	0.54***	11.38	0.50***	12.22
RC→PM	0.26***	3.70	0.23***	4.20
TI → PM	0.27***	4.40	0.23***	5.01
MI → PM	0.18**	2.94	0.14*	2.54

PLS model fit: Considering PM as formative construct. R^2_{TI} =0.20, R^2_{MI} = 0.25, R^2_{PM}= 0.23. Bootstrap with 5,000 subsamples.

P<0.05 *, P<0.01 **, P<0.001 ***

The analysis regarding the path coefficients and their t-value is presented in Table 13, which also includes the results for the same structural model using the PLS-SEM (SmartPLS). The CB-SEM reveals a good fit of the structural model specification (χ^2=326.26, d.f.=184, GFI=0.94, AGFI=0.92, CFI=0.99, NNFI (TLI)=0.99 and RMSEA=0.033), and so does the PLS-SEM. For the proposed hypotheses, the technological innovation (product and process) is positively affected by the relational collaboration (β =0.50, t-value=10.18), lending support for H1. The H2 posits that relational collaboration positively affects the management collaboration of firms. Our result shows that the coefficient for this proposed path is 0.54 and the t-value is 11.38, hence H2 is also accepted. The result shows that relational collaboration has a direct positive effect on the performance of firms (β=0.26, t-value=3.7), therefore H3 is supported. Moreover, the proposed path relations between innovation and firm performance are also verified by the analysis. Specifically, technological innovation has a positive impact on the performance of firms (β=0.27, t-value=4.40), providing support for H4. Regarding to the H5 which proposed that management innovation also positively affects performance, it is supported by β=0.18 and t-value=2.94.

For the moderating analysis, we also found that only size and industry moderate the relationship from RC to MI (H2). The relational collaboration in SMEs shows a stronger effect on management innovation. Similarly, High-Tech firms are associated with higher coefficients in H2 (0.59) than other firms (0.42), significant at P<0.05 level. Results of the multigroup analysis were provided in Table 14.

Table 14 Multigroup analysis

Path	Comparison	Coeff. difference	p-value (parametric)	p-value (permutation)
RC→TI	size (large-small)	-0.007	0.934	0.938
	age (mature-young)	0.099	0.211	0.216
	industry (hightech-others)	0.056	0.483	0.479
	AC (high-others)	0.137	0.206	0.170
RC→MI	size (large-small)	**-0.173***	**0.043**	**0.043**
	age (mature-young)	-0.037	0.651	0.648
	industry (hightech-others)	**0.174***	**0.031**	**0.036**
	AC (high-others)	0.048	0.676	0.627
TI → PM	size (large-small)	-0.082	0.386	0.386
	age (mature-young)	0.025	0.788	0.789
	Industry (hightech-others)	-0.110	0.246	0.243
	AC (high-others)	0.007	0.967	0.956
MI → PM	size (large-small)	0.039	0.726	0.721
	age (mature-young)	-0.041	0.712	0.717
	industry (hightech-others)	-0.009	0.939	0.937
	AC (high-others)	-0.169	0.346	0.244
RC→PM	size (large-small)	-0.091	0.428	0.421
	age (mature-young)	0.045	0.679	0.699
	industry (hightech-others)	-0.057	0.616	0.613
	AC (high-others)	0.124	0.484	0.408

Note: P<0.05 *, P<0.01 **, P<0.001 ***

5.6 Discussion

This paper transfers the economics conception of relational-based collaboration to the realm of the University-Industry relationship, shedding light on why and how developing relational collaboration with universities can be an advantage for firms in terms of increasing their innovation capabilities and performance. Previous literature has confirmed the effects of formal collaboration on the technological and non-technological innovations of firms (Pippel 2014; Hewitt-Dundas et al. 2019b; Moon et al. 2019). Using data from Chinese manufacturing firms, we find that innovation outputs can also be promoted by relational collaboration channels with universities. Establishing formal links with universities requires a long-term commitment and heavy investment by firms. Since the market value of university patents is unpredictable, engaging in formal collaboration increases opportunity costs and puts firm profitability at risk (Paranhos et al. 2019). However, firms can get access to university knowledge by establishing social networks with university staff, attending conferences, sending employees to training programmes, and exchanging staff through forms of secondment/student placement. As people are the main carriers of knowledge, these people-based activities encourage knowledge exchange, leading to specific innovation outcomes (Moon et al. 2019).

The knowledge accumulated through informal interactions with university staff is less associated with fundamental novelty and is more concerned with know-how-based personal experiences; hence it often contributes to the incremental innovation of current products or business practices rather than to the development of radical innovation (Thomä 2017). For example, inviting engineering researchers from universities to work on the production frontline allows firms to receive valuable advice and suggestions for improvements to their current production methods. By helping firms to solve practical problems in production, researchers can test and modify their ongoing research, and accumulate knowledge for their future research. Likewise, companies also benefit from appointing professors from management schools to sit on the company board as independent directors who can offer advice on management innovation and long-term business operations.

Our results also lend support to H4 and H5, which indicate the positive relationship that exists between innovation outcomes and firm's performance. Whether innovation contributes to better performance is an ongoing debate, and this relationship may be influenced by how performance is measured (e.g., objective financial indicators or self-reported subjective indicators) (Damanpour 1990). Our results suggest that product innovation and process innovation positively contribute to the productivity, profitability, market performance, and sales revenue of firms. Product innovation, when compared to the current product available in the market, offers more benefits to the customers, and it will be viewed by the customer as unique and different from the competing products. As the product innovations introduced through relational collaboration are most likely to be incremental innovations (since the knowledge used is mostly tacit in nature), the development process is more familiar to developers and correspondingly it can enable firms to shorten the time to market (Chen et al. 2010). Incremental product innovation is often developed without huge R&D investment, which results in cost-saving benefits and further contributes to the profitability of firms. The smartphone giant Apple normally introduces its revolutionary product line every two years (e.g., iPhone), but to maintain sales revenue, an updated version (e.g., iPhone plus) is released in the intervening period as an incremental innovation. A newly improved process has an even stronger association with performance improvements. For example, a refined manufacturing workflow can enable firms to produce more goods in a time unit or may possibly reduce production costs, resulting in an increase in sales revenue.

Compared to technological innovation, only limited academic attention has been given to the effects of management innovation on firms' performance (Walker et al. 2010). Our results suggest that management innovation positively contributes to firm performance, but that this effect (β=0.18 and t-value=2.94) is weaker compared to technological innovation (β=0.27, t-value=4.40). This is an expected result, as an innovative product/process constitutes an immediate source of competitive advantage (Fagerberg 2004). More importantly, we conclude this weak effect is largely due to the fact that management innovation influences performance in a complex manner. On one hand, management innovation promotes organisational adaptation to the external environment and increases the effectiveness of the internal process, through which it directly contributes to the overall performance (Walker et al. 2010). On the other hand, the positive effect of management innovation on performance can also be mediated by technological innovation. In practice, establishing a research team that involves both salespersons and the R&D staff (organisational innovation) can help product developers to be better informed about customer needs, which ensures the market success of product innovation. In this example, the effect of management innovation (new team) on performance is through the success of technological innovation. For manufacturing firms, a better marketing strategy makes its incremental product innovation more competitive by improving its customer perception, thus prolonging product life cycle and increasing profit margins.

Our results suggest that only size and sector significantly moderate the relationship between collaboration and management innovation. Given the stronger financial resources and R&D capability of large firms, they favour a collaboration that transfers the cutting-edge knowledge to firms, and they have an internal R&D department that enables them to absorb this knowledge for commercial purpose (Bekkers and Bodas Freitas 2008). However, such firms' internal bureaucracy can slow down reforms to the relevant management practices. Conversely, SMEs often have the advantage of a flexible internal structure which means they can nimbly respond to new knowledge absorption; this may help them achieve higher organisational efficiency. This supposition is confirmed by our results, which find that when SMEs collaborate with universities through relational channels, they perform better than large firms in terms of management innovation. We also observe that firms operating in high-tech sectors have a stronger relationship between relational collaboration and management innovation than firms in other sectors. This is a somewhat counterintuitive result, considering that high-tech firms usually require more technological breakthroughs to compete in the market. However, as previously stated, a relational collaboration might not generate enough of the kind of scientific knowledge that directly leads to radical technological innovation. Alternatively, high-tech firms will proactively seek relevant managerial knowledge that helps them to better administer the R&D process and market their novel products to customers. The main verified hypotheses are presented in Table 15.

Table 15 Verified hypotheses

Hypotheses	Results
H1 Relational collaboration with universities positively affects technological innovation	Supported
H2 Relational collaboration with universities positively affects management innovation	Supported
H3 Relational collaboration with universities positively affects the performance of firms	Supported
H4 Technological innovation positively affects the performance level of firms	Supported
H5 Management innovation positively affects the performance level of firms	Supported

5.7 Conclusion

Transferring knowledge from universities to firms is a difficult process, given the institutional and cultural differences between the two parties. Moreover, the costs associated with formal collaboration channels and the limited absorptive capacity make firms reluctant to choose universities as their innovation partners. This study explores how collaboration via relational channels can be an advantage for firms that wish to introduce innovation outputs and improve their economic performance. Based on data from the Chinese manufacturing industry, we find that: (1) relational collaboration positively affects technological and non-technological innovations; and (2) relational collaboration has a positive direct effect on firm's performance and (3) both types of innovation positively affect firm's performance. In addition, we performed a multi-group analysis to test whether moderating effects exist in our theoretical model, and we find that SMEs and high-tech firms tend to have better management innovation performance when collaborating through relational channels.

This study expands the definition of relational collaboration from the transaction cost theory to the domain of university-industry collaboration. We highlight the role of relational collaboration in supporting the firm's innovation activities and economic performance improvements. It is vital to recognise the value of relational capabilities as they may help firms seize new opportunities for technological innovation by combining its resources with those of focal partners (Fitjar et al. 2013). Traditionally, universities and other research institutions have been seen mainly as STI partners who help firms to develop innovative products and processes. This contrasts with firms who adopt the DUI innovation mode by interacting mainly with their customers, suppliers, and competitors to achieve management innovation (Jensen et al. 2007). Our research argues that by effectively engaging in relational channels with universities, firms have the opportunity to obtain tacit knowledge (DUI type) that contributes to a consolidation of internal R&D capability and improves organisational efficiency.

The empirical evidence shows that universities, aside from their traditional role of 'technology powerhouse', are also valuable partners for firms that adopt the DUI mode of innovation.

This study provides strong managerial implications for business managers. First, instead of relying on the formal technology-transfer contract, firms can access useful (if not particularly novel) knowledge from universities by encouraging frequent interactions with academic researchers. Although such a relationship might be less formal than a research partnership, it nevertheless contributes to better organisational performance. This interaction-based collaboration can take many forms, from sending employees to university conferences or training programmes, to encouraging staff secondments or student placements. These activities enable firms to be flexible in collaboration, thus the risks and costs of collaboration can be better controlled. Wenger (2009) proposed the concept of community of practice, in which a group of people with shared learning interests is formed to exchange information/knowledge of a specific topic in a flexible manner. In such communities, face to face meetings and informal interactions are the foundation of achieving collective learning goals (Storck and Hill 2000). Through relational collaborations, university researchers and firm staffs can also form a flexible community of practice, in which knowledge is produced and transferred among the community members through the frequent communication and interactions. Second, for SMEs with limited R&D capabilities and financial resources, relational collaboration is a practical path to better innovation performance. While Chen et al. (2011) suggest that manufacturing firms should expand their open innovation strategy beyond the technological developments, our finding goes further by indicating that relational collaboration can also contribute to management innovation. Although this relationship is stronger in SMEs, most of the benefits of establishing a relational collaboration are not exclusive to SMEs, as our research shows that size does not moderate other proposed paths in our conceptual model. Large firms can use relational collaboration as complementary to their internal R&D capabilities, thus promoting the introduction of new products and processes.

Our study is also relevant to public policy makers. To encourage innovation collaboration between universities and firms, the Chinese State Council has utilised a series of policy tools, including preferential tax policies, intellectual property legislation, and the establishment of special funding programmes (Zhang et al. 2020). However, these preferential policies are largely targeted at fostering university technology-transfer, and they have failed to encourage more SMEs to participate in collaborations with universities. Given the positive impact of collaboration on SMEs identified in this research, policy-makers can certainly introduce relevant policies to foster the relational links between universities and SMEs. Universities can also take action by getting involved in local collaborations through flexible channels, expanding their social and economic influence to a larger context (Breznitz and Feldman 2012a).

This research is not without limitations. First, our sample did not include service firms, which have very different innovation orientation compared to manufacturing firms. Innovation in service firms relies more on tacit knowledge inflows, hence it would be interesting for future research to examine the impact of relational collaboration on service firms. Second, as previous literature has suggested, lag effects can help us to better infer the causal relationship among constructs. The survey employed in this research asked firms to measure their performance for 2018 only and so our data, although somewhat lagged, is nevertheless cross-sectional in nature. Future research based on longitudinal data is needed to better understand the relationship between collaboration, innovation, and performance. Lastly, as our data was collected in 2019, it is unknown whether relational collaboration, which highly prioritises face-to-face interactions between employees, will be hampered by the global pandemic of Covid-19.

Chapter 6 Conclusion

6.1 Introduction

Innovation has become a keyword in today's economic activities, as well as drawing the focus of policy-makers around the world. However, the value of innovation was recognised as early as the 1770s when Adam Smith indicated that technology change comes from the division of labour and leads to an increase in productivity (Smith 2010). Further, Karl Marx argued that new production technologies are adopted to reduce labour intensity so that capitalists can maximise their profits (Rosenberg 1976). In more recent years, innovation has been argued to be a critical factor for driving sustainable growth, increasing employment, and promoting social welfare (Dereli 2015).

In developed economies, such as the European countries, the major challenges to long-term economic growth and social developments are closely linked to issues related to innovation. Uppenberg (2009) has pointed out that although European policy-makers have repeatedly stressed their goal of addressing economic stagnation, little real progress has been made in terms of innovation. Rodríguez-Pose and Wilkie (2016) indicated that EU has encountered challenges in translating the substantial R&D investments into tangible innovations, which is impeding the economic growth and regional development. In emerging economies, such as China, innovation has been seen as the means of overcoming the 'middle-income trap'. Since China launched its economic reform in the 1970s, it has committed to promote economic growth by shaping a better institutional environment. However, the decades have passed and the '*low-hanging fruits of institutional reforms have been picked*' (Wei et al. 2017, p.50), meaning that it is now difficult to come up with institutional reforms that are radical enough to generate future growth. Therefore, Chinese policy-makers have identified innovation as the best approach for improving the economy's slow growth rate and escaping the middle-income trap.

It has been argued that even the most capable R&D firms need to connect themselves and their innovation activities to external knowledge sources if they are to be sustainable in offering new products and services to their customers (Chesbrough 2003). For firms with in-house R&D that is less optimal, it is crucial they identify and collaborate with appropriate external partners to improve their innovation performance. In this regard, the university, as an important knowledge producer and transmitter, is critical to the firm's innovation collaborative network. Scholars have suggested that collaboration between universities and firms can help address the market failure of innovation and promote the efficiency of firms' R&D investments; hence, such collaborations have been increasingly recognised as important vehicles for industrial innovation (Perkmann et al. 2013; Shi et al. 2019). Although studies have made significant progress in understanding the collaborative relationships between universities and firms, limitations still exist. First, previous work on UIC was mainly focused on the formal R&D collaboration and its relevant channels, such as joint research, licensing and patenting, spin-offs, etc.

Such research neglected the importance of informal collaborative methods (Ankrah and Al-Tabbaa 2015; Apa et al. 2020; Schaeffer et al. 2020), even though these are especially relevant to SMEs seeking flexible collaboration methods and lower collaboration costs. Second, previous research on the outputs of collaboration mainly focused on the firm's technological innovation, whereas the impact of collaboration on firms' non-technological innovations was largely overlooked (Pippel 2014). Firm-level innovation can go beyond its technological realm, since new organisational practices and marketing strategies are also important innovations that improve a firm's overall productivity and profitability (OECD 2005). Therefore, the issue of whether and how UIC affects firms' non-technological innovation needs to be further investigated for a more comprehensive understanding of UIC.

This thesis seeks to contribute to the literature by exploring the relations between UICs (formal/informal) and innovations (technological/management). Our exploration began with a systematic literature review on UIC, with a particular focus on papers published during the last ten years (Chapter 2). The limited time frame is necessary because the studies on UIC are abundant, and the research paradigms have changed rapidly in recent years. It is necessary for scholars to keep informed with the latest scholarly debate on U-I collaboration. Meanwhile, given that the context of this research is China, it is relevant to investigate China's institutional environment for innovation. Chinese innovating firms are highly exposed to their institutional settings, with government policies and initiatives having a profound impact on firms' innovation activities (Chesbrough et al. 2020b). For this reason, Chapter 3 explored the Chinese innovation systems at both national and regional levels. Chapter 4 and Chapter 5 are two empirical chapters in which the contractual/relational UICs and their impacts on firms' innovation outputs and economic performance were investigated using data from Chinese manufacturing firms. These two chapters also investigated how contextual factors such as the university's research quality and firm age and size affect UIC outcomes.

6.2 Main findings and responses to research questions

Research Question 1: What is a university-industry collaboration and what is the state-of-the-art of research?

The university-industry collaboration (UIC) refers to the interactions between higher education institutions and industrial firms. Such interactions aim to facilitate the technology and knowledge exchange between partners through a variety of channels (e.g., seminars/conferences, exchange of staff, joint research, patenting, etc.) (D'Este and Perkmann 2011; Perkmann et al. 2013). As summarised by

Ankrah and Al-Tabbaa (2015), UICs are beneficial to both universities and firms. For instance, collaborating with universities in the R&D process enables firms to obtain external knowledge for new product/process developments, gain access to public grants/subsidies, improve competitiveness, etc. For universities, industrial collaborations represent an important source of revenue. Meanwhile, the UIC is a platform for feedback on academics' new research ideas, as well as for offering opportunities for student training and placements.

Previous studies have largely focused on three aspects of UIC: its drivers, collaboration patterns, and collaboration outcomes. The formation of a UIC is driven by a wide range of factors, including the firm's R&D activity, size, industry, public incentives, proximity to universities, etc. (Tether and Tajar 2008; Laursen et al. 2011; Fantino et al. 2015; Lopez et al. 2015; Aiello et al. 2019). Regarding patterns of collaboration, previous research has extensively examined the formal collaboration methods that promote the technology transfer between universities and firms (Perkmann et al. 2013). The channels that accompany these formal methods include technological consultancy, research grants, joint/contract research, patent/license transaction, sharing facilities, creating joint ventures/spin-offs, etc. For the collaboration outcomes, a large number of studies have highlighted the positive link between UICs and firms' R&D capabilities with technological innovations (for example, see Hewitt-Dundas et al. 2019b; Tang et al. 2019). Another strand of research has focused on the relations between UICs and firms' economic performance, and it has been found that having an R&D alliance with universities helped firms to share the R&D costs and risks, increasing productivity and enabling firms to expand their market shares (Ivascu et al. 2016a; Jones and Corral de Zubielqui 2017).

Research Question 2: What is the contractual collaboration between university and industry?

Exchange hazards exist in collaborations between organisations. According to the transaction costs theory, asset specificity, uncertainty, and transaction frequency are the three main types of exchange hazard (Williamson 1985). Faced with these exchange hazards, managers tend to use formal contracts/agreements in which the promises and obligations of the collaboration and the methods for resolving any disputes are specified. As argued by Poppo and Zenger (2002), the more complex the hazard, the more likely the use of formal contracts.

The UIC is not exempt from exchange hazards. Considering that UICs are often aimed at exchanging knowledge, which is less tangible, more easily stolen, and very difficult to measure, formal contracts are frequently used by universities and firms to regulate their collaborations. In essence, the U-I contractual collaboration is a transaction that includes all channels of technology transfer, as well as some specific channels of knowledge-exchange activities. Compared with informal collaborations, contractual UICs are associated with higher costs and more commitments. Echoing previous literature and interviews with business managers, the channels of contractual UIC in this research were identified as technological consultancy, research grants, joint/contract research, patent/license transaction, sharing facilities, and creating joint ventures/spin-offs (Poppo and Zenger 2002; Garcia-Perez-de-Lema et al. 2017).

Research Question 3: What is the relational collaboration between university and industry?

The concept of relational collaboration, like that of contractual collaboration, was established by transaction cost economists to manage inter-organisational collaborations (Heide and John 1992; Poppo and Zenger 2002). Although contracts can be established to address transaction hazards, they can be dysfunctional if they are costly or difficult to enforce. As such, social relationships and interactions between partners may reduce transaction costs by encouraging mutual trust, which is the foundation of inter-organisational collaborations. In this sense, relational collaboration is a collaboration pattern that occurs through social interactions, which promotes flexibility, information exchange, and unity between partners.

This research extended the concept of relational collaboration from the transaction costs studies to the domain of university-industry collaboration. In the context of China, relational collaboration finds its root in the *Guanxi* – a unique Chinese social philosophy that originated from Confucianism. *Guanxi* is a term that describes interpersonal bonds that rely on friendship and mutual support (Shen et al. 2019). Ramasamy et al. (2006) examined the relationship between *Guanxi* and interfirm knowledge transfer in China, and found that the greater the level of *Guanxi*, the greater the degree of knowledge transfer between firms, resulting from a high level of trust and more effective communication. Our research, based on previous literature and interviews with business managers, identified social networking activities, forums/conferences, joint PGR supervisions, student internships, graduate recruitments, staff secondments, and training programmes as channels of relational UIC (Poppo and Zenger 2002; Garcia-Perez-de-Lema et al. 2017). Although previous studies have made attempts to identify the informal aspects of UIC (Apa et al. 2020; Schaeffer et al. 2020), this study is among the few that provided a more holistic picture of the informal channels of UIC.

Research Question 4: How does the contractual UIC affect a firm's technological and management innovation?

The impacts of a contractual UIC on technological innovation can be explained by the firm's knowledge-exploitation and knowledge-exploration behaviours (March 1991). In contractual UICs, firms can exploit the intellectual property of the university by purchasing patents or acquiring licences to use university intellectual property. This intellectual property and knowledge will directly add to the internal knowledge base of firms, and thereby contribute to the development of new products/processes. Meanwhile, firms can establish collaborations with universities to explore and gain knowledge that both parties lack. Such problem-solving exploration activities improve firms' R&D capabilities by combining and optimising the innovation resources held by both parties, increasing the firm's expertise in R&D, and resolving production issues; these factors all contribute to firms' technological innovations.

Our research found that the impacts of contractual UIC on firms' management innovation can take two paths. First, certain contractual collaboration channels directly improve the ability of firms to introduce management innovation. For example, sharing university facilities creates a platform where the firm's R&D staff can observe and imitate the way university experts organise and conduct their research. Furthermore, new organisational routines may be established by the firm's staff as a reflection of the observed knowledge. Second, our findings revealed that technological innovation mediates the impact of contractual collaboration on management innovation. As the technological innovation developed from the university's knowledge has a fairly radical nature, it is necessary that firms adjust their current organisational structure/marketing strategy so as to manufacture the technological innovations and profit from them. These findings indicated that, apart from the expected impacts on firms' technological innovation, the formal R&D partnerships can also help firms to facilitate profound organisational changes and innovative business practices.

Research Question 5: Do geographical proximity and the research quality of universities affect the firm's innovation outputs in contractual UICs?

This research found that regional proximity did not produce stronger effects on firm's innovation outputs. This is contrary to the findings from previous research that the proximity of partners facilitates the exchange of tacit knowledge, which is relevant for the introduction of management innovation (Hewitt-Dundas 2013b; Pippel 2014). However, although proximity is important to the exchange of knowledge, the rapid development of communication technology has meant that permanent co-location is not always necessary. Temporary proximity, such as that produced by trade fairs/shows, conferences, etc, could be sufficient for effective knowledge exchange (Torre 2008). Short encounters between partners enable them to communicate in a face-to-face manner at a lower cost. Meanwhile, the presence of geographical proximity only is not a sufficient condition for better collaboration performance. Proximity is a multidimensional concept, and other types of proximity (e.g. institutional, cognitive) are also affecting the innovation outputs in the collaborative network (Boschma 2005a; Fitjar et al. 2015). Also, this research found that in a contractual UIC, the firm's management innovation was mainly influenced by technological innovations. As such, geographical distance becomes less relevant given the reliance of technological innovation on codified knowledge, the transmission of which is not affected by spatial distance (Boschma 2005b).

Regarding the research quality of universities, this research found that there was no significant difference in technological innovation when firms collaborate with universities that have different levels of research quality. Lower ranked regional universities, unlike their elite counterparts, may be unable to produce excellent academic outputs in basic research. However, many such institutions specialise in the applied sciences and are often practice-based; this enables them to provide necessary knowledge that helps firms to improve or refine their current products/manufacturing process. In this regard, the regional university could be a valuable partner for a firm's innovation activities. Moreover, the collaborative links between science and industry are relatively weak in China, suggesting that firms may not be able to benefit as much as western firms from collaborating with research-excellent universities. The insignificant role of geographic proximity and research quality found in this research shows that, in the context of China, knowledge appropriateness is the key to better UIC performance as it determines whether and how firms can assimilate and utilise external knowledge into their innovation activities.

Research Question 6: How does the relational UIC affect the firm's technological and management innovation?

The impacts of relational UIC on the firm's technological innovation can be viewed from the perspective of the nature of knowledge. Nonaka and Takeuchi (1995a) defined explicit knowledge as knowledge that can be codified and transferred formally and systematically. Tacit knowledge, in contrast, is informal, non-verbalizable, and unarticulated. Explicit knowledge is tangible in nature and can be written as instructions, formulas, and functions, whilst tacit knowledge is less tangible and it is specific to the person or organisation who possesses it. Scholars have found that while technological innovation is heavily associated with explicit knowledge, management innovation relies more on tacit knowledge (Pippel 2014; Piening and Salge 2015).

The link between relational UIC and the firm's management innovation is straightforward. The knowledge relevant to management innovation has a somewhat tacit nature and is most likely to be acquired by frequent contacts with both internal and external knowledge sources. Relational UIC therefore creates a platform upon which staff can frequently communicate face to face, and through which universities can transfer management expertise to firms. This is relevant to the reformulation of the organisational structure and the product positioning strategy.

Relational UIC can support a firm's technological innovation in two ways. First, as indicated by Cavusgil et al. (2003), the more tacit knowledge is transferred from universities to firms, the more likely it is that the firm develop intellectual capital that makes it unique and effective in producing technological innovations. For example, a firm's engineers, through frequent interactions with university researchers, can combine their expertise with the tacit knowledge held by those researchers to create a unique knowledge base for the firm's new product developments. Second, as knowledge usually manifests both explicit and tacit attributes, the acquisition of relevant tacit components can help the explicit components of knowledge to be better assimilated and interpreted (Hall and Andriani 2003). For example, when firms acquire a production technology licence from universities, the firm's developers need to also have the relevant tacit knowledge that will enable the new technology to be effectively applied. Through the discussion of how relational collaboration can boost firm' innovation performance, this research opens a new line of inquiry on the role of universities in firms' DUI innovation network.

Research Question 7: Do firm's innovation outputs contribute to better economic performance?

Whether innovation does in fact contribute to better economic performance is an ongoing debate among scholars, as previous studies have discovered both positive and negative effects (for example, see Rogers 2010; Hashi and Stojčić 2013). Unlike previous research that only focused on the impacts of technological innovations, this research investigates the impacts of technological and management innovations on a firm's economic performance. Based on data collected from the Chinese manufacturing industry, this research found that innovations of both types positively contribute to firms' economic performance; hence, we contribute new evidence for the positive relations between innovation and economic performance.

Our results suggest that product innovation and process innovation positively contribute to the productivity, profitability, market performance, and sales revenue of firms. New or improved products offer customers greater benefits compared to current products, and the new offering will be viewed by the customer as unique and different from competing products, thus giving firms a better competitive advantage in the market. For manufacturing firms, process innovation refers to new or significant changes in the methods of production, according to the Oslo Manual (2005). Process innovation helps to improve the product quality, production flexibility, and reduces both processing time and marginal costs.

Management innovation includes new/significantly improved organisational practices and marketing strategies, which are closely linked to higher economic performance. The ability to renew and reconfigure an organisational practice helps firms adapt better to the external environment, increasing administrative efficiency and employee satisfaction and creativity, thus improving the firm's financial returns. Meanwhile, successful marketing innovation improves firms' promotion of their products, earns customer loyalty, and expands firms' market share. It has been recognised as an important approach to achieving superior business performance (Naidoo 2010).

Research Question 8: Do firm's size, age, industry, and absorptive capacity affect the outputs of the relational UICs?

Findings provided by this research suggest that only size and sector significantly moderate the relationship between relational UIC and management innovation. Specifically, SMEs tend to perform better in management innovation when they are engaged in relational UICs. Large firms favour collaborations that transfer cutting-edge technologies while they can further commercialise these technologies through the efforts of their internal R&D departments (Bekkers and Bodas Freitas 2008). However, internal bureaucracy can slow down the process of reforming relevant management practices. Thus, the flexible internal structure of SMEs keeps them relatively nimble when responding to knowledge that may help them achieve higher organisational efficiency.

This research also shows that firms operating in high-tech sectors have a stronger relationship between collaboration and management innovation than firms in other sectors. As argued in Chapter 5, the major advantage of relational collaboration is that it creates a platform for the exchange of tacit knowledge, therefore this form of collaboration may not incorporate enough of the scientific knowledge that directly leads to radical technological innovation. Thus, high-tech firms will proactively seek relevant managerial knowledge that helps them to better administer their R&D processes and market their novel products to their customers. This finding further highlights the relevance of relational collaboration, as it is not only important to firms with lower absorptive capacity, but also high-tech firms can use the relational channels to obtain knowledge that is crucial to their profitability.

Research Question 9: How does the institutional environment shapes the innovation systems in China?

The deterioration of the external economic environment and the disappearance of China's demographic advantages have prompted Chinese policy-makers to identify innovation as key to sustainable economic growth. However, as one of the world's few communist countries, the trajectory of innovation in China has followed a top-down governance model. Thus, innovation networks are greatly influenced by institutional factors such as government policies, initiatives, laws, and regional legislations (Li et al. 2020c).

Prior to the 1980s, China's economic structure was dominated by state-owned firms. During that time, China followed a centrally planned economic system, and national innovation projects were mainly undertaken by some key public research institutions/laboratories, with little or no involvement from private firms. However, starting with the S&T reform initiated in 1985, China has been committed to using a wide range of policy tools to create a national system of innovation. A common feature of these policies is the extensive range of R&D investments allocated to enterprises and public universities, with the aim of encouraging technology transfer and collaboration between knowledge producers and knowledge users. The national innovation projects have shifted from a primarily military focus to also having a civil purpose. The '*Medium-and Long-Term Plan for the Development of Science and Technology (2006-2020)*' introduced in 2006 marks the most significant change in the 'National Innovation System' as, for the first time in history, it prioritises private firms in the allocation of public innovation resources (e.g., funds, tax, legislation) (Gu et al. 2009). Meanwhile, China's regional innovation systems have grown rapidly. Our research has identified the Yangtze River Delta, the Pearl River Delta, and the Jingjinji economic zone as the most developed regional systems of innovation in mainland China. These are regions that have been strongly supported by the central government and they benefit from preferential policies introduced by local governments. However, regional disparities remain a major issue in the current economic landscape.

6.3 Contributions to theory

This research has conceptualised two significant patterns for the collaboration between universities and industries. Further, it has explored the impact of these patterns on firms' innovation outputs and economic performance. The findings of this research contribute to theory as follows.

First, this research has made a novel contribution to the current literature by expanding the application of transaction costs theory to the domain of university-industry collaboration, exploring how relational collaboration can produce innovation outputs and improve the economic performance of firms. According to transaction cost economics, the inter-firm transaction costs can be categorised as (1) search and information costs, (2) negotiating and contracting costs, and (3) monitoring and enforcement costs (Williamson 1989). To minimise transaction costs and protect against possible opportunistic behaviour, the most prominent safeguard is the use of formal contract/agreement (Dyer 1997), which explicitly specifies the quantity, quality and price of the goods/service. The relational collaboration is however a viable alternative to the contractual collaboration because a strong social relationship encourages the application of trust and cooperation between partners, and thereby reduces transaction costs (Dyer 1997; Poppo and Zenger 2002).

Collaborations between universities and firms are not exempt from transaction costs. Finding an appropriate university partner is difficult due to information asymmetry, and the negotiating and monitoring of the contract could also be difficult given the different norms followed by academics and business. Furthermore, Williamson (1985) suggested that a formal contract can address three types of exchange hazards: specialised asset investments, transaction frequency, and uncertainty. However, the exchange hazards in UIC are less likely to be remedied by the use of formal contracts alone. First, the greater amount of R&D investment (e.g., human capital, expertise, knowledge) means that the assets involved in UICs are highly specialised, making them less tradable outside the specified contract. Second, the collaboration frequency can be very flexible due to the diverse nature of collaboration projects and channels. Third, as the process of scientific research is characterised by uncertainty such that desirable research outcomes cannot be guaranteed, firms collaborating with universities under the terms of a formal contract are at greater risk (e.g., financial risk, market risk, leakage of proprietary information). Therefore, relational collaboration could serve as an important method to further reduce the transaction costs merged in UICs. Although scholars have highlighted the necessity of exploring the informal methods of UIC, the literature in this area is nevertheless scarce (Ankrah 2013b; Perkmann et al. 2013). By investigating the frequently used UIC channels, this research has defined contractual and relational UIC and contributed to the understanding of how transaction costs can be minimised through these two collaboration patterns. Compared to other studies that explored the informal method of UIC (for example, see Olmos-Peñuela et al. 2014; Garcia-Perez-de-Lema et al. 2017; Apa et al. 2020), this research has not only developed a theoretical framework for relational collaboration in the UIC, but it also provides a novel understanding of how the relational UIC affects firms' innovation outputs and economic performance.

Second, this research contributes to the innovation literature by highlighting the importance of non-technological innovation. Innovation studies have hitherto largely focused on firms' new products and processes, and the empirical measures of innovation have mainly been based on the technological attributes of firms, such as their R&D intensity, number of patents, and new product sales (Taques et al. 2020). However, as indicated by Schumpeter (1942), innovation can also be achieved by identifying new sources of suppliers and markets or by finding new ways of organising business practice. These less tangible innovations were designated by the Oslo Manual (2005) as 'non-technological' innovations, which derive from a firm's implementation of new or significantly improved organisational practices and marketing strategies. As noted by the Oslo Manual, non-technological innovations are critical to firms' performance as they help firms reduce administrative/transaction costs, gain access to external knowledge, and better position their products in the market.

Although previous literature has extensively examined how collaboration with universities affects firms' innovation outputs, the impacts of UIC on non-technological innovations has been long absent from discussions in innovation studies (Pippel 2014). Using the non-technological innovation defined by the Oslo Manual (2005), this research measures the impacts of UIC on both the technological and management innovations of firms; thus it provides a more holistic understanding of how UIC brings innovative changes to firms. Specifically, this research shows that a contractual collaboration with a university most directly impacts the firm's internal R&D capability. As such, the impact on the firm's management innovation is mainly through the mediating effects of technological innovation. For example, through the breakthrough in battery technology that is in collaboration with Cranfield University, Jaguar Land Rover was able to establish a marketing strategy to promote its environmentally friendly brand image. However, for relational UICs, this research found a strong link between collaboration and management innovation, as relational channels can better facilitate the transfer of tacit knowledge from universities to firms. These findings suggest that, aside from providing the expected technological knowledge, universities are also capable of transferring (tacit) knowledge that is relevant to the firm's organisational changes and management innovations.

Third, this research contributes to the literature on firm's innovation mode by exploring the universities' role as a Doing, Using, and Interacting (DUI) partner for firms. Jensen et al. (2007) drew on the seminal work by Lundvall (1992a) to introduce two different modes of innovation and learning to the scholarly debate about the knowledge drivers of innovation. The first mode places emphasis on R&D activities and is termed the Science and Technology-based Innovation (STI mode). The second mode is characterised by learning by Doing, Using and Interacting (DUI mode). For firms dominated by the STI mode, innovation is a result of continuous investments in R&D and scientific human capital. The process is characterised by R&D collaborations with consultancies, universities, and research centres (Cunningham and Link 2015). In this sense, universities are often considered to be important STI partners for firms.

In contrast, the DUI mode is dominated by the informal process of learning, and innovations are generated via broader interactions. The knowledge accumulated through DUI is largely based on personal experiences and feedback, hence it is mainly shared through tacit knowledge flows among members within/outside the organisation (Apanasovich et al. 2016). As such, universities are considered less relevant to the firm's DUI collaboration network as they are seen as places where codified scientific knowledge is produced and transferred to industries. Previous research suggested that it is difficult for universities to participate in the daily innovation process of firms and that DUI firms benefit from UIC mainly through the education and training of students/employees (Benneworth et al. 2009; Isaksen and Karlsen 2010). Our research has argued that by effectively engaging in relational channels with universities, firms have the opportunity to obtain tacit (DUI type) knowledge that consolidates their internal R&D capability and improves organisational efficiency. As such, our research makes a novel contribution to the literature by exploring the role of universities as a DUI partner; this is particularly pertinent for SMEs who cannot afford the high costs associated with contractual UICs.

6.4 Managerial and policy implication

This research is highly relevant for business managers who are seeking to get most of collaborating with universities. First, since the collaboration with the university is often associated with higher costs and there is no guarantee that the collaboration will generate the expected outcome, firms may be reluctant to choose universities as their R&D partner. This is evidenced by the Chinese National Enterprise Survey 2019 (NBS 2020), which shows that out of all the available innovation partners (e.g., industry associations, suppliers, customers), only 25.8% of firms chose universities as their primary innovation partner. Our research suggests that, despite the known shortcomings, collaborating with universities has a strong impact on firms' technological innovations, and that such collaborations will also promote innovative organisational changes. As such, business managers are encouraged, wherever necessary, to collaborate with universities for better innovation performance.

Second, for SMEs who cannot defray the costs/risks of entering into a formal collaboration or are not capable of absorbing cutting-edge codified knowledge, collaboration with universities via the relational channels is an important pathway to better innovation and economic performance. As shown in Chapter 5, firms can get access to useful (if not novel) knowledge from the university by encouraging frequent interactions with university researchers. Although such interactions might not be as formal as a research partnership, they are nevertheless capable of transferring tacit knowledge that can incrementally contribute to the technological and management innovation of firms. This interaction-based collaboration can take many forms ranging from sending employees to university conferences or training programmes through to encouraging staff secondments or student placements. These activities enable firms to be flexible in collaboration, and thus they can manage the collaboration's risks and costs.

Third, previous research suggests that proximity plays an important role in UIC, both in the search for university partners and in the collaboration process itself (Fantino et al. 2015; Geldes et al. 2017). Indeed, being engaged in relational UICs implies frequent face-to-face interactions that will enable firms to access the tacit knowledge held by university researchers. As such, being geographically close to university is important for better collaboration outcomes. However, as it was amply demonstrated during the Covid-19 pandemic, permanent co-location is not always necessary thanks to the rapid development of communication technology. Today, partners communicate through a variety of technological tools (e.g., video meetings) and one can expect yet more revolutionary technology to be introduced with the industrial application of 5G technology (e.g., visual reality). Such technologies can create a temporary proximity that allows partners to interact without having to be physically adjacent to each other and, to a degree, they supplement the permanent proximity. However, people still need to actually 'see' the transaction goods and each other if they are to build trust and a close relationship.

Hence, business managers should ensure that temporary proximity does not compromise the importance of geographical adjacency. As suggested by Goldenberg and Levy (2009), information technology has not fundamentally changed the method of social interactions, which implies that it has not changed the fundamental pathways in today's UICs either.

This research offers at least two key implications for policy-makers. First, the importance of the informal innovation network should be fully recognised, especially in countries where formal links between science and industries have not yet to be well established. To encourage innovation collaboration between universities and firms, the Chinese State Council has utilised a series of policy tools that include preferential tax policies, intellectual property legislation, and special funding programmes (Zhang et al. 2020). However, these extremely expensive policies are largely focused on fostering the university technology-transfer, and the policy package has been criticised for its overall low efficiency (Liu et al. 2017). Moreover, the current policy tools have generally failed to encourage SMEs to participate in the collaboration. Given that this research has identified a clear positive impact of relational collaboration on SMEs, policy-makers are recommended to introduce the appropriate policies to foster relational links between universities and SMEs.

Furthermore, instead of solely encouraging collaboration between elite universities and industries, policy-makers should also recognise the value that the practice-led regional/lower ranked universities can add to a more balanced innovation system. Although such universities may not be able to produce excellent academic outputs in basic research, many of the regional universities are specialists in applied sciences, making them valuable partners that can support a firm's efforts to bring about incremental improvements in its current products and manufacturing processes. Combined with our finding that SMEs can benefit greatly from having relational links with universities, it is evident that lower ranked regional universities have much untapped potential for supporting the innovation activities of local SMEs. For local SMEs, establishing relational links with regional universities will enable them to gain access to necessary innovation information and knowledge at lower cost; for regional universities, becoming involved in local collaboration activities will enable them to connect their practice-based research to industry experience, which in turn will improve their academic performance. In addition, collaborating with local SMEs helps regional universities to expand not only their income sources but also to improve their impact in that they can exert social and economic influence within a wider context (Breznitz and Feldman 2012a).

6.5 Limitations and future research directions

This research is subject to the empirical and methodological limitations. First of all, the data employed in this research were collected through a questionnaire survey, which is cross-sectional in nature. As suggested by previous literature, it takes time for R&D efforts to transfer into innovation outputs, and still more time for innovation outputs to generate better economic performance (Damanpour and Evan 1984; Ken et al. 2008). Hence, time lags are considered to be important when inferring the causal relationship between constructs. However, as the measurements of some constructs in this research are based on a subjective evaluation from managers (e.g., radicalness of innovation), it would be difficult for the respondent to give an accurate evaluation of a construct on a yearly basis. Future research that relies on longitudinal data is therefore recommended for a more thorough investigation into how UIC affects firms' innovation outputs as well as their economic performance over time.

Our second limitation concerns the generalisability of the research findings. This is a limitation that is common to studies that rely on data from one specific industry. Our data were collected from manufacturing firms; thus, this research did not investigate or discuss how service firms might collaborate with universities for innovation and better performance. As suggested by previous literature, manufacturing and service firms experience different types of innovation (Aboal and Garda 2015; Zhao and Wu 2017). For example, an improvement in the production process is considered a process innovation in manufacturing firms, whereas a new delivery method is often considered to be a product innovation in service firms. Also, service firms may have different expectations from university collaboration. For example, manufacturing firms often expect to boost their R&D capability with the cutting-edge knowledge held by university scientists, which is why R&D collaborations are more prevalent in this sector. For service firms, technological progress is rarely the goal of a UIC. Rather, it is their organisational practice and marketing strategies that are most likely to benefit from the collaboration. As such, the findings of this research cannot be generalised to service firms. It is recommended that future research specifically investigates whether a UIC can improve the innovation performance of service firms, and if so, what collaboration method is capable of delivering benefits.

Third, the UIC could be affected by a wide range of variables such as firm's size, age, absorptive capacity, etc. Although this research has included some of these in the empirical analysis, we recommend future research to introduce more control variables to the empirical models. For example, in Chapter 3 we described how government subsidies have affected the UIC in China, but this was information that could not be included in the empirical model because most firms were reluctant to reveal such information in the pilot survey. Moreover, the Chinese government has imposed strict environmental protection regulations on manufacturing firms, which have greatly affected their innovation activities business operations and profitability. Due to the availability of data, we did not introduce such indicators in our empirical model. For a more holistic understanding of UIC, future research is encouraged to introduce additional control variables that are both relevant and feasible.

Last but not the least, although the current research is not intended to make a direct comparison between contractual and relational UICs, it would be relevant for future research to do so. It has been argued that collaborations with STI and DUI partners appear to be substitutes, as simultaneously involving in these two may result in knowledge 'over-searching', and it could be difficult for firms to absorb these excessive knowledge (Haus-Reve et al. 2019). According to previous literature, relational and contractual collaborations can act either as substitutes or complements. Although the purpose of the contract is to protect the interests of the partners, an explicit and sophisticated contract may actually encourage opportunistic behaviour as it is a signal of distrust (Fehr and Gächter 2002). As such, relational collaborations are often viewed as substitutes for formal contracts. However, some research has found that well-executed contracts can in fact promote trust between partners and lead to the establishment of a long-term collaborative relationship. Therefore, relational and contractual collaborations may function as complements (Poppo and Zenger 2002; Garcia-Perez-de-Lema et al. 2017). Based on the theoretical framework provided in this research, it would be interesting for future research to add more empirical evidence that explains the relationship between contractual and relational UICs.

References

Abbas, A., Avdic, A., Peng, X. B., Hasan, M. M. and Ming, W., 2019. University-government collaboration for the generation and commercialization of new knowledge for use in industry. *Journal of Innovation & Knowledge*, 4 (1), 23-31.

Aboal, D. and Garda, P., 2015. Technological and non-technological innovation and productivity in services vis-à-vis manufacturing sectors. *Economics of Innovation and New Technology*, 25 (5), 435-436.

Adner, R. and Levinthal, D., 2001. Demand heterogeneity and technology evolution: implications for product and process innovation. *Management science*, 47 (5), 611-628.

Aghion, P., Akcigit, U. and Howitt, P., 2015. The Schumpeterian growth paradigm. *economics*, 7 (1), 557-575.

Aghion, P., Bergeaud, A., Lequien, M. and Melitz, M. J., 2018. *The impact of exports on innovation: Theory and evidence*. National Bureau of Economic Research Cambridge, MA.

Aghion, P., Ljungqvist, L., Howitt, P., Howitt, P. W., Brant-Collett, M. and García-Peñalosa, C., 1998. *Endogenous growth theory*. MIT press.

Ahlstrom, D., Yang, X., Wang, L. and Wu, C., 2018. A global perspective of entrepreneurship and innovation in China. *Multinational Business Review*.

Aiello, F., Cardamone, P. and Pupo, V., 2019. New evidence on the firm-university linkages in Europe. The role of meritocratic management practices. *International Review of Applied Economics*.

Al-Tabbaa, O., Ankrah, S. and Zahoor, N., 2019. *Systematic Literature Review in Management and Business Studies: A Case Study on University–Industry Collaboration*.

Alcouffe, A. and Kuhn, T., 2004. Schumpeterian endogenous growth theory and evolutionary economics. *Journal of Evolutionary Economics*, 14 (2), 223-236.

Alexander, A. T. and Martin, D. P., 2013. Intermediaries for open innovation: A competence-based comparison of knowledge transfer offices practices. *Technological Forecasting and Social Change*, 80 (1), 38-49.

Ali, A., 1994. Pioneering versus incremental innovation: Review and research propositions. *Journal of product innovation management*, 11 (1), 46-61.

Amara, N., Landry, R., Becheikh, N. and Ouimet, M., 2008. Learning and novelty of innovation in established manufacturing SMEs. *Technovation*, 28 (7), 450-463.

Ankrah, S., 2013a. <University-Industry Interorganisational Relationships for TechnologyKnowledge Transfer A Systematic Literature Review.pdf>.

Ankrah, S. and Al-Tabbaa, O., 2015. Universities–industry collaboration: A systematic review. *Scandinavian Journal of Management*, 31 (3), 387-408.

Ankrah, S. N., Burgess, T. F., Grimshaw, P. and Shaw, N. E., 2013. Asking both university and industry actors about their engagement in knowledge transfer: What single-group studies of motives omit. *Technovation*, 33 (2-3), 50-65.

Ankrah, S. N. J. K. T. A. S. L. R., 2013b. University-Industry interorganisational relationships for technology/knowledge transfer: A systematic literature review.

Anselin, L., Varga, A. and Acs, Z. J. J. P. i. r. s., 2000. Geographic and sectoral characteristics of academic knowledge externalities. 79 (4), 435-443.

Apa, R., De Marchi, V., Grandinetti, R. and Sedita, S. R., 2020. University-SME collaboration and innovation performance: the role of informal relationships and absorptive capacity. *The Journal of Technology Transfer*.

Apanasovich, N., Heras, H. A. and Parrilli, M. D., 2016. The impact of business innovation modes on SME innovation performance in post-Soviet transition economies: The case of Belarus. *Technovation*, 57, 30-40.

Arundel, A. and Geuna, A., 2004. Proximity and the use of public science by innovative European firms. *Economics of Innovation and new Technology*, 13 (6), 559-580.

Arvanitis, S. and Woerter, M., 2009. Firms' transfer strategies with universities and the relationship with firms' innovation performance. *Industrial and Corporate Change*, 18 (6), 1067-1106.

Asheim, B. and Parrilli, M. D., 2012. Interactive learning for innovation. *A Key Driver within Clusters and Innovation Systems, Basingstoke*.

Asheim, B. T. and Coenen, L., 2005. Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy*, 34.

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

Atta-Owusu, K., Dahl Fitjar, R. and Rodríguez-Pose, A., 2020. What drives university-industry collaboration: Research excellence or firm collaboration strategy?

Attour, A., Burger-Helmchen, T., Zhong, J. and Nieminen, M., 2015. Resource-based co-innovation through platform ecosystem: experiences of mobile payment innovation in China. *Journal of Strategy and Management*.

Audretsch, D. B. and Feldman, M. P., 1996. R&D spillovers and the geography of innovation and production. *The American economic review*, 86 (3), 630-640.

Audretsch, D. B. and Keilbach, M. J. J. o. M. S., 2007. The theory of knowledge spillover entrepreneurship. 44 (7), 1242-1254.

Augier, M., Guo, J. and Rowen, H., 2016. The Needham puzzle reconsidered: Organizations, organizing, and innovation in China. *Management and Organization Review*, 12 (1), 5-24.

Azar, G. and Ciabuschi, F., 2017. Organizational innovation, technological innovation, and export performance: The effects of innovation radicalness and extensiveness. *International Business Review*, 26 (2), 324-336.

Baldwin, R. and Tomiura, E., 2020. Thinking ahead about the trade impact of COVID-19. *Economics in the Time of COVID-19*, 59.

Baron, R. M. and Kenny, D. A., 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of personality and social psychology*, 51 (6), 1173.

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

Belderbos, R., Carree, M. and Lokshin, B. J. R. p., 2004. Cooperative R&D and firm performance. 33 (10), 1477-1492.

Belderbos, R., Gilsing, V. A. and Suzuki, S., 2016. Direct and mediated ties to universities: "Scientific" absorptive capacity and innovation performance of pharmaceutical firms. *Strategic Organization*, 14 (1), 32-52.

Belleflamme, P. and Peitz, M., 2015. *Industrial organization: markets and strategies*. Cambridge University Press.

Bennat, T. and Sternberg, R., 2020. Knowledge bases in German regions: what hinders combinatorial knowledge dynamics and how regional innovation policies may help. *European Planning Studies*, 28 (2), 319-339.

Benner, M., Liu, L. and Serger, S. S., 2012. Head in the clouds and feet on the ground: Research priority setting in China. *Science and Public Policy*, 39 (2), 258-270.

Benneworth, P., Coenen, L., Moodysson, J. and Asheim, B., 2009. Exploring the multiple roles of Lund University in strengthening Scania's regional innovation system: towards institutional learning? *European Planning Studies*, 17 (11), 1645-1664.

Berbegal-Mirabent, J., Garcia, J. L. S. and Ribeiro-Soriano, D. E., 2015. University-industry partnerships for the provision of R&D services. *Journal of Business Research*, 68 (7), 1407-1413.

Bercovitz, J. and Feldman, M. J. T. J. o. T. T., 2006. Entpreprenerial universities and technology transfer: A conceptual framework for understanding knowledge-based economic development. 31 (1), 175-188.

Biedenbach, T., Marell, A. and Vanyushyn, V., 2018. Industry-university collaboration and absorptive capacity: an empirical study in a Swedish context. *International Journal of Technology Management*, 76 (1-2), 81-103.

Bigliardi, B. and Dormio, A. I., 2009. An empirical investigation of innovation determinants in food machinery enterprises. *European Journal of Innovation Management*.

Bimber, B., 1990. Karl Marx and the three faces of technological determinism. *Social studies of science*, 20 (2), 333-351.

Blindenbach-Driessen, F. and Van Den Ende, J. J. R. p., 2006. Innovation in project-based firms: The context dependency of success factors. 35 (4), 545-561.

Bodas Freitas, I. M., Geuna, A. and Rossi, F., 2013a. Finding the right partners: Institutional and personal modes of governance of university–industry interactions. *Research Policy*, 42 (1), 50-62.

Bodas Freitas, I. M., Marques, R. A. and Silva, E. M. d. P. e., 2013b. University–industry collaboration and innovation in emergent and mature industries in new industrialized countries. *Research Policy*, 42 (2), 443-453.

Bollen, K. A. and Stine, R., 1990. Direct and indirect effects: Classical and bootstrap estimates of variability. *Sociological methodology*, 115-140.

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

Boschma, R. and Frenken, K., 2009. *The spatial evolution of innovation networks: a proximity perspective*. Utrecht University, Department of Human Geography and Spatial Planning ….

Boschma, R. J. R. s., 2005b. Proximity and innovation: a critical assessment. 39 (1), 61-74.

Bozeman, B., 2000. Technology transfer and public policy: a review of research and theory. *Research Policy*, 29 (4), 627-655.

Breznitz, S. M. and Feldman, M. P., 2012a. The engaged university. *The Journal of Technology Transfer*, 37 (2), 139-157.

Breznitz, S. M. and Feldman, M. P., 2012b. The larger role of the university in economic development: introduction to the special issue. *The Journal of Technology Transfer*, 37 (2), 135-138.

Breznitz, S. M. and Ram, N., 2012. Enhancing economic growth? University technology commercialization. *Creating Competitiveness*. Edward Elgar Publishing.

Bruneel, J., D'Este, P. and Salter, A., 2010a. Investigating the factors that diminish the barriers to university-industry collaboration. *Research Policy*, 39 (7), 858-868.

Bruneel, J., D’Este, P. and Salter, A., 2010b. Investigating the factors that diminish the barriers to university–industry collaboration. *Research Policy*, 39 (7), 858-868.

Bstieler, L., Hemmert, M. and Barczak, G., 2017. The changing bases of mutual trust formation in inter-organizational relationships: A dyadic study of university-industry research collaborations. *Journal of Business Research*, 74, 47-54.

Cai, F., 2020. The Second Demographic Dividend as a Driver of China's Growth. *China & World Economy*, 28 (5), 26-44.

Cancino, C. A., La Paz, A. I., Ramaprasad, A. and Syn, T., 2018. Technological innovation for sustainable growth: An ontological perspective. *Journal of Cleaner Production*, 179, 31-41.

Cao, C., Ning, L., Xia, L. and Liu, L., 2015. Reforming China's S&T system: A new perspective. *Journal of Dialectics of Nature*, 37 (1), 12.

Caraça, J., Lundvall, B.-Å. and Mendonça, S., 2009. The changing role of science in the innovation process: From Queen to Cinderella? *Technological Forecasting and Social Change*, 76 (6), 861-867.

Carayannis, E. G. and Campbell, D. F. J. I. j. o. t. m., 2009. 'Mode 3'and'Quadruple Helix': toward a 21st century fractal innovation ecosystem. 46 (3-4), 201-234.

Carbaugh, R. J. and St Brown, M., 2012. Industrial policy and renewable energy: Trade conflicts. *Journal of International and Global Economic Studies*.

Cardamone, P., Pupo, V. and Ricotta, F., 2018. Exploring the relationship between university and innovation: evidence from the Italian food industry. *International Review of Applied Economics*, 32 (5), 673-696.

Cassiman, B., Veugelers, R., Zuniga, P. J. I. and Change, C., 2008. In search of performance effects of (in) direct industry science links. 17 (4), 611-646.

Cavusgil, S. T., Calantone, R. J. and Zhao, Y., 2003. Tacit knowledge transfer and firm innovation capability. *The Journal of Business and Industrial Marketing*, 18 (1), 6-21.

Central Government of the People's Republic of China, 1985a. *The Decisions of the Central Committee of the Communist Party on the Reform of the S&T System* [online]. Available from: http://www.gov.cn/test/2009-10/23/content_1447117.htm [Accessed 28/10/2020].

Central Government of the People's Republic of China, 1985b. *Decisions on Establishing the Pearl River Delta Economic Zone* [online]. Available from: http://www.gov.cn/test/2009-10/09/content_1434323.htm [Accessed 01/11/2020].

Central Government of the People's Republic of China, 2015a. *Coordinated Development Plan for the Beijing-Tianjin-Hebei region* [online]. Available from: http://www.gov.cn/zhengce/2015-08/23/content_2918246.htm [Accessed 01/11/2020].

Central Government of the People's Republic of China, 2015b. *Made in China 2025* [online]. Available from: http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm [Accessed 28/10/2020].

Central Government of the People's Republic of China, 2017. *Mass Entrepreneurship and Innovation* [online]. Available from: http://www.gov.cn/zhengce/content/2017-07/27/content_5213735.htm [Accessed 28/10/2020].

Central Government of the People's Republic of China, 2019. *Outline Development Plan for the Guangdong-Hongkong-Macao Great Bay Area* [online]. Available from: http://www.gov.cn/zhengce/2019-02/18/content_5366593.htm#1 [Accessed 01/11/2020].

Central Government of the People's Republic of China, 2020. *The Outline of the Integrated Regional Development of the Yangtze River Delta* [online]. Available from: http://www.gov.cn/zhengce/2019-12/01/content_5457442.htm [Accessed 01/11/2020].

Chakrabarti, A. K. and Santoro, M. D., 2004. Building social capital and learning environment in university–industry relationships. *International Journal of Learning and Intellectual Capital*, 1 (1), 19-36.

Chen, A., Patton, D. and Kenney, M., 2016. University technology transfer in China: A literature review and taxonomy. *The Journal of technology transfer*, 41 (5), 891-929.

Chen, H. and Xie, F., 2018. How technological proximity affect collaborative innovation? An empirical study of China's Beijing–Tianjin–Hebei region. *Journal of Management Analytics*, 5 (4), 287-308.

Chen, J., Chen, Y. and Vanhaverbeke, W., 2011. The influence of scope, depth, and orientation of external technology sources on the innovative performance of Chinese firms. *Technovation*, 31 (8), 362-373.

Chen, J., Damanpour, F. and Reilly, R. R., 2010. Understanding antecedents of new product development speed: A meta-analysis. *Journal of Operations Management*, 28 (1), 17-33.

Chen, J., Huang, S.-f. and Xu, Q.-r., 2015. Firm innovation systems: Perspectives of researches on state-owned key enterprises. *Frontiers of Engineering Management*, 2 (1), 64-70.

Chen, S. W., 2010. Comparison of National Innovation Systems in China, Taiwan, and Singapore: Is Bayh-Dole One-Size that Fits All?

Chesbrough, H., Heaton, S. and Mei, L., 2020a. Open innovation with Chinese characteristics: a dynamic capabilities perspective. *R&D Management*.

Chesbrough, H., Heaton, S. and Mei, L., 2020b. Open innovation with Chinese characteristics: a dynamic capabilities perspective. *R&D Management*, n/a (n/a).

Chesbrough, H. W., 2003. *Open innovation: The new imperative for creating and profiting from technology*. Harvard Business Press.

Chesbrough, H. W., 2006. The era of open innovation. *Managing innovation and change*, 127 (3), 34-41.

Chinese Academy of Sciences, 2020. *Profile* [online]. Available from: http://english.cas.cn/about_us/introduction/201501/t20150114_135284.shtml [Accessed 27/10/2020].

Christopherson, S., Kitson, M. and Michie, J., 2008. Innovation, networks and knowledge exchange: Oxford University Press.

Chung, C. J., 2014. An analysis of the status of the Triple Helix and university-industry-government relationships in Asia. *Scientometrics*, 99 (1), 139-149.

Chung, S., 2002. Building a national innovation system through regional innovation systems. *Technovation*, 22 (8), 485-491.

Cohen, W. M. and Levinthal, D. A., 1989. Innovation and learning: the two faces of R & D. *The economic journal*, 99 (397), 569-596.

Cohen, W. M. and Levinthal, D. A., 1990. Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35 (1).

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

Cooke, P., 1992. Regional innovation systems: competitive regulation in the new Europe. *Geoforum*, 23 (3), 365-382.

Cooke, P., 2001. Regional innovation systems, clusters, and the knowledge economy. *Industrial and corporate change*, 10 (4), 945-974.

Cooke, P., 2002. Regional innovation systems: general findings and some new evidence from biotechnology clusters. *The Journal of Technology Transfer*, 27 (1), 133-145.

Cooke, P., Uranga, M. G. and Etxebarria, G., 1997. Regional innovation systems: Institutional and organisational dimensions. *Research policy*, 26 (4-5), 475-491.

Cortina, J. M., 1993. What is coefficient alpha? An examination of theory and applications. *Journal of applied psychology*, 78 (1), 98.

Costa, D. d. M. and Zha, Q., 2020. Chinese Higher Education: The role of the economy and Projects 211/985 for system expansion. *Ensaio: Avaliação e Políticas Públicas em Educação*, (ahead).

Crowther, M., Lim, W. and Crowther, M. A., 2010. Systematic review and meta-analysis methodology. *Blood*, 116 (17), 3140-3146.

Cunningham, J. A. and Link, A. N., 2015. Fostering university-industry R&D collaborations in European Union countries. *International Entrepreneurship and Management Journal*, 11 (4), 849-860.

Czarnitzki, D., Ebersberger, B. and Fier, A. J. J. o. a. e., 2007. The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany. 22 (7), 1347-1366.

D'Este, P. and Perkmann, M., 2011. Why do academics engage with industry? The entrepreneurial university and individual motivations. *Journal of Technology Transfer*, 36 (3), 316-339.

D’Este, P. and Patel, P., 2007a. University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy*, 36 (9), 1295-1313.

D’Este, P. and Patel, P. J. R. p., 2007b. University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? 36 (9), 1295-1313.

Daghfous, A. J. T. L. O., 2004. Organizational learning, knowledge and technology transfer: a case study. 11 (1), 67-83.

Damanpour, F., 1990. Innovation effectiveness, adoption and organizational performance. *Innovation and creativity at work: Psychological and organizational strategies*, 125-141.

Damanpour, F., 2010. An integration of research findings of effects of firm size and market competition on product and process innovations. *British Journal of Management*, 21 (4), 996-1010.

Damanpour, F. and Aravind, D., 2015. Managerial Innovation: Conceptions, Processes and Antecedents. *Management and Organization Review*, 8 (2), 423-454.

Damanpour, F. and Evan, W. M., 1984. Organizational innovation and performance: the problem of" organizational lag". *Administrative science quarterly*, 392-409.

Damanpour, F., Walker, R. M. and Avellaneda, C. N., 2009. Combinative Effects of Innovation Types and Organizational Performance: A Longitudinal Study of Service Organizations. *Journal of Management Studies*, 46 (4), 650-675.

Daron, A. and Robinson, J. A., 2012. Why nations fail: the origins of power, prosperity, and poverty. *New York: Crown Business*.

Davenport, T. H., 1993. *Process innovation: reengineering work through information technology*. Harvard Business Press.

De Dominicis, L., 2014. Inequality and growth in European regions: Towards a place-based approach. *Spatial Economic Analysis*, 9 (2), 120-141.

De Faria, P., Lima, F. and Santos, R., 2010. Cooperation in innovation activities: The importance of partners. *Research policy*, 39 (8), 1082-1092.

De Fuentes, C. and Dutrenit, G., 2016. Geographic proximity and university-industry interaction: the case of Mexico. *Journal of Technology Transfer*, 41 (2), 329-348.

De Silva, M. and Rossi, F., 2018. The effect of firms' relational capabilities on knowledge acquisition and co-creation with universities. *Technological Forecasting and Social Change*, 133, 72-84.

de Wit-de Vries, E., Dolfsma, W. A., van der Windt, H. J. and Gerkema, M. P., 2018. Knowledge transfer in university–industry research partnerships: a review. *The Journal of Technology Transfer*, 44 (4), 1236-1255.

Dereli, D. D., 2015. Innovation management in global competition and competitive advantage. *Procedia-Social and behavioral sciences*, 195, 1365-1370.

Doğan, M. and Doğan, H., 2020. Knowledge Sharing, Innovation and Firm Performance: Evidence from Turkey. *Financial Studies*, 24 (1), 36-52.

Dollar, D., Huang, Y. and Yao, Y., 2020. *China 2049: Economic challenges of a rising global power*. Brookings Institution Press.

Dyer, J., 1997. Effective interfirm collaboration: How firms minimize transaction costs and maximize complements. *Strategic Management Journal*, 23 (8), 707-725.

Dyer, J. H. and Singh, H., 1998. The relational view: Cooperative strategy and sources of interorganizational competitive advantage. *Academy of management review*, 23 (4), 660-679.

Etzkowitz, H. and Leydesdorff, L., 2000. The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. *Research Policy*, 29.

Etzkowitz, H. and Leydesdorff, L. A., 1995. Universities and the global knowledge economy: A triple helix of university-industry-government relations.

Etzkowitz, H. and Zhou, C., 2017. *The triple helix: University–industry–government innovation and entrepreneurship*. Routledge.

Etzkowitz, H. J. S. s. i., 2003. Innovation in innovation: The triple helix of university-industry-government relations. 42 (3), 293-337.

Eurostat, O., 2005. Oslo manual: guidelines for collecting and interpreting innovation data. *A joint publication of OECD Eurostat. Paris: OECD.*

Faems, D., Van Looy, B. and Debackere, K., 2005. Interorganizational collaboration and innovation: Toward a portfolio approach. *Journal of product innovation management*, 22 (3), 238-250.

Fagerberg, J., 2004. Innovation: A guide to the literature: Georgia Institute of Technology.

Fan, S., Kanbur, R. and Zhang, X., 2011. China's regional disparities: Experience and policy. *Review of Development Finance*, 1 (1), 47-56.

Fantino, D., Mori, A. and Scalise, D., 2015. Collaboration Between Firms and Universities in Italy: The Role of a Firm's Proximity to Top-Rated Departments. *Italian Economic Journal*, 1 (2), 219-251.

Fehr, E. and Gächter, S., 2002. Do incentive contracts undermine voluntary cooperation?

Felipe, J., Abdon, A. and Kumar, U., 2012. Tracking the middle-income trap: What is it, who is in it, and why? *Levy Economics Institute, Working Paper*, (715).

Ferguson, R. J., 2005. Contractual Governance, Relational Governance, and the Performance of Interfirm Service Exchanges: The Influence of Boundary-Spanner Closeness. *Journal of the Academy of Marketing Science*, 33 (2), 217-234.

Fernandes, G. and O’Sullivan, D., 2020. Benefits management in university-industry collaboration programs. *International Journal of Project Management*.

Fernandez-Esquinas, M., Pinto, H., Yruela, M. P. and Pereira, T. S., 2016. Tracing the flows of knowledge transfer: Latent dimensions and determinants of university-industry interactions in peripheral innovation systems. *Technological Forecasting and Social Change*, 113, 266-279.

Fiaz, M., 2013. An empirical study of university–industry R&D collaboration in China: Implications for technology in society. *Technology in Society*, 35 (3), 191-202.

Fitjar, R. D. and Gjelsvik, M., 2018. Why do firms collaborate with local universities? *Regional Studies*, 52 (11), 1525-1536.

Fitjar, R. D., Gjelsvik, M. and Rodríguez-Pose, A., 2013. The combined impact of managerial and relational capabilities on innovation in firms. *Entrepreneurship & Regional Development*, 25 (5-6), 500-520.

Fitjar, R. D., Huber, F. and Rodríguez-pose, A., 2015. Not too close, not too far. Towards an Empirical Test of the Goldilocks Principle of Non-Geographical Distance in Collaboration Networks for Innovation. *DRUID*, 15, 15-17.

Fitjar, R. D. and Rodríguez-Pose, A., 2013. Firm collaboration and modes of innovation in Norway. *Research policy*, 42 (1), 128-138.

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

Fornell, C. and Larcker, D. F., 1981. Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, 18 (1), 39-50.

Freel, M. S. J. E., Government, P. C. and Policy, 2002. On regional systems of innovation: illustrations from the West Midlands. 20 (5), 633-654.

Freeman, C., 1987. *Technology, policy, and economic performance: lessons from Japan*. Pinter Pub Ltd.

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

Freeman, C. and Soete, L., 1997. *The economics of industrial innovation*. Psychology Press.

Freitas, I. M. B., Geuna, A. and Rossi, F., 2013a. Finding the right partners: Institutional and personal modes of governance of university-industry interactions. *Research Policy*, 42 (1), 50-62.

Freitas, I. M. B., Marques, R. A. and Silva, E., 2013b. University-industry collaboration and innovation in emergent and mature industries in new industrialized countries. *Research Policy*, 42 (2), 443-453.

Frey, B. S. and Rost, K., 2010. Do rankings reflect research quality? *Journal of Applied Economics*, 13 (1), 1-38.

Fu, J., 1992. Technological Innovation: The Way to Develop Chinese Enterprises: Enterprise Management Publishing House Beijing.

Fu, W., Diez, J. R. and Schiller, D., 2013. Interactive learning, informal networks and innovation: Evidence from electronics firm survey in the Pearl River Delta, China. *Research Policy*, 42 (3), 635-646.

Fu, X. and Gong, Y., 2011. Indigenous and foreign innovation efforts and drivers of technological upgrading: evidence from China. *World development*, 39 (7), 1213-1225.

Gao, H. and Ren, M., 2020. Overreliance on China and dynamic balancing in the shift of global value chains in response to global pandemic COVID-19: an Australian and New Zealand perspective. *Asian Business & Management*, 1-5.

Garcia-Perez-de-Lema, D., Madrid-Guijarro, A. and Martin, D. P., 2017. Influence of university–firm governance on SMEs innovation and performance levels. *Technological Forecasting and Social Change*, 123, 250-261.

García-Pérez, I., Fernández-Izquierdo, M. Á. and Muñoz-Torres, M. J., 2020. Microfinance Institutions Fostering Sustainable Development by Region. *Sustainability*, 12 (7), 2682.

Ge, Y., Yu, W., Shi, D. and Dang, J., 2020. China's Bayh-Dole Act and University Patenting: A Contingency Perspective, *Academy of Management Proceedings* (Vol. 2020, pp. 18538): Academy of Management Briarcliff Manor, NY 10510.

Geldes, C., Heredia, J., Felzensztein, C. and Mora, M., 2017. Proximity as determinant of business cooperation for technological and non-technological innovations: a study of an agribusiness cluster. *Journal of Business & Industrial Marketing*, 32 (1), 167-178.

Geyskens, I., Gielens, K. and Dekimpe, M. G., 2002. The market valuation of internet channel additions. *Journal of marketing*, 66 (2), 102-119.

Giuliani, E. and Arza, V., 2009. What drives the formation of 'valuable' university–industry linkages? *Research Policy*, 38 (6), 906-921.

Goel, R. K., Goktepe-Hulten, D. and Grimpe, C., 2017. Who instigates university-industry collaborations? University scientists versus firm employees. *Small Business Economics*, 48 (3), 503-524.

Goel, R. K., Rich, D. P. J. J. o. I. and Jite, T. E., 2005. Organization of markets for science and technology. 161 (1), 1-17.

Goldenberg, J. and Levy, M., 2009. Distance is not dead: Social interaction and geographical distance in the internet era. *arXiv preprint arXiv:0906.3202*.

González-Blanco, J., Coca-Pérez, J. L. and Guisado-González, M., 2019. Relations between technological and non-technological innovations in the service sector. *The Service Industries Journal*, 39 (2), 134-153.

Gonzalez-Pernia, J. L., Parrilli, M. D. and Pena-Legazkue, I., 2015. STI-DUI learning modes, firm-university collaboration and innovation. *Journal of Technology Transfer*, 40 (3), 475-492.

Gopalakrishnan, S. and Santoro, M. D. J. I. t. o. E. M., 2004. Distinguishing between knowledge transfer and technology transfer activities: The role of key organizational factors. 51 (1), 57-69.

Gronum, S., Verreynne, M. L. and Kastelle, T., 2012. The role of networks in small and medium-sized enterprise innovation and firm performance. *Journal of Small Business Management*, 50 (2), 257-282.

Gu, S., 2004. *China's Industrial Technology: market reform and organisational change*. Routledge.

Gu, S., Liu, J., Lundvall, B.-Å. and Schwaag Serger, S., 2008. China's system and vision of innovation: analysis of the national medium-and long-term science and technology development plan (2006-2020): Georgia Institute of Technology.

Gu, S. and Lundvall, B.-Å., 2006. China’s innovation system and the move toward harmonious growth and endogenous innovation. *The Learning Economy and the Economics of Hope*, 269.

Gu, S., Lundvall, B.-Å., Liu, J., Malerba, F. and Schwaag Serger, S., 2009. China's system and vision of innovation: an analysis in relation to the strategic adjustment and the medium-to long-term S&T development plan (2006–20).

Gu, S., Schwaag Serger, S. and Lundvall, B.-Å., 2016. China’s innovation system: ten years on. *Innovation,* 18 (4), 441-448.

Guellec, D., Van Pottelsberghe de la Potterie, B. J. E. o. I. and Technology, N., 2002. The value of patents and patenting strategies: countries and technology areas patterns. 11 (2), 133-148.

Guimón, J., 2013. Promoting university-industry collaboration in developing countries. *World Bank*, 3, 12-48.

Gunday, G., Ulusoy, G., Kilic, K. and Alpkan, L., 2011. Effects of innovation types on firm performance. *International Journal of Production Economics*, 133 (2), 662-676.

Guzzini, E. and Iacobucci, D., 2017. Project failures and innovation performance in university-firm collaborations. *Journal of Technology Transfer*, 42 (4), 865-883.

Hagen, R. J. I. J. o. P. S. M., 2002. Globalization, university transformation and economic regeneration: A UK case study of public/private sector partnership. 15 (3), 204-218.

Hagen, S., 2008. From tech transfer to knowledge exchange: European universities in the marketplace. *Wenner-Gren International Series*, 84, 103-117.

Hakala, H., 2011. Strategic orientations in management literature: Three approaches to understanding the interaction between market, technology, entrepreneurial and learning orientations. *International Journal of Management Reviews*, 13 (2), 199-217.

Hall, B. H., 2003. On copyright and patent protection for software and databases: a tale of two worlds. *Economics, Law and Intellectual Property*. Springer, 259-277.

Hall, J., Matos, S. V. and Martin, M. J., 2014. Innovation pathways at the base of the pyramid: Establishing technological legitimacy through social attributes. *Technovation*, 34 (5-6), 284-294.

Hall, R. and Andriani, P., 2003. Managing knowledge associated with innovation. *Journal of business Research*, 56 (2), 145-152.

Hamel, G., 2006. The why, what, and how of management innovation. *Harvard business review*, 84 (2), 72.

Handoko, F., Smith, A. and Burvill, C., 2014. The role of government, universities, and businesses in advancing technology for SMEs’ innovativeness. *Journal of Chinese Economic and Business Studies*, 12 (2), 171-180.

Hanid, M., Mohamed, O., Othman, M., Danuri, M. S. M., Ye, K. M. and Berawi, M. A., 2019. Critical Success Factors (CSFS) in University-Industry Collaboration (UIC) Projects in Research Universities. *International Journal of Technology*, 10 (4), 667-676.

Hardy, C., Phillips, N. and Lawrence, T. B. J. J. o. m. s., 2003. Resources, knowledge and influence: The organizational effects of interorganizational collaboration. 40 (2), 321-347.

Hashi, I. and Stojčić, N., 2013. The impact of innovation activities on firm performance using a multi-stage model: Evidence from the Community Innovation Survey 4. *Research Policy*, 42 (2), 353-366.

Haus-Reve, S., Fitjar, R. D. and Rodríguez-Pose, A., 2019. Does combining different types of collaboration always benefit firms? Collaboration, complementarity and product innovation in Norway. *Research Policy*, 48 (6), 1476-1486.

Hayhoe, R. and Zha, Q., 2010. The polytechnic universities in China’s transformation. *International Higher Education*, 60, 11-13.

Hayter, C. S., Rasmussen, E. and Rooksby, J. H., 2020. Beyond formal university technology transfer: Innovative pathways for knowledge exchange. *The Journal of Technology Transfer*, 45 (1), 1-8.

He, C., Lu, J. and Qian, H., 2019. Entrepreneurship in China. *Small Business Economics*, 52 (3), 563-572.

Heide, J. B. and John, G., 1992. Do norms matter in marketing relationships? *Journal of marketing*, 56 (2), 32-44.

Hemmert, M., Bstieler, L. and Okamuro, H., 2014. Bridging the cultural divide: Trust formation in university-industry research collaborations in the US, Japan, and South Korea. *Technovation*, 34 (10), 605-616.

Henry, A. and Odei, S. A., 2018. The Influence of Public Support on University-Industry-Government Collaboration: the Case of the Czech Republic, Slovakia, Hungary and Romania. *Statistika-Statistics and Economy Journal*, 98 (4), 352-361.

Hertzfeld, H. R., Link, A. N. and Vonortas, N. S. J. R. P., 2006. Intellectual property protection mechanisms in research partnerships. 35 (6), 825-838.

Hewitt-Dundas, N., 2012. Research intensity and knowledge transfer activity in UK universities. *Research Policy*, 41 (2), 262-275.

Hewitt-Dundas, N., 2013a. The role of proximity in university-business cooperation for innovation. *The Journal of Technology Transfer,* 38.

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

Hewitt-Dundas, N., Gkypali, A. and Roper, S., 2019a. Does learning from prior collaboration help firms to overcome the 'two worlds' paradox in university-business collaboration? *Research Policy*, 48 (5), 1310-1322.

Hewitt-Dundas, N., Gkypali, A. and Roper, S., 2019b. Does learning from prior collaboration help firms to overcome the ‘two-worlds’ paradox in university-business collaboration? *Research Policy,* 48 (5), 1310-1322.

Hoc, L. H. and Trong, N. D., 2019. University-Industry Linkages in Promoting Technology Transfer: A Study of Vietnamese Technical and Engineering Universities. *Science Technology and Society*, 24 (1), 73-100.

Hoffmann, W. H. and Schlosser, R. J. L. r. p., 2001. Success factors of strategic alliances in small and medium-sized enterprises—An empirical survey. 34 (3), 357-381.

Holmes, T. J., McGrattan, E. R. and Prescott, E. C., 2015. Quid pro quo: Technology capital transfers for market access in China. *The Review of Economic Studies*, 82 (3), 1154-1193.

Holsapple, C. W. and Singh, M. J. E. s. w. a., 2001. The knowledge chain model: activities for competitiveness. 20 (1), 77-98.

Hong, J., Zhu, R., Hou, B. and Wang, H., 2019. Academia-industry collaboration and regional innovation convergence in China. *Knowledge Management Research & Practice,* 17 (4), 396-407.

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

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

Horta, H. and Shen, W., 2020. Current and future challenges of the Chinese research system. *Journal of Higher Education Policy and Management*, 42 (2), 157-177.

Howell, A., 2017. Picking ‘winners' in China: Do subsidies matter for indigenous innovation and firm productivity? *China Economic Review*, 44, 154-165.

Howells, J. R. J. U. s., 2002. Tacit knowledge, innovation and economic geography. 39 (5-6), 871-884.

Howitt, P., 2005. Health, human capital, and economic growth: A Schumpeterian perspective. *Health and economic growth: Findings and policy implications*, 1, 19-40.

Hsin-Mei, L. J. I. J. o. M., 2006. Interorganizational collaboration, social embeddedness, and value creation: A theoretical analysis. 23 (3), 548.

Hu, A. G., 2014. China’s R&D intensification and the role of the state. *China's Evolving Industrial Policies and Economic Restructuring.* Routledge, 92-104.

Huang, C., Arundel, A. and Hollanders, H., 2010. How firms innovate: R&D, non-R&D, and technology adoption.

Huang, K.-F. and Yu, C.-M. J., 2011. The effect of competitive and non-competitive R&D collaboration on firm innovation. *The Journal of Technology Transfer*, 36 (4), 383-403.

Hughes, A. and Kitson, M., 2012. Pathways to impact and the strategic role of universities: new evidence on the breadth and depth of university knowledge exchange in the UK and the factors constraining its development. *Cambridge journal of economics*, 36 (3), 723-750.

Hult, G. T. M., Hurley, R. F. and Knight, G. A., 2004. Innovativeness: Its antecedents and impact on business performance. *Industrial marketing management*, 33 (5), 429-438.

Isaksen, A. and Karlsen, J., 2010. Different modes of innovation and the challenge of connecting universities and industry: case studies of two regional industries in Norway. *European Planning Studies,* 18 (12), 1993-2008.

Isik, Z., Arditi, D., Dilmen, I. and Birgonul, M. T., 2010. The role of exogenous factors in the strategic performance of construction companies. *Engineering, Construction and Architectural Management*.

Ismail, A. I., Rose, R. C., Abdullah, H. and Uli, J., 2010. The relationship between organisational competitive advantage and performance moderated by the age and size of firms. *Asian Academy of Management Journal*, 15 (2), 157-173.

Itakura, K., 2020. Evaluating the impact of the US–China trade war. *Asian Economic Policy Review,* 15 (1), 77-93.

Ivanov, C.-I. and Avasilcăi, S., 2014. Measuring the Performance of Innovation Processes: A Balanced Scorecard Perspective. *Procedia - Social and Behavioral Sciences*, 109, 1190-1193.

Ivascu, L., Cirjaliu, B. and Draghici, A., 2016a. Business Model for the University-industry Collaboration in Open Innovation. *Procedia Economics and Finance*, 39, 674-678.

Ivascu, L., Cirjaliu, B. and Draghici, A., 2016b. Business model for the university-industry collaboration in open innovation. *Procedia Economics and Finance*, 39 (November 2015), 674-678.

Jacobs, J., 1969. *The Economy of Cities*. Random House.

Jaffe, A. B., Trajtenberg, M. and Henderson, R., 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. *the Quarterly journal of Economics,* 108 (3), 577-598.

Jaffe, A. B. J. A. e. r., 1989. Real effects of academic research. 79 (5), 957-970.

Jakšić, M. and Jakšić, M., 2018. Inclusive institutions for sustainable economic development. *Journal of Central Banking Theory and Practice*, 7 (1), 5-16.

Jensen, M. B., Johnson, B., Lorenz, E. and Lundvall, B. Å., 2007. Forms of knowledge and modes of innovation. *Research Policy*, 36 (5), 680-693.

Jiang, J., Wang, S. and Zhao, S., 2012. Does HRM facilitate employee creativity and organizational innovation? A study of Chinese firms. *The International Journal of Human Resource Management*, 23 (19), 4025-4047.

Jin, P., Peng, C. and Song, M., 2019. Macroeconomic uncertainty, high-level innovation, and urban green development performance in China. *China Economic Review*, 55, 1-18.

Jones, J. and Corral de Zubielqui, G., 2017. Doing well by doing good: A study of university-industry interactions, innovationess and firm performance in sustainability-oriented Australian SMEs. *Technological Forecasting and Social Change*, 123, 262-270.

Kahn, K. B., 2018. Understanding innovation. *Business Horizons*, 61 (3), 453-460.

Kandil, M., Shahbaz, M., Mahalik, M. K. and Nguyen, D. K., 2017. The drivers of economic growth in China and India: globalization or financial development? *International Journal of Development Issues*.

Ke, W., 2012. Exploring work: the interaction between scientists and policy-makers. Case study of 863 Plan of China. *Journal of Science Communication,* 11 (3), C04.

Keizer, J. A. and Halman, J. I. J. R.-T. M., 2007. Diagnosing risk in radical innovation projects. 50 (5), 30-36.

Ken, Y., Tsai, T.-Y. and Ou, Y.-K., 2008. Study of the time lag effect of patent impact on profitability of US pharmaceutical industry from innovation to profit, *PICMET'08-2008 Portland International Conference on Management of Engineering & Technology* (pp. 2588-2596): IEEE.

Khosravi, P., Newton, C. and Rezvani, A., 2019. Management innovation: A systematic review and meta-analysis of past decades of research. *European Management Journal*, 37 (6), 694-707.

Kim, Y., Lee, K. J. R. and Management, D., 2003. Technological collaboration in the Korean electronic parts industry: patterns and key success factors. 33 (1), 59-77.

Kline, S. J. and Rosenberg, N., 1986. An overview of innovation. *In:* Ladau, R. and Rosenberg, N., eds. *The positive sum strategy: Harnessing technology for economic growth.* Washington, DC: National Academy Press.

Klingebiel, R. and Rammer, C., 2014. Resource allocation strategy for innovation portfolio management. *Strategic Management Journal*, 35 (2), 246-268.

Kobarg, S., Stumpf-Wollersheim, J. and Welpe, I. M., 2018. University-industry collaborations and product innovation performance: the moderating effects of absorptive capacity and innovation competencies. *Journal of Technology Transfer*, 43 (6), 1696-1724.

Kopel, M. and Löffler, C. J. J. o. E., 2008. Commitment, first-mover-, and second-mover advantage. 94 (2), 143-166.

Kroll, H., Conlé, M. and Schüller, M., 2008. China: innovation system and innovation policy. *New Challenges for Germany in the Innovation Competition*, 169.

Kuha, J. and Mills, C., 2020. On group comparisons with logistic regression models. *Sociological Methods & Research*, 49 (2), 498-525.

Lai, W. H., 2011. Willingness-to-engage in technology transfer in industry-university collaborations. *Journal of Business Research*, 64 (11), 1218-1223.

Lam, A., 2004. Organizational innovation.

Lam, L. W., 2012. Impact of competitiveness on salespeople's commitment and performance. *Journal of Business Research*, 65 (9), 1328-1334.

Laursen, K., Reichstein, T. and 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. and Salter, A. J. R. p., 2004. Searching high and low: what types of firms use universities as a source of innovation? 33 (8), 1201-1215.

Lavoratori, K., Mariotti, S. and Piscitello, L., 2020. The role of geographical and temporary proximity in MNEs' location and intra-firm co-location choices. *Regional Studies*, 1-15.

Law, C. C. and Ngai, E. W., 2008. An empirical study of the effects of knowledge sharing and learning behaviors on firm performance. *Expert systems with applications*, 34 (4), 2342-2349.

Lee, K. and Kim, B.-Y., 2009. Both institutions and policies matter but differently for different income groups of countries: Determinants of long-run economic growth revisited. *World development*, 37 (3), 533-549.

Lee, R., Lee, J.-H. and Garrett, T. C., 2019. Synergy effects of innovation on firm performance. *Journal of Business Research*, 99, 507-515.

Lee, S. and Kim, D. H., 2021. Knowledge stocks, government R&D, institutional factors and innovation: evidence from biotechnology patent data. *Innovation and Development*, 1-19.

Lee, Y.-N. and Walsh, J. P., 2016. Inventing while you work: Knowledge, non-R&D learning and innovation. *Research policy*, 45 (1), 345-359.

Lei, J., Liu, Y., Qi, Y. and Zhang, Q., 2019. 40 Years of Technological Innovation in China: A Review of the Four-Stage Climbing Track. *Journal of Industrial Integration and Management*, 4 (03), 1950008.

Leonard, D. and Sensiper, S., 1998. The role of tacit knowledge in group innovation. *California management review*, 40 (3), 112-132.

Levinthal, D. A. and March, J. G. J. S. m. j., 1993. The myopia of learning. 14 (S2), 95-112.

Leydesdorff, L. and Guoping, Z., 2001. University—Industry—Government relations in China: An emergent national system of innovation. *Industry and Higher Education*, 15 (3), 179-182.

Li, F., Chen, J. and Su, Y.-S., 2018. Managing the university-industry collaborative innovation in China. *Journal of organizational change management*.

Li, L., 2018. China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0". *Technological Forecasting and Social Change*, 135, 66-74.

Li, M., Balistreri, E. J. and Zhang, W., 2020a. The US–China trade war: Tariff data and general equilibrium analysis. *Journal of Asian Economics*, 69, 101216.

Li, R., Zheng, S., Wang, E., Chen, J., Feng, S., Wang, D. and Dai, L., 2020b. Advances in BeiDou Navigation Satellite System (BDS) and satellite navigation augmentation technologies. *Satellite Navigation*, 1 (1), 1-23.

Li, X., 2015. Specialization, institutions and innovation within China's regional innovation systems. *Technological Forecasting and Social Change*, 100, 130-139.

Li, Y., Ji, Q. and Zhang, D., 2020c. Technological catching up and innovation policies in China: What is behind this largely successful story? *Technological Forecasting and Social Change*, 153, 119918.

Li, Y., Liu, Y. and Ren, F., 2007. Product innovation and process innovation in SOEs: evidence from the Chinese transition. *The Journal of Technology Transfer*, 32 (1-2), 63-85.

Lieberthal, K. and Oksenberg, M., 1988. *Policy making in China: Leaders, structures, and processes*. Princeton University Press.

Lin, J. Y., Cai, F. and Li, Z., 2003. *The China miracle: Development strategy and economic reform*. Chinese University Press.

Liu, F.-c., Simon, D. F., Sun, Y.-t. and Cao, C., 2011. China's innovation policies: Evolution, institutional structure, and trajectory. *Research Policy*, 40 (7), 917-931.

Liu, H. and Jiang, Y., 2001. Technology transfer from higher education institutions to industry in China: nature and implications. *Technovation*, 21 (3), 175-188.

Liu, X., Schwaag Serger, S., Tagscherer, U. and Chang, A. Y., 2017. Beyond catch-up—can a new innovation policy help China overcome the middle income trap? *Science and Public Policy*, 44 (5), 656-669.

Lokshin, B., Belderbos, R. and Carree, M., 2008. The productivity effects of internal and external R&D: Evidence from a dynamic panel data model. *Oxford bulletin of Economics and Statistics*, 70 (3), 399-413.

Lopez, S. F., Astray, B. P., Pazos, D. R. and Calvo, N., 2015. Are firms interested in collaborating with universities? An open-innovation perspective in countries of the South West European Space. *Service Business*, 9 (4), 637-662.

Lundvall, B.-A., 1992a. National systems of innovation: towards a theory of innovation and interactive learning.

Lundvall, B.-A., Dosi, G. and Freeman, C., 1988. Innovation as an interactive process: from user-producer interaction to the national system of innovation. *1988*, 349-369.

Lundvall, B., 1992b. Å National systems of innovation: towards a theory of innovation and interactive learning. *Pinter, London*.

Macpherson, A., Ziolkowski, M. J. E. and Development, R., 2005. The role of university-based industrial extension services in the business performance of small manufacturing firms: case-study evidence from Western New York. 17 (6), 431-447.

Madariaga, N. and Poncet, S., 2007. FDI in Chinese cities: Spillovers and impact on growth. *World Economy*, 30 (5), 837-862.

Magnier-Watanabe, R. and Benton, C., 2017. Management innovation and firm performance: The mediating effects of tacit and explicit knowledge. *Knowledge Management Research & Practice*, 15 (3), 325-335.

Maietta, O. W., 2015a. Determinants of university-firm R&D collaboration and its impact on innovation: A perspective from a low-tech industry. *Research Policy*, 44 (7), 1341-1359.

Maietta, O. W., 2015b. Determinants of university–firm R&D collaboration and its impact on innovation: A perspective from a low-tech industry. *Research Policy*, 44 (7), 1341-1359.

Malerba, F. and Orsenigo, L., 2002. Innovation and market structure in the dynamics of the pharmaceutical industry and biotechnology: towards a history-friendly model. *Industrial and corporate change*, 11 (4), 667-703.

Mansury, M. A. and Love, J. H. J. T., 2008. Innovation, productivity and growth in US business services: A firm-level analysis. 28 (1-2), 52-62.

March, J. G. J. O. s., 1991. Exploration and exploitation in organizational learning. 2 (1), 71-87.

Martino, G. and Polinori, P., 2019. An analysis of the farmers contractual preferences in process innovation implementation. *British Food Journal*.

Marx, K., 1953. Grundrisse der Kritik der politischen Ökonomie:(Rohentwurf) 1857-1858; Anhang 1850-1859.

Mascarenhas, C., Ferreira, J. J. and Marques, C., 2018. University–industry cooperation: A systematic literature review and research agenda. *Science and Public Policy*, 45 (5), 708-718.

Mateos-Garcia, J. and Sapsed, J., 2011. The role of universities in enhancing creative clustering. *Brighton Fuse*.

Mauricio Sanchez, D. S. and López Mendoza, X. P., 2018. A systematic literature review on technology transfer from university to industry. *International Journal of Business and Systems Research*, 12 (2).

McCann, P., 2020. Perceptions of regional inequality and the geography of discontent: Insights from the UK. *Regional Studies*, 54 (2), 256-267.

Miller, K., McAdam, R., McAdam, M. J. R. and Management, D., 2018. A systematic literature review of university technology transfer from a quadruple helix perspective: toward a research agenda. 48 (1), 7-24.

Ministry of Education, 2020a. *Annual Report on the National Higher Education* [online]. Available from: http://www.moe.gov.cn/jyb_sjzl/sjzl_fztjgb/202005/t20200520_456751.html [Accessed 01/11/2020].

Ministry of Education, 2020b. *S&T Statistical Yearbook of Higher Education Institutions 2019* [online]. Available from: http://www.moe.gov.cn/s78/A16/A16_tjdc/202009/W020200918378029706686.pdf [Accessed 03/11/2020].

Ministry of Science and Technology, 1986. *The 863 programme* [online]. Available from: http://www.most.gov.cn/fggw/zfwj/zfwj2011/201109/W020110906407126409193.pdf [Accessed 28/10/2020].

Ministry of Science and Technology, 2015. *Revisions on the Law on Promoting the Transformation of Scientific and Technology Achievements* [online]. Available from: http://www.most.gov.cn/kjzc/gjkjzc/kjcgyzscq/201512/t20151203_122619.htm [Accessed 03/11/2020].

Ministry of Science and Technology, 2020. *Annual Report of Regional Innovation Capacity* [online]. Available from: http://www.most.gov.cn/cxdc/cxdcjcbg/202002/P020200212664930785955.pdf [Accessed 01/11/2020].

Miotti, L. and Sachwald, F. J. R. p., 2003. Co-operative R&D: why and with whom?: An integrated framework of analysis. 32 (8), 1481-1499.

Mirowski, P. and Van Horn, R., 2005. The contract research organization and the commercialization of scientific research. *Social studies of science*, 35 (4), 503-548.

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

Moilanen, M., Østbye, S. and Woll, K., 2014. Non-R&D SMEs: external knowledge, absorptive capacity and product innovation. *Small Business Economics*, 43 (2), 447-462.

Mol, M. and Birkinshaw, J., 2013. Relating management innovation to product and process innovation: Private rents versus public gains. *Handbook of organizational and managerial innovation*. Edward Elgar Publishing.

Montesinos, P., Carot, J. M., Martinez, J. M. and Mora, F., 2008. Third mission ranking for world class universities: Beyond teaching and research. *Higher education in Europe*, 33 (2-3), 259-271.

Moon, H., Mariadoss, B. J. and Johnson, J. L., 2019. Collaboration with higher education institutions for successful firm innovation. *Journal of Business Research*, 99, 534-541.

Morgan, K., 2004. The exaggerated death of geography: learning, proximity and territorial innovation systems. *Journal of economic geography*, 4 (1), 3-21.

Mothe, C. and Thi, T. U. N., 2010. The link between non-technological innovations and technological innovation. *European Journal of Innovation Management*.

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.

Motohashi, K. and Muramatsu, S., 2012. Examining the university industry collaboration policy in Japan: Patent analysis. *Technology in Society*, 34 (2), 149-162.

Mowery, D. C., 1992. The US national innovation system: origins and prospects for change. *research policy*, 21 (2), 125-144.

Mowery, D. C., Nelson, R. R., Sampat, B. N. and Ziedonis, A. A., 2015. *Ivory tower and industrial innovation: University-industry technology transfer before and after the Bayh-Dole Act*. Stanford University Press.

Mowery, D. C. J. I. i. S. and Technology, 1998. Collaborative R&D: how effective is it? 15 (1), 37-44.

Naidoo, V., 2010. Firm survival through a crisis: The influence of market orientation, marketing innovation and business strategy. *Industrial Marketing Management*, 39 (8), 1311-1320.

Nakamura, D., 2020. The Economies of Regional Agglomeration: An Applied Framework. *The Journal of Economics*, 60 (5-6), 81-90.

National Bureau of Statistics, 2016. *China Statistical Yearbook 2015* [online]. Available from: http://www.stats.gov.cn/tjsj/ndsj/2015/indexch.htm [Accessed 01/11/2020].

National Bureau of Statistics, 2019. *Report on National Expenditure on Science and Technology in 2018* [online]. Available from: http://www.stats.gov.cn/tjsj/tjgb/rdpcgb/qgkjjftrtjgb/201908/t20190830_1694754.html [Accessed 27/10/2020].

National Bureau of Statistics, 2020a. *China Statistical Yearbook 2019* [online]. Available from: http://www.stats.gov.cn/tjsj/ndsj/2019/indexch.htm [Accessed 01/11/2020].

National Bureau of Statistics, 2020b. *GDP* [online]. Available from: http://www.stats.gov.cn/tjsj/zxfb/index_1.html [Accessed 23/10/2020].

National Bureau of Statistics, 2020c. *Report on National Expenditure on Science and Technology in 2019* [online]. Available from: http://www.stats.gov.cn/tjsj/zxfb/202008/t20200827_1786198.html [Accessed 30/10/2020].

NBS, 2017. *High-Tech Industry Classification, 2017* [online]. Available from: 28 March 2020].

NBS, 2019. *GDP Ranking* [online]. Available from: http://data.stats.gov.cn/search.htm?s=gdp [Accessed 15 June 2019].

NBS, 2020. *National Enterprise Innovation Survey* [online]. Available from: http://www.stats.gov.cn/tjsj/ [Accessed 15 May 2020].

Nelson, R. L., 1959. The Merger Movement from 1895 through 1920. *Merger Movements in American Industry, 1895-1956*. Princeton University Press, 33-70.

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

Newberg, J. and Dunn, R. J. A. B. L. J., 2002. Keeping secrets in the campus lab: law, values and rules of engagement partnerships for industry-university R&D. 39.

Niosi, J. and Bas, T. G., 2003. Biotechnology megacentres: Montreal and Toronto regional systems of innovation. *European planning studies*, 11 (7), 789-804.

Nonaka, I. and Takeuchi, H., 1995a. *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford university press.

Nonaka, I. and Takeuchi, H. J. N. Y., 1995b. The Knowledge Creating. 304.

Nonaka, I. and Toyama, R., 2005. The theory of the knowledge-creating firm: subjectivity, objectivity and synthesis. *Industrial and corporate change*, 14 (3), 419-436.

Noordewier, T. G., John, G. and Nevin, J. R., 1990. Performance outcomes of purchasing arrangements in industrial buyer-vendor relationships. *Journal of marketing*, 54 (4), 80-93.

Odei, S. A., 2018. Determinants influencing firm's R&D collaborations with universities: Empirical evidence from Europe, *Proceedings of the European Conference on Knowledge Management, ECKM* (Vol. 2, pp. 1080-1088): Academic Conferences and Publishing International Limited.

Olander, H., Hurmelinna-Laukkanen, P., Blomqvist, K. and Ritala, P., 2010. The dynamics of relational and contractual governance mechanisms in knowledge sharing of collaborative R&D projects. *Knowledge and Process Management*, 17 (4), 188-204.

Olmos-Peñuela, J., Molas-Gallart, J., Castro-Martínez, E. J. S. and Policy, P., 2014. Informal collaborations between social sciences and humanities researchers and non-academic partners. 41 (4), 493-506.

Ōmae, K. i. and Ohmae, K., 1995. *The end of the nation state: The rise of regional economies*. Simon and Schuster.

Organisation for Economic Co-operation and Development, 2005. Oslo manual: guidelines for collecting and interpreting innovation data. *A joint publication of OECD Eurostat. Paris: OECD*.

Oswald, K. and Zhao, X., 2019. Innovation in China: a Systematic Literature Review. *Frontiers in Educational Research*, 2 (12).

Otero-Neira, C., Lindman, M. T. and Fernández, M. J., 2009. Innovation and performance in SME furniture industries. *Marketing Intelligence & Planning*.

Ozili, P. K. and Arun, T., 2020. Spillover of COVID-19: impact on the Global Economy. *Available at SSRN 3562570*.

Paranhos, J., Perin, F. S., Mercadante, E. and Soares, C., 2019. Industry-university interaction strategies of large Brazilian pharmaceutical companies. *Management Research-the Journal of the Iberoamerican Academy of Management*, 17 (4), 494-509.

Parker, H. J. I. M. and Systems, D., 2000. Interfirm collaboration and the new product development process. 100 (6), 255-260.

Parrilli, M. D., 2019. Clusters and internationalization: the role of lead firms' commitment and RIS proactivity in tackling the risk of internal fractures. *European Planning Studies*, 27 (10), 2015-2033.

Parrilli, M. D., Balavac, M. and Radicic, D., 2020. Business innovation modes and their impact on innovation outputs: Regional variations and the nature of innovation across EU regions. *Research Policy*, 49 (8), 104047.

Parrilli, M. D. and Heras, H. A., 2016. STI and DUI innovation modes: Scientific-technological and context-specific nuances. *Research Policy*, 45 (4), 747-756.

Parrilli, M. D., Nadvi, K. and Yeung, H. W.-C., 2013. Local and regional development in global value chains, production networks and innovation networks: A comparative review and the challenges for future research. *European planning studies*, 21 (7), 967-988.

Parrilli, M. D. and Radicic, D., 2020. STI and DUI innovation modes in micro-, small-, medium-and large-sized firms: distinctive patterns across Europe and the US. *European Planning Studies*, 1-23.

Patel, P. and Pavitt, K., 1994. National innovation systems: why they are important, and how they might be measured and compared. *Economics of innovation and new technology*, 3 (1), 77-95.

Pawson, R., 2006. *Evidence-based policy: a realist perspective*. sage.

Pereira, C. S. and Romero, F. C. C., 2013. Non-Technological Innovation: Current Issues and Perspectives. *Independent Journal of Management & Production*, 4 (1).

Perkmann, M., King, Z. and Pavelin, S., 2011. Engaging excellence? Effects of faculty quality on university engagement with industry. *Research Policy*, 40 (4), 539-552.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A. and Sobrero, M., 2013. Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy*, 42 (2), 423-442.

Perkmann, M. and Walsh, K., 2007a. University–industry relationships and open innovation: Towards a research agenda. *International journal of management reviews*, 9 (4), 259-280.

Perkmann, M. and Walsh, K., 2010. 12. How firms source knowledge from universities: partnering versus contracting, *Creating wealth from knowledge: meeting the innovation challenge* (pp. 273): Edward Elgar Publishing.

Perkmann, M. and Walsh, K. J. I. J. o. M. R., 2007b. University–industry relationships and open innovation: Towards a research agenda. 9 (4), 259-280.

Petruzzelli, A. M., 2011a. The impact of technological relatedness, prior ties, and geographical distance on university-industry collaborations: A joint-patent analysis. *Technovation*, 31 (7), 309-319.

Petruzzelli, A. M., 2011b. The impact of technological relatedness, prior ties, and geographical distance on university–industry collaborations: A joint-patent analysis. *Technovation*, 31 (7), 309-319.

Piening, E. P. and Salge, T. O., 2015. Understanding the Antecedents, Contingencies, and Performance Implications of Process Innovation: A Dynamic Capabilities Perspective. *Journal of Product Innovation Management*, 32 (1), 80-97.

Pinheiro, R., Langa, P. V. and Pausits, A., 2015. One and two equals three? The third mission of higher education institutions. *European journal of higher education*, 5 (3), 233-249.

Pippel, G., 2014. R&D cooperation for non-technological innovations. *Economics of Innovation and New Technology*, 23 (7), 611-630.

Pittaway, L. and Cope, J. J. I. s. b. j., 2007. Entrepreneurship education: A systematic review of the evidence. 25 (5), 479-510.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y. and Podsakoff, N. P., 2003. Common method biases in behavioral research: a critical review of the literature and recommended remedies. *Journal of applied psychology*, 88 (5), 879.

Polanyi, M., 1966. The logic of tacit inference. *Philosophy*, 41 (155), 1-18.

Ponds, R., Oort, F. v. and Frenken, K., 2009. Innovation, spillovers and university–industry collaboration: an extended knowledge production function approach. *Journal of Economic Geography*, 10 (2), 231-255.

Ponds, R., van Oort, F. and Frenken, K., 2010. Innovation, spillovers and university-industry collaboration: an extended knowledge production function approach. *Journal of Economic Geography*, 10 (2), 231-255.

Ponomariov, B., 2013. Government-sponsored university-industry collaboration and the production of nanotechnology patents in US universities. *The Journal of Technology Transfer*, 38 (6), 749-767.

Poppo, L. and Zenger, T., 2002. Do formal contracts and relational governance function as substitutes or complements? *Strategic Management Journal*, 23 (8), 707-725.

Portes, A. J. A. r. o. s., 1998. Social capital: Its origins and applications in modern sociology. 24 (1), 1-24.

Powell, W. W., Koput, K. W. and Smith-Doerr, L. J. A. s. q., 1996. Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. 116-145.

Price, J. L. and Mueller, C. W., 1986. Handbook of organizational measurement. Marshfield, MA: Pitman Publishing, Inc.

Radosevic, S., Lepori, B. J. S. and Policy, P., 2009. Public research funding systems in central and eastern Europe: between excellence and relevance: introduction to special section. 36 (9), 659-666.

Ramasamy, B., Goh, K. and Yeung, M. C., 2006. Is guanxi (relationship) a bridge to knowledge transfer? *Journal of business research*, 59 (1), 130-139.

Ramirez, M., Li, X. and Chen, W., 2013. Comparing the impact of intra-and inter-regional labour mobility on problem-solving in a Chinese science park. *Regional Studies*, 47 (10), 1734-1751.

Ramos-Vielba, I., Fernandez-Esquinas, M. and Espinosa-de-los-Monteros, E., 2010. Measuring university-industry collaboration in a regional innovation system. *Scientometrics*, 84 (3), 649-667.

Rein, S., 2014. *The end of copycat China: The rise of creativity, innovation, and individualism in Asia*. John Wiley & Sons.

Ringle, C. M., Wende, S. and Becker, J.-M., 2015. SmartPLS 3. *Boenningstedt: SmartPLS GmbH.*

Rodríguez-Pose, A. and Ezcurra, R., 2010. Does decentralization matter for regional disparities? A cross-country analysis. *Journal of Economic Geography*, 10 (5), 619-644.

Rodríguez-Pose, A. and Wilkie, C., 2016. Putting China in perspective: a comparative exploration of the ascent of the Chinese knowledge economy. *Cambridge Journal of Regions, Economy and Society*, 9 (3), 479-497.

Rodríguez-Pose, A. and Zhang, M., 2020. The cost of weak institutions for innovation in China. *Technological Forecasting and Social Change*, 153, 119937.

Roesler, C. and Broekel, T., 2017. The role of universities in a network of subsidized R&D collaboration: The case of the biotechnology-industry in Germany. *Review of Regional Research-Jahrbuch Fur Regionalwissenschaft*, 37 (2), 135-160.

Roessner, J. D. and Wise, A. J. P. S. J., 1994. Public policy and emerging sources of technology and technical information available to industry. 22 (2), 349-358.

Rogers, E. M., 2010. *Diffusion of innovations*. Simon and Schuster.

Rolnick, A. J. and Weber, W. E., 1986. Gresham's law or Gresham's fallacy? *Journal of political economy*, 94 (1), 185-199.

Rosenberg, N., 1976. Marx as a Student of Technology. *Monthly Review*, 28 (3), 56-77.

Rosenbusch, N., Brinckmann, J. and Bausch, A., 2011. Is innovation always beneficial? A meta-analysis of the relationship between innovation and performance in SMEs. *Journal of Business Venturing*, 26 (4), 441-457.

Rosenthal, S. S. and Strange, W. C., 2001. The determinants of agglomeration. *Journal of urban economics*, 50 (2), 191-229.

Rothaermel, F. T. and Alexandre, M. T. J. O. s., 2009. Ambidexterity in technology sourcing: The moderating role of absorptive capacity. 20 (4), 759-780.

Rousseau, D. M., Sitkin, S. B., Burt, R. S. and Camerer, C. J. A. o. m. r., 1998. Not so different after all: A cross-discipline view of trust. 23 (3), 393-404.

Roy, R., 1972. University-Industry Interaction Patterns: Past models are analyzed, some recent experiments described, and recommendations for the future given. *Science*, 178 (4064), 955-960.

Rua, O. L. and França, A., 2017. The linkage between intangible resources and export performance: The mediating effect of innovation. *International Journal of Innovation*, 5 (3), 399-410.

Rybnicek, R. and Königsgruber, R., 2018. What makes industry–university collaboration succeed? A systematic review of the literature. *Journal of Business Economics*, 89 (2), 221-250.

Rychen, F. and Zimmermann, J.-B., 2008. Clusters in the global knowledge-based economy: knowledge gatekeepers and temporary proximity. *Regional studies*, 42 (6), 767-776.

Ryu, H.-S., 2016. The Relationship between Non-Technological Innovation and Technological Innovation on Firm Performance. 27-32.

Santoro, M. D. and Saparito, P. A. J. I. T. o. E. M., 2003. The firm's trust in its university partner as a key mediator in advancing knowledge and new technologies. 50 (3), 362-373.

Schaeffer, V., Öcalan-Özel, S. and Pénin, J. J. T. J. o. T. T., 2020. The complementarities between formal and informal channels of university–Industry knowledge transfer: A longitudinal approach. 45 (1), 31-55.

Schiller, D., 2011. The role of foreign and domestic firms in regional innovation sysems of latecomer countries: empirical evidence from the eletronics industry in the Pearl River Delta. *Erdkunde*, 25-42.

Schmidt, T. and Rammer, C., 2007. Non-technological and technological innovation: strange bedfellows? *ZEW-Centre for European Economic Research Discussion Paper*, (07-052).

Schumpeter, J., 1942a. Creative destruction. *Capitalism, socialism and democracy*, 825, 82-85.

Schumpeter, J. A., 1939. *Business cycles*. Vol. 1. McGraw-Hill New York.

Schumpeter, J. A., 1942b. *Socialism, capitalism and democracy*. Harper and Brothers.

Schumpeter, J. A., 1982. The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle (1912/1934). *Transaction Publishers.–1982.–January*, 1, 244.

Segarra-Blasco, A. and Arauzo-Carod, J.-M., 2008a. Sources of innovation and industry–university interaction: Evidence from Spanish firms. *Research Policy*, 37 (8), 1283-1295.

Segarra-Blasco, A. and Arauzo-Carod, J.-M. J. R. P., 2008b. Sources of innovation and industry–university interaction: Evidence from Spanish firms. 37 (8), 1283-1295.

Shen, L., Zhang, C. and Teng, W., 2019. The double-edged effects of guanxi on partner opportunism. *Journal of Business & Industrial Marketing*.

Sherer, S. A. J. J. o. S. B. M., 2003. Critical success factors for manufacturing networks as perceived by network coordinators. 41 (4), 325-345.

Shi, X., Wu, Y. and Fu, D., 2019. Does University-Industry collaboration improve innovation efficiency? Evidence from Chinese Firms◊. *Economic Modelling*.

Shumpeter, J., 1942. Capitalism, socialism and democracy. *New York*.

Siddaway, A. P., Wood, A. M. and Hedges, L. V., 2019. How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. *Annu Rev Psychol*, 70, 747-770.

Siegel, D. S., Waldman, D. A., Atwater, L. E. and Link, A. N., 2003. Commercial knowledge transfers from universities to firms: improving the effectiveness of university–industry collaboration. *Journal of High Technology Management Research*, 14.

Sjöö, K. and Hellström, T., 2019. University–industry collaboration: A literature review and synthesis. *Industry and Higher Education*, 33 (4), 275-285.

Slater, S. F., Mohr, J. J. and Sengupta, S., 2014. Radical product innovation capability: Literature review, synthesis, and illustrative research propositions. *Journal of Product Innovation Management*, 31 (3), 552-566.

Smith, A., 2010. *The Wealth of Nations: An inquiry into the nature and causes of the Wealth of Nations*. Harriman House Limited.

Spithoven, A., Teirlinck, P. and Ysebaert, W., 2020. What determines the size of contract research from firms to universities? The role of geographical distance and regional co-location. *Industrial and Corporate Change.*

Stenbacka, R. and Tombak, M., 2020. University-firm competition in basic research and university funding policy. *Journal of Public Economic Theory*.

Stevens, R. H., Millage, J. and Clark, S., 2010. Waves of knowledge management: The flow between explicit and tacit knowledge. *American Journal of Economics and Business Administration*, 2 (1), 129.

Storck, J. and Hill, P. A., 2000. Knowledge Diffusion through "Strategic Communities". *Sloan Management Review,* 41 (2), 63-74.

Storer, M. and Hyland, P., 2009. Dynamic capabilities and innovation in supply chains.

Sun, Y., Zhang, C. and Kok, R. A., 2020. The role of research outcome quality in the relationship between university research collaboration and technology transfer: empirical results from China. *Scientometrics*, 122 (2), 1003-1026.

Suttmeier, R. P., Cao, C. and Simon, D. F., 2006. " Knowledge Innovation" and the Chinese Academy of Sciences: American Association for the Advancement of Science.

Szucs, F., 2018. Research subsidies, industry-university cooperation and innovation. *Research Policy,* 47 (7), 1256-1266.

Tadelis, S. and Williamson, O. E. J. T. h. o. o. e., 2012. Transaction cost economics. 159-193.

Taheri, M. and van Geenhuizen, M., 2019. Knowledge relationships of university spin-off firms: Contrasting dynamics in global reach. *Technological Forecasting and Social Change*, 144, 193-204.

Takeishi, A. J. S. m. j., 2001. Bridging inter-and intra-firm boundaries: management of supplier involvement in automobile product development. 22 (5), 403-433.

Taketoshi, K., 2020. How and to what extent has the demographic dividend affected China's economic growth? *International Journal of Economic Policy Studies*, 14 (2), 337-350.

Tan, Y., 2011. *Chinnovation: How Chinese innovators are changing the world*. John Wiley and Sons.

Tang, Y., Motohashi, K., Hu, X. and Montoro-Sanchez, A., 2019. University-industry interaction and product innovation performance of Guangdong manufacturing firms: the roles of regional proximity and research quality of universities. *The Journal of Technology Transfer*, 1-41.

Taques, F. H., López, M. G., Basso, L. F. and Areal, N., 2020. Indicators used to measure service innovation and manufacturing innovation. *Journal of Innovation & Knowledge.*

Teece, D. J., 2008. The multinational enterprise: Market failure and market power considerations. *World Scientific Book Chapters*, 405-419.

Tether, B. S. and 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.

Tether, B. S. J. R. p., 2002. Who co-operates for innovation, and why: an empirical analysis. 31 (6), 947-967.

Thomä, J., 2017. DUI mode learning and barriers to innovation—A case from Germany. *Research Policy*, 46 (7), 1327-1339.

Thune, T., 2007. University-industry collaboration: the network embeddedness approach. *Science and Public Policy,* 34 (3), 158-168.

Torre, A., 2008. On the role played by temporary geographical proximity in knowledge transmission. *Regional studies*, 42 (6), 869-889.

Torre, A., 2011. The role of proximity during long-distance collaborative projects. Temporary geographical proximity helps. *International Journal of Foresight and Innovation Policy*, 7 (1-3), 213-230.

Torres, A., Dutrenit, G., Sampedro, J. L. and Becerra, N., 2011. What are the factors driving university-industry linkages in latecomer firms: evidence from Mexico. *Science and Public Policy*, 38 (1), 31-42.

Tranfield, D., Denyer, D. and Smart, P. J. B. j. o. m., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. 14 (3), 207-222.

Tseng, F.-C., Huang, M.-H. and Chen, D.-Z., 2020. Factors of university–industry collaboration affecting university innovation performance. *The Journal of Technology Transfer*, 45 (2), 560-577.

Un, C. A., Cuervo-Cazurra, A. and Asakawa, K., 2010. R&D collaborations and product innovation. *Journal of Product Innovation Management*, 27 (5), 673-689.

UniversitiesUK, 2016. *University funding explained*. Universities UK London.

Uppenberg, K., 2009. Innovation and economic growth. *eib Papers*, 14 (1).

Van Auken, H., Madrid-Guijarro, A. and Garcia-Perez-de-Lema, D., 2008. Innovation and performance in Spanish manufacturing SMEs. *International Journal of Entrepreneurship and Innovation Management*, 8 (1), 36-56.

Vokoun, M. and Píchová, R., 2020. Market Orientation and Marketing Innovation Activities in the Czech Manufacturing Sector. *International Journal of Financial Studies*, 8 (1), 10.

Walker, R. M., Damanpour, F. and Devece, C. A., 2010. Management Innovation and Organizational Performance: The Mediating Effect of Performance Management. *Journal of Public Administration Research and Theory*, 21 (2), 367-386.

Walker, R. M., Damanpour, F. and Devece, C. A., 2011. Management innovation and organizational performance: The mediating effect of performance management. *Journal of Public Administration Research and Theory*, 21 (2), 367-386.

Wang, E. T. and Wei, H.-L., 2005. The importance of market orientation, learning orientation, and quality orientation capabilities in TQM: An example from Taiwanese software industry. *Total Quality Management & Business Excellence*, 16 (10), 1161-1177.

Wang, J. and Shapira, P., 2012. Partnering with universities: a good choice for nanotechnology start-up firms? *Small Business Economics*, 38 (2), 197-215.

Wei, S.-J., Xie, Z. and Zhang, X., 2017. From" Made in China" to" Innovated in China": Necessity, prospect, and challenges. *Journal of Economic Perspectives*, 31 (1), 49-70.

Wenger, E., 2009. Communities of practice: A brief introduction.

Werker, C. and Ooms, W., 2020. Substituting face-to-face contacts in academics' collaborations: modern communication tools, proximity, and brokerage. *Studies in Higher Education*, 45 (7), 1431-1447.

Williamson, O. E., 1985. The economic institutions of capitalism. New York: Free Press: Douglas.

Williamson, O. E., 1989. Transaction cost economics. *Handbook of industrial organization*, 1, 135-182.

World Bank, 2019a. *Research and Development Expenditure, China* [online]. Available from: https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=CN [Accessed 23/10/2020].

World Bank, 2019b. *Research and Development Expenditure, United States* [online]. Available from: https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=US [Accessed 27/11/2020].

World Bank, 2020a. *Fertility Rate, China* [online]. Available from: https://data.worldbank.org/indicator/SP.DYN.TFRT.IN?locations=CN [Accessed 23/10/2020].

World Bank, 2020b. *Foreign Direct Investment, China* [online]. The World Bank Group. Available from: https://data.worldbank.org/indicator/BX.KLT.DINV.WD.GD.ZS?locations=CN [Accessed 23/10/2020].

World Bank, 2020c. *GDP, People's Republic of China* [online]. The World Bank Group. Available from: https://data.worldbank.org/country/CN [Accessed 23/10/2020].

World Bank, 2020d. *Gross domestic product 2019* [online]. Available from: https://databank.worldbank.org/data/download/GDP.pdf [Accessed 27/11/2020].

World Bank, 2020e. *Overview, China* [online]. The World Bank Group. Available from: https://www.worldbank.org/en/country/china/overview#1 [Accessed 23/10/2020].

World Intellectual Property Organization, 2019. *World IntellectualL Property Indicators 2019*.

Wright, M., Clarysse, B., Lockett, A. and Knockaert, M. J. R. p., 2008. Mid-range universities' linkages with industry: Knowledge types and the role of intermediaries. 37 (8), 1205-1223.

Wu, J. and Zhang, P., 2018. Local government innovation diffusion in China: An event history analysis of a performance-based reform programme. *International Review of Administrative Sciences*, 84 (1), 63-81.

Wu, W., 2010. Managing and incentivizing research commercialization in Chinese Universities. *The journal of technology transfer*, 35 (2), 203-224.

Wübbeke, J., Meissner, M., Zenglein, M. J., Ives, J. and Conrad, B., 2016. Made in china 2025. *Mercator Institute for China Studies. Papers on China*, 2, 74.

Xiao-hua, L., 2004. Thinking on" Trading Domestic Market for Technology" Under the WTO Framework. *China Industrial Economy*, (4), 2.

Xiong, Z., Ye, J. and Wang, P., 2019. Does the Institutional Environment Affect the Failed Technological Innovation in Firms? Evidence from Listed Companies in China's Phamarceutical Manufacturing Industry. *Transformations in Business & Economics*, 18 (1).

Xiwei, Z. and Xiangdong, Y., 2007. Science and technology policy reform and its impact on China's national innovation system. *Technology in society*, 29 (3), 317-325.

Xu, Q., Chen, J. and Guo, B., 1998. Perspective of technological innovation and technology management in China. *IEEE Transactions on Engineering Management*, 45 (4), 381-387.

Xu, W., Yu, L., Zhu, Y. and Lin, L., 2016. Beyond human capital: determinants of migrant labor market outcomes in urban China. *The China Review*, 175-211.

Xue, L., 2006. Universities in China’s national innovation system, *United Nations Educational, Scientific, and Cultural Organization’s online Forum on Higher Education, Research, and Knowledge, November* (pp. 27-30).

Yan, J. and Min, J., 2020. Analysis of Manufacturing Transfer Characteristics Based on Global Value Chain Reconstruction, *International Academic Conference on Frontiers in Social Sciences and Management Innovation (IAFSM 2019)* (pp. 207-215): Atlantis Press.

Yang, T., Long, R., Li, W. and Rehman, S. U., 2016. Innovative application of the public–private partnership model to the electric vehicle charging infrastructure in China. *Sustainability*, 8 (8), 738.

Yao, W., Li, H. and Weng, M., 2018. The role the university could play in an inclusive regional innovation system. *Triple Helix*, 5 (1), 1-21.

Ye, Y., De Moortel, K. and Crispeels, T., 2019. Network dynamics of Chinese university knowledge transfer. *The Journal of Technology Transfer*, 1-27.

Yeo, Y., 2009. Remaking the Chinese State and the Nature of Economic Governance? The early appraisal of the 2008 ‘super-ministry’reform. *Journal of Contemporary China*, 18 (62), 729-743.

Yun, J. J., 2015. How do we conquer the growth limits of capitalism? Schumpeterian Dynamics of Open Innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, 1 (2), 17.

Zahra, S. A. and George, G. J. A. o. m. r., 2002. Absorptive capacity: A review, reconceptualization, and extension. 27 (2), 185-203.

Zavale, N. C., 2018. Expansion versus contribution of higher education in Africa: University-industry linkages in Mozambique from companies' perspective. *Science and Public Policy*, 45 (5), 645-660.

Zhang, C., 2008. The institutional framework of the united nations development programme–ministry of science and technology (undp–most) telecenter project in rural china. *Information Technologies & International Development*, 4 (3), pp. 39-55.

Zhang, F., Wu, F. and Cooke, P., 2010. China’s changing national and regional innovation systems and regional distribution of R&D. *Geography Compass*, 4 (6), 532-544.

Zhang, H., Patton, D. and Kenney, M., 2013. Building global-class universities: Assessing the impact of the 985 Project. *Research Policy*, 42 (3), 765-775.

Zhang, X., Wu, S. and Jin, L., 2019. Evaluation of Innovation Efficiency in Shibaolang Comprehensive Innovation Reform Pilot Zone.

Zhang, Z., Cheng, H. and Yu, Y., 2020. Relationships among Government Funding, R&D Model and Innovation Performance: A Study on the Chinese Textile Industry. *Sustainability*, 12 (2), 644.

Zhao, J. Y. and Wu, G. D., 2017. Evolution of the Chinese Industry-University-Research Collaborative Innovation System. *Complexity*.

Zhou, K. Z., 2006. Innovation, imitation, and new product performance: The case of China. *Industrial Marketing Management*, 35 (3), 394-402.
Zhou, P., Tijssen, R. and Leydesdorff, L., 2016. University-industry collaboration in China and the USA: A bibliometric comparison. *PloS one*, 11 (11), e0165277.
Zhu, Y., Wittmann, X. and Peng, M. W., 2012. Institution-based barriers to innovation in SMEs in China. *Asia Pacific Journal of Management*, 29 (4), 1131-1142.
Zhuang, L. and Ye, C., 2020. Changing imbalance: Spatial production of national high-tech industrial development zones in China (1988-2018). *Land Use Policy*, 94, 104512.
Zollo, M., Reuer, J. J. and Singh, H. J. O. s., 2002. Interorganizational routines and performance in strategic alliances. 13 (6), 701-713.
Zou, L. and Zhu, Y.-w., 2020. Research on Innovation Performance in Heterogeneous Region: Evidence from Yangtze Economic Belt in China. *Complexity*, 2020.

Appendix A. Search terms applied

Umbrella Term	University	Industry	collaboration
Alternatives	• Higher Education • academic	• Business • Firms • enterprises	• interaction • relationship • partnership • cooperation • engagement • relation • linkage • ties

Appendix B. Reviewed papers

Article	Research Objectives	Method	Detp. Variable	Findings
Aiello et al. (2019)	the determinants of university-industry links in five European countries.	probit regression	Establishment of collaboration (dummy)	Firm innovative efforts, the export status and the R&D government support are positively related to business-university links in almost all countries, human capital and firms' size in two out of five countries under scrutiny, while belonging to science-based sectors does not seem to play a significant role in all countries but Italy
Belderbos et al. (2016)	The benefits of direct and indirect ties to universities.	negative binomial regression models	Innovative performance	Firms with high absoprive capacity benefits from direct ties with university; firms with low absorptive capacity benefits from mediated ties with university, but this effect could be reduced if such firms collaborating with top universities.
Berbegal-Mirabent et al. (2015)	Drivers for successful U-I collaboration.	Linear regression	(1) number of R&D contracts (2) income from R&D contracts	Successful R&D contracts depend on individual capabilities and TTO characteristics, as well as the location of university.
Biedenbach et al. (2018)	The role of absorptive capacity of firms in creating innovation for U-I collaboration	Logit regression	Innovativeness of firms	Engaging with universities does not translate into innovaiton putput for low absorptive capacity firms; firms with medium to high absorptive capacity benefits most from collaborating with universities.
Bruneel et al. (2010b)	Factors that diminish the U-I collaboration; and mechanisms that lowering	Logit regression	(1) orientation-related barriers (2) transaction-related barriers	Trust reduce both types of barrier and prior collaboratoin experiences reduce orientation-related barriers. Interaction breadth increase transaction-related barrier but reduce orientation-related barriers.

	the U-I collaboration barriers			
Bstieler et al. (2017)	Trust development in U-I relationship	Actor-Partner interdependenc Model	Trust between university and industry	Ties strength positively assoicated with trust; firms develop lower trust when collaborating with universities, compared with collaboration with companies. Perception of decision process similarity and reciprocal comminication are positively related to trust.
Cardamone et al. (2018)	The role of technology-transfer activities in Italian food industry	Probit regression model	Innovaiton output (dummy)	Collaborating with universities simulate innovation output of food industry, and this effect is stronger comparing to other manufacturing sectors. This positive effect is geographically bouded.
De Fuentes and Dutrenit (2016)	The relations between geographic proximity and U-I collaboration channels.	Linear regression	(1) Collaboraiton (dummy) (2) Collaboratoin with universities at regional, country or international level (categorical)	Firms with higher level of absorptive capacity interact with universities regardless of location; interacting with non-local universities favor channels that transfer codified knowledge while intera
De Silva and Rossi (2018)	How relational capability of firms influence the co-creating and acquiring knowledge from universities.	Probit regression	(1) knowledge acquisition (dummy) (2) knowledge co-creation (dummy)	Communication capabilities are significant important to kowledge acquisition while capabilities in aligning goals/routines/practices to universities are significantly important only for co-creation of knowledge.
D'Este and Perkmann (2011)	The motivations for engaging in U-I collaboration	Logit regression	Channels of collaboration (joint/contract research, consulting, spin-off, patenting)	Academics engaging in collaboration are more for research purposes rather than for commercialisation purpose. Commercialisatoin strongly motivates the formation of spin-off

				and pantenting, while joint/contract research and consulting activities are strongly motiveted by research purpose.
Fantino et al. (2015)	Determinants of U-I collaboration	Probit regression	The establishment of collaboration (dummy)	The geographical distance is the most important factor, especially for SMEs in determining whether to collaborate with universities. The presense of different innovation source increase the probability of U-I collaboration.
Fernandez-Esquinas et al. (2016)	The determinants for engaging in different U-I collaboration channels	Probit regression	The evolvement in certain U-I collaboration channels (binary)	Exploitation activities of firms determines the parallel exploration activities; the absorptive capacity determines the choice of U-I collaboration channels.
Fiaz (2013)	Motivations for U-I collaboration; collaboration patterns and outcomes	Linear regression	R&D collaborations between U-I	Significant R&D determinants include R&D tendency, R&D risks, state incentives; The main collaboration outputs are innovative incentives, technological gains and sharing R&D costs.
Freitas et al. (2013a)	The governance modes of U-I collaboration: the institutional and personal contractual mode.	Logit regression	Interaction modes: no interaction/personal/institutional (categorical)	Small firms with open innovation strategy are more engaged in personal contractual collaborations; large firms are more involved in institutional interaction with universities.
Goel et al. (2017)	How different modes of collaboration was instigated and managed	Probit regression	Five modes of collaboration (joint research/contract research/technology consulting/licensing and acquisition of technology/informal contacts)	Collaboration was typically instigated by university scientists except Consulting and informal contacts are often initiated by firms. Collaborations are often managed by firms. Meanwhile, initiating collaborations is more difficult with large firms compared with small firms.

Gonzalez-Pernia et al. (2015)	The relationship between different collaborative strategy and firm innovation.	Logit regression	(1) product innovation (binary) (2) process innovation (binary)	For product and process innovation, STI and DUI are important both separately and in combination; The combination of STI and DUI contributes to product innovation and DUI is more associated with process innovation. Findings also reveal that U-I collaboration is week for product innovation if such collaboration is without other STI or DUI agents.
Guzzini and Iacobucci (2017)	The factors lead to U-I failure and the relationship between U-I failure projects and innovation of firms; the impacts of collaboration	Probit regression	(1) delay of innovation projects (dummy) (2) abandonment of innovation projects (dummy)	Collaboration is associated with delay of innovation projects. Compared with collaboration with firms, it does not increase the innovation performance nor the project failure. A positive relation between projects delay and innovation performance is discovered.
Hanid et al. (2019)	Factors that ensure the success of U-I collaboration performance	Descriptive statistics based on primary survey data	The success factors	From the perspective of firms, constant communication, strong teamwork and positive environment are the key success factor in U-I collaboration.
Hemmert et al. (2014)	The relationship between relational mechanisms and trust formation in U-I collaboration	Hierarchical regression	Trust (latent variable)	The innovation champion activity, tie strength, partner reputation and contractual safeguards are critical in trust formation.
Henry and Odei (2018)	The role of public funding in firm's collaboration with universities.	Logit regression	Firms collaboration with other entities (categorical)	Funding from the central government has a significantly positive impact on the collaboration with universities; local and EU funding encourage more collaborations with other firms and government.
Hewitt-Dundas (2013b)	The mediating influence of proximity in the formation of U-I collaboration.	Probi regression	U-I Collaboration (dummy)	1. The size, sale profile, location, absorptive capacity and innovation capacity are all factors determining firms to collaborate with local or non-local university. 2. Locating nearby a top university increase the trend of cooperating locally, but

				higher local concentration of universities makes firms to cooperate with non-local university.
Hewitt-Dundas et al. (2019b)	The relationship between prior collaboration experiences and innovation performance.	Probit regression	New to market innovation (dummy)	Previous experiences increase both the radical innovation performance and the chance to benefits from those innovations of firms. For smaller firms this experience comes from collaboration with customer, for larger firms this comes from prior collaboration with consultants.
Hong and Su (2013a)	Determinants of the formation of U-I collaboration	Logit regression	U-I collaboration (dummy)	Geographical distance is significant in collaboration formation; as well as the social proximity and institutional proximity.
Jones and Corral de Zubielqui (2017)	The role of U-I collaboration in firm innovation and performance.	Multiple regression by structural equation modelling	(1) Firm performance (2) Firm innovation	U-I collaboration in human resource transfer have a significant positive effect on firm innovation. Firm innovation positively affects firm performance.
Kobarg et al. (2018)	The role of absorptive capacity and innovation competencies in collaboration for production innovation.	Linear regression	(1) incremental innovation (2) radical innovation	1. absorptive capacity negatively moderate the relationship between collaboration and incremental innovation and has no effect on radical innovation 2. employee know-how related absorptive capacity has no moderating effects on incremental innovation but has positive effects on radical innovation 3. innovation competency has no moderating effects on incremental innovation but positively affects radical innovation

Lai (2011)	The determinants of collaboration	Linear regression	The formation of collaboration	From the point of industry, the incentives for technology resources and the capability have major influence on the willingness to collaboration.
Laursen et al. (2011)	The role of geographical proximity in the formation of collaboration	Logit regression	The U-I collaboration (categorical)	1. Being nearby a low-tier university reduce the propensity for firms to collaborate locally; 2. Being nearby a top-tier university increase the propensity for firms to collaborate locally; 3. research quality of universities is more important than geographical distances in the formation of collaboration
Lopez et al. (2015)	The determinants of the U-I collaboration formation	Probit regression	U-I collaboration (dummy)	1. more innovative firms are more interested in collaborating with universities; 2. firm size is not significant in the formation of collaboration 3. high-tech firms are strongly unwilling to collaborate with universities; 4. firms carrying innovative activities are more willing to collaborate with universities.
Maietta (2015b)	The drivers of collaboration formation and the outcomes of collaboration	Probit regression	R&D collaboration with university (dummy)	1. collaboration positively affects process innovation; 2. product innovation is positively affected by U-I geographical proximity; 3. academic policy in commercialising research output negatively affects innovation of local firms
Moon et al. (2019)	Modes of collaboration and their impact on innovation	Linear regression	(1) Product innovation	1. people-based collaboration does not affect firm innovation;

	of firms; the moderating role of absorptive capacity in collaboration and innovation		(2) process innovation	2. problem-solving collaboration positively affect firm innovation 3. absorptive capacity moderate the relationship between collaboration and firm innovation
Petruzzelli (2011a)	The role of technological relatedness, prior collaboration ties and relational attributes in the success of collaboration	Logit regression	The value of joint innovation	1. technological relatedness has an inverted U-shaped relation with performance success 2. prior ties and geographical distances positively affect collaboration success.
Ramos-Vielba et al. (2010)	Indicators measuring U-I collaboration in regional innovation system	Descriptive statistics based on primary survey data	U-I collaboration indicators	1. interpersonal network act as a primary source of collaboration 2. patens collaboration and spin-offs creation is of low incidence 3. university plays a significant role in transferring tacit knowledge
Taheri and van Geenhuizen (2019)	The international knowledge relationships of university spin-off firms	Logit regression	Reach in international knowledge relationships (categorical)	The size, market-related training and experiences positively affects the reaches of knowledge relationships
Torres et al. (2011)	Factors that influence the formation of collaboration	Logit regression	The establishment of collaboration (dummy)	1. large firms are less willing to collaborate than small ones; 2. Firms carrying innovation and R&D activities are more willing to collaborate with university.
Wang and Shapira (2012)	The resources possessed by university; the benefits of collaboration.	Tobit regression	The technology potential of firms	The benefits of collaboration include increased research capacity and technology potential of firms, and in turn those benefits attract more external funding for firms.

Zavale (2018)	The collaboration modes and its impact on innovation and performance of firms; the incentive and barriers of collaboration	Descriptive statistics based on primary survey data	(1) channels and intensity of collaboration (2) benefits of collaboration (3) incentives and barriers	1. The service, commercial and bidirectional channels are less used in collaboration. 2. most companies reports no benefits from collaboration. 3. Getting short term production-skills are the main drivers for collaboration. 4. value differences, universities' capacity and government policies are the main barriers for collaboration.

Appendix C. The typologies of collaboration mode

Articles	Modes	Channels/characteristics
Ramos-Vielba et al. (2010)	(a) R&D activities and formal consulting work	1. Consultancy work from a university or public research centre 2. Commissioned R&D projects (financed exclusively by the firm) 3. Joint R&D projects (shared financing or with public support)
	(b) Training and transfer of personnel	4. Training of postgraduates and internships at the firm 5. Temporary exchange of personnel 6. Specific training of the firm workers provided by the university
	(c) Commercialization related to IPR	7. Use or renting of facilities or equipment 8. Exploitation of a patent or utility model/joint patents 9. Creation of a new firm (spin-offs and start-ups)
	(d) Other contacts	10. Participation in a joint venture of hybrid research centre 11. Informal relationships 12. Other types of collaborative activities 13. Non-academic knowledge diffusion activities
Goel et al. (2017)	(a) Formal Collaboration	1. Joint research

		2. Contract research 3. Technology consulting 4. Licensing and acquisition of technologies
	(b) Informal collaboration	5. informal contacts
Zavale (2018)	(a) Traditional channels (DUI)	1.Offer of job opportunities to students/graduates 2. Offer of internship to students without signed agreement with the HEIs 3. Offer of internship to students with signed agreement with the HEIs 4. Participation in conferences organized by HEIs 5. Participation in informal meetings with HEIs 6. Joint organization of sciences and technology exposition
	(b) Traditional channels (Resources)	7. Funding of university conferences 8. Offer of scholarships to students HEIs 9. use company's labs 10. Funding of university materials, equipment, facilities and infrastructures 11. Company uses HEIs' labs
	(c) Service channels (DUI)	12. Commission of consultancy or technical assistance

		13. Hiring professors or contracts with universities for employee's training 14. Offer of job opportunities to academics
	(d) Bi-directional channels (STI)	15. Pure research with HEIs 16. Applied research with HEIs 17. Commission of pure research to HEIs 18. Commission of applied research to HEIs 19. Joint publication of research findings
	(e) Commercial channels (STI)	20. Purchasing of university patents 21. Creation of incubators, starts-ups or spin-offs from university research
Freitas et al. (2013a)	(a) Personal contractual collaborations	1. Individual scientist is hired as external 2. consultant to work on the firm's project 3. Scientist works on the project as a self-employed external consultant 4. Firm decides scope and content of the project 5. Firm organizes and monitors project activities 6. Firm "fully" appropriates the results of the project
	(b) Institutional collaborations	7. Firm contracts with the university for the realization of a project

		8. Scientist works on the project as a university employee 9. Firm needs to organize scope and content of the project so that it is acceptable to university organization 10. Firm and university jointly organize and monitor project activities 11. Firm negotiates with the university the results of the project that are going to be publicly diffused and those that the firm will “appropriate”
Fernandez-Esquinas et al. (2016)	(a) knowledge exploration	1. Generation and adaptation of knowledge 2. Training and exchange of human resource,
	(b) knowledge exploitation	3. Creation of new organisation 4. Intellectual property transaction 5. The use of university facility
Moon et al. (2019)	(a) People-based activities	1.training staff through enrolment on HEI courses or through personnel exchange 2. supervising in-course student projects 3. developing joint curricula with HEIs 4.attending conferences which have HEI participation 5. attending conferences organized by HEIs 6. participating in standard-setting forums involving HEIs

		7. participating in networks involving HEIs 8. sitting on advisory boards of HEIs, 9. organizing invited lectures
	(b) Problem-solving activities	10. hosting academics on a short- or long-term basis 11.using personnel secondment to HEIs 12. engaging in joint research with HEIs 13. using contract research 14. participating in research consortia 15. consulting 16. seeking informal advice 17. using HEIs for prototyping and testing
Jones and Corral de Zubielqui (2017)	(a) Generic links	1. Cooperation in the education of graduate students 2. Vocational training for employees 3. Employed new graduate (s) 4. Used research results published by these Institutions 5. Used patents, designs, or other IP initially for these Institutions 6. Sources of ideas from HEIs and other institutions
	(b) Relational links	7. Used research facilities of these Institutions

		8. Contracted out research and development to these institution 9. Contracted academic or research staff 10. Collaborative research

Appendix D. Questionnaire

1. General Information

Please describe your position:

Middle Management ___

Top Management ___

Name of the enterprise

____

Registered address (only province and city)

____

Registration year

____

Main product

____

1.1 Please provide the following information of your enterprise in the end of 2018: (in 10,000 RMB)

Total Revenue ___________

Total Profit ___________

Average number of employees ____________

1.2 For the past three years (2016-2018), how would you evaluate the performance of your enterprise:

	very low	low	medium	high	Very high
Sales Revenue					
Profitability					
Market Shares					
Productivity					

1.3 For the past three years (2016-2018), how would you evaluate the impact of general economy environment on the performance of your enterprise?

(General economy environment mainly considers the macro economy factors, including market demands, policy, Sino-China trade dispute….)

	No impact	Minor impact	Medium impact	Major impact	Huge impact
General environment					

1.4 For the past three years (2016-2018), how was the absorptive capacity of your enterprise?

	Strongly disagree	disagree	medium	agree	Strongly disagree
We can quickly acquire information about customer needs/advance technology in our industry					
We can quickly assimilate the newly acquired information/knowledge					
We have established procedure for effectively apply the assimilated external knowledge					
We can quickly introduce product/process innovation with new knowledge					
We can quickly introduce management/marketing innovation with new knowledge					

1.5 For the past three years (2016-2018), what was the average R&D intensity of your firms? (R&D investment/sales revenue)

No R&D expenses <5% 5-10% 10-15% >15%

2. University Collaboration

2.1 For the past three years (2016-2018), has your enterprise ever engaged in the interactions with university/universities?

(The forms of U-I interaction can be variety and flexible. The social activities between staffs, recruitment of graduates, establishment of joint ventures…. It includes any interactions from individual level or institutional level)

Yes _____

No _____

2.2 Please fill in the name of the university which has the closest relationship with your enterprise.

____

2.3 For the past three years (2016-2018), please evaluate the frequency or duration of following interaction activities with university:

Based on the nature of activities, they can be classified as: very often (or long term), regularly (comparatively long term), sometimes (comparatively short term), rarely (short term) and no.

	none	rarely	sometimes	regularly	Very often
Social activities with university staff					
Academic forums/conference held by university					
Joint PGR supervision					
Students internship					
Graduates recruitment					
University staff secondment (part-time job/consultant)					
Training programme					

2.4 For the past three years (2016-2018), please evaluate the frequency or duration of following interaction activities with university:

	none	rarely	sometimes	regularly	Very often
Consultancy service provided by university					
research grant/ scholarship					
Joint/contract research					
Patent/licence transaction					
Use of university facilities (e.g. labs, offices, science park)					
Joint venture establishment					

2.5 Please indicate what are the barriers to collaborate with university (please tick 1-3 barriers). For non-collaborators

University	Tick 1 to 3
University bureaucracy	
University technology is not mature to industry	
Geographical distance to the university	
Previous collaboration failure with university	
Enterprise	
Lack of funds	
Lack of necessary information of universities	
Lack of knowledge assimilation capability	

Difficulties in obtaining financial subsidiaries from government	
Collaboration risks are unpredictable	
Concerns of intellectual property conflict	
No needs to collaborate with universities	

3. Innovation

3.1 For the past three years (2016-2018), has your enterprise ever introduced technological innovation? (product innovation/ process innovation)

Yes ____

No ____

3.1.1 For the past three years (2016-2018), has your enterprise ever introduced product innovation? (if so, please evaluate the radicalness)

(Product Innovation refers to new or significantly improved products. it must be the first time introduced by your enterprise)

	none	New to firm	New to regional market	New to national market	New to world
New product					

3.1.2 For the past three years (2016-2018), has your enterprise ever introduced process innovation? (if so, please evaluate the radicalness)

(Process innovation refers to new method of manufacturing, new production supporting activities such as procurement, accounting and software etc.)

	none	New to firm	New to regional market	New to national market	New to world
New method of manufacturing					
New supporting activities such as purchasing, logistics, accounting					

3.2 For the past three years (2016-2018), has your enterprise ever introduced management innovation? (organisational innovation/ marketing innovation)

Yes ____

No ____

3.2.1 For the past three years (2016-2018), has your enterprise ever introduced organisational innovation? (if so, please evaluate the importance to your firm)

(Organisational Innovation refers to new business practice, new organisational structure and new external relationship with others)

	none	Not important	Less important	important	Very important
New business practice					
New organisational structure					
New external relationship					

3.2.2 For the past three years (2016-2018), has your enterprise ever introduced marketing innovation? (if so, please evaluate the importance to your firm)

(Marketing innovation refers to new packaging, new promotion method, new sales channels and new pricing strategy)

	none	Not important	Less important	important	Very important
New packaging					
New method of promotion					
New sales channel					
New pricing strategy					