The Formation of Different Collaborative Structures and their Implications for Innovative Performance

An empirical study of public R&D projects in the Digital Healthcare sector of Korea

Kyung J. Han

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I hereby declare that this thesis has not been submitted, either in the same or different form, to this or any other university for a degree.

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While the name on this thesis is my own, its creation would not have been possible without the assistance of a great number of people. I would like to gratefully acknowledge their support.

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Abstract

The role of collaboration is becoming progressively more important to achieve innovation in an environment that is continually experiencing rapid technological changes as well as changing modes of knowledge production such as in the digital healthcare sector. However, little attention has been paid to understanding underlying inter-organisational collaboration mechanisms among diverse organisational types such as firms, universities, public research institutes, and hospitals in this sector. More specifically, this thesis examines why these organisations in the Korean digital healthcare sector establish inter-organisational collaborations, how different collaborative structures are established, and what effects these different collaborative structures have on innovative performance.

In order to address these issues, this thesis proposes and verifies a novel conceptual framework based on three theoretical approaches (i.e. the national innovation system, transaction cost economics, and the resource-based view) in explaining strategic motives in the establishment of different collaborative structures categorised by focal organisational type. Mixed methods analysis, based on data regarding information on inter-organisational R&D collaborations, strategic motives in establishing the collaborations, and their respective innovative performance collected by a combination of desk-based research, a survey, and interviews, is employed.

This thesis makes an interesting empirical contributions by finding different patterns in R&D productivity levels when one breaks down collaborative structures from the perspective of the type of focal organisations, whilst the productivity levels of R&D collaboration projects are generally lower than those of non-collaboration R&D projects in all aspects of R&D performance. We also confirm that each type of focal organisations is largely influenced by distinctive motives, although the strategic motive ‘to access complementary capabilities or resources’ relating to the resource-based view perspective has a primary effect on all focal organisations in developing collaborative structures. Additionally, the thesis provides detailed information concerning how strategic motives affect focal organisations in choosing a particular type of collaborating partners.

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Abbreviations

AAL	Ambient Assisted Living
AED	Automated External Defibrillator
AI	Artificial Intelligence
ANOVA	Analysis of Variance
BOK	Bank of Korea
CDM	Common Data Model
CDW	Clinical Data Warehouse
CEO	Chief Executive Officer
CHII	The Presidential Commission on Healthcare Industry Innovation
CIS	Community Innovation Survey
CPOE	Computerized Physician Order Entry
CPR	Cardio-Pulmonary Resuscitation
CTO	Chief Technology Officer
DDA	Doha Development Agenda
EMR	Electronic Medical Record
EU	European Union
FDA	Food and Drug Administration
FP	For-Profit
GBP	Great Britain Pound
GDP	Gross Domestic Product
HIRA	Health Insurance Review and Assessment Service
HIS	Health Information System
ICT	Information and communications technology
IITP	Institute for Information and Communications Technology Promotion
IoT	Internet of Things
IP	Intellectual Property
IRCC	Industry and Research-based hospitals Cooperation Centre
IT	Information Technology
ITU	International Telecommunication Union
KDI	Korea Development Institute
KEIT	Korea Evaluation Institute of Industrial Technology
KESS	Korean Educational Statistics Service
KHEI	Korea Higher Education Research Institute
KHIDI	Korea Health Industry Development Institute
KIAT	Korea Institute for Advancement of Technology
KIET	Korea Institute for Industrial Economics and Trade
KIRMS	Korea Institute of Radiological Medical Sciences
KIST	Korea Institute of Science and Technology
KISTEP	Korea Institute of Science and Technology Evaluation and Planning
KISTI	Korea Institute of Science and Technology Information
KMD	Korean Medicine Doctor
KOSIS	Korea Statistical Information Service
KRW	Korean Won
KSIC	Korean Standard Industrial Classification

MD	Medical Doctor
MFDS	Ministry of Food and Drug Safety
MoE	Ministry of Education
MoHW	Ministry of Health and Welfare
MoLIT	Ministry of Land, Infrastructure, and Transport
MoTIE	Ministry of Trade, Industry, and Energy
MSIT	Ministry of Science and Information and Communications Technology
MSS	Ministry of SMEs and Start-ups
NARS	National Assembly Research Service
NCC	National Cancer Centre
NFP	Not-For-Profit
NHID	National Health Information Database
NHIS	National Health Insurance Service
NIH	National Institutes of Health
NIS	National Innovation System
NRF	National Research Foundation of Korea
NSCST	National Standard Classification of Science and Technology
NST	National Research Council of Science and Technology
NTIS	National Science and Technology Information Service
OECD	Organisation for Economic Cooperation and Development
PACS	Picture Archiving and Communication System
PACST	Presidential Advisory Council on Science and Technology
PI	Principal Investigator
PRI	Public Research Institute
R&D	Research and Development
RBV	Resource-Based View
RFPs	Request for Proposals
SCI	Science Citation Index
SME	Small and Medium-sized Enterprise
TCE	Transaction Cost Economics
TIPA	Korea Technology & Information Promotion Agency for SMEs
UICC	University and Industry Cooperation Centre
U-I-P	University-Industry-Public Research Institute
UN	United Nations
US	United States
WHO	World Health Organization
WTO	World Trade Organisation

Chapter 1. Introduction

1.1. Motivation and Research Questions

The digital revolution based on information and communications technology (ICT), has accelerated a paradigm shift from an industrial economy to a knowledge-based economy where knowledge is at the centre of economic development (Harris, 2001; Qamruzzaman, et al., 2014). Hence, intellectual capabilities such as technological knowledge production, dissemination and exploitation, are key elements for achieving innovation through scientific and technical advance in the knowledge-based economy (OECD, 1996; Powell, et al., 2004). Nevertheless, innovations can be also achieved through the first use or adoption of new or improved products, processes, marketing activities, or organisational forms as well as scientific and technological development (Freeman, 1982; Rothwell, 1992). At the time of this transition, the balance of forms of knowledge production moved from Mode 1 (i.e. single-discipline-based) to Mode 2 (i.e. inter-/multi-disciplinary-based)[1] (Gibbons, et al., 1994; Van Rijnsoever, et al., 2011). Creating innovation can almost never be achieved by a single organisation operating in isolation, and interaction with other organisations in the knowledge-based economy is most often required (Edquist, 2005; Fagerberg, 2006; Markard, et al., 2008), and the role of collaboration is becoming progressively vital for achieving innovation (Contractor, et al., 2002; Dahlander, et al., 2010; Kristensen, et al., 2012; Paier, et al., 2011). Thus, this thesis aims to understand underlying collaboration mechanisms for achieving innovation. More specifically, the objectives of this research are to investigate the motives in the establishment of inter-organisational collaboration, the characteristics of different collaborative structures, and their implications for innovative performance.

Meanwhile, globalisation of innovation has been strengthening the importance of intellectual capabilities as a strategic competitive resource in the intensified global competition, and accelerating collaboration between actors, both across and within national boundaries (Archibugi, et al., 1999; Martin, 2003). In addition, growing social welfare issues such as wellbeing and health stemming from growing economic inequality and the ageing population have been contributing to a decrease in autonomy in public

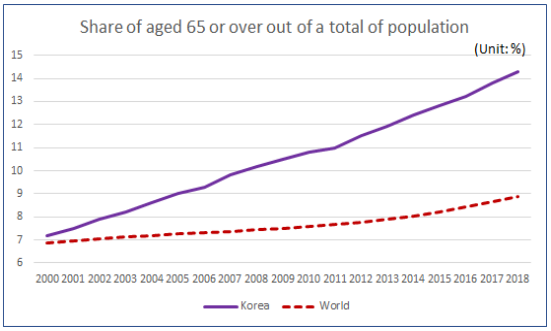
[1] This change only means the mode of knowledge production has shifted to focus more on Mode 2 rather than Mode 1, altering the balance between the already extant forms of knowledge production (Martin, et al., 2000).

research (Curristine, et al., 2007; Martin, 2003). Decreased autonomy is a consequence of increased expectation of societal accountability for public research funds and is causing us to revisit social contract for research funding. In the revised social contract, researchers are required to assign more priority to unmet social and economic needs of the nation, which will likely involve the research participation from a variety of stakeholders, than to pursuing scientific exploration (Hessels, et al., 2008; Martin, et al., 2000). Both growing competition and the revised social contract tend to lead researchers to focusing more on meeting current and future needs in society and economy through establishing research collaboration among a variety of stakeholders and actors in the innovation system such as firms, governmental bodies, universities, and non-profit organisations (Selsky, et al., 2005; The Royal Society, 2011).

As a consequence, collaborative activities such as the establishment of inter-organisational collaborations that also cross boundaries among a variety of disciplines and actors appear to be essential to address the unmet social and economic needs. For example, the digital healthcare sector [2] is confronted by demographic changes, particularly with an ageing population in many parts of the world, not least Korea (see *Figure 1.1*), and these demographic changes give rise to unmet social and economic needs such as increasing healthcare expenditures (see *Figure 1.2*) and undermining the expectation of universal health coverage. These are likely to be attributed to the fact that the increase in the proportion of the elderly is associated with a growing demand for healthcare due to the greater number of people with limited mobility and morbidity in older age (Hayes, et al., 2016; UN, 2013). Indeed, the elderly (65 or over) account for 39.0% of total healthcare expenses in Korea in 2017 while they represent only 13.4% of the population of Korea (HIRA, 2018), and 38.7% of the elderly (65 or over) in the US exhibit at least one disability (e.g. ambulatory, vision, hearing, cognitive, self-care, and independent-living) and around two-thirds of the total elderly population with a disability reported having serious difficulty in mobility (He, et al., 2014).

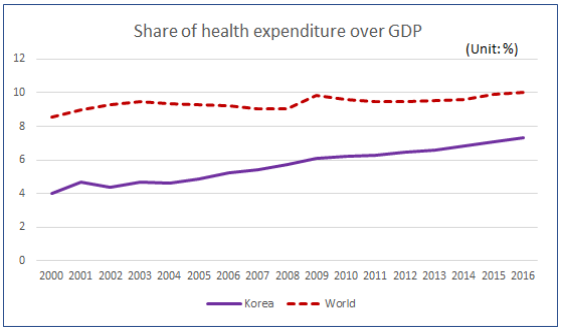
[2] Although digital health has defined as "**an improvement in the way healthcare provision** is conceived and delivered by healthcare providers through **the use of information and communication technologies to monitor and improve the wellbeing and health of patients** and **to empower patients** in the management of their health and that of their families" (Iyawa, et al., 2016, p. 246), the digital healthcare sector in this thesis for the analysis is regarded as the areas involving '**health information and health information system technologies**' by the Korean National Standard Classification of Science and Technology (NSCST).

Figure 1.1 The ratio of population aged 65 or over: Korea vs World



Source: by author based on World Population Prospects (UN, 2019)

Figure 1.2 The Ratio of health expenditure out of GDP



Source: by author based on Global Health Expenditure Database (WHO, 2019)

Therefore, paying attention to a better understanding of inter-organisational collaboration mechanisms as a central feature of the innovative process in the digital healthcare sector may be meaningful, given the current environmental conditions of this sector in which collaborative activities play a core role and addressing the unmet social and economic needs is becoming imperative. Hence, this sector can contribute to reducing the burden of healthcare expenses, achieving the expectation of universal health coverage in a real sense, and increasing the quality of healthcare services. Indeed, several empirical studies have shown that the application of digital technology to healthcare services has a positive impact in reducing costs of healthcare services (e.g. Buntin, et al., 2011; Park H., et al., 2015) and increasing the quality of healthcare services such as diminishing the rate of medication errors (e.g. Mullett, et al., 2001) and achieving better medication delivery (e.g. Chiarelli, et al., 1990), and promoting universal health coverage for the elderly and residents who live in remote areas (Chang, et al., 2004).

Personalised medicine/precision medicine[3] has been spreading as a result of the rapid development of the healthcare-related technologies such as biomedical science, ICT, and clinical science (Frizzo-Barker, et al., 2016). This is shedding more light on care/prevention and patient-centred healthcare where knowledge reconfiguration and integration through collaborations with various partners in diverse areas are more essential than conventional cure and healthcare provider-centred healthcare (Anderson, et al., 2005; Gérvas, et al., 2008; Traver, et al., 2010). This change could contribute to opening a new window of opportunity (niche or emerging markets) for newcomers or latecomers in the healthcare sector dominated by very strong incumbents in conventional

[3] Digital healthcare-related technologies such as genomics, biotechnology, wearable sensors, or artificial intelligence provide the foundations of precision medicine (Mesko, 2017).

healthcare sectors such as the pharmaceutical and medical device industries (e.g. Roche, Pfizer, Merck, Novartis, Medtronic, Johnson & Johnson, GE Healthcare, and Philips Healthcare). One of the examples, the digital healthcare sector, an emerging and inter-/multi-disciplinary sector, has been emerging thanks to this shift in the healthcare sector. Particularly, the market demands are being expanded from just patients to persons who do not even have a disease but who are seeking care and prevention, and knowledge integration between bio and medical science and ICT plays an essential role in this sector. In addition, the issue of ambiguous boundaries between health and social care, for instance at-home medical genetic tests and smartphone-based diagnostic devices, may give rise to issues in terms of regulatory applications. In order to adapt to or prepare for these changes with regard to the market demands, the knowledge bases, and the regulatory applications, we need to understand the key features of the actors involved and how they interact with each other within the institutional context.

However, little attention has been paid to understanding the characteristics of collaborative activities and their innovative performance in the digital healthcare sector. Thus, understanding the characteristics of collaboration for developing intellectual capabilities through public R&D should yield important insights and policy implications for this sector, because public R&D is likely to play a pivotal role in emerging markets such as the digital healthcare sector, given that private firms are reluctant to invest in these markets due to the large risks (Bozeman, 2000). Hence, this research aims (1) to identify why organisations that participate in public R&D projects in the Korean digital healthcare sector establish organisational collaboration, (2) to explore why different structures of the inter-organisational collaboration are established, and (3) to explain what effects those different collaborative structures have on innovative performance. Accordingly, three research questions to address these issues are:

(i) What are the motives of the focal organisations[4] influencing the establishment of inter-organisational collaboration in public R&D projects of the Korean digital healthcare sector?

(ii) How are different collaborative structures developed in the public R&D projects?

(iii) What effects do these different collaborative structures have on diverse aspects of R&D performance?

[4] The role of focal organisations, which launch initiatives with the strategic purpose of establishing collaboration, is vital in R&D projects.

1.2. Theoretical Context

This research aims to arrive at a better understanding of the underlying inter-organisational collaboration mechanisms as a core part of the innovative process, for example, why organisations establish collaboration, why they develop different collaborative structures, and how the establishment of collaboration has an impact on innovative performance. In order to address these research questions, we assumed that the behaviour of organisations in the real world largely relies on external environmental influences, namely, institutions. The reason is because organisations are embedded in an institutional context, which has a considerable influence on the pace and direction of innovation processes by stimulating or constraining collaboration among diverse organisations in the innovation system (Edquist, 2006; Nelson, et al., 2002). At the same time, it is also assumed that the behaviour of organisations including the establishment of collaboration is determined by the organisations' self-interests related to strategic logic (e.g. cost-minimising and value-maximising reasons). Hence, we will take into consideration both the intrinsic properties of individual organisations (i.e. the cost-minimising and value-maximising reasons) and institutional properties of the system as part of strategic decisions/motives that may play an important role in developing the inter-organisational collaborative structures, and their implications for R&D performance.

Here, the National Innovation System (NIS) approach forms the basis of the conceptual framework of this thesis because this research focuses on exploring underlying collaboration mechanisms in an emerging sector where government institutions such as a R&D policy, part of the national innovation system, play a pivotal role due to high risks and uncertainty. Additionally, the NIS perspective emphasises the importance of collaboration among diverse actors as an important learning process in order to achieve novelty. Meanwhile, a cost-minimising approach to choosing the most economic governance mode based on Transaction Cost Economics (TCE) and the perspective of securing strategic resources for value maximisation relating to the Resource-Based View (RBV) are used for filling in the missing dimension of the NIS perspective. Thus, a combination of these three theoretical approaches provides us with a holistic picture of underlying collaboration mechanisms in the innovation system through incorporating both the intrinsic properties at the organisational level and the institutional properties of the innovation system, thereby offering a better framework for understanding the motives

in establishing inter-organisational collaborations and their implications for innovative performance.

1.3. Research Design and Methods

In order to address the research questions, we will use mixed quantitative and qualitative methods based on desk-based research, a survey, and interviews. Data for the mixed quantitative and qualitative methods were generally collected on the basis of a total of 207 public R&D collaboration projects in the Korean digital healthcare sector between 2012 and 2015, which account for around £92.5 million of the R&D budget[5]. The aim of the mixed methods will be mainly motivated by obtaining additional information to arrive at a more holistic understanding of inter-organisational collaboration mechanisms, although the mixed methods were also partially employed in order to provide cross-validation of the findings. For a more holistic understanding of the mechanisms, different quantitative or qualitative methods are assigned to research purposes in a research question in order to match the distinctive strengths of a particular method to a specific research purpose, and each method is utilised to study a separate part of the overall research question (Morgan, 2013). Thus, this research design involves collecting both qualitative and quantitative data, integrating these two types of data, and using the distinctive strengths of particular methods for specific research purposes. In this regard, this research design is more likely to provide a better understanding of the research questions than employing a single research method (Creswell, 2014).

More specifically, for dealing with the first research question, closed questions involving motives linked to both the institutional properties of the system and intrinsic properties of individual organisations were asked via a survey for understanding to what extent each motive linked to three theoretical approaches (i.e. the NIS, TCE, and the RBV perspectives) affects the establishment of inter-organisational collaboration. Through the survey, 57 project topics (44.5%) and 92 R&D projects (44.4%) were covered out of a total of 128 project topics and 207 R&D projects in the digital healthcare sector of Korea for the period from 2012 to 2015, accounting for about £47.7 million of the R&D budget.

In addition, an open-ended question was tested through interviews for cross-validation of

[5] The average currency exchange rate in 2017 (£1 = ₩1,455.1) is applied for the conversion from Korean won to GBP

the findings in which respondents[6] are able to introduce their own answers that do not fit the interviewer's coding schemes (Roulston, 2008b). In course of the interviews, 39 project topics and 64 R&D projects were covered through interviews with 35 principal investigators (28.2%) out of a total of 124 principal investigators, 128 project topics, and 207 R&D projects in the Korean digital healthcare sector for the period from 2012 to 2015, accounting for around £37.6 million of the R&D budget.

In contrast to intrinsic properties of individual organisations, respondents in research organisations are likely to have bounded information in terms of the institutional properties of the innovation system, or they might not even perceive them because these institutional properties tend to be 'taken-for-granted' within the national R&D system, being accepted without question (Lu, 2002). Thus, an additional investigation of the institutional pressures affecting the establishment of collaboration by enforcing or encouraging was carried out through exploring the 'request for proposals' (RFPs) of each R&D project in order to obtain a better understanding of the motives with regard to the institutional properties of the innovation system in establishing collaboration.

In order to address the second research question, the survey-based data and interview data on the motives in the establishment of R&D collaboration were classified in terms of focal organisational types (i.e. firms, universities, PRIs, and hospitals). Thus, this classification provides information on how the development of different collaborative structures based on various focal organisational types depends on different motives in establishing collaboration. Furthermore, the survey-based data were classified by collaborating partner type, and these classified groups were employed to analyse how the motives influence focal organisations to choose a particular type of partners in establishing R&D collaboration. In order to carry out a more in-depth investigation, interview-based data were utilised. These data were collected to gain information on the strategic expectations of focal organisations with regard to their partner organisations in the establishment of different collaborative structures. Thus, this analysis may also contribute to a better understanding of how different focal organisations developed R&D collaborations with particular types of collaborating partners.

The last research question was generally addressed by quantitative analysis in order to

[6] The respondents are principal investigators in R&D collaboration projects, who are mostly CEOs /CTOs, professors, medical doctors, and senior researchers in the PRIs in the digital healthcare sector (see *Table 3.5*).

understand how different collaborative structures categorised by focal organisational type have an effect on various aspects of R&D performance – SCI papers, patent applications, patents-granted, and technology licensing. In addition, we carried out an investigation to ascertain the institutional implications for R&D performance through exploring the 'request for proposals' (RFPs) of each R&D project. Finally, unrevealed aspects of R&D performance that are not captured through the national R&D information system were explored based on interview data. Hence, this analysis also contributes to arriving at a better understanding of how the establishment of inter-organisational R&D collaboration has an effect on various aspects of R&D performance.

1.4. Outline of Thesis Structures

This thesis consists of four main parts. The first part sets out the conceptual and analytical frameworks of this research (Chapter 2 and 3). The second part presents the contextual characteristics of the Korean digital healthcare sector together with the characteristics of the four main actors in the sector (Chapter 4). The third part empirically analyses the characteristics of strategic motives in establishing collaboration, the characteristics of different collaboration structures, and their implications for R&D performance (Chapter 5, 6, and 7). The last part of this research covers overall discussion and provides a conclusion.

Chapter 2 critically reviews the literature that provides a theoretical and methodological foundation for the study in order to address the research questions and to identify relevant research gaps in need of filling with research contributions. First, the NIS, the basis of the conceptual framework of this thesis is reviewed, from a collaboration perspective, and then intrinsic properties of individual organisations in establishing collaboration are illuminated based on TCE and the RBV perspectives in order to provide the missing dimension of the NIS. Finally, the relationships between diverse collaborative structures and innovative performance are examined, which supports the analytical scheme of this thesis. Chapter 3 introduces the mixed methodology in order to explain the implementation of this research. In addition, research design, data sources, the means of data collection, and analytical methods are also explained in detail in this chapter.

In the second part of this thesis, Chapter 4 focuses on exploring the characteristics of the Korean digital healthcare sector in terms of the healthcare payment system, healthcare

service providers, ageing population and healthcare expenses, the features of ICT and digitalisation infrastructure, recent policies and (de)regulations in this sector, and the barriers and importance of collaboration in the sector. Moreover, the general characteristics of main actors such as firms, universities, public research institutes (PRIs), and hospitals in the national innovation system of Korea are investigated to illustrate the contextual characteristics of the Korean digital healthcare sector.

In the third part of the thesis, each chapter corresponds to the three research questions, respectively. Thus, in Chapter 5 we exploited mixed methods based on both quantitative and qualitative data collected from a survey and interviews in order to address the first research question, and this chapter put the emphasis on understanding strategic motives in establishing R&D collaboration. In addition, another analysis based on requests for proposals (RFPs) as R&D policy instruments is carried out to understand the institutional influences on the establishment of R&D collaboration. Chapter 6 also reports the mixed methods analysis to deal with the second research question, how are different collaborative structures developed in the public R&D projects. Through this chapter, we expect to identify how different motives influence the development of different collaborative structures categorised by focal organisational type (i.e. a firm, university, PRI, and hospital). In addition, the strategic motives of the focal organisations in the choice of the particular type of collaborating partners were also explored through the mixed methods analysis. Chapter 7 mainly focuses on quantitative analysis to address the third research question, what effects the different collaborative structures have on diverse aspects of R&D performance. This analysis presents the characteristics of various aspects of R&D performance, namely, SCI papers, patent applications, patents-granted, and technology licensing according to different collaborative structures categorised by types of focal and collaborating partner organisations in comparison with the R&D performance of non-collaboration R&D projects. Additionally, the institutional implications for R&D performance and unrevealed aspects of R&D performance that are not captured through the national R&D information system were analysed.

Finally, Chapter 8 synthesises and discusses the overall findings of this thesis, drawing together the theoretical, methodological, and empirical contributions, and the policy implications. This chapter closes with an identification of the limitations of this thesis and sets out the options for further research.

1.5 Contributions to the Science and Technology Policy Studies Literature

This thesis makes conceptual, methodological, and empirical contributions to knowledge, which will be discussed in section 8.2 in more detail. It proposes and validates a novel conceptual framework based on three theoretical approaches in explaining *strategic motives in the establishment of different collaborative structures categorised by focal organisational type such as a firm, university, public research institute, and hospital*. This is important because existing literature on inter-organisational collaboration lacks a shared understanding of the underlying collaboration mechanisms in the not-for-profit sector (Weber, et al., 2017) and from a perspective of not-for-profit organisations (Omar, et al., 2014). These three theoretical approaches are combined on the basis of the institutional properties of the innovation system linked to the NIS perspective and the intrinsic characteristics of individual organisations (i.e. cost-minimising and value-maximising through securing strategic resources approaches) associated with the TCE and RBV perspectives, respectively.

This thesis makes a methodological contribution by employing *mixed (i.e. quantitative and qualitative) methods analysis with direct variables* for examining the relationships between different forms of collaboration and their innovation performance in order to overcome the limitations of extant literature on account of its restricted data sources. The existing literature tends to limit or restrict opportunities for a deep explanation of complicated issues like exploring collaboration mechanisms because most of them depends largely on quantitative methods utilising indirect variables based on survey data such as the Community Innovation Survey.

This thesis also makes a very interesting empirical contribution by finding *different patterns in R&D productivity levels when one breaks down collaborative structures* from the perspective of the type of focal organisations, whilst the productivity levels of *R&D collaboration projects are generally lower than those of non-collaboration R&D projects in all aspects of R&D performance*. In addition, we confirmed that each type of focal organisations (i.e. firms, universities, PRIs, and hospitals) is largely influenced by distinctive motives, although the strategic motive '*to access complementary capabilities or resources* (an RBV perspective)' is seen to have a primary effect on overall focal organisations in developing collaborative structures when addressed through mixed (i.e. both quantitative and qualitative) methods analysis. Additionally, this thesis provides

detailed information in terms of how strategic motives affect focal organisations in choosing a particular type of collaborating partners.

1.6. Conclusion

This chapter has introduced the thesis by providing a general overview of research motivation and topics and the theoretical context of this thesis. It has also summarised the research design and methods of this research and the structure of the study carried out to address three research questions. It has concluded by discussing the conceptual, methodological, and empirical contributions through this thesis.

The following chapter will begin to discuss the institutional properties of the innovation system and the intrinsic properties of individual organisations in forming the strategic motives of different organisational types in establishing collaborations. The combination of both these institutional and intrinsic properties aims to address the research questions as a backbone of the conceptual framework employed in this thesis. It will also explore extant literature regarding the relationships between collaborations and their implications for innovative performance in order to ascertain whether they are any research gaps with regard to those relationships.

Chapter 2. Literature Review

2.1. Introduction

The main objectives of this chapter are to understand the theoretical background on strategic motives in establishing collaborative structures and to understand the relationship between diverse collaborative structures influenced by the motives and their innovative performance. In order to meet these objectives, this chapter is composed of two conceptual parts. The first part aims at developing a theoretical framework to explain the motives in developing inter-organisational collaboration through combining relevant theoretical approaches such as the national innovation system (NIS), transaction cost economics (TCE), and the resource-based view (RBV). Here, this chapter also identifies some theoretical gaps that are not covered by extant theoretical approaches to collaboration. The second part of this chapter is devoted to examining diverse collaborative structures based on organisational types and their implications for innovative performance. This part of the literature review contributes to addressing empirical gaps in understanding the relationship between collaborative structures and their effects on innovative performance.

This chapter is divided into four main sections. The first three are about the conceptual framework, which explains strategic motives for establishing diverse collaborative structures based on the theoretical approaches. Section 2.2 describes the importance of collaboration to achieve novelty in the NIS through identifying the main components of the NIS which include collaboration, institutions, and organisations. Section 2.2 also shows that the characteristics of the different organisational types and their interaction are heavily dependent on institutions, which will be defined below, and how they may affect the motives behind the various behaviours involved in the establishment of collaboration.

The main purpose of both section 2.3 and 2.4 is to complement the missing dimensions of the NIS as part of the conceptual framework for the thesis because the NIS perspective tends to shed relatively little light on the intrinsic properties of individual organisations. In other words, the intrinsic properties of individual organisations in establishing different collaborative structures seem to be neglected in the NIS. In section 2.3, the cost economising approach of individual organisations in choosing an optimal governance structure is examined based on the TCE, which forms another part of the conceptual framework. Here, the origin and the evolution of the TCE are explored in order to

articulate its relevance to the conceptual framework. This is then followed by a discussion on how collaboration may be considered as an optimal governance structure from the cost-economising perspective in response to three observable dimensions of 'asset specificity', 'uncertainty', and 'frequency of the transaction'.

The third theoretical component of the conceptual framework lies in the concept of securing strategic resources for value maximisation of individual organisations. The value maximisation driven by securing and exploiting strategic resources is examined in the RBV, which is covered in section 2.4. Based on exploring the origin and the evolution of the RBV, this section describes how the RBV is related to collaboration. In addition, this section addresses the importance of collaboration in terms of a way of securing strategic resources for maximising value to individual organisations, and thus for attaining a competitive advantage. In particular, this section emphasises the role of the collaboration in the transfer of strategic resources between collaborating organisations if the strategic resources are tacit or intangible assets, in that collaboration tends to act as a vehicle for intangible and tacit knowledge transfer between collaborating organisations via interactive learning. In summary, TCE and the RBV perspectives help toward filling the theoretical gap of the NIS perspective, and the conceptual framework combining these three theoretical concepts in a complementary manner makes possible the analysis of different collaborative structures and their implications for innovative performance based on both intrinsic properties of individual organisations and institutional properties of the system.

Section 2.5 then explores the impact of different collaborative structures, assuming that they are reliant on the strategic motives of individual organisations, on their innovative performance. It starts with a review focusing on the positive influences of diverse collaborative structures on innovative performance. This is followed by a discussion of the literature on inconsistent influences of different collaborative structures on innovative performance, which is covered in the second part of this section. Based on these controversial results in the relationship between the impact of diverse collaborative structures and innovative performance, this section identifies certain empirical gaps in the existing literature, which are likely to result from limitations of data and the research design. It is plausible that these empirical gaps are likely to bring about these inconsistent results regarding the correlations. These empirical gaps could also lead to neglecting the

strategic motives of individual organisations and institutional factors in collaborative activities.

2.2. National Innovation System from a collaboration perspective

This section reviews the different definitions of the NIS, and how it is relevant as a main theoretical component of this thesis through a discussion of its core components (organisations, collaboration, and institutions). This is followed by a review of the literature on the importance of collaboration in the NIS, introducing the notions of novelty and specialisation. Moreover, this section identifies the role of institutions in establishing collaboration because this could help to determine the strategic motives behind the various organisational behaviours. This section ends by highlighting the missing dimension of the NIS perspective in explaining inter-organisational collaboration mechanisms.

2.2.1. Constituents of the National Innovation System

The NIS was developed by commitments of many economists who have levelled criticism against the mainstream economic approach to innovation, namely neoclassical economics. In contrast to advocates of neoclassical economics, they emphasised the role of the market's guiding-hand such as the institutional role of government as well as shedding light on learning and the acquisition of knowledge and technology as an important process for economic growth (Lundvall, 2007; Sharif, 2006). These distinguishing characteristics of the NIS, however, were originally advanced by Friedrich List in his conception of 'The National System of Political Economy' (1841) for the protection of infant and emerging industries and for accelerating economic advancement (Freeman, 1995; Johnson, et al., 2004). Accordingly, these characteristics are well embedded in the various definitions of the NIS, although there remains a lack of consensus on a single definition of the NIS. The NIS was initially defined by Freeman in his study of the innovative development of Japan. According to him, the NIS is "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987, p. 1). Here, he seems to view 'interactions' and 'institutions' in the public sector as well as in the private sector as relevant to encouraging technological advances as core ingredients for innovative performance. Lundvall (1992, p. 2)[7] defined the NIS as

[7] In this, Lundvall gives more attention to institutions and to capabilities supporting learning and the acquisition of knowledge.

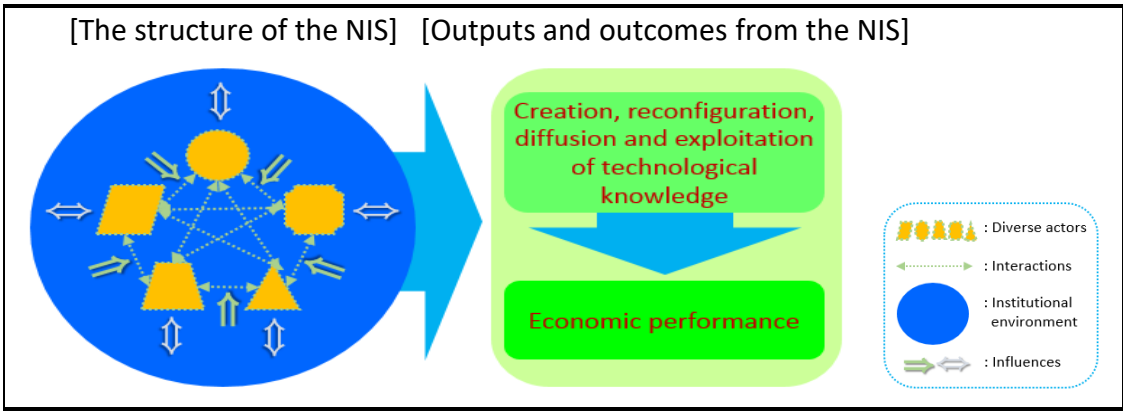
"elements and relationships which interact in the production, distribution, and use of economically useful knowledge and are either located within or rooted inside the borders of a nation state." Later, Nelson (1993, p. 4) explained the NIS as "a set of institutions whose interactions determines the innovative activity of national firms." Both scholars also emphasise 'interaction' and 'institutions' in their definitions even though the 'institutions' are implicitly defined by Lundvall (1992, p. 2) as "… located within or rooted inside the borders of a national state." However, there is an ambiguity in the notion of the 'institution' in these three definitions. The notion of the 'institution' in the definition of Freeman (1987) comprises governmental rules as well as organisations and their activities (Werle, 2012). In the same vein, Godin (2009, p. 478) has noted that "the institutions are firms, public laboratories, and universities, but also financial institutions, the educational system, government regulatory bodies, and others that interact together." However, the notion of 'institutions' is employed in different senses by Nelson (1993) and Lundvall (1992). Nelson (1993) focused more on organisational actors in his notion of 'institutions' while Lundvall (1992) views 'institutions' as the behavioural patterns or institutional rules including certain ground rules for economic behaviour (Edquist, 2006). Such differences are likely to emerge owing to different approaches to the NIS either with an empirical perspective (e.g. Nelson, 1993) or with a theoretical perspective (e.g. Lundvall, 1992). According to Edquist, et al. (2005), from an empirical perspective, the term 'institution' seems to cover things that deal with the organisation and utilisation of research and development (R&D) such as universities, research institutes, R&D divisions in large firms, patent offices, and technical service institutes. Conversely, it can refer to patterning behaviour such as routines, norms and shared expectations including certain ground rules for the economic behaviour from a more theoretical perspective. In this regards, the OECD (1997, p. 9) has defined the NIS from an empirical perspective as "a complex set of relationships among actors producing, distributing and applying various kinds of knowledge, … and these actors are primarily private enterprises, universities and public research institutes and the people within them." Golichenko (2016, p. 470) has also offered a more recent definition of the NIS in terms of "a collection of national public, private, and nongovernmental organizations and their mechanisms for interactions that act to create, store, disseminate and use new knowledge and technologies."

Based on the above definitions of the NIS (e.g. Freeman, 1987; Godin, 2009; Lundvall, 1992; Nelson, 1993), the two main constituents of the NIS for innovative performance

can be regarded as 'interactions' and 'institutions'. However, the notion of an 'institution' tends to be uncertainly described in terms of diverse types of organisations, in terms of the roles of government such as setting rules or regulations, or in both of the former senses. The reason could be that organisations are extensively influenced, characterised and shaped by institutions (rules or regulations) since organisations are embedded in an institutional environment. At the same time, the institutions are rooted in organisations because many institutions evolve within organisations and are utilised in, or are linked to, organisations, according to (Edquist, 2006). Therefore, the concept of an 'institution' will be divided into two elements, namely 'organisations (actors or players)' and 'institutions (rules or regulations established by the government that affect the behaviour of organisations or individuals)' in order to avoid any ambiguity in the concept of the institution for this thesis. Hence, this thesis will consider institutions by focusing on government roles and on organisations and their interactions (collaboration)[8] as the main components of the NIS. Here, the operational processes for knowledge creation, reconfiguration and flows that stimulate innovative activities leading to economic performance are undertaken in the NIS through interactions among diverse types of organisations (see *Figure 2.1*). The organisations are interdependent on institutions at the national level. As institutions are sets of rules, laws, and policies that regulate or affect the interactions and relations between organisations, they can shape the behaviour of organisations and the establishment of interactions (Edquist, 2006; Johnson, 2005). Consequently, institutions can be incentives or constraints to accomplish effective processes for knowledge creation, reconfiguration, and flows in the pursuit of economic performance. Thus, by understanding institutions, which can be the external environment of organisations that have an impact on inter-organisational interactions, and organisations' distinctive activities in the NIS, this thesis should be able to contribute to understanding inter-organisational collaboration mechanisms.

[8] According to Johnson, et al. (2012, pp. 1-2), an interaction is defined as a casual collision and socializing that lead to "building relationships, trust, and other factors critical to the social fabric of a group or organization." However, collaboration is much more than a casual encounter, and in order to collaborate, "individuals or organizations must share knowledge in pursuit of a common goal." Moreover, an interaction is defined as "an occasion when two or more people or things communicate with or react to each other" whilst collaboration is "the situation of two or more people working together to create or achieve the same thing" in the Cambridge dictionary. Hence, 'collaboration' would seem to be a more appropriate terminology rather than 'interaction' in this context of the NIS. However, we will use both terms interchangeably in this thesis.

Figure 2.1 The structure of the NIS and its products



Source: author's elaboration based on definitions of the NIS by Freeman (1987), Lundvall (1992), Nelson (1993), OECD (1997), and Golichenko (2016)

2.2.2. Importance of Collaboration in the Nation Innovation System

Novelty is key in innovation for economic growth. The concept of the NIS emphasises technological knowledge as a core ingredient. Thus, novelty is likely to be achieved through reconfiguring existing technological knowledge in a new way or generating new technological knowledge in the NIS[9]. A common assumption behind the concept of the innovation system perspective including the NIS is that knowledge is different from information (Polanyi, 1966) because knowledge, as opposed to information, encompasses two distinctive types. These are codified or explicit and tacit or implicit knowledge. Knowledge is basically localised and not easily moved from one place to another (Johnson, et al., 2004), and tacit knowledge is harder to transfer than codified knowledge because most tacit knowledge is embedded in the minds of people, in the routines of organisations and in relationships between people and organisations. Hence, tacit knowledge is likely to be transferred through learning by doing and learning by interaction processes (Howells, 2002). The role of learning processes is particularly critical in the NIS since it is almost impossible to achieve novelty without it (Golichenko, 2016). Similarly, Lundvall (1992, p. 1) argues that "the most fundamental resource in the modern economy is knowledge and, accordingly, the most important process is learning (by doing or interaction)."

[9] In addition, novelty is provided in the economic system by new firms (i.e. Schumpeter Mark Ⅰ) but it is also brought about by incumbent firms as they adapt to the new competitive environment or as they produce innovations through in-house R&D (i.e. Schumpeter Mark Ⅱ). Schumpeter Mark Ⅰ is characterized in terms of 'creative destruction through entrepreneurs' with technological ease of entry, while Schumpeter Mark Ⅱ is characterised by 'the importance of technological competition through internal R&D within incumbent firms' (Malerba, et al., 1995).

Furthermore, specialisation has been regarded as a natural consequence of the knowledge generating process (Loasby, 1998) since Adam Smith first introduced the notion of the division of labour. According to this, the specialisation of labour force is seen as lying at the root of economic growth in his seminal book "The Wealth of Nations" published in 1776. Firms are likely to develop their specialised competence as a means of promoting their competitive advantages (Prahalad, et al., 1990) or of being selected in the competitive marketplace. Hence, these processes lead to a lessening in the scope of their technological knowledge and to focusing on their specialised technological capabilities. Consequently, the growing specialisation of firms' competences could reduce the diversity of technological knowledge within firms. Thus, complementary technological knowledge or capabilities often cannot be found in a single firm. This arguably leads to the need to establish collaboration among firms and other types of organisations, and collaboration plays a crucial role in innovation processes at a time of growing complexity of technology. The reason is that other organisations with different types of specialised capabilities frequently possess the necessary complementary capabilities (Kogut, et al., 1992; OECD, 2001). Furthermore, the growing diversification of specialised organisational forms [10] such as universities, public research agencies, industrial laboratories and hospitals, contributes to more opportunities to develop collaboration and interactions between knowledge seekers (mostly firms, particularly, in emerging industries) and knowledge providers (mostly universities, research agencies, and hospitals).

To achieve novelty in the NIS, technological knowledge is the most essential resource and learning is the most important process – both are vital in the innovation process. The specialisation of firms and knowledge providers tends to facilitate the learning process through interactions and collaboration among different organisational forms. In the NIS, interactions and collaboration are interdependently associated with national institutions. In the process of interactive learning, reconfiguring existing knowledge in a new way, creating new knowledge, diffusing and exploiting existing knowledge can all take place within the borders of the economic structure and institutions of a nation (Lundvall, 1992). Lundvall (2010) has argued that interactive learning is the essential activity of the NIS. Similarly, OECD (1997, p. 9) has proposed that "understanding the linkages among the

[10] In fact, universities have largely dominated the area of knowledge production since the first academic revolution (Jung, 2002) while the role of research in universities became more important after the Second World War.

actors involved in innovation is key to improving technology performance. Innovation and technical progress are the results of a complex set of relationships among actors." Smith (1995) also stated that the overall innovation performance depends not so much on how specific organisations perform, but on how they interact with each other, although the learning of new practices by organisations is a costly, time-consuming and risky activity (Nelson, et al., 2002).

In the NIS, the characteristics of diverse organisations and their interactions within the dynamic technological environment are interdependently reflected in institutions such as regulations, policies, laws and standards. Hence, understanding institutions can offer a better insight into comprehending and analysing the characteristics of organisations and the aims of organisational collaboration. The reason is that institutions may be able to influence the behaviour of organisations and to stimulate or constrain interactions among them (Edquist, 2006; Nelson, et al., 2002). As a consequence, they may determine the strategic motives behind the various behaviours including the establishment of collaboration (Edquist, et al., 1999; Golichenko, 2016). In addition, firms almost never innovate in isolation but in interaction with other organisations, and the behaviour of the firms is shaped by institutions, which also have an intensive influence on innovation processes (Edquist, 2005).

However, the NIS sheds little light on the intrinsic properties of individual organisations (such as cost economisation and value maximisation perspectives) to form a collaborative structure, even though collaboration influenced by institutional properties is focused more on achieving innovation for the whole national system. Indeed, the NIS can be generally conceptualized as a set of organisations and institutions, and relationships among them, according to Edquist (2006). Therefore, to complement the relevance of the NIS for understanding the innovation process, it is helpful to combine this concept with other theoretical approaches. These will be, as noted above, Transaction Cost Economics (TCE) and the Resource-based View (RBV), which explain the cost economisation and the value maximization perspectives of individual organisations, respectively. These two bodies of literature will help to yield further insights into the strategic motives for understanding collaboration. Thus, this combined conceptual approach could provide a comprehensive approach to understanding and identifying both the intrinsic properties of individual organisations and the institutional properties of the whole system in developing

collaborative structures. This could also contribute to a better understanding of collaboration mechanisms and their potential impact on the performance of different collaborative structures.

2.3. Intrinsic Properties for Collaboration: Transaction Cost Economics and Collaboration

This section reviews the literature on the cost economisation approach in choosing different governance structures such as market, collaboration, and hierarchy (i.e. vertical integration) based on the TCE. In order to articulate the linking points of this theoretical approach to collaboration, the origin and the evolution of the TCE are first explored. A discussion follows on how collaboration is chosen as an optimal governance structure with regard to three observable dimensions, namely, 'asset specificity', 'uncertainty', and 'frequency of the transaction'. This section concludes with an explanation of how TCE helps overcome a missing dimension of the NIS perspective.

2.3.1. Transaction Cost Economics

TCE arguably began with Coase (1937) offering a corrective perspective to the assumptions of the neoclassical economics. In neoclassical economics, the market is assumed to consist of perfectly rational agents with unlimited access to information engaged in perfect competition. In this market, resource allocation is completely guided by aggregate demand and supply which determine the market price. Firms are treated as 'black boxes' where resources go in and goods come out, but with little attention being paid to the process (Demsetz, 1997). Through this perspective, Coase (1937) raised a core question that is fundamental to research on the economic organisation. The question was 'Why is there any (internal) organisation?' He explained that a firm exists because relying on the market incurs a transaction cost. The transaction cost can, however, be greatly reduced if the transaction takes place within the firm because of the hierarchical coordination of the entrepreneur who allocates resources and directs production within the firm, 'an island of conscious power', at lower cost than the transaction cost of engaging in the market (Coase, 1937). Later, Williamson (1975) refined the reason for the existence of the firm by re-defining the cost of using the price mechanism and paying more attention to the question of 'why some transactions are more costly than others' (Hansen, et al., 2009). In order to describe his reasoning, Williamson presented the concept of incomplete contracts which arise from two plausible behavioural assumptions

of 'bounded rationality' and 'opportunism'[11], according to Hansen, et al. (2009). Inefficiency and uncertainty (i.e. cost) occur because of the limited capability for dealing with diverse information and knowledge due to bounded rationality. Opportunism occurs when the other party in a transaction neglects or takes advantage of the incompleteness of contracts in pursuit of their self-interest. This opportunistic behaviour (i.e. opportunism) raises the level of uncertainty owing to one being unable to secure oneself against all kinds of contingencies (Habimana, 2015). In addition, the opportunistic behaviour raises safeguarding issues between contracting parties who are engaged in exchange in the market, and this contractual hazard is likely to take place in the market rather than in the firm or hierarchy. Here, laws or institutions need to be put in place to protect them from such opportunistic behaviour, for instance, through monitoring and enforcing contracts (Habimana, 2015).

Based on these assumptions, Williamson (1975) pointed to the relative efficiency of alternative governance structures against the contractual hazard due to bounded rationality and opportunistic behaviour, and he provided three observable dimensions - 'asset specificity', 'uncertainty' and 'frequency of the transaction' - which should be considered in the choice of the governance structure (Williamson, 1979). This implies that transaction costs heavily depend on how the transaction is organised, and the governance structures in which the transaction takes place give rise to distinguishing transaction costs. To sum up, the economization of the transaction cost (efficiency) is crucial in choosing an appropriate governance structure between 'buy' (market) and 'make' (hierarchy)[12] in that the transaction cost differs between these two governance structures. This difference is influenced by the contractual hazard based on the two behavioural assumptions of bounded rationality and opportunism.

2.3.2. Collaboration in Transaction Cost Economics

Interestingly, literature on TCE had not paid much attention to the collaborative structure until Williamson (1985) introduced this form into his book, where he emphasised the conditions for effective governance structures of transactions in order to understand how different governance structures act to economise on transaction costs. Here, Williamson

[11] Bounded rationality can be defined as follows: "behaviour is intendedly rational, but only limitedly so (Simon, 1957, p. xxiv)" that is different from the full rationality in neoclassical economics. In addition, opportunism refers to "self-interest seeking **with guile**" which is more than simple self-interest seeking in neoclassical economics (Williamson, 1975, p. 9; 1996, p. 152).

[12] A new form of governance structure, a 'hybrid form' called 'network' by Powell (1990), was introduced as a discrete form later in the book on 'the economic institutions of capitalism' (Williamson, 1985).

(1985) announced a new form of the governance structure, namely a hybrid form in order to avoid overlooking the intermediate governance structure between markets and firms. At the same time, he tried to cover all degrees of the corresponding costs by diverse governance structures through the introduction of the hybrid form. This diversification of the governance structures is expected based on his hypothesis that "transactions, which differ in their attributes, are aligned with governance structures, which differ in their costs and competencies, in a discriminating (mainly, transaction-cost-economizing) way" (Williamson, 1991, p. 277). Through this diversification of the governance structures, hybrid forms (e.g. reciprocal trading, franchising, and various forms of long-term contracting (Williamson, 1985, 1991)) are considered to be alternative governance forms which economise transaction costs. Similarly, Powell (1990, p. 297) recognized three forms of the organisation, namely market, hierarchy and network and defined the network in terms of "firms … blurring their established boundaries and engaging in forms of collaboration that resemble neither … market contracting nor … vertical integration."

Consequently, one needs to figure out how firms arrange and decide the appropriate governance structure for the collaboration, and why they choose the market, hierarchy, or a hybrid form in the light of TCE. It is thus expected that the collaboration arrangement could be regarded as an alternative governance structure in place of the market and hierarchy when this arrangement can bring about a reduction in the transaction costs through minimising coordination costs and expanding the scale or scope of the transaction (e.g. Hennart, 1988, 1989; Kogut, et al., 1992, 1993). Moreover, the costs affecting a choice of an preferred governance structure are measurable in terms of three observable dimensions, 'asset specificity', 'uncertainty' and 'frequency of the transaction', introduced by Williamson (1975). Nonetheless, it has been proposed that 'asset specificity' is a critical determinant over 'uncertainty' and 'frequency of the transaction' in choosing the optimal governance structure (Geyskens, et al., 2006; Williamson, 1985). More specifically, the benefits from access to specialised assets externally within the hybrid form could outweigh the opportunity costs for safeguarding the specialised assets at some point compared with a hierarchical structure.

In comparison to the market structure, this hybrid governance can also be favoured over the market governance because the hybrid governance can deal with safeguarding problems better than market governance. For instance, the opportunism posed by high

asset-specificity is likely to be minimised with mutual 'hostage' exchange in the hybrid form (Geyskens, et al., 2006; Veugelers, et al., 2005) (see *Table 2.1*). Conversely, some R&D activities that are not core, or highly specialized technology assets of the firm and which are expensive, can be shared with other partners in order to obtain benefits from both cost-savings[13] and R&D performance (Hagedoorn, 2002; Katz, 1986). Such benefits usually arise from expanding their knowledge sources with limited investments and from shortening the time to the market of their items (Mitchell, et al., 1992; Schoonhoven, et al., 1990). In addition, asset specificity is a critical determinant in choosing the governance structure (Williamson, 1985) because asset specificity means that there are limited or few substitutes possible in the market. Hence, the value of this asset is substantially greater within the particular transaction where this asset is traded in comparison with any other transactions (Bylund, 2011).

Table 2.1 Distinguishing features of governance structures

Features	Governance Structure		
	Market	Hybrid	Hierarchy
Cost of opportunism	++	+	0
Degree of flexibility	++	+	0
Administrative control	0	+	++
Methods of conflict resolution	Legal action	Norm of reciprocity	Fiat/Authority

* ++ = strong, + = semi-strong, 0 = weak

Source: author's elaboration based on Powell (1990) and Williamson (1991)

Uncertainty, the second dimension, comes about when the relevant contingencies resulting from transactions are too unpredictable to be specified ex-ante in a contract (what is called as external/environmental uncertainty such as the costs of searching and negotiation) or performance cannot be easily verified ex-post (what is called internal/behavioural uncertainty such as the costs of fulfilling specific agreements) (Geyskens, et al., 2006; Kuhlmann, 2012). Williamson presumed that both uncertainties could provide incentives for vertical integration because he believed that managerial fiat greatly reduces the hazard of contractual uncertainties (Williamson, 1971, 1975). Nonetheless, inconsistent results have been found in terms of the relationship between external/environmental uncertainty and the level of vertical integration (Klein, et al., 1990), which may be because the growing uncertainty of economic activities can raise

[13] The reason may be that the growing specialisation of economic activities can raise both transaction and coordination costs (Williamson, 1991).

both transaction and coordination costs (Williamson, 1991). Furthermore, several empirical studies have shown that technological uncertainty is negatively related to or reduces internal integration (e.g. Balakrishnan, et al., 1986; Harrigan, 1986). The reason may arise from the lower degree of flexibility in the governance structure of internal integration that could result in failing to respond to rapid environmental and technological change. In this respect, a positive relationship between technological uncertainty and R&D alliances, a form of collaboration, has been referred to in terms of the degree of flexibility of the governance structure responding to changes in the environment (Robertson, et al., 1998). Here, alliances are seen as a flexible governance structure to adapt to a change in technology and to stimulate the knowledge transfer between different organisations (Dodgson, 1993). Transaction costs generated by building alliances are likely to be more than compensated for by the potential benefits resulting from the timely market reaction (Robertson, et al., 1998). In the case of the digital healthcare sector, this sector is not only an emerging and infant industry but also an area in which combinations of biomedical technology and ICT are central for accomplishing innovation. Hence, this may lead to choosing the collaborative structure as an optimal governance structure through a calculation of the risks or costs in comparison with the returns or benefits (Powell, et al., 1996) in that these features of this sector could give rise to an increase in technological uncertainty and demands for managerial coordination at the same time (see *Table 2.1*).

For frequency of transaction, the benefits of a hierarchical governance structure through the greater volume of repeated transactions can potentially offset the set-up costs of this specialised governance structure, and a high level of frequency or a long-term relationship for transactions increases the probability of choosing hierarchy as an optimal governance structure (Klein, 2006). Conversely, small numbers or non-recurring transactions lead potential contractual hazards because it is difficult to recover set-up costs for the specialised governance structure from the low level of frequency (Williamson, 1979). As noted previously in this section (Hagedoorn, 2002; Katz, 1986), if assets are not core or highly specialized technology, which is expensive to produce internally, outside procurement via the market or a collaborative form for obtaining these assets may be preferred to the hierarchical governance structure (Williamson, 1979). In addition, once an investment has been made, the operation between transacting parties is effectively conducted on the basis of bilateral or at least quasi-bilateral exchange relations for a

considerable period (Williamson, 1981). Thus, transactions could potentially move the governance structure from the market toward a collaborative form in this case.

To summarize, transactions are associated with governance structures which differ in their costs in a cost-economising way for individual organisations. This difference is influenced by the contract hazard based on bounded rationality and opportunistic behaviour, which is measured in terms of three observable dimensions, 'asset specificity', 'uncertainty', and 'frequency of the transaction'. This contributes to choosing a preferred governance structure between market, collaboration, and hierarchy from the perspective of cost economisation. Thus, the notion of the economising approach from this theoretical perspective can fill the gap relating to one missing dimension in the NIS, which is due to shedding little light on the strategic motives of individual organisations. Through combining TCE with the NIS in the conceptual framework, the cost economisation perspective of individual organisations is able to provide a motive for establishing a specific kind of collaborative structures. At the same time, this complementary combination aims to fill a theoretical gap within the TCE, which focuses on profit-seeking firms[14] and neglects the institutional role in developing collaborative structures, while the NIS emphasises the role of public organisations and institutions, thus filling the theoretical gap of TCE. Thus, together these help to contribute to a better understanding of the collaboration mechanisms and its potential impact on the performance of public R&D projects in the digital healthcare sector on which this thesis focuses.

2.4. Intrinsic Properties for Collaboration: The Resource-based View and Collaboration

This section reviews the literature on securing and exploiting strategic resources for the value maximisation based on the RBV. In order to explain its relevance as part of the conceptual framework and collaboration, the origin and the evolution of the RBV are first explored. Then, we discuss why the collaborative structure becomes important from the perspective of securing strategic resources for value maximisation, and thus for attaining competitive advantage. This section concludes with an explanation of how this approach

[14] Although public organisations such as a university, a hospital, or a public research institute are much less sensitive to efficiency pressures than private firms (Coles, et al., 1998), producing the greatest public value for their stakeholders at a reasonable cost is a core goal of them (Bryson, et al., 2007). Accordingly, a cost-economisation approach can also offer a meaningful motive for them in developing R&D collaboration to achieve the maximisation of public value with limited financial resources, in particular, in competitive R&D funding circumstances.

complements another missing dimension of the NIS perspective.

2.4.1. The Resource-based View

In contrast to the TCE which starts from addressing the questions 'why do firms exist?' and 'why is one specific governance structure more efficient than others?', the resource-based view has emerged to explain 'why do some firms outperform others?' (Barney, et al., 2001). It is worth noting that both the TCE and the RBV concepts followed from criticisms of neoclassical economics in which firms do not have to exist or are viewed as 'black boxes' based on the assumption of a perfectly competitive market and perfect information on the part of all economic agents (Hansen, et al., 2009). In addition, the RBV focuses on value maximisation or value creation of the firm through combining and exploiting valuable resources (Das, et al., 2000). Hence, the RBV is likely to be related to strategic management in choosing the most valuable transaction in order to secure strategic resources, whereas TCE tends to find the most cost-economizing transaction through choosing an efficient and effective governance mode (Neves, et al., 2014). Here, Neves et al.'s observation implies that the RBV approach to collaboration helps to complement a missing dimension in the NIS and TCE approaches to collaboration.

The concept of the RBV rests on previous theoretical work such as the traditional study of distinctive competencies and Ricardian economics (Barney, et al., 2001). In the former, performance differences between firms are attributed to general management capability, a perspective which was later developed by Selznick (1957) in terms of 'institutional leadership'. On the other hand, the RBV is based on Ricardian economics which suggests that a number of resources utilised by firms are inelastic in terms of supply, and firms that own or control these kinds of resources are able to produce economic rents (Barney, et al., 2001). In other words, the resources in inelastic supply could be translated into Barney (1991)'s assumptions of strategic resources such as value, scarcity, inimitability, and non-substitutability of resources based on resource heterogeneity and immobility for achieving competitive advantages. Thus, firms that own or utilise these strategic resources can generate economic rents and achieve a competitive advantage. Leadership and strategic resources play a crucial role in the decision to establish a collaboration, because searching and appreciating the strategic resources are heavily dependent on the leader's managerial competencies, and acquisition of the strategic resources is a central part of strategic motives in choosing an optimal governance structure.

Building on these prior theoretical perspectives, Penrose (1959) argued that firms should be perceived as a collection of productive resources and an administrative framework. In this view, firms are fundamentally heterogeneous in that a collection of the productive resources including physical resources, managerial skills, and entrepreneurial skills can vary from firm to firm. As research on the RBV has progressed, the notion of resources has been extended. For instance, Wernerfelt (1984) defines them as tangible and intangible assets of the firm which are tied semi-permanently to the firm. Various researchers also describe the resources which lead to competitive advantages of the firm as human resources (Amit, et al., 1993), organisational routines[15] (Winter, et al., 1982), core competencies[16] (Prahalad, et al., 1990), or invisible assets[17] which are difficult to imitate (Itami, et al., 1987). Therefore, the RBV arguably needs a more comprehensive and concrete framework to identify strategic resources for generating sustainable competitive advantages, although some developments have been made to this concept. Barney (1991) in his seminal work develops a RBV framework for the firm. In this framework, he assumes that strategic resources and capabilities are heterogeneously distributed across firms and that they are imperfectly mobile and stable over time. According to this viewpoint, the strategic resources and capabilities, as elements for achieving sustainable competitive advantage for the firm, should be both valuable and rare. In addition, they should not be easily imitable and substitutable at the same time. Therefore, value, rarity, inimitability and non-substitutability of their strategic resources and capabilities are necessary for a firm to attain sustainable competitive advantages (Hoskisson, et al., 1999) [18]. The strategic resources facilitate the activities of the firm to become more efficient (operating more economically) and effective (better in satisfying demand-side needs) in its product market (Barney, 1991; Peteraf, 1993). Hence, economic rents are created from efficiency in using strategic resources to generate greater perceived benefits for the same cost or the same perceived benefits for a lower cost, in the perspective of the RBV. This means that the firm can achieve competitive advantages by

[15] Winter, et al. (1982, p. 14) defined organisational routines as "all regular and predictable behavioural patterns of firms."

[16] According to Prahalad, et al. (2000, p. 4), "Core competencies are the collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies."

[17] "Invisible assets are information-based resources such as technology, customer trust, brand image, and control of distribution, corporate culture, and management skills" (Itami, 1987).

[18] According to Hoskisson, et al. (1999, p. 439), **value** is defined as "the extent to which the firm's combination of resources fits with the external environment so as to exploit opportunities and/or to neutralize threats in the competitive environment. **Rareness** refers to the physical or perceived physical rareness of the resources in the markets, and **inimitability** is that resources cannot be obtained or recreated by other firms without a cost disadvantage. Finally, **non-substitutability** is that a firm's strategic resources and capabilities cannot be substitutable by competitors."

creating distinctive products through pooling complementary resources or by attaining a low-cost position to exploit similar resources relative to its rivals (Nielsen, 1987). Consequently, the firm is thought of as a seeker of unique assets, or costly-to-copy resources (Conner, 1991)[19]. To sum up, seeking, appreciating and acquiring strategic resources, which stimulate the value maximisation of organisations, could be shaped by strategic motives of the individual organisations in the place where they take place. Thus, the establishment of collaboration, which is a way of seeking, appreciating and acquiring strategic resources, can rely significantly on the motives of individual organisations for value maximisation and thus achieving competitive advantage in the RBV.

2.4.2. Collaboration in the Resource-based View

Firms may not necessarily be willing to improve their internal resources and capabilities as long as they are able to access this from other organisations. Through the collaboration, they are in a position to complement the firms' requirements in the market (Barney, 1991; Penrose, 1959). In this sense, firms are more likely to rely on the market for the acquisition of available strategic resources (Eisenhardt, et al., 1996). However, valuable resources of firms are normally scarce, and often hard to imitate or substitute (Barney, 1991; Peteraf, 1993). Furthermore, certain resources are not easily tradable if resources are embedded in organisations such as routines and tacit assets (Chi, 1994). In addition, the efficient market exchange of resources is not always possible in the real market. Thus, it is necessary to take into consideration where strategic resources are traded under the different governance structures of market, collaboration, and hierarchy. For example, firms tend to establish collaboration and view it as an optimal governance structure if the benefits from collaboration exceed those of carrying on alone (Parkhe, 1993). In addition, the collaborative structure provides a variety of advantages to firms such as offering opportunities to develop new competencies (e.g., Hagedoorn, 1993; Hennart, 1991), and preserving their strategic resources and sharing risks (e.g., Hamel, et al., 1989).

Consequently, the RBV considers collaborative structures to be strategies for accessing other organisations' resources with the aim of creating value to the firm, and thus for attaining competitive advantage (Das, et al., 2000). According to Eisenhardt, et al. (1996), the underlying logic of forming a collaborative structure is based on strategic needs and

[19] 'Costly-to-copy' means that "rivals would have to pay more to obtain, duplicate, or substitute for, resources than did the originating firm while 'unique assets' are those that for analytic purpose can be regarded as infinitely costly to copy" (Conner, 1991, p. 149).

social opportunities. They found that a collaborative structure forms when firms are in a vulnerable strategic position where the firms are competing in emergent or highly competitive markets, or where they are pursuing a pioneering technical strategy. They also found that a collaborative structure forms when firms are in a strong social position by virtue of large, experienced and well-connected top-management teams. Kogut (1988) identified possible reasons for a firm establishing collaboration based on firm resources such as knowledge and technology. He argued that there are two possible reasons for this. The first is to access the other firm's organisational know-how or strategic resources. The other is to retain the firm's own know-how or strategic resources.

Another example is that firms tend to seek R&D cooperation when they conduct expensive, risky or complex research projects, typically in high-tech sectors. Since R&D is a major part of cooperation in high-tech and emerging industries, incumbents may utilise the R&D cooperation to enter new technological areas. The firms can obtain a cost advantage through limited investments to expand their knowledge sources, and can secure potential options for attaining competitive advantages in the future at the same time (Mitchell, et al., 1992). There are a number of these kinds of cases in the pharmaceutical sector where incumbents have extensively relied on collaboration with biotechnology companies to expand their knowledge base (Gleadle, et al., 2014; Rafols, et al., 2014). Meanwhile, small biotechnology firms often cooperate with the giant incumbents. The reason is that these small firms can obtain not only complementary resources from the large firms such as operation know-how, marketing, and financial resources (Das, et al., 2000; Shan, et al., 1994), but also legitimacy and reputation to attract external stakeholders to collaborate with them (Stuart, et al., 1999).

Furthermore, firms actively build and expand their collaboration networks to secure complementary assets (Gomes-Casseres, 1996) and to develop dynamic capabilities[20] in response to a rapidly changing environment (Teece, et al., 1997). On top of that, the growing specialisation and uncertainty of economic activities can raise both transaction and coordination costs (Williamson, 1991), and these can intensify the heterogeneity of strategic resources. As a result, the need for collaboration is becoming important because

[20] Dynamic capabilities, reflecting an firm's ability to achieve new forms of competitive advantage, emphasise both the 'dynamic' nature referring to the capacity to reconfigure competences in order to respond to a rapidly changing environment, and the term 'capabilities', highlighting the essential role of strategic management (a perspective which is consistent with the notion of Schumpeter Mark Ⅰ) to match the requirements of the rapidly changing environment (Teece, et al., 1997).

complementary resources are often attained from other firms possessing different kinds of strategic resources. Hence, collaboration becomes the optimal governance structure to attain such competitive advantages via securing strategic resources of individual organisations even in a dynamic environment.

Firms seek to create valuable, rare, inimitable and non-substitutable strategic resources and capabilities for attaining sustainable competitive advantages (Barney, 1991). However, not all firms can create them and even a distinctive firm cannot create them all. Moreover, resources such as tacit knowledge, firm reputation and organisational culture are simply not tradable (Das, et al., 2000) in that they are normally embedded in organisations (Chi, 1994). In addition, tacit knowledge is hard to imitate and transfer as well, and the transfer of tacit knowledge entails non-trivial costs due to the difficulty of communication, although the tacit knowledge tends to generate long-lasting advantages (McEvily, et al., 2002; Teece, 1977). Thus, firms need to acquire these strategic resources and capabilities not from the market but from other organisations through developing a collaboration. Here, collaboration can be a vehicle for intangible and tacit knowledge transfer among organisations (Kogut, 1988) because partners within the collaborative network put in resources and work together on a continuing basis. Such collaboration allows them to have many opportunities for interactive learning (Das, et al., 2000). Consequently, exploiting resources from external sources, for example through collaboration, could provide firms with opportunities to enhance and enrich their internal resources (knowledge and technology) and capabilities (Mowery, et al., 1996; Powell, et al., 1996). Such collaboration could also give rise to better innovative performance through launching various products to the marketplace (Eisenhardt, et al., 1996).

Therefore, the notion of the value maximisation approach through exploiting or securing strategic resources can fill a gap in the NIS, which sheds little light on the motives (such as value maximisation) of individual organisations in the establishment of collaboration. Through combining the RBV perspective with the NIS perspective in the conceptual framework of the thesis, the value maximisation of individual organisations through obtaining strategic resources can be included as a motive in the establishing collaborative structure. At the same time, this complementary combination can help to fill theoretical

gaps in the RBV as follows. The RBV tends to focus on profit-seeking firms[21] looking to maximise the value of their products, and on whether firms' internal or internalised resources provide a suitable basis for competitive advantages (Arya, et al., 2007; Blomqvist, et al., 2006). Nonetheless, there are diverse organisational types in the innovation system and they possess their own strategies in response to market failure or technological and environmental changes (Ghoshal, et al., 1996). Consequently, little attention is paid to knowledge infrastructure including public organisations, although this is likely to have a significant impact on the diverse market environment such as government roles and policies in the NIS. Furthermore, the RBV pays little attention to external factors that surround each organisation such as institutions, although they can stimulate or constrain the establishment of collaboration, or influence organisational behaviour. Thus, these complementary features are able to contribute to a better understanding regarding the collaboration mechanism and its potential impact on the performance of public R&D projects in the digital healthcare sector.

2.5. Collaborations and Innovative Performance

This section is devoted to reviewing the literature that examines diverse collaborative structures based on organisational types and their implications for innovative performance. The literature concerning both positive and inconsistent influences of diverse collaborative structures on innovative performance is explored. Based on these differing results on the relationship between them, this section identifies certain empirical gaps in the existing literature resulting from limitations of data and research design. Here, we assume that the combinational structures of the inter-organisational collaboration influenced by the motives of individual organisations play a crucial role with regard to innovative performance in terms of publications, patenting and commercialisation activities.

2.5.1. Collaborative Structures and their Positive influences on Innovative Performance

According to Powell, et al. (1996), the locus of innovation is not found in individual firms but in collaborative networks when the knowledge base of an industry is complex and

[21] Public organisations such as a university, hospital, or PRI confront growing demands to become more efficient and effective in their service delivery and to improve their performance for the public good (Hartley, et al., 2013; Mack, et al., 2008), although they are much less sensitive to efficiency pressures than private firms (Coles, et al., 1998). In this respect, the function of public organisations as a collection of strategic resources is being emphasised in achieving better public value and service delivery like for-profit firms (Bryson, et al., 2007). Hence, a value-maximisation perspective can also be a meaningful motive for public organisations in developing R&D collaboration to achieve maximisation of public value with limited financial resources, in particular, in competitive R&D funding circumstances.

expanding. Knowledge integration through collaboration between different disciplinary areas and different types of organisations, is becoming an essential challenge to achieving competitive advantages in an era of increasing environmental complexity and accelerating technological change (Alexiev, et al., 2016; Hacklin, et al., 2013; Nieto, et al., 2007). In order to meet this challenge and to achieve competitive advantage, understanding how collaboration influences innovative performance could be potentially beneficial. Thus, a large number of studies have examined combinational forms of internal and external sources of technological knowledge such as inter-organisational collaborations, and their impact on innovative performance.

Collaboration with suppliers is likely to contribute to a focal firms' innovative performance through such means as lowering production costs (Atallah, 2002; Hagedoorn, 1993; Scannell, et al., 2000) and flexible and short-cycle manufacturing (Clark, et al., 1991). Moreover, it can contribute to process innovation (Freel, et al., 2006; Fritsch, et al., 2001) through reducing coordination costs, improving inventory management, providing reliable lead times (Clemons, et al., 1993), and benefiting from additional technology sources (Rouvinen, 2002). Similarly, Belderbos, et al. (2004b) have suggested that collaboration with suppliers concentrate on incremental innovations, and they also found that this form of R&D collaboration significantly facilitates the labour productivity of firms (Belderbos, et al., 2006). In addition, Faems, et al. (2005) and Dittrich (2001) have proposed that collaboration with suppliers may lead to improving existing production processes or levels of turnover through focusing on existing products.

Collaboration with customers may contribute to an accurate understanding of customers' unmet or future needs, which in turn leads to an improvement of customers' attraction towards producers and to reducing commercial failures thanks to focusing on customized products (Jeppesen, et al., 2003; Tidd, et al., 2005). According to Rothwell (1994), collaboration with customers positively impacts on the product and process development of producers by providing complementary knowledge and a specific bundle of customer requirements to both extant and new products. In a similar vein, Freel, et al. (2006) and Fritsch, et al. (2001) found a positive relationship between product innovation and collaboration with customers. This collaborative structure is significantly associated with the likelihood of radical product innovation such as positively affecting growth in sales of new-to-the-market products (Fitjar, et al., 2013). In particular, interacting with lead-

users can contribute to reducing the time and cost for product concept generation (Herstatt, et al., 1992).

The notion of collaborating with competitors can seem unusual, given safeguarding issues and potential opportunistic behaviour by competitors. However, collaboration with competitors is quite common in current industry practice (Luo, et al., 2007), and firms are likely to cooperate with their competitors in higher technology sectors on the basis of R&D intensity (Tidd, et al., 2005). Such collaboration can be triggered due to the benefits from pooling of resources, sharing R&D costs and improving knowledge exchange (Das, et al., 2000; Lado, et al., 1997; Miotti, et al., 2003). In particular, collaboration with rivals in the upstream aspects of the value chain such as R&D and technology innovation can lead to a substantial positive impact on high-tech industries through economies of scale, pooling of complementary assets, reduction of duplicating investments, and strengthening know-how trading (Gnyawali, et al., 2011; von Hippel, 1987). In addition, this form of the collaboration plays an important role in dealing with technical standards and regulations (Gnyawali, et al., 2011; Nakamura, 2003). Hence, this collaboration form contributes to innovative performance through such mean as the level of the innovation sales (Lööf, et al., 2002), labour productivity growth (Belderbos, et al., 2004b), and the creation of new-to-the-market innovation (Hagedoorn, 2002).

Collaborations with universities and public research institutes tend to contribute to radical innovation through the creation of new technological knowledge (Belderbos, et al., 2004a; Tidd, et al., 2005) and making an effort for its dissemination (Intarakumnerd, et al., 2018). According to McMillan, et al. (2000) and Bozeman (2000), technology innovation depends considerably on external sources of knowledge from universities and public research institutes, and collaboration with them has a positive influence on product innovation in terms of higher degree of novelty (Belderbos, et al., 2004b; Faems, et al., 2005; Nieto, et al., 2007). Monjon, et al. (2003) and Rouvinen (2002) suggested that collaboration with universities and public research institutes tends to aim at radical and product innovation that may contribute to developing a new product or to opening a new market as well. In the same vein, Belderbos, et al. (2015) argued that this collaborative structure significantly increases the innovative performance defined by the ratio of sales from new products to the market per the total number of employees. Both universities and public research institutes play a similar role in the national R&D system as a knowledge

provider and transfer intermediary. However, there are distinguishing features between universities and public research institutes in the NIS. Public research institutes are likely to engage more in relatively larger R&D projects with extremely expensive, often unique scientific equipment and facilities on their premises (Bozeman, 2000). The R&D projects tend mainly to be conducted based on internally interdisciplinary research groups with organisational mandates and missions to resolve existing social and economic issues as well as to address the creation of new technologies for the next generation (Intarakumnerd, et al., 2018). Meanwhile, universities tend to place more emphasis on smaller R&D projects conducted by individual academic researchers within the same disciplinary domain with relatively high levels of autonomy (Bozeman, 2000).

Collaboration with hospitals is less well explored in innovation studies. Indeed, Miller, et al. (2016) and Thune, et al. (2016) even contend that no research has yet taken account of the direct and explicit influence of hospitals in innovation studies. However, beginning with Hicks, et al. (1996), who highlighted the importance of the hospital, namely 'a hidden research system', several researchers have shown the core role of the hospital in health innovation and the usefulness of the hospital-based research system (Hopkins, 2006; Lander, et al., 2011). Because of the distinctive characteristics of the hospital such as utilising its patient population as a 'living laboratory', and involving the broad innovation process across the stages from discovery and development to verification, implementation and dissemination, hospitals are able to play an important role in the health innovation system (French, et al., 2012; Thune, et al., 2016; Wright, et al., 2011). They also provide a collective and accumulative learning process through clinical practice in the course of adopting and adapting new technologies, and this process contributes to improvements in procedures in clinical practice and to a better understanding of strong and weak aspects of current technologies (Morlacchi, et al., 2011). In addition, hospitals have become hubs in healthcare networks thanks to performing multiple roles at a key intersection of the healthcare system (Ramlogan, et al., 2007). Thus, they can act as intermediaries among different knowledge sources for scientific, translational, clinical, technical, and commercialised knowledge in diverse domains (Thune, et al., 2016). Yet the features of collaboration between hospitals and other organisations remain relatively poorly understood. Therefore, the role of hospitals in inter-organisational collaboration should be explored as one of the main actors in order to attain a better understanding of the influence of collaborative structures on innovative performance in the healthcare

sector.

2.5.2. Collaborative Structures and their Inconsistent Influences on Innovative Performance

Even though much of the extant literature argues that diverse collaborative structures have a positive influence on innovative performance, not all forms of collaboration result in successful innovation at all times[22]. There is a lack of evidence in the literature with regard to positive relationships between collaborative structures and the level of innovative performance in various contexts. Ledwith, et al. (2005) found that the frequency of collaboration of small electronics firms with their suppliers is negatively associated with the satisfaction level of commercial performance. A possible explanation for this is that small firms tend to be weak at coordinating collaboration with suppliers. Song, et al. (2006) also found that there is a negative correlation between the impact of collaboration with suppliers and knowledge generation in IT-related firms. A plausible explanation for this is that priority is given to cost-related factors in the trade-off from associating with suppliers between cost-minimisation and value maximisation. Lööf, et al. (2002) found a negative link between the influence of collaboration with domestic customers and the growth rate and the level of labour productivity, although knowledge from customers is a crucial factor for the size of innovation investments. This puzzling outcome can be explained by the time lag effect in generating innovative performance after the collaboration activities.

In addition, Miotti, et al. (2003) found that collaboration with competitors has no significant impact on patent performance and the share of innovative products in turnover. The reason may be that it is difficult to sort out the collaboration's specific contribution to the innovation performance due to the rarity of this collaboration type. Meanwhile, Nieto, et al. (2007) found that collaboration with competitors has a negative impact on the probability of achieving radical innovations, defined as introducing a new product function. This result was explained by a lack of trust between rivals given the risk of opportunistic behaviour with highly novel technology.

Lastly, Monjon, et al. (2003) found collaboration with domestic (French) universities and research institutes has a negative influence on introducing a new item to market (radical

[22] Studies have shown that around 30 to 50% of collaboration is unsuccessful (e.g. Bleeke, et al., 1991; De Man, et al., 2005).

innovation), while there is a significant positive impact on radical innovation when firms cooperate with international universities and research institutes elsewhere in Europe. This can possibly be explained in terms of highly innovative firms with a state-of-the-art research division, marginally benefiting from domestic universities and research institutes even though they need new forms of novel knowledge obtained from international universities and research institutes. Accordingly, no significant difference is found between a group collaborating with universities and public research institutes and a non-collaborating group in terms of innovation performance. One conceivable explanation for this result seems to be that universities and public research institutes fail to provide a significant contribution to firms in a timely and effective manner (Guan, et al., 2005)

The overview of the effect of collaborative structures on innovation presented above supports the view that there is a lack of consensus on the benefits from various collaborative structures in terms of improved innovative performance (Tsai, 2009). There are certain reasons for this. They could be the result of data limitations and research design, leading to inconsistent results on the impact of collaborative activities on innovative performance. For instance, many studies demonstrate that indirect variables based on survey data tend to be utilised for examining the relationships between different forms of collaboration and their innovation performance (e.g. Amara, et al., 2005; Amponsah Odei, et al., 2019; Arranz, et al., 2008; Becker, et al., 2004; Belderbos, et al., 2004b; Bjerke, et al., 2015; Caldas, et al., 2019; Fey, et al., 2005; Luo, et al., 2007; Okamuro, 2007; Scannell, et al., 2000). In addition, many studies in terms of the impact of collaborative activities on innovative performance are conducted in different analytical boundaries with different indicators for measuring innovative performance. For instance, the numbers of academic papers (e.g. Callaert, et al., 2015; Hsu, et al., 2011; Ynalvez, et al., 2011), patent activities (e.g. Czarnitzki, et al., 2007; Hagedoorn, et al., 2018; Vanhaverbeke, et al., 2015), and commercialisation-related indices (e.g. Belderbos, et al., 2004b; Faems, et al., 2005; Nishimura, et al., 2018) are mostly employed as indicators in different sectoral or national contexts, respectively. Another reason is that most research designs largely depend on quantitative methods, which tends to limit or restrict opportunities for deeper exploration of complicated issues (Choy, 2014), where carefully crafted interview questionnaires may be more effective. Therefore, to a large degree, quantitative methods do not provide much opportunity to explore issues such as motives, institutional factors, and the distinctive features of individual organisations participating in collaborative activities.

Each type of organisations, whether a firm, university, PRI, or hospital, has its own attributes contingent on intrinsic and institutional properties such as strategic organisational goals, institutions, organisational missions, and the manager's role (Rainey, 2009). Furthermore, managerial and technical leadership is argued to have a substantial impact on both R&D and innovative performance (DiBella, 1995; Pelz, et al., 1966; Shim, et al., 2001). Consequently, the role of leading organisations, which launch initiatives with the strategic purpose of establishing R&D collaboration, is crucial. Hence, a study on diverse collaborative structures and their different types of performance would benefit from taking account of different organisational types of leading organisations and from using direct variables based on homogeneous domains. To summarize, it could be beneficial to take into consideration the attributes of each organisational type and the strategic motives of individual organisations that affect the establishment of different collaborative structures. Therefore, this thesis will collect and use a number of direct variables including data on collaborative structures and their direct performance in academic papers, patent activities, and commercialisation-related activities together with comprehensive interview data to analyse the characteristics of collaborative structures and their effects on innovative performance in the same analytical domain. These efforts could contribute to arriving at a clearer understanding with regard to the relationship between different collaborative structures and their innovative performance, including how the collaborative structures and their innovative performance are influenced by strategic decisions of individual organisations in establishing collaboration.

2.6. The Coordination Role of Focal Organisations

As mentioned earlier, creating innovation can almost never be achieved by a single organisation operating in isolation, and interaction with other organisations in the knowledge-based economy is most often required (Edquist, 2005; Fagerberg, 2006; Markard, et al., 2008). The role of collaboration is becoming more important, particularly in a sector where combinations of diverse and new technologies are essential for achieving innovation such as the digital healthcare sector. The reason is that the combinations of diverse and new technologies tend to be accomplished through crossing boundaries between a variety of disciplines and actors (Howells, 2002). However, each organisation in an inter-organisational collaboration has its own attributes contingent upon internal and external factors such as strategic organisational goals, institutions, organisational missions, and its own motivations and priorities (Gulati, et al., 2012a;

Isaksen, et al., 2017; Rainey, 1989). Here, the coordination role[23] of the focal organisation in inter-organisational collaboration can play an instrumental role in managing collaboration challenges such as opportunism, safeguarding issues, and conflicts between partners as well as in dealing with diverse specialisation tasks because of the complex division of labour involved (Becker, et al., 1992). In addition, each type of organisation, whether a firm, university, PRI, or hospital, has distinctive characteristics reflecting its own organisational conditions that may affect the process of coordination as well.

The coordination role of focal organisation also has a substantial impact on R&D and innovative performance (DiBella, 1995; Pelz, et al., 1966; Shim, et al., 2001). For instance, technical and procedural coordination diminishes technological and economic risks in inter-organisational collaborations (Kumar, et al., 1996), although over-coordination (e.g. in the form of over-communication) in an inter-organisational context, has been shown to negatively affect organizational performance (Andres, et al., 2002; Olson, et al., 1995). Thus, effective coordination that minimises unforeseen behaviours and problems during the operation of the inter-organisational collaboration may be crucial in achieving good innovative performance through sustaining and promoting the partners' commitment and trust (Gulati, et al., 2012b). Consequently, effective coordination enables organisations in the collaboration to exchange information efficiently and engages in jointly determined planning and goals, and to ensure productive combination of resources and capabilities (Das, et al., 2000), along with agile responses to environment changes in the marketplace (Uzzi, 1997). Gulick (1937) and Chandler Jr (1962) stated that managers' capabilities in ad-hoc interventions are instrumental in order to increase productivity and avoid losses.

On the other hand, the coordination does not always work effectively. Coordination failure may result from the bounded rationality of a manager in the focal organisation, cultural differences between organisations, and organisational inertia such as existing organisational structures, routines, and resources (Gulati, et al., 2012b). In spite of the challenges that bring about the coordination failure, those coordination challenges can be addressed by clearly allocating tasks, roles, and responsibilities among partners (Carson, et al., 2006; Mayer, et al., 2004) based on mutual agreement, by facilitating communication channels for information-sharing between partners (Argyres, et al., 2007),

[23] Here, the coordination role is defined as "the deliberate and orderly alignment or adjustment of partners' actions to achieve jointly determined goals," (Gulati, et al., 2012b, p. 12).

by learning from partners' capabilities and resources (Gulati, et al., 2012b), and by building contingency plans in order to respond to internal and external environment changes (Ring, et al., 1994). In addition, both formal rules and informal norms, or more sector-, profession-, or organisation-specific institutions can all help deal with these challenges (DiMaggio, 1997).

Therefore, understanding the coordination role of focal organisations in inter-organisational collaboration and how to deal with the challenges may contribute to understanding its potential impact on innovative performance in which acquiring complementary resources is crucial to attain innovation due to the growing complexity and specialisation of technology.

2.7 Conceptual Framework of the Thesis

This thesis aims to identify why organisations that participate in public R&D projects establish inter-organisation collaboration, to explore how different structures of the collaboration are established, and to explain what effects these different collaborative structures have on innovative performance. As discussed in the previous sections, three theoretical approaches, the national innovation system (NIS), transaction cost economics (TCE), and the resource-based view (RBV) are combined to address these research questions as a backbone of the conceptual framework, which explains strategic motives in establishing diverse collaborative structures. Here, the NIS approach forms the basis of the conceptual framework of this thesis because this research focuses on exploring underlying inter-organisational collaboration mechanisms in an emerging sector where government institutions such as a R&D policy, part of the national innovation system, play a pivotal role due to high risks and uncertainty, while TCE and the RBV perspectives are used to fill in the missing dimension of the NIS.

More specifically, the NIS emphasises the importance of collaboration among diverse actors as an important learning process in order to achieve novelty, especially at a time of the growing diversity of specialised technological capabilities along with the growing complexity of technology. In the NIS, the characteristics of diverse organisations and their interactions within a dynamic technological environment are interdependently reflected in institutions such as regulations, policies, laws and standards. In addition, institutions are viewed as pivotal elements in shaping how they (e.g. firms, universities, PRIs, and hospitals) relate to each other and how they learn and use their knowledge (Johnson,

1992). Hence, understanding institutions can offer a better insight into comprehending strategic motives in establishing inter-organisational collaboration, because institutions are likely to influence the behaviour of organisations and to stimulate or constrain collaboration among actors.

However, the innovation system perspective tends to pay little attention to the motives of individual organisations determined by the organisations' self-interests related to strategical logic (e.g. cost-minimising and value-maximising reasons) in establishing collaboration (Acs, et al., 2017; Markard, et al., 2008; Markard, et al., 2009). Nevertheless, it puts the main emphasis on the role of institutions in the whole system,[24] which have an intensive influence on innovation processes such as interaction (Edquist, 2006). In addition, the formation of the motives in establishing collaboration, which cannot be covered within a single theoretical perspective, is likely to be influenced by the strategic decision-making process among a variety of the internal and external determinants (Tsang, 1998). In other words, the intrinsic properties of individual organisations in establishing different collaborative structures seem to have been somewhat neglected in the NIS literature. Thus, the TCE and the RBV perspectives need to be combined with the NIS in order to complement the missing dimension of the NIS as part of the conceptual framework for this thesis. The TCE approach highlights the cost-economising approach of individual organisations in choosing an optimal governance structure between market, collaboration, and integration, and transaction costs are generated owing to two behavioural assumptions of bounded rationality and opportunism. Meanwhile, the RBV identifies the value-maximisation or value-creation perspective of individual organisations in order to achieve competitive advantages driven by securing and exploiting strategic (complementary) resources which are often obtained from other organisations possessing different kinds of strategic resources, in particular, in an environment of growing complexity and specialisation of technology. Here, the role of the collaboration for the transfer of strategic resources between collaborating organisations is given more attention if the strategic resources are tacit or intangible assets such as technological knowledge, in that collaboration tends to act as a vehicle for the

[24] Little attention has been paid to a single organizational level in innovation system approaches, because innovation systems can be characterised as **a holistic approach** embracing a wide array or all of the determinants of innovation and they can be generally conceptualised as **a set of organisations** and institutions, and relationships among them (Edquist, 2005).

transfer of intangible and tacit knowledge between collaborating organisations via interactive learning.

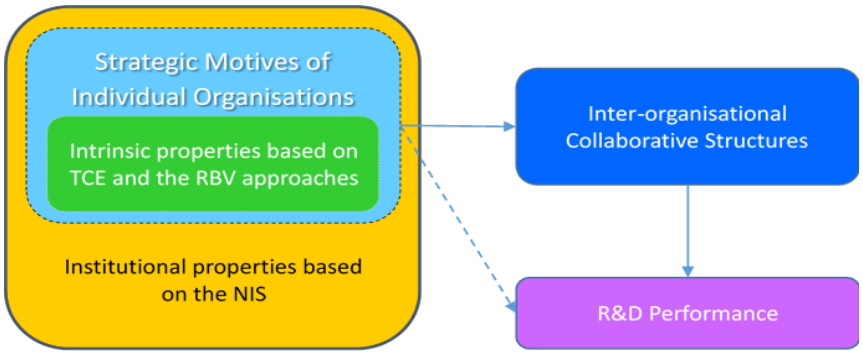
Furthermore, we assume that strategic motives based on a combination of these three theoretical approaches may affect the development of different collaborative structures, and these different collaborative structures may have a crucial influence on the direction and the level of innovative performance reflected in such things as academic papers, patents, and technology licensing activities. As noted previously, even though much of the extant literature argues that diverse collaborative structures have a positive influence on innovative performance, not all forms of collaboration result in successful innovation at all times. In addition, there is a lack of consensus on the benefits of collaboration in terms of improved innovative performance levels (Tsai, 2009). It could be the result of methodological limitations such as using variables which are not directly involved on the basis of quantitative survey data, and also employing different types of variables for determining performance such as papers, patents, and commercialisation activities in different studies, leading to inconsistent results on the impact of collaboration activities on innovative performance. This could also be a result of neglecting the attributes of different organisational types (e.g. a firm, university, PRI, and hospital), which are reliant on intrinsic and institutional properties such as strategic organisational goals, institutions, organisational missions, and the manager's role (Rainey, 2009).

Moreover, managerial and technical leadership are argued to have a substantial impact on both R&D and innovative performance (DiBella, 1995; Pelz, et al., 1966; Shim, et al., 2001). Hence, a study exploring the strategic motives in establishing diverse collaborative structures and understanding their relationships with performance would benefit from taking account of the attributes of leading organisational types in collaboration, of directly engaged variables between collaborative structures in R&D projects and their R&D performance (e.g. papers, patents, and technology licensing activities generated directly from the R&D projects) as explained in section 2.5.2, and analysing different types of performance-related variables in the same analytical domain.

In summary, strategic motives in the establishment of R&D collaboration taking account of both the intrinsic properties of individual organisations (based on TCE and RBV approaches) and institutional properties of the innovation system (based on the NIS perspective) form part of strategic decisions that may play an important role in developing

inter-organisational collaborative structures, and these inter-organisational collaborative structures may have a substantial impact on R&D performance. It is also assumed that R&D performance depends directly or indirectly on those motives. Thus, the conceptual framework of this thesis is developed along with the above assumptions based on the NIS complemented by TCE and the RBV perspectives (see *figure 2.2*). Lee, et al. (2005) built a similar conceptual model to this conceptual framework in terms of the relationship between collaboration and productivity, although they focused more on individual or socially related motives such as individual characteristics, rank (tenured) and job satisfaction rather than the motives of organisations related to institutions, cost economisation, and strategic resources for value maximisation.

Figure 2.2 Conceptual framework of the thesis



* The intrinsic properties of individual organisations are a cost economisation approach based on TCE and the perspective of securing strategic resources for value maximisation based on the RBV, while the institutional properties for the whole system rely on institutions such as policies and regulations in the NIS.

: Direct influence : Indirect influence

Source: author' elaboration

2.8. Conclusion

This chapter aimed to propose a novel theoretical framework based on three theoretical approaches that will be employed to address the underlying inter-organisational collaboration mechanisms among four different organisational types (i.e. a firm, university, PRI, and hospital). Hence, it has discussed the institutional properties of the innovation system involving the NIS perspective and the intrinsic properties of individual organisations linked to TCE and the RBV perspectives in forming the strategic motives of different organisational types in establishing collaborations. The institutional properties are combined with intrinsic properties explaining strategic motives in establishing collaborations to comprise a backbone of the conceptual framework employed in this thesis. This chapter has explored extant literature regarding the

relationships between collaborations and their implications for innovative performance in order to identify certain empirical and methodological gaps in the existing literature resulting from limitations of data and research design. Based on this literature review, the chapter concludes by suggesting a novel conceptual framework in which strategic motives in establishing R&D collaboration taking account of both the intrinsic properties of individual organisations (based on TCE and RBV approaches) and institutional properties of the innovation system (based on the NIS perspective) form part of strategic decisions. These strategic decisions may play an important role in developing the inter-organisational collaborative structures, and these inter-organisational collaborative structures may have a substantial impact on R&D performance.

The following chapter will discuss the research design, methodology, and data collection utilised to operationalise the conceptual framework in order to address the research questions in this thesis. In other words, this chapter will describe the overall process involved in linking the research purpose (in terms of research questions) to the research procedures (in terms of research methods) at every step of the analysis.

Chapter 3. Methodology

This chapter aims to set out the research methods employed in this thesis and to discuss how they are adopted to address the main research questions through operationalising the conceptual framework developed in chapter 2 and analysing the empirical data. In other words, this chapter describes the process involved in linking the research purpose (in terms of research questions) to the research procedures (in terms of research methods) at every step of the analysis (Morgan, 2013). In order to remind the reader of the research questions discussed in chapter 1, we recapitulate the objectives of this thesis which are to identify why organisations that participate in public R&D projects in the Korean digital healthcare sector establish inter-organisational collaboration, to explore how different structures of such collaboration are established, and to understand how those different collaborative structures have an effect on subsequent innovative performance. Accordingly, three research questions to address these issues were generated, which are: (i) What are strategic motives influencing the establishment of inter-organisational collaboration in public R&D projects of the digital healthcare sector? (ii) How are different collaborative structures developed in the public R&D projects? (iii) What effects do these different collaborative structures have on diverse aspects of R&D performance? Thus, the rationale for mixed methods research as the research strategy of this thesis is discussed in section 3.1, while section 3.2 describes the research design adopted in this thesis with the analytical framework being set out in more detail. This is followed in section 3.3 by a detailed explanation of the data sources and the methods for data collection. Then, section 3.4 describes how the collected data were analysed in order to address the research questions of this thesis. The last section provides a short summary of this chapter.

3.1. Rationale for Mixed Methods Research as a Research Strategy

According to Creswell (2009, 2014), the core assumption of mixed methods research, which is an approach involving the collection and integration of the two different forms of quantitative and qualitative data, provides a more comprehensive and enriching understanding of research questions through viewing them from multiple perspectives. In addition, the integration of two different forms of data can help develop a complementary picture of contextualising information by taking a macro picture of the system and adding information in terms of a micro- or meso-level picture (Creswell, et al., 2011). These

advantages of the mixed methods research result from “offsetting the weaknesses inherent within one method with the strengths of the other or conversely, the strength of one adds to the strength of the other method” (Creswell, 2009, p. 213). More specifically, the qualitative method can be employed to assess the validity of findings from a quantitative method. Similarly, the quantitative method can be used to provide support for explaining findings from the qualitative method (Fetters, et al., 2013). These two forms of qualitative and quantitative methods can complement each other because qualitative methods research is typically inductive, subjective, and contextual, while quantitative methods research is generally deductive, objective, and general (Morgan, 2013).

The practice of research is closely influenced by the selection of a research strategy, and that research strategy can be chosen based on philosophical perspectives in order to address the research questions, although the philosophical perspectives are often largely hidden in the research (Creswell, 2009). There are several types of philosophical perspectives leading to embracing qualitative, quantitative, or mixed methods research discussed by Creswell (2009), these including post-positivism, constructivism, and pragmatism. According to him, post-positivists hold a deterministic philosophy and the research questions dealt with by them are relevant to identifying and assessing the causes that affect outcomes, whereas constructivists hold an assumption that individuals look for an understanding of diverse phenomena based on where they work or live. Thus, a post-positivist approach is generally seen in quantitative methods research while a constructivist perspective is typically seen in qualitative methods research. Another philosophical perspective derives from the work of pragmatists who believe that reality, or an external world, is not lodged in a duality between being independent of mind and within the mind. Instead, they believe the reality is located independently of mind as well as within the mind because all research questions researchers face are grounded in a social, historical, political, or economic context (Creswell, 2009). Many pragmatists agree that pragmatism is more concerned with actions, phenomena, and consequences relevant to problems rather than to antecedent conditions (Creswell, 2009). Hence, they pay more attention to applications and to solutions for addressing research problems and questions (Patton, 1990), and thus researchers embracing pragmatism concentrate on the research problems and questions and attempt to utilise all possible approaches to answer the problems and questions, instead of focusing on the methods themselves (e.g. Rossman, et

al., 1985)[25]. Hence, researchers imbued with pragmatism tend to open their minds to multiple methods such as mixed methods and different assumptions regarding their research, as well as different methods of data collection and analysis (Creswell, 2009).

As noted above, there are three research questions that need to be addressed in this thesis, the first and third regarding 'what' while the second one is expressed in terms of 'how'. The 'how' question is more explanatory and is associated with the operational links that need to be traced, and this type of a question is less likely to be dealt with using quantitative methods research only, while the 'what' type of question tends to be better addressed with quantitative methods research such as a survey (Yin, 1994). In addition, the main point of the first two questions is related to strategic motives reflecting the intrinsic properties of individual organisations and institutional properties of the system in establishing R&D collaboration among four different organisational types - the firm, university, public research institutes, and hospital. These questions can be simplified by adopting two distinct perspectives of inquiries that are engaged in identifying or assessing the motives (causes) influencing diverse collaborative structures (outcomes) in a post-positivism approach as well as in seeking an in-depth understanding of intrinsic and institutional properties interacting with the motives in a constructivist approach. Similarly, the inquiry on the third research question is not limited to a simple understanding of the relationships between different collaborative structures based on the motives and R&D performance. It also encompasses other understandings such as how does R&D policy influence the performance and what other types (i.e. not quantitative) of performance does the collaboration contribute to. Thus, mixed methods research in the perspective of pragmatism was appealing and was adopted here in order to address appropriately the research questions in this thesis. The mixed methods research contributed to obtaining a broader and deeper understanding by integrating both qualitative and quantitative methods research.

3.2. Research Design

In this section, a research design is set out that shows how to combine specific qualitative and quantitative research methods and how they are adopted for data collections and analysis in order to appropriately address the research questions of this thesis. According

[25] In this literature, Rossman et al. introduced diverse methods from the pragmatists' position, which can cover the full range of analysis stages from convergence in findings, providing richness and detail, to offering new interpretations.

to Morgan (2013), there are three general purposes of combining qualitative and quantitative methods, which are ‘sequential contributions’, ‘convergent findings or cross-validation’, and ‘additional coverage’. In this thesis, the purpose of mixed qualitative and quantitative methods was mainly motivated by additional coverage, although the mixed methods were also partially employed in order to provide cross-validation of the findings. For the additional coverage, different methods are assigned to research purposes in a research question in order to match the distinctive strengths of a particular method to a specific research purpose, and each method is utilised to study a separate part of the overall research question (Morgan, 2013). Thus, this research design involves collecting both qualitative and quantitative data, integrating these two types of data, and using the distinctive strengths of particular methods for specific research purposes. In this regard, this research design is more likely to provide a better understanding of the research questions than either research method alone (Creswell, 2014). There are three research questions to be addressed in this thesis: (i) What are the strategic motives influencing the establishment of inter-organisational collaboration in public R&D projects of the Korean digital healthcare sector? (ii) How are different collaborative structures developed in the public R&D projects? (iii) And what effects do these different collaborative structures have on diverse aspects of R&D performance? As noted in chapter 1 and in chapter 4, the public R&D projects of the Korean digital healthcare sector was chosen for the investigation in this thesis because digital healthcare technology can deal directly with the issues confronted by demographic changes, particularly with an ageing population in many parts of the world, not least Korea. These issues include increasing the burden of healthcare expenses and undermining the expectation of universal healthcare coverage. In addition, the role of public R&D is likely to be very important in emerging markets such as the digital healthcare sector given that private firms are reluctant to invest in the markets due to high risks and uncertainty. Knowledge integration through establishing collaboration between biomedical technology, healthcare service, and ICT plays a pivotal role in this sector for addressing the issues mentioned above as well. Hence, to answer the research questions of this thesis in public R&D projects in the Korean digital healthcare sector can contribute to coping appropriately with the issues we are facing.

For dealing with the first research question, we assume that the motives in establishing inter-organisational collaboration in public R&D projects are determined by the institutional properties of the national innovation system (NIS) and by certain intrinsic

properties of individual organisations. It is also assumed that the intrinsic properties of individual organisations consist of a cost-economising perspective based on transaction cost economics (TCE) and a securing-strategic-resources perspective for value maximisation based on the resource-based view (RBV), as explained in section 2.6. Hence, closed questions involving specific variables linked to both the institutional properties of the system and intrinsic properties of individual organisations were asked via a survey for understanding to what extent each motive linked to the above three theoretical approaches affects the establishment of inter-organisational collaboration. This sort of questions can limit responses within the frame of the closed questions, and clarify and simplify the questions' meaning for respondents in complicated inquiries like those regarding motives (Roulston, 2008a). Moreover, open-ended questions were tested through face-to-face interviews for the cross-validation of the findings in which respondents are able to introduce their own answers that do not fit the interviewer's coding schemes (Roulston, 2008b).

In contrast to questions regarding the intrinsic properties of individual organisations, respondents in the organisations are likely to have bounded information in terms of the institutional properties of the system, or they might not even perceive them because these institutional pressures tend to be 'taken-for-granted' within the national R&D system, being accepted without question (Lu, 2002). Thus, an additional investigation of the institutional pressures affecting the establishment of collaboration was conducted through exploring 'request for proposals' (RFPs) of each R&D project in order to obtain a better understanding of the motives involving the institutional properties of the national innovation system in establishing collaboration. The reason is that the aim of the RFPs is to present relevant information that is needed for prospective researchers to prepare a proposal as well as for the government in order to attain its policy goals, which includes "various representations and certifications that are required of prospective offerors, proposed terms and conditions that would be applicable to any resultant contract, instructions on how to prepare proposals, and information as to how the government will evaluate proposals and determine who is selected for award" (NIH, 2018a, Contracts section, para.6). Hence, the RFPs of the public R&D program play a crucial role in the national innovation system as one of the R&D policy instruments, which can be defined as "techniques of governance which, one way or another, involve the utilization of state resources, or their conscious limitation, in order to achieve policy goals" (Howlett, et al.,

2007, p. 2).

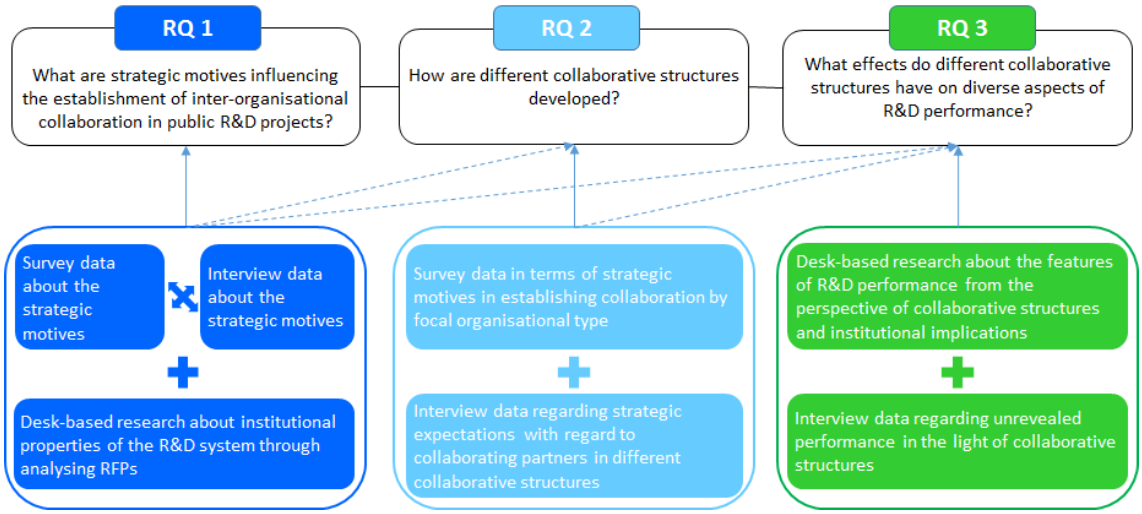
In order to address the second research question, how different collaborative structures are developed in the public R&D projects, the survey data employed for addressing the first research question were used again, but the data were classified in terms of the features (i.e. for-profit and not-for-profit organisations) and types (i.e. a firm, university, PRI, and hospital) of focal organisations and this classification provides information on how for different collaborative structures there are the different characteristics of the motives in establishing collaboration. Conversely, this approach enables us to show how the development of different collaborative structures relies on different characteristics of the motives in the establishment of different collaborative structures. Furthermore, another analysis will be carried out to understand how strategic motives affect focal organisations in choosing their collaborating partner types. Hence, the survey-based data are also classified by collaborating partner types, and these classified groups are employed to analyse how each motive has an effect on a particular focal organisational feature and type in establishing inter-organisational R&D collaborations with a particular collaborating partner type.

In order to carry out a more in-depth investigation, semi-structured face-to-face interviews (using open-ended questions in order to validate the conceptual framework of this thesis) were conducted. These interviews were primarily aimed at gathering information on the strategic expectations of focal organisations (i.e. such as a firm, hospital, PRI, and university) with regard to their partner organisations in the establishment of different collaborative structures. The reason is that collaborative structures depend heavily on the organisational strategic expectations of other partners, which are vital elements in the motives of R&D projects in which inter-organisational collaborative structures had been developed. Thus, the findings from interviews can provide the additional information regarding the second research questions.

The last research question, which focuses on what effects the different collaborative structures reflecting the motives have on diverse aspects of R&D performance, was generally dealt with by quantitative analysis in order to explore the relationships between different collaborative structures and R&D performance in terms of such factors as SCI papers, patent applications, patents granted, and technology licensing agreements. The R&D productivity levels across different collaborative structures were compared with

those of non-collaboration R&D projects to provide a clearer understanding of the influence of different collaborative structures on the various aspects of R&D performance. Based on this understanding, we carried out a more in-depth statistical analysis employing binary logistic regressions in terms of the four different R&D performance aspects from the perspective of the different collaborative structures compared with non-collaboration R&D projects. Then, we conducted an additional investigation of how institutional pressures based on RFPs in establishing collaboration have an effect on the various aspects of R&D performance of different collaborative structures. Moreover, the analysis was conducted by using the data collected by the interviews to investigate other aspects of R&D performance that are not collected or captured through the national R&D information service in the perspective of different collaborative structures. Thus, the analytical framework for addressing three research questions of this thesis can be summarised as shown below (see *Figure 3.1*).

Figure 3.1 Analytical framework of the thesis



⟶: A direct link to address research questions ⇢: An indirect link to address research questions
Combining qualitative and quantitative methods for cross-validation (✖) and additional coverage (✚)

Source: author's elaboration

3.3. Data Sources and Collection

3.3.1. Desk-based Research

As *Figure 3.1* shows, there are primarily two types of data that are collected from the desk-based research with regard to the RFPs of the R&D projects participating in collaboration in Korean digital healthcare sector, and data on their R&D performance. The data on public R&D projects between 2012 and 2015 based on funding years that this

thesis will draw on are collected via the National Science and Technology Information Service (NTIS)[26], which provide the basis for identifying the collaboration information on different kinds of projects. Here, the NTIS provides collaboration information with four different organisational types (i.e. firm, university, PRI, and other). Hence, another type of organisations, a hospital, was confirmed and classified by principal investigators' affiliations[27] because hospitals tend to be classified as a university type if they are university hospitals, or as 'other' type if they are generic hospitals. In addition, the R&D projects should be defined according to whether their research areas fall within the digital healthcare sector, prior to utilising them for conducting an analysis. The information on R&D projects in the digital healthcare sector was collected based on the areas involving 'health information and health information system technologies (code name: 256G-06)' in the Korean National Standard Classification of Science and Technology (NSCST). The data on the R&D projects in the digital healthcare sector were also utilised for identification in the fieldwork studies for a survey and interviews.

Moreover, this database comprises life-cycle data on the R&D process from information on R&D projects, through to output performance (e.g. academic papers, patenting activities) and to outcome performance (e.g. technology licensing), as shown in *Table 3.1*. These outputs and outcomes are commonly employed as an indicator in many quantitative innovation studies. The reason is that new technologies generally go through the process of scientific, technological, and economic developments and the future potentials of new technologies can be anticipated with these indicators (e.g. academic papers as an indicator for scientific performance, patenting activities as an indicator for technological performance, and technology licensing as an indicator for commercialisation performance) (Hullmann, et al., 2003). Hence, these performance data generated between 2012 and 2017 were collected in order to analyse from the perspectives of collaborative structures.

However, it is unfortunately not possible to adopt specified goals set by government as a dependent variable in that around 97~98% of a total of R&D projects are evaluated as a 'success' in the Korean public R&D system (MSIT, 2017b).

[26] The data are managed and verified by the Ministry of Science and ICT (MSIT), the Korea Institute of Science and Technology Evaluation and Planning (KISTEP), and the Korea Institute of Science and Technology Information (KISTI). In addition, this database has been certified by the Office for Statistics Korea as providing 'national statistics' since 2016.
[27] If a PI carries out clinical practice although he/she is affiliated with both a university and a hospital at the same time, the PI's organisation is classified as a hospital type.

Table 3.1 R&D projects information in the NTIS

Input[1)]	Output[2)]	Outcome[2)]
Project no., project name, year of the project, amount of funding, funding sources, organisational name of participants, collaboration information and NSCST information.	Detailed information on SCI papers and patent performance linked to the project no.	Information on technology licensing linked to the project no.

1) The project information on collaborative R&D projects in the digital healthcare sector was collected between 2012 and 2015 based on funding years; 2) This information was collected from 2012 to 2017 based on when the output and outcome was created.

Source: author's elaboration

As a consequence, a total of 207 R&D projects with 484 sub-projects involving collaborating partners were collected out of 682 R&D projects[28] in the digital healthcare sector from 2012 to 2015. These 207 R&D projects generated 126 SCI papers, 291 patent applications, 158 patents granted, and 64 technology licensing agreements between 2012 and 2017, as of April 30th 2019 (see *Appendix 1*). The RFPs of the selected 207 R&D projects in the Korean digital healthcare sector were employed with the aim of a providing additional understanding about the institutional motives in establishing collaboration, and they were collected from the websites of each funding agency (including their ministries' websites) such as Korea Health Industry Development Institute (KHIDI), National Research Foundation of Korea (NRF), Korea Evaluation Institute of Industrial Technology (KEIT), Korea Institute for Advancement of Technology (KIAT), Institute for Information and Communications Technology Promotion (IITP), and Korea Technology & Information Promotion Agency for SMEs (TIPA). A total of 82 RFPs were collected through this process as described in *Table 3.2*. The difference between the number of R&D projects and RFPs is caused by the fact that more than one R&D project won in a RFPs or one R&D project in a RFPs lasts over one funding year.

Table 3.2 A list of request for proposals (RFPs) and funding sources

No.	R&D programs	Sources	No.	R&D programs	Sources
1	Advanced technology centre establishment	MoTIE	42	Medical research information centre establishment	MSIT
2	Application of the next generation omics technology	MSIT	43	National core research centre establishment	MSIT
3	Personal healthcare devices development based on bio-markers	MSIT	44	National standard technology development	MoTIE
4	Business services development for SMEs	MSS	45	New product development under a purchase agreement	MSS
5	Commercialisation promotion R&D	MoTIE	46	Bio-medical devices development	MoTIE

[28] This number comprises 207 collaboration projects excluding 401 non-collaboration projects, six projects whose focal organisational type is not one of a firm, hospital, PRI, and university, eight security projects, and 60 independent non-collaboration partners of the collaboration projects.

No.	R&D programs	Sources	No.	R&D programs	Sources
6	Cutting-edge 3D oral scanner and SW development	MoTIE	47	Personal mobile healthcare technology development based on bio-markers	MSIT
7	Cutting-edge core technology development in medical information and systems	MoHW	48	Post-genomic technology development	MoTIE
8	Development of smart patches for monitoring patients and of a homecare service solution	MoTIE	49	Preventive research for health improvement based on Korean traditional medicine	MSIT
9	Design innovation capacity enhancement	MoTIE	50	Private-Public co-investment for supporting SMEs capabilities	MSS
10	Cooperation development for the economic belt promotion	MoTIE	51	R&D collaboration platform development between hospitals and firms	MoTIE
11	Globally creative SW development	MSIT	52	Regionally specialised industry promotion- Gangwon	MoTIE
12	Globally specialised technology development - bottom-up and IT related new industry	MSIT	53	Regionally specialised industry promotion- private firm supports	MoTIE
13	Globally specialised technology development - IT convergence	MoTIE	54	Regionally specialised industry promotion-Gwangju	MoTIE
14	Healthcare service delivery refinement	MoHW	55	Science and technology ODA program	MSIT
15	Healthcare management system development based on the personal health records (PHRs)	MoTIE	56	Smart healthcare support centre establishment	MoTIE
16	Healthcare platform establishment for wellness	MoTIE	57	Smart u-healthcare service model development for the disabled	MoHW
17	Healthcare information technology development	MoHW	58	Standard development for mobile biometric technology for information security	MoTIE
18	Housing environment development	MoLIT	59	State-of-the-art technology development for SMEs innovation	MSS
19	Human resource development for regional innovation	MoE	60	Strategic planning for healthcare big data	MoHW
20	Industrial original technology development- multi-platforms-based healthcare management service development	MSIT	61	Strategic planning for healthcare technology development	MoHW
21	Industrial original technology development - service design development for a better interface between patients and doctors	MoTIE	62	Strategic technology development- next generation medical devices development	MoTIE
22	Industrial specialisation development in megaregions- Daegu-Gyeongbuk	MoTIE	63	Industrial specialisation development in megaregions- Gangwon	MoTIE
23	Supports for developing medical devices and their certification	MoTIE	64	SW convergence technology development	MSIT
24	Industrial technology development in regional areas	MoTIE	65	SW platform development for the next generation	MSIT
25	Industry convergence promotion	MoTIE	66	System informatics R&D	MSIT
26	Industry-University-Public research institute collaboration (2014)	MSS	67	Systemic approach to Korean traditional medical information	MSIT
27	Industry-University-Public research institute collaboration (2015)	MSS	68	Technological convergence-based new healthcare service development	MoHW
28	Infrastructure development for ICT commercialisation	MSIT	69	Technological supports for start-ups	MSS

No.	R&D programs	Sources	No.	R&D programs	Sources
29	Infrastructure development of medical devices for the elderly	MSIT	70	Technology convergence for SMEs- research field planning project	MSS
30	International cooperation R&D for acquiring technologies	MoTIE	71	Technology convergence promotion for SMEs- bottom-up	MSS
31	International cooperation R&D for mutual benefits	MoTIE	72	Technology convergence promotion for SMEs- Industry-PRI collaboration	MSS
32	International standard registration support	MoTIE	73	Technology convergence promotion for SMEs- smart medication management system	MSS
33	International standard technology development	MoTIE	74	Technology development for mental healthcare	MoHW
34	Internationally co-funded R&D program	MoTIE	75	Technology innovation improvement for SMEs- 2013	MSS
35	Technology transfer promotion in science parks	MSIT	76	Technology innovation improvement for SMEs- 2014	MSS
36	IT convergence technology development- invasive health monitoring system for patients with chronic diseases	MSIT	77	IT convergence technology development- cyber doctor development	MSIT
37	IT convergence technology development- wellness system development for the elderly	MSIT	78	u-health monitoring system development for diagnosing respiratory diseases	MoTIE
38	Local business cooperation R&D- Gangwon	MoTIE	79	Thematic clusters establishment for enhancing competitiveness	MoTIE
39	Medical device development	MoHW	80	Test-bed establishment for Smart after-care	MSIT
40	Medical device-integrated digital hospital development	MoTIE	81	Ubiquitous computing and networking technology development	MoTIE
41	Medical micro-robot development for blood vessel diseases	MoTIE	82	Wearable sensor module development for mental disease	MSIT

* The names of funding sources are adopted with the latest ones, which are MoTIE (Ministry of Trade, Industry, and Energy), MSS (Ministry of SMEs and Start-ups), MoHW (Ministry of Health and Welfare), MSIT (Ministry of Science and ICT), MoE (Ministry of Education), and MoLIT (Ministry of Land, Infrastructure, and Transport).

Source: author's elaboration

3.3.2. Survey Data

As described in section 3.2, the survey data were collected to understand the strategic motives involved in establishing inter-organisational collaboration in public R&D projects and how those motives influence the development of different inter-organisational collaborative structures. As noted earlier, it is assumed that the motives are based partly on institutional properties of the national innovation system (NIS) and partly on intrinsic properties of individual organisations such as a cost-economising perspective based on transaction cost economics (TCE) and a securing-strategic-resources perspective for the value maximisation based on the resource-based view (RBV). Hence, questions about particular motives linked to three different theoretical approaches

influencing the establishment of inter-organisational collaboration were put to the principal investigators in each R&D project in order to obtain answers to the question, 'How much you agree or disagree that each motive influenced the establishment of collaboration with other partners?'. Here, principal investigators were chosen as respondents in the survey, because principal investigators in public R&D projects play an enormously important role in designing, coordinating and aligning research avenues for the scientific community, funding agency priorities and programs and market demands (Todeva, et al., 2005). Through this survey, data were collected using a seven-point Likert-type scale to rate the degree of importance attached to specific motives in developing the collaboration. For instance, respondents can choose one of seven points from 'strongly disagree (i.e. point one)', to 'neither disagree nor agree (i.e. point four)', and to 'strongly agree (i.e. point seven)' for each motive affecting the establishment of collaboration. Furthermore, the specific motives were generally selected based on Todeva, et al. (2005), Veugelers (1998), Dachs, et al. (2008), Hagedoorn (1993), Lee, et al. (2005) and Radas (2006), and they were classified using the three different theoretical approaches, according to the features of each motive.

More specifically, motives, which are imposed by or relevant to institutions such as government policies, regulations, organisational roles, and technical standards, are classified into the NIS approach. Motives related to "minimising the sum of production and transaction costs" in order to achieve economic efficiency such as economising or minimising any costs, time, and risks are allocated into the TCE perspective (Kogut, 1988, p. 322). Lastly, the RBV approach includes motives which are relevant to obtaining partners' resources or capabilities and to retaining or developing individual organisations' own resources or capabilities through combining collaborating partners' resources or capabilities (Das, et al., 2000) (see *Table 3.3*). Here, the strategic motives relevant to 'obtaining partners' resources or capabilities' are likely to reflect the level of existing resources and capabilities of focal organisations. On top of that, we will carry out reliability analyses to assess the internal consistency of questionnaires engaging each theoretical approach before conducting quantitative analysis in section 5.2.1.

Table 3.3 Motives for the survey in the establishment of collaboration in public R&D projects classified in terms of different theoretical approaches

Institutional motives based on the national R&D system (NIS)	Intrinsic motives of individual organisations	
	A cost economising perspective (TCE)	A securing strategic resources perspective for value maximisation (RBV)
- To get help with overcoming legal or regulatory barriers - To get information on current trends of government policies and regulations - To pursue certain missions mandated from the government or society - Enforced by funding agencies or government - To develop technical standards - To achieve benefits from potential grants[29]	- To minimise research costs through developing economies of scale - To minimise research costs through developing economies of scope - To minimise research expenses through costs sharing/reduction in research - For sharing any risks and losses - To shorten lead time - To reduce administrative costs	- To gain priority over intellectual property right - To develop existing technologies or products - To access human resources - To get benefits from partner's reputation - To gain access to new technologies or markets - For learning and internalisation of embedded skills from partners - To gain access to complementary resources and capabilities - To obtain help for R&D commercialisation - To understand demand-side needs - To gain help from a partner's administrative division - To utilise partner's research facilities

Source: author's elaboration based on Todeva, et al. (2005), Veugelers (1998), Dachs, et al. (2008), Hagedoorn (1993), Lee, et al. (2005) and Radas (2006)

Through the survey, 57 project topics (44.5%) and 92 R&D projects (44.4%) were covered out of a total of 128 project topics and 207 R&D projects[30] in the digital healthcare sector of Korea for the period from 2012 to 2015 (see *Table 3.4*). This survey was conducted based on an approval (ER/KH282/1) by the Social Sciences & Arts Research Ethics Committee at Sussex University with two different methods, the data for 39 project topics were collected through face-to-face means immediately after the interview program, over the period of Oct. 31st to Dec. 5th 2017. The rest of the survey data were collected through an online survey by using both e-mail systems of KHIDI and Sussex University and 'Google Doc' from Dec. 7th 2017 to Feb. 6th 2018 (see *Table 3.5*). The contact information of principal investigators (PIs) was mainly collected through the website of researchers' affiliations, and additional contact information was collected through the healthcare R&D information system in the case that researchers voluntarily disclosed their contact information. Through this process, 97 PIs' contact information out

[29] The motive, 'to achieve benefits from potential grants', can be interpreted for organisations as gaining opportunities to participate into public R&D programs by adapting to institutional pressure, given that more than 70% of RFPs in the digital healthcare sector are enforced or encouraged the establishment of collaboration. In particular, more than 90% of firms in the Korean digital healthcare sector are SMEs and this motive may greatly affect the firms' desire to establish collaboration.

[30] In the Korean R&D system, it is counted as two R&D projects, for instance, if one research topic is conducted for two years.

of 124 PIs in total was collected. Then, the respondents for the online survey were recruited by a series of email notifications with a participant information sheet (translated into Korean) which includes the information on the purpose of the survey, on how the PIs were invited, and so on (see *Appendix 2*). Additionally, the sheet of survey questionnaires was presented together (see *Appendix 3*). Fortunately, there are no missing data and all the respondents responded to the survey. These data collected through this procedure were used to develop an understanding of the attributes of strategic motives (based on the NIS, TCE, and RBV perspectives) in developing R&D collaboration in the Korean digital healthcare sector.

Table 3.4 A response rate for a survey by focal organisation's types

Focal organisation's types	No. of projects	Survey response rate
Firm	94	28.7% (27)
University	59	49.2% (29)
Public Research Institute (PRI)	24	75.0% (18)
Hospital	30	60.0% (18)
Total	207	44.4% (92)

Table 3.5 A list of respondents in the survey based on research topics

No.	Focal org. types	Respondents (YYYY)[31]	Collaborating partners				
			Firm	Univ.	PRI	Hosp'l	Etc.
1	University	Full Professor (2004)	5	-	-	-	
2	Firm	Founder/CEO (2011)	-	-	1	1	1
3	Firm	Founder/CEO (2012)	4	4	-	3	-
4	Hospital	Research Assistant Professor (2011-2016)	-	-	-	1	-
5			-	1	-	-	-
6	PRI	Team Head/Principal researcher (2001)	-	3	-	2	-
7	PRI	Principal Researcher (2008)	1	-	-	10	-
8	Firm	CTO (2008)	1	3	1	1	1
9	Firm	Founder/CEO (2006)	1	1	1	-	-
10			1	-	-	1	1
11	Firm	CTO (2008)	-	1	-	-	-
12	PRI	Principal Researcher (1989)	1	-	-	1	-
13	University	Full Professor (MD, 2003)	5	2	2	-	-
14	University	Full Professor (MD, 2005)	-	1	-	1	-
15			1	2	-	-	-
16	Hospital	Full Professor/Director (MD, 1988)	1	-	-	-	-
17	University	Full Professor/Dean (2011)	-	-	-	1	-
18	University	Full Professor (2010)	-	-	-	1	-
19	University	Full Professor (MD, 1996)	-	2	-	1	-
20	Firm	CTO/Executive Director (1999)	1	1	-	-	-
21	Firm	Founder/CEO (MD, 2013)	-	-	-	1	1
22	University	Assistant Professor (2013)	1	-	-	-	-
23	PRI	Assistant Vice President (1995)	1	3	1	1	-

[31] The year of starting work in the institute

No.	Focal org. types	Respondents (YYYY)[31]	Collaborating partners				
			Firm	Univ.	PRI	Hosp'l	Etc.
24	Firm	CTO (2007)	3	-	-	6	-
25	Hospital	Full Professor (MD, 1984)	4	-	1	1	-
26	PRI	Team Head (2007)	6	-	1	4	-
27	University	Full Professor (MD, 2001)	3	2	-	-	-
28			-	-	-	2	1
29	Hospital	Full Professor (MD, 1978)	2	-	-	-	1
30	Hospital	Principal Researcher (2010)	-	1	-	-	-
31	Hospital	Full Professor/Vice Dean (MD, 2010)	1	-	-	-	-
32	Firm	CTO (2010)	-	-	1	-	-
33	Hospital	Full Professor (MD, 1992)	5	-	1	1	-
34	Firm	Founder/CEO (2013)	-	-	-	1	-
35	Firm	Executive Director (2008-2012)	1	-	-	2	-
36	Hospital	Full Professor (MD, 2007)	5	2	-	1	-
37	PRI	Director of Research Centre (1996)	-	1	2	-	-
38	Firm	Team Head (2015)	-	-	-	1	-
39	Firm	CTO (1998)	3	1	-	-	-
40	PRI	Principal Researcher/Director (2004)	-	2	-	-	
41	PRI	Principal Researcher/Director (1986)	-	2	1	-	2
42	University	Associate Professor (2005)	1	-	-	1	-
43	Firm	Director (2010)	3	-	1	1	-
44	PRI	Principal Researcher (KMD, 2004)	-	1	-	-	-
45	PRI	Team Head (2005)	-	-	1	-	-
46	PRI	Team Head (1999)	-	-	-	-	2
47	Firm	Director (1995)	1	-	-	1	-
48	PRI	Principal Researcher/Director (KMD, 2005)	-	1	-	-	-
49	University	Full Professor (1990)	1	1	1	-	1
50	Hospital	Full Professor (MD, 1981)	1	-	-	-	-
51*	University	Research Professor (2010)	-	1	-	-	-
52	Firm	Founder/CEO (Dentist, 2005)	-	-	1	-	-
53	Firm	Founder/CEO (2001)	-	1	-	1	-
54	Firm	Managing Director/CTO (2014)	-	-	1	-	-
55	Firm	CTO (MD, 2013)	1	-	1	-	-
56	University	Full Professor (MD, 1996)	-	1	-	-	-
57	PRI	Principal Researcher/ Director (1985)	1	-	-	-	1

* This survey was conducted with a research professor who was in charge of the R&D project, instead of a principal investigator.

Source: author's elaboration

3.3.3. Interview Data

The semi-structured face-to-face interviews were conducted between Oct. 31st 2017 and Dec. 5th 2017 based on an approval (ER/KH282/1) by the Social Sciences & Arts Research Ethics Committee at Sussex University. These interviews were carried out with the purpose of understanding how different collaborative structures are developed and of shedding light on unrevealed aspects of R&D performance which are not officially collected or dealt with by funding agencies, even though such aspects of performance may be quite meaningful for each research team. In course of the interviews, 39 project

topics and 64 R&D projects were covered through interviews with 35 principal investigators (28.2%) out of a total of 124 principal investigators,[32] 128 project topics, and 207 R&D projects in the Korean digital healthcare sector for the period from 2012 to 2015 (see *Table 3.6 and 3.7*). The interviewees were recruited by telephone after a series of email notifications[33] with a participant information sheet (translated into Korean) which includes information on the purpose of the interview, on how interviewees were invited, on the procedure of interviews, and so on (see *Appendix 2*). Additionally, brief interview questions were sent in advance (see *Appendix 4*). The recruiting of additional interviewees ended when the interviews had reached "a point of diminishing returns" - i.e. when the last nine interviewees repeatedly provided similar answers to each of the interview questions. Prior to conducting the interviews, the interviewer read a consent form and received verbal agreement for participating in the interview from each interviewee. All interview procedures, except for the case of two interviewees[34], were audio-recorded including the verbal agreement, and each interview on average lasted just over 70 minutes. Important information on interviewees' answers to every interview question was briefly noted during the interviews, and these notes were developed immediately after the interview program together with the audio recordings in order to avoid forgetting or losing any meaningful information. Moreover, these notes were thoroughly developed once again after finishing the fieldwork research for analytical purposes of this thesis.

Table 3.6 A response rate for interviews by focal organisation's types

Focal organisation's types	No. of projects in total	Interview response rate
Firm	94	21.3% (20)
University	59	33.9% (20)
Public Research Institute (PRI)	24	33.3% (8)
Hospital	30	53.3% (16)
Total	207	30.9% (64)

Source: author's elaboration

[32] The PIs are mostly CEOs /CTOs, professors, medical doctors, and senior researchers in the PRIs in this sector.
[33] The contact information was collected through the website of researchers' affiliations and the healthcare R&D system in the case of researchers who voluntarily disclosed their contact information. Through this process, 97 PIs' contact information out of 125 PIs was collected.
[34] One interviewee did not want to record his interview and another interview was conducted as a written interview with a following-up telephone interview.

Table 3.7 A list of interviewees

ID	Focal org. types	Interviewees (YYYY)[35]	Collaborating partners					Annual funding	Interview duration
			Firm	Univ.	PRI	Hosp'l	Etc.		
U01	Univ.	Full Professor (2004)	5	-	-	-		£1.72M	1h 12m (on Oct. 31)
F01	Firm	Founder/CEO (2011)	-	-	1	1	1	£0.33M	25m (on Nov. 1)
F02	Firm	Founder/CEO (2012)	4	4	-	3	-	£2.83M	1h (on Nov. 2)
H01	Hosp'l	Research Assistant Professor (2011-2016)	-	-	-	1	-	£0.17M	1h 02m (on Nov. 2)
			-	1	-	-	-	£0.13M	
P01	PRI	Team Head/Principal Researcher (2001)	-	3	-	2	-	£0.61M	48m (on Nov. 3)
P02	PRI	Principal Researcher (2008)	1	-	-	10	-	£0.92M	56m (on Nov. 3)
F03	Firm	CTO (2008)	1	3	1	1	1	£0.61M	1h 02m (on Nov. 6)
F04	Firm	Founder/CEO (2006)	1	1	1	-	-	£0.46M	1h 02m (on Nov. 7)
			1	-	-	1	1	£1.03M	
F05	Firm	CTO (2008)	-	1	-	-	-	£0.39M	43m (on Nov. 8)
P03	PRI	Principal Researcher (1989)	1	-	-	1	-	£0.29M	45m (on Nov. 8)
U02	Univ.	Full Professor (MD, 2003)	5	2	2	-	-	£1.67M	2h 07m (on Nov. 9)
U03	Univ.	Full Professor (MD, 2005)	-	1	-	1	-	£0.12M	52m (on Nov. 10)
			1	2	-	-	-	£0.11M	
H02	Hosp'l	Full Professor/Director (MD, 1988)	1	-	-	-	-	£0.06M	59m (on Nov. 10)
U04	Univ.	Full Professor/Dean (2011)	-	-	-	1	-	£0.10M	34m (on Nov. 10)
U05	Univ.	Full Professor (2010)	-	-	-	1	-	£0.09M	1h 12m (on Nov. 13)
U06	Univ.	Full Professor (MD, 1996)	-	2	-	1	-	£0.07M	1h 01m (on Nov. 14)
F06	Firm	CTO/Executive Director (1999)	1	1	-	-	-	£0.32M	1h 04m (on Nov. 14)
F07	Firm	Founder/CEO (MD, 2013)	-	-	-	1	1	£0.18M	1h 09m (on Nov. 15)
U07	Univ.	Assistant Professor (2013)	1	-	-	-	-	£0.05M	49m (on Nov. 15)
P04	PRI	Assistant Vice President (1995)	-	3	-	-	-	£2.75M	45m (on Nov. 16)
F08	Firm	CTO (2007)	3	-	-	6	-	£1.61M	1h 4m (on Nov. 16)
H03	Hosp'l	Full Professor (MD, 1984)	4	-	1	1	-	£1.37M	1h 43m (on Nov. 17)
P05*	PRI	Team Head (2007)	6	-	1	4	-	£2.41M	Written (on Nov. 17)
U08	Univ.	Full Professor (MD, 2001)	3	2	-	-	-	£1.37M	No recording
			-	-	-	2	1	£0.10M	2h 30m (on Nov. 22)

[35] The year of starting work in the institute

ID	Focal org. types	Interviewees (YYYY)[35]	Collaborating partners					Annual funding	Interview duration
			Firm	Univ.	PRI	Hosp'l	Etc.		
H04	Hosp'l	Full Professor (MD, 1978)	2	-	-	-	1	£0.15M	52m (on Nov. 24)
H05	Hosp'l	Principal Researcher (2010)	-	1	-	-	-	£0.09M	1h 08m (on Nov. 24)
H06	Hosp'l	Full Professor/Vice Dean (MD, 2010)	1	-	-	-	-	£0.08M	30m (on Nov. 27)
F09	Firm	CTO (2010)	-	-	1	-	-	£0.16M	44m (on Nov. 27)
H07	Hosp'l	Full Professor (MD, 1992)	5	-	1	1	-	£0.92M	51m (on Nov. 28)
F10	Firm	Founder/CEO (2013)	-	-	-	1	-	£0.35M	57m (on Nov. 29)
F11	Firm	Executive Director (2008-2012)	1	-	-	2	-	£0.75M	51m (on Nov. 29)
H08	Hosp'l	Full Professor (MD, 2007)	5	2	-	1	-	£0.34M	34m (on Nov. 30)
P06	PRI	Director of Research Centre (1996)	-	1	2	-	-	£1.37M	46m (on Dec. 1)
F12 *	Firm	Team Head (2015)	-	-	-	1	-	£0.58M	51m (on Dec. 1)
F13	Firm	CTO (1998)	3	1	-	-	-	£0.89M	50m (on Dec. 5)

* A written interview was conducted for P05 and additional information was gathered from a follow-up telephone interview; a face-to-face interview was conducted with the team head (F12) who was in charge of the R&D project, instead of a principal investigator (CEO) due to his overseas business trip.
** The average currency exchange rate in 2017 (£1 = ₩1,455.1) is applied for the conversion from Korean won to GBP.

Source: author's elaboration

3.4. Data Analysis

There are three research questions to be addressed in this thesis: (i) What are the motives influencing the establishment of inter-organisational collaboration in public R&D projects of the Korean digital healthcare sector? (ii) How are different collaborative structures developed in the public R&D projects?; (iii) And what effects do these different collaborative structures have on diverse aspects of R&D performance? In this section, it will be shown how the different data collected by diverse methods including a survey, interviews, and desk-based research were utilised for addressing each research question. Prior to carrying out the analysis to address each research question, the general characteristics of R&D projects collected for analysing in this thesis were illustrated to provide background information on the projects in the digital healthcare sector. In addition, the 23 strategic motives based on Todeva, et al. (2005), Veugelers (1998), Dachs, et al. (2008), Hagedoorn (1993), Lee, et al. (2005), and Radas (2006) were selected for a survey, and they were classified into the three different theoretical approaches (i.e. the

NIS, TCE, and the RBV) according to the characteristics of each motive. In addition, we have carried out reliability analyses in order to assess the internal consistency of the strategic motives involving each theoretical perspective in section 5.2.1.

☞ Research question Ⅰ: What are the motives of the focal organisations influencing the establishment of inter-organisational collaboration in public R&D projects of the Korean digital healthcare sector?

Both quantitative and qualitative data collected by a survey and interviews were analysed in order for the cross-validation concerning what strategic motives affect the establishment of inter-organisational collaboration in the public R&D projects. The quantitative data collected from a survey show how much specific motives based on the three theoretical approaches, namely, the NIS, TCE, and the RBV, influence the establishment of the collaboration. Consequently, it will be revealed which specific motives and which theoretical approaches linking to the motives are most influential on the establishment of the collaboration through comparing the mean scores of each motive as measured on the seven-point Likert scale. This finding was also validated with qualitative data collected through open-ended interview questions about the motives involved in establishing the collaboration. In addition, a statistical test, one-way analysis of variance (ANOVA), was carried out in SPSS to compare the three theoretical groups involving the motives, and this test can indicate which theoretical approach is the more influential among three theoretical perspectives in establishing collaboration. Additionally, the findings from analysing qualitative data on the RFPs were used for additional coverage of the motives relating to the institutional influences of the national R&D system. The RFPs were analysed in the light of factors that might affect the establishment of collaboration such as the purpose of the R&D programs and any words related to compelling or facilitating the establishment of the collaboration.

☞ Research question Ⅱ: How are different collaborative structures developed in the public R&D projects?

The quantitative data collected by a survey showing how much specific motives based on the three theoretical approaches, namely, the NIS, TCE, and the RBV, influence the establishment of the collaboration were categorised by focal organisational type (i.e. firm, university, public research institute, and hospital). Based on these collaborative structures

categorised by focal organisational type, the ANOVA test was employed to determine whether there are any differences between the different collaborative structures in terms of the level of the strategic motives as measured on the seven-point Likert scale. Thus, this analysis identifies how different features of each strategic motive and of each theoretical approach influence the development of the different collaborative structures, mainly according to the type of focal organisation. Additionally, the qualitative data collected from open-ended interview questions (without any theoretical restrictions) on the strategic motives in establishing collaboration were analysed by focal organisational type to provide the additional coverage and to validate the conceptual framework of this thesis. Here, we may be able to understand more specific strategic motives in developing different collaborative structures by focal organisational type.

Furthermore, the survey-based data were classified by collaborating partner type, and these classified groups were employed to analyse how the motives influence focal organisations to choose a particular type of partners in establishing R&D collaboration. In order to carry out a more in-depth investigation, interview-based data were utilised. These data were collected to gain information on the strategic expectations of focal organisations with regard to their partner organisations in the establishment of different collaborative structures in that the organisational strategic expectations of other collaborating partners are vital elements in the motives of the R&D projects in which different collaborative structures had been developed. Thus, these results should contribute to a better understanding of why a specific type of focal organisations developed collaboration with particular types of collaborating partners.

☞ Research question Ⅲ: What effects do these different collaborative structures have on diverse aspects of R&D performance?

In order to address this research question, quantitative analysis was performed. First, we carried out an analysis of the general characteristics of the R&D performance of different collaborative structures based on organisational types and funding features. Moreover, the R&D performance associated with the different collaborative structures of R&D collaboration projects were compared with the R&D performance of non-collaboration R&D projects in order to provide a better understanding of the characteristics of the R&D performance of each of the different collaborative structures.

Second, we also carried out a more in-depth statistical analysis, binary logistic regression in SPSS, in terms of the various aspects of R&D performance (i.e. SCI papers, patent applications, patents-granted, and technology licensing) from the perspective of the different collaborative structures in comparison to non-collaboration R&D projects. Hence, these analyses provided statistical evidence regarding how much different collaborative structures of R&D projects affects each type of R&D performance compared with the all of non-collaboration R&D projects.

In addition, we carried out an investigation to ascertain the institutional implications for R&D performance through exploring the 'request for proposals' (RFPs) of each R&D project. Thus, we could address the implications of the attributes of RFPs as an R&D policy instrument for the various aspects of R&D performance according to different collaborative structures by focal organisational type.

Lastly, the qualitative data relating to additional benefits and unrevealed outcomes, not captured through the national R&D information system, from the establishment of inter-organisational R&D collaboration were analysed, and these data were directly collected from interviews with PIs in the focal organisations leading R&D collaborative projects. Through this investigation, we can perhaps arrive at a better understanding of how different collaborative structures have an effect on various aspects of R&D performance.

3.5. Conclusion

This chapter has presented the research design and methodology used to address the research questions and the theoretical framework. More specifically, it has discussed with regard to the adoption of mixed methods research, how to combine specific qualitative and quantitative research methods, and how those methods were adopted for data collection and analysis in order to appropriately address the research questions of this thesis. Then, it has discussed the data sources and how to collect the different types of data using diverse methods such as a survey, interviews, and desk-based research, and how the different data are utilised for addressing each research question.

The following chapter will present the contextual characteristics of the digital healthcare section of South Korea. It will explore the important role of the digital healthcare sector and of collaboration in this sector of Korea in dealing with economic and social issues

related to an ageing population, and the characteristics of main actors in the innovation system in the Korean digital healthcare sector such as a firm, university, PRI, and hospital.

Chapter 4. Korea's Digital Healthcare Sector

This chapter aims to explore to understand the context of the digital healthcare section of South Korea. The digital healthcare sector is a suitable focus for this thesis, with its aim of obtaining a better understanding of underlying inter-organisational collaboration mechanisms, in that knowledge integration through establishing collaboration between biomedical technology, healthcare service, and ICT plays a pivotal role in this sector. Thus, this research in the digital healthcare section can contribute to addressing the issues we are confronting due to demographic changes. More specifically, the Korean digital healthcare sector was chosen for the investigation in this thesis because digital healthcare technology can deal directly with the issues confronted by demographic changes, particularly with an ageing population in many parts of the world, not least Korea as noted previously in section 1.1. These issues include increasing the burden of healthcare expenses and undermining the expectation of universal healthcare coverage.

In order to identify the context of the digital healthcare sector of Korea, this chapter comprises two sections. The first concentrates on both the supply and demand sides of the healthcare system such as the characteristics of healthcare service providers and the healthcare payment system, and of an ageing population due to demographic changes in Korea. This section also deals with the attributes of ICT infrastructure in Korea and with the trend of regulations and policies in the digital healthcare sector of Korea. Meanwhile, the characteristics of main actors in the innovation system in the digital healthcare sector (firms, universities, PRIs, and hospitals) will be explored in the second section of this chapter.

4.1. Characteristics of the Digital Healthcare Sector in Korea

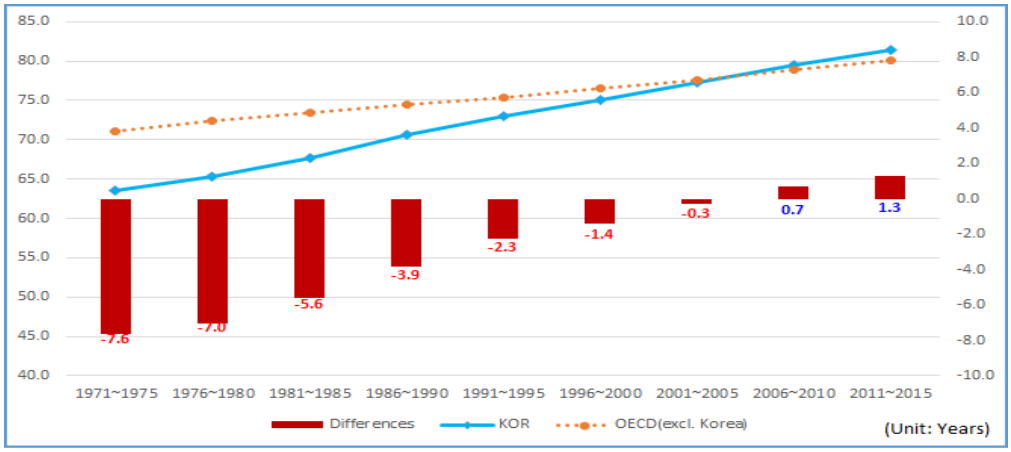
This section aims to investigate the characteristics of the healthcare system in Korea in order to understand the context of the digital healthcare sector of Korea. Hence, the characteristics of healthcare service providers and the healthcare payment system, and of an ageing population due to demographic changes in Korea are examined. Moreover, ICT infrastructure in Korea, which is essential to combine with the healthcare system for developing the digital healthcare sector, and trends in regulations and policies related to the digital healthcare sector will be explored.

4.1.1. Characteristics of Healthcare Payment System and Healthcare Service Providers

In order to understand the characteristics of Korea's digital healthcare sector, it is

necessary first to comprehend the healthcare system of Korea, which is characterised by the social health insurance system and the certain attributes of the healthcare service providers. Since a social health insurance system was first introduced in Korea in 1977, which initially covered only 8.8% of the whole population, it had rapidly expanded and achieved universal population coverage in 1989 (Son, 1998; WHO, 2015). It thus took only 12 years for the accomplishment of universal health coverage in Korea, which is a far shorter period compared with 127 years in Germany, 79 years in Austria and 36 years in Japan (Carrin, et al., 2005). Thanks to the achievement of universal health coverage, the quality of the health status in Korea has dramatically improved in terms of the average life expectancy at birth and the infant mortality rate compared with other OECD countries (see *Figure 4*.1 and *4.2*).

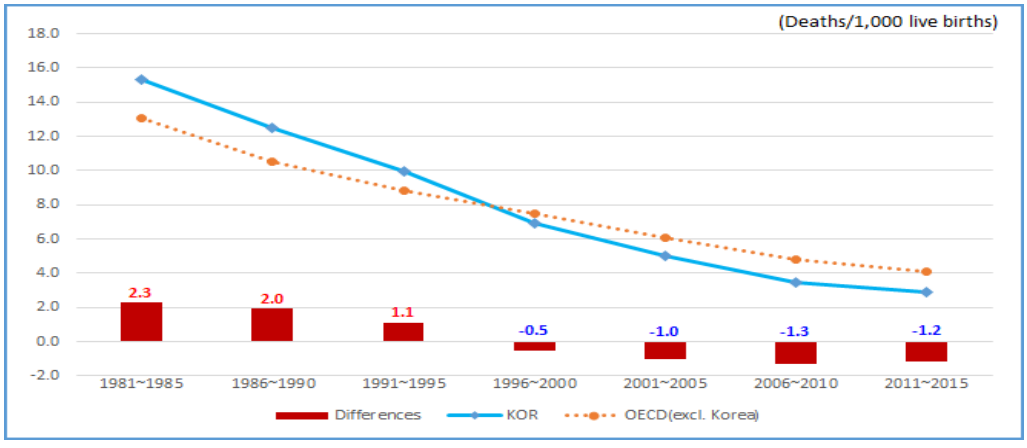
Figure 4.1 Average life expectancy between 1971 and 2015



* Y-axis to the right side gives the difference of the life expectancy between Korea and OECD countries

Source: by the author based on OECD health data (OECD, 2017)

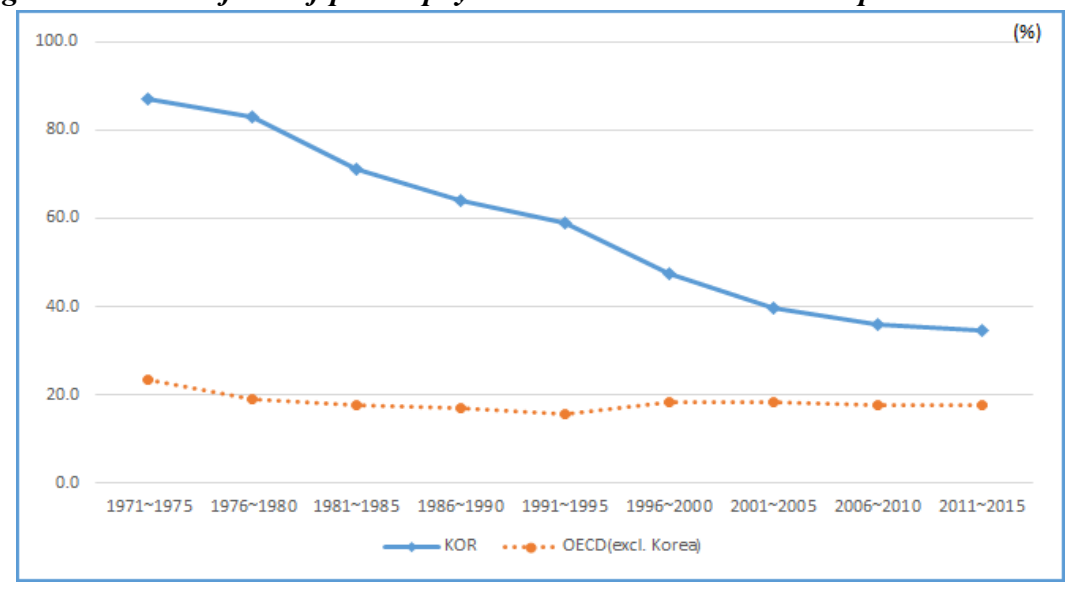
Figure 4.2 Infant mortality rate between 1981 and 2015



Source: by the author based on OECD health data (OECD, 2017)

However, this policy for achieving universal health coverage within a very short period has led to a high proportion of out-of-pocket payments on health expenses. More specifically, people in Korea are suffering from almost twice-as-high out-of-pocket payments for health expenses in comparison with people in other OECD countries, although the gap between the two groups has plummeted since the social health insurance system was introduced in Korea in 1977 (see *Figure 4.3*). In addition, this high ratio of out-of-pocket payments compared to the total health expenses may be partly due to the failure of the payment system, which is based on fee-for-service, in the social health insurance system. Under this reimbursement system, the Korean government has managed the fees for insured medical services at a low rate because the government made the expansion of health coverage as a high priority (Kwon, 2003). Hence, healthcare providers are likely to increase the volume and intensity of medical services that are not essential and they tend to charge higher service fees for uninsured healthcare services in order to achieve a greater profit margin under this reimbursement system (WHO, 2015). Indeed, uninsured medical expenses accounted for 43.3% of the total out-of-pocket payments between 2006 and 2016, although the reminder is explained by the shared responsibility payment (NHIS, 2006~2016). The number of claims for unnecessary medical treatments that are not required explains the range of between 5.3% and 6.2% over the total number of claims to the social health insurance system from 2010 to 2013 (HIRA, 2018; KPA-NEWS, 2014).

Figure 4.3 Share of out-of-pocket payments over the total health expenses



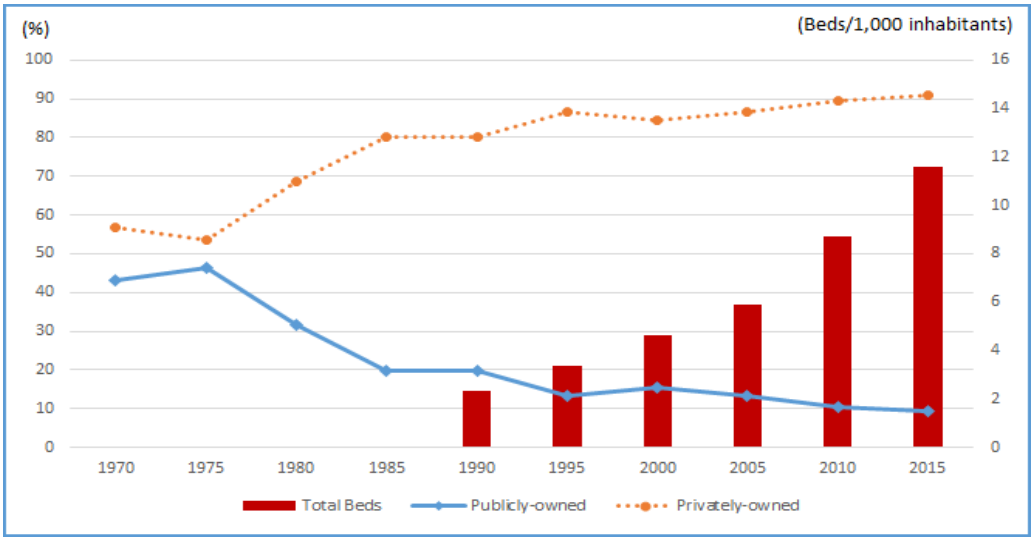
Source: by the author based on OECD health data (OECD, 2017)

The policy of pursuing universal health coverage within a short period has also led to a high level of dependency on privately owned healthcare providers in the Korean healthcare market because the government has allowed healthcare providers in the private sector[36] to cater for the increase in healthcare demands. Hence, the proportion of beds in publicly owned hospitals has rapidly declined since the introduction of the social health insurance system in 1977, and reached less than 10% in 2015 (see *Figure 4.4*), which is not comparable to other OECD countries such as Germany (40.8%), Spain (68.7%), France (62.1%), Italy (67.6%), and Greece (65.0%) (Eurostat, 2018). Moreover, 94.6% of primary healthcare-providers and 95.6% of secondary healthcare-providers are under private ownership while privately owned hospitals account for 82.0% of tertiary healthcare-providers (KOSIS, 2018a). This high level of dependency on privately owned hospitals is likely to adversely affect the universal health coverage in a real sense given that they tend to provide their services in urban areas to attract more patients rather than in remote or isolated areas such as those surrounded by mountains or islands[37]. 50% of tertiary healthcare providers (21 out of 42) are located in Seoul and Gyeonggi province, which account for only 10.8% of the Korean (South) territory (MoHW, 2017; MoLIT, 2018). This unbalanced distribution of healthcare infrastructure has given rise to substantial differences in the avoidable mortality rate by region. For instance, the largest gap was 78.2 deaths per 100,000 between the rate in the highest area (107.8 deaths per 100,000) and that in the lowest area (29.6 deaths per 100,000) in 2015 (KHIDI, 2017b). In order to resolve this problem, the Korean government may be required to invest more resources in social health insurance or in remote and isolated areas, or to improve the healthcare delivery system through the utilisation of digital health technology such as telemedicine, which can contribute to reaching out to these area by overcoming geographical barriers (Amanatidou, et al., 2014).

[36] All hospitals and clinics in Korea have to provide their services for the public under the single social health insurance scheme regardless of their ownership types.

[37] Forest land in Korea represents 64% of the total land (OECD, 2015a), and there are 3,677 islands in Korea (MoLIT, 2016).

Figure 4.4 Hospital beds by the type of ownership and the number of total beds in Korea



* Y-axis to the right side gives the total number of beds per 1,000 inhabitants in Korea
** Privately-owned hospitals comprise of not-for-profit and for-profit hospitals owned by private owners

Source: by the author based on OECD health data (OECD, 2017), Lee (2013) and Nam (2016)

4.1.2. Ageing Population and Healthcare Expense

The population in Korea is rapidly ageing, and the transition period from an aging society to an aged society (at 18 years: between 2000 and 2018) has been significantly shorter[38] than in other countries such as Japan (25 years), the UK (45 years), the US (69 years), and France (115 years) (He, et al., 2016; KOSIS, 2018b). This rapid demographic change along with the rapid implementation of the policy for achieving universal health coverage has considerably added to the burden of government health expenses because a growing elderly population tends to result in increasing chronic diseases and healthcare expenses. According to HIRA (2018), the elderly (65 or over) in Korea account for 39.0% of total healthcare expenses in 2017 although they represent only 13.4% of the population of Korea. Undoubtedly, the annual growth rate in health expenses per capita on government spending and compulsory health insurance was very high at 11.0% between 1989 and 2016 since universal health coverage was achieved, while the GDP growth rate per capita was 6.1% annually during the same period (OECD, 2017, 2018a). Thus, it may be difficult to devote more financial resources to the social healthcare insurance or to healthcare service infrastructure.

[38] An aging society is defined as one where more than 7% of the population is 65 years or older whereas a society in which more than 14% of the population is 65 years or older is considered as an aged society, according to the UN definition.

4.1.3. Features of ICT and Digitalisation Infrastructure

Korea has achieved a competitive advantage in the ICT sector compared with other OECD countries. Korea was ranked first in terms of internet accessibility among OECD countries between 2005 and 2017 (OECD, 2018c), and Korea has been in second place for the amount of ICT goods exports among the same peer group from 2009 to 2012[39], which accounts for 13.7% of total ICT goods exports for 34 OECD countries (OECD, 2018b). In addition, Korea was placed first in the world on the ICT Development Index in both 2015 and 2016, the index released by the International Telecommunication Union (ITU) (ITU, 2016).

Together with these competitive advantages in the ICT sector, Korea has high penetration rates for electronic medical records (EMRs), computerized physician order entry (CPOE)[40] systems and picture archiving and communication systems (PACSs)[41], which are regarded as the main elements of the clinical information system (Choi, et al., 2010) and support the best clinical practices through allowing hospital professionals to better deal with patients (Vegoda, 1987). According to KHIDI (2017a), 91.4%, 93.8%, and 69.1% of secondary and tertiary healthcare providers have installed EMRs, CPOE, and PACSs (c.f. 99.7% of tertiary healthcare providers that have adopted PACSs), while 77%, 79.8%, and 28.0% of primary healthcare providers have adopted each of these clinical information systems, respectively.

Additionally, Korea has a competitive advantage with regard to securing public health data, namely the National Health Information Database (NHID) which includes information in terms of healthcare service utilisation (e.g. diagnosis and services received records, treatment costs, the length of stay, and prescription records), health examination records throughout the entire life-cycle from birth to death, and socio-demographic variables (e.g. personal income, property tax, family relations, residence, and the date of birth and death) for the whole population of Korea (Cheol Seong, et al., 2017). These health data are collected and managed by the National Health Insurance Service (NHIS), a single insurer of the social health insurance. The national cancer incidence data have been collected since 1999 and managed by National Cancer Centre (NCC) in Korea,

[39] Data for 2012 are up-to-date.
[40] Computerized physician order entry (CPOE) is "the process of a medical professional entering medication orders or other physician instructions electronically (Rouse, 2014)."
[41] Picture archiving and communication system (PACS) refers to "a medical imaging technology used primarily in healthcare organizations to securely capture, store, and digitally transmit electronic images" (Rouse, 2018).

which has logged more than 2.8 million cancer cases between 1999 and 2015 (NCC, 2015). The Korea Centers for Disease Control and Prevention has collected around 250,000 whole genomes via cohort studies between 2001 and 2014 (Park s., et al., 2015). Thanks to these strengths in the health information system, Korea occupied second place among of OECD member countries in the availability, maturity and use of key health datasets in 2013 (OECD, 2015b).

4.1.4. Policies and (De)Regulations in the Digital Healthcare Sector

Based on the circumstances described in the previous three sections (4.1.1, 2, and 3) including the competitive advantages in the ICT and digitalisation infrastructure, the high level of hospital digitisation, and the increasing burden of healthcare expenses and the undermining of the expectation of universal health coverage, the Korean government has introduced various policies and (de)regulations in an effort to stimulate the digital healthcare sector to address these issues. The introduction of policies and (de)regulations in Korea includes deregulations of healthcare data utilisation through applying de-identification technology and through allowing healthcare providers to store medical records in the cloud storage. There have also been many pilot studies for introducing telemedicine in diverse areas such as prisons, military sites, ocean-going vessels, islands, and deep mountain areas, and for patients suffering from chronic diseases. Additionally, the Korean government adopted a regulatory sandbox[42] in convergence industries such as artificial intelligence (AI), big data, and the internet of things (IoT)-related industries relating to the digital healthcare sector in 2018, and this regulatory sandbox allows for trials and empirical tests of new products, services and business models in the digital healthcare sector that cannot currently work under the existing regulations (see *Table 4.1*). These policies and (de)regulations have been introduced to achieve a reduction in regulatory uncertainty and to promote the digital healthcare sector, and they may contribute to reducing the burden of healthcare expenses, achieving the expectation of universal health coverage in a real sense, and increasing the quality of healthcare services. Indeed, several empirical studies show that the application of digital technology to healthcare services has had a positive impact in reducing costs of healthcare services (e.g. Buntin, et al., 2011; Park H., et al., 2015) and increasing the quality of healthcare services

[42] According to OECD (2019, p. 36), "Regulatory sandboxes provide a limited form of regulatory waiver, or flexibility for firms to test new products or business models with reduced regulatory requirements, while preserving some safeguards … which also … help identify and better respond to regulatory breaches, and enhance regulatory flexibility".

such as diminishing the rate of medication errors (e.g. Mullett, et al., 2001) along with better medication delivery (e.g. Chiarelli, et al., 1990), and promoting universal health coverage for the elderly and residents who live in remote areas (Chang, et al., 2004).

Table 4.1 Recent policies and (de)regulations related to the digital healthcare sector

Policies or Regulations	Year	Main contents
Telemedicine in prisons	2005~	Providing telemedicine services for patients in prisons
Smart healthcare program	2010 ~2013	Pilot studies of telemedicine for patients suffering from chronic diseases
Big data master plan	2012	Establishing collaborative strategies across diverse ministries for employing useful data in the public sector and for releasing them for research or commercial uses such as healthcare data
Wellness human-care platform establishment	2013	Development of the personal healthcare solution platform based on personal lifelog data for encouraging prevention and care of people who are not patients
Development of the standardized model for sharing medical data	2014 ~2015	Development of the standardized model for sharing EMR data between healthcare providers
Telemedicine for achieving universal healthcare coverage	2015~	Providing telemedicine services for patients in remote areas such as military sites, ocean-going vessels, islands, and deep mountain areas
Guidance for classifying between medical devices and general wellness devices	2015	General wellness devices that are low risk to the safety of users and other persons are excluded in the scope of medical devices, and they do not have to comply with the same regulations by the Korea FDA as medical devices
The initiative for the healthcare industry development	2016	- Platform establishment for the healthcare data sharing, integration and exploitation for promoting precision medicine[43] - Facilitating commercialisation activities of healthcare technology through the establishment of the hospital-focused collaborative ecosystem
Amendment of the enforcement rule medical service act	2016	*Healthcare data can be stored and managed via cloud storages outside healthcare providers*
Data de-identification[44] guidance for personally identifiable information	2016	The de-identified data that comply with the guidance are able to be exploited for research and commercial purposes without obtaining informed consent
Development of the healthcare information system for precision medicine	2017	- Development of the international standardised healthcare information system and its utilisation based on a cloud service - System establishment for sharing healthcare data between healthcare providers using a common data model (CDM)
Innovation strategy and investment for fostering new growth engines	2018	Data, Artificial Intelligence (AI), and Bio-health-related industries are selected as strategic investment sectors

[43] Precision medicine refers to "an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment, and lifestyle for each person" (NIH, 2018b).

[44] According to (Nelson, 2015), de-identification of data refers to "the process of removing or obscuring any personally identifiable information from individual records in a way that minimizes the risk of unintended disclosure of the identity of individuals and information about them", and anonymization of data refers to "the process of data de-identification that produces data where individual records cannot be linked back to an original as they do not include the required translation variables to do so."

Policies or Regulations	Year	Main contents
Amendment of the industrial convergence promotion act	2018	***Introduction of a regulatory sandbox*** for promoting convergence industries such as artificial intelligence (AI), big data, and the internet of things (IoT)-related industries

Source: author's elaboration based on KIET (2017)

4.1.5. Barriers and the Importance of Collaboration in the Digital Healthcare Sector

As described above, Korea has competitive advantages in ICT infrastructure, the level of hospital digitalisation, and the volume of digitalised healthcare data in the public sector. In addition, the Korean government has introduced many policies and (de)regulations to promote the digital healthcare sector (see *Table 4.1*). However, there are still many socio-economic and technical issues to overcome in order to promote the digital healthcare sector. First, the main problem of healthcare data in the public and private sector is that the data are fragmented within different locations and management systems, and they need to be standardised and integrated for sharing effectively and to be used economically (Lee, et al., 2018). The reason is that public and private organisations in the healthcare sector collect and store data for their own purposes. For instance, the NHIS collects and stores required information as a single insurer in the social health insurance system in Korea for paying costs based on the billing records of healthcare providers. Privately owned healthcare providers account for 94.6% of total healthcare providers in Korea in 2018 (KOSIS, 2018a), and are more likely to be reluctant to share their data without proper incentives because the data are considered to be a strategic resource in the digital healthcare industry. In addition, the utilisation of healthcare data for commercial purposes was banned by governmental regulations until 2016 (see *Table 4.1*). Thus, the survey conducted by OECD (2015b) shows that the degree of accessibility to both de-identified public healthcare data by healthcare providers and for-profit companies was 0% in 2013 while it was 77.4% and 59.1% in peer countries, respectively. Second, de-identification does not guarantee complete anonymity and cannot be solely sufficient for protecting personal information because de-identification data can be re-identified merging with additional data in the technical perspective (Cavoukian, et al., 2011). Lastly, the introduction of the healthcare information system to healthcare providers can become an effective and efficient way in the healthcare sector in terms of reducing healthcare expenses, intensifying universal health coverage, and facilitating the quality of healthcare services. However, it is not clear 'who pays for' and 'who benefits from' the implementation of the digital healthcare service (Shekelle, et al., 2006), and this issue may lead to conflicts of interest among healthcare providers, the government, the insurer,

and patients.

In order to address these socio-economic and technical issues and to promote the digital healthcare industry in Korea, the optimal utilisation of healthcare data is essential. The optimal utilisation of healthcare data is based on effective sharing and integrating the data through collaboration among different public and private organisations such as firms, hospitals, universities, and PRIs. Specifically, firms in the digital healthcare sector have to collaborate with healthcare providers to secure healthcare data, and they tend to collaborate with PRIs in order to access healthcare data in PRIs and to obtain knowledge and information on policies and regulations associated with the digital healthcare industry. Collaboration with universities is also likely to be beneficial in the development of digital healthcare technologies such as de-identification and standardisation technologies, and the development of common data models (CDMs)[45]. In addition, stakeholders such as healthcare providers, firms and patients in the digital healthcare sector are required to collaborate closely with the government including PRIs in order to address the 'who pays for' issue. Thus, inter-organisational collaboration among different stakeholders potentially plays a crucial role in addressing socio-economic and technical issues to be overcome in order to relieve the burden of healthcare expenses, strengthen the expectation of universal healthcare coverage, and promote the digital healthcare sector.

4.2. General Characteristics of the Main Actors: Firms, Universities, PRIs, and Hospitals

This section examines the general characteristics of each main actor in the innovation system in the digital healthcare sector. They are firms, universities, PRIs, and hospitals. Hence, this examination will be helpful to understand distinguishing characteristics of the four main actors and attributes of the environment embracing the actors. Thus, this section will shed light on the importance of establishing collaboration based on the actors' own characteristics, and the environment for them.

4.2.1. Firms

In order to explore the general characteristics of firms, the scope of firms is defined in terms of being a member of one of the digital healthcare-related associations registered with government ministries and also having participated in one or more public R&D

[45] CDM refers to translating the data from different data models to a common data model, allowing users to employ healthcare data from a wide variety of sources. Thus, it can support collaborative research across data sources for large-scale systematic analysis (OHDSI, 2018; Overhage, et al., 2011).

projects in the digital healthcare sector between 2012 and 2015. These associations are the Korea Digital Health Industry Association, the Korea Digital Hospital Export Agency, and the Korea Smart Healthcare Association. There are 81 firms included in the three associations and 49 firms were involved in public R&D projects as firms in the digital healthcare sector, excluding those that have been closed or duplicate firms. Detailed information on the firms such as turnover between 2014 and 2017, the number of employees in 2017, the year of establishment, and the area of their economic activity has been collected based on MSS (2018) and Saramin (2018). The area of economic activity of the firms is later classified in terms of the Korean Standard Industrial Classification (KSIC), and the firms are categorised into micro, small, medium, or large-sized enterprises by their business sizes based on established EU criteria (EC, 2016).

According to the data, 32.3% of the firms have less than ten years of business experience in the digital healthcare sector and 74.6% of them have less than 20 years of business experience in the sector. From this, it may be inferred that many of the firms in the digital healthcare sector consist of new start-ups or of those established by existing companies in order to expand their business scope. In this regard, the proportion of small (including micro) and medium-sized enterprises (SMEs) in the Korean digital healthcare sector is 82.3% in terms of both the number of employees and the size of annual turnover (see *Table 4.2*). In particular, micro and small companies account for relatively high ratios which are 49.2% or 56.5% according to the same criteria[46].

Table 4.2 Classification of firms in the Korea digital healthcare sector by business sizes

Categories	Criteria		No. of employees		Annual turnover	
	No. of employees	Annual turnover	No. of Firms	%	No. of Firms*	%
[Micro]	< 10	< € 2M	[12]	[9.2]	[32]	[25.8]
Small	< 50	< € 10M	64	49.2	70	56.5
Medium-sized	50 ≤ & < 250	€ 10M ≤ & < € 50M	43	33.1	32	25.8
Large	250 ≤	€ 50M ≤	23	17.7	22	17.7
Total	-	-	130	100.0	124	100.0

* The turnover information on six firms cannot be collected, although they are all small-sized firms in the light of the number of employees.

[46] Similarly, the ratio of SMEs in the digital healthcare sector of Korea accounts for 87.1% (including 42.7% of small-sized enterprises) by the criteria of the Korean government based on 'Enforcement Decree of the Framework Act on Small and Medium Enterprises (17. 10. 2017).'

Source: author's elaboration

When it comes to the area of economic activity of the firms in the digital healthcare sector of Korea, 87.6% of them are running their business based in both the ICT and manufacturing sectors, followed by the wholesale and retail trade sector (7.7%). More specifically, the medical device-related manufacturing sub-sector represents 38.5% of the firms, followed by the software-related publishing sub-sector in the ICT sector with 26.2% (see *Table 4.3*). The firms in the digital healthcare sector show that the main players for promoting the digital healthcare sector are based in the service and manufacturing sectors engaging in ICT and in the manufacturing sector involving healthcare technologies. In other words, collaboration or integration of firms within these sub-sectors could play a significant role in promoting the digital healthcare sector of Korea.

Table 4.3 Standard industrial classification for the firms in the digital healthcare sector

Sectors	No. of Firms	Ratios (%)	Sub-sectors	No. of Firms	Ratios (%)
Business facilities management and business support services; rental and leasing activities	1	0.8	Business support services	1	0.8
Information and communication (ICT)	44	33.8	Computer programming, consultancy and related activities	2	1.5
			Information service activities	6	4.6
			Postal activities and telecommunications	2	1.5
			Publishing activities (including software publishing)	34	26.2
Manufacturing	70	53.8	Manufacture of electrical equipment	1	0.8
			Manufacture of electronic components, computer; visual, sounding and communication equipment	8	6.2
			Manufacture of food products	1	0.8
			Manufacture of medical, precision and optical instruments, watches and clocks	50	38.5
			Manufacture of other machinery and equipment	4	3.1
			Manufacture of pharmaceuticals, medicinal chemical and botanical products	5	3.8
			Other manufacturing	1	0.8
Professional, scientific and technical activities	5	3.8	Architectural, engineering and other scientific technical services	2	1.5
			Other professional, scientific and technical services	1	0.8
			Professional services	1	0.8
			Research and development	1	0.8
Wholesale and retail trade	10	7.7	Retail trade, except motor vehicles and motorcycles	1	0.8

Sectors	No. of Firms	Ratios (%)	Sub-sectors	No. of Firms	Ratios (%)
			Wholesale trade on own account or on a fee or contract basis	9	6.9
Total	130	100.0	-	130	100.0

Source: author's elaboration

To sum up, far more than half of firms in the Korean digital healthcare sector are small-sized firms, and particularly more than 25% of a total of firms were identified as micro-sized firms in terms of annual turnover (see *Table 4.2*). Moreover, only around 40% of all firms in the Korean digital healthcare sector are based on the healthcare-related business. For instance, 38.5% of them are in the industrial sector of 'manufacture of medical, precision and optical instruments, watches and clocks', and just 3.8% of them are classified in the industrial sector of 'manufacture of pharmaceuticals, medicinal chemical and botanical products' (see *Table 4.3*). Therefore, firms in the Korean digital healthcare sector would tend to establish collaboration so as to obtain complementary resources or capabilities from collaborating partners. This is because the majority of them are not based on healthcare-related business, and the majority of them are small-sized firms, suffering from a lack of financial and strategic resources, or do not have any business experience in the healthcare-related sector.

4.2.2. Universities

Korean universities have dramatically grown in number, with the number of four-year universities rising from 96 in 1980 to 188 in 1999 and the total number of the universities reached 202 in 2005 (KESS, 2018b). This growth has taken place alongside economic growth over the same period in Korea (the average annual GDP growth rate was 7.95% over the period, (BOK, 2018)). Until the 1990s, the role of Korean universities in the national innovation system of Korea tended to be limited to being a supplier of employees who have some adsorptive capability. They were likely to focus on teaching undergraduate students rather than actively taking part in research and development for knowledge creation. Instead, the role of knowledge production and dissemination was covered by public research institutes until the 1980s, although large-scale companies have dominated and continued to dominate the role of knowledge production through developing technological competencies based on in-house R&D in the 1990s (Han, 2012).

Korean universities have also greatly increased the number of their students and tuition fees since the government introduced de-regulation that removed the cap on the number

of enrolled students in 1994, and a de-regulatory policy in Korean higher education whereby privately owned universities[47] were given the authority in 1989 to decide their own fees with no government intervention[48]. Hence, the number of students at conventional four-year universities rapidly increased from 1,150,788 in 1994, reaching over 2 million (2,023,546) in 2003. The average annual growth rate in the university fees between 1990 and 2008 (excluding the years of 1998 and 1999 in order to avoid any effect due to the Asian financial crisis) was 8.5% in national and public universities and 9.9% in private universities[49], while the average annual growth rate of the retail price index was only 4.6% during the same period (KESS, 2018d; KHEI, 2013). Meanwhile, the growing number and size of universities is leading to an increase in the level of competition in the higher education market, given that the number of high school graduates will continue to fall from 648,468 in 2011 to 472,702 in 2021 on account of a continuing reduction in the birth rate[50] (KESS, 2018a; Park, 2009). In addition, the notion of competition has spread in academia since the Korean government introduced 'A restructuring plan for national universities' as part of the plan for public sector restructuring under the IMF bailout program in 1998. Yet, Korean universities have confronted real challenges when the government introduced a plan for a reduction in the number of undergraduate entrants by around 160,000 between 2014 and 2022 (Jang, et al., 2017), and the amendment of the 'Higher Education Act' in terms of university fees in 2010, which limited the growth rate of fees to 150% of the growth rate of the retail price index in the aftermath of the great recession in 2008. The Korean government also started to utilise a national scholarship scheme as an incentive to restrain raising the fees in 2012. As a consequence, the average annual growth rates of national/public and private university fees were maintained, which are minus 0.14% and 0.02% below the average annual growth rate of the retail price index (1.19%) between 2010 and 2017 (KHEI, 2013). Through experiences such as the IMF bailout program and the transition to a competitive environment in academia, the Korean government and universities recognized that products based on low labour costs are no longer competitive, and sustainable competitive advantages in the global market are likely to be secured by focusing more on research capabilities and on technological innovation

[47] The number of private universities accounted for 70.4% of total universities in 1989 (KESS, 2018c).
[48] After nationwide democratic movements against the military regime in 1987, Korean people finally achieved their freedom and democratic society in a real sense. Thus, the notion of autonomy became more important than ever at that time.
[49] Private universities accounted for 82.6% of the total number of conventional four-year universities in Korea in 2017 (KESS, 2018c).
[50] The fertility rate was 1.656 in 1994, 1.191 in 2003, and reached 1.052 in 2017 (KOSIS, 2018c).

(Shin, et al., 2015). Thus, the Korean government has invested a substantial budget in universities in order to exploit them as a main actor for technological innovation as well as to encourage them to evolve into research-oriented universities by offering competitive R&D grants (e.g. Brain Korea 21 program - £2.16 billion/1999~2012; World Class University program- £0.53 billion/2008~2012; and Brain Korea 21 Plus program – est. £1.31 billion/2013~2020).[51] Moreover, the government introduced the 'Technology Transfer and Commercialization Promotion Act' in 2002 and the 'The Promotion of Industrial Education and Industry-Academic Cooperation Act' in 2003 in order to facilitate cooperation between universities and firms. These policies in the competitive environment gave rise to the rapid establishment of the University and Industry Cooperation Centre, the role of which is to stimulate collaboration between universities and industrial partners, in 74.4% of four-year universities by 2009 and it reached 77.7% of four-year universities by 2016 (NRF, et al., 2012, 2017). Increased competition for funding due to the stagnation of incomes from university fees and the growing number of competitors have led universities to look more closely for new sources of funding such as government research grants or funding opportunities from collaboration with industrial partners, and for a way to develop their research capabilities in order to attain competitive advantages. In this regard, the number of research-oriented universities and of entrepreneurial universities sharply increased from 13 to 31, and from 9 to 24, respectively, out of a total of 115 conventional four-year universities in Korea[52] over the period from 2006 to 2010 (Han, 2012).

In particular, the number of departments involved in the digital healthcare sector, namely departments of medical treatment engineering, and the number of enrolled undergraduate, masters, and doctoral students in departments of Korean universities have risen considerably between 2011 and 2017, although the total number of departments, and the total number of enrolled undergraduate, masters, and doctoral students have either declined or stagnated over the same period (see *Table 4.4*). This trend may imply that the digital healthcare sector is regarded as a prospective area for achieving economic growth as well as for meeting social demands in upcoming years, and the Korean government has been likely to invest more resources in this sector and universities have

[51] The average currency exchange rate in 2017 (£1 = ₩1,455.1) has been applied for the conversion from Korean won to GBP.

[52] Ten teachers' universities, 11 industrial universities, 17 online universities, 17 religious universities, 2 universities which do not have a postgraduate program, and universities which had not submitted data are excluded.

correspondingly given more attention to cultivating human resources in this sector in order to secure research capabilities and to exploit them to obtain more funding.

Table 4.4 Comparison of the growing rates of the number of departments and students in the medical treatment engineering sector and in total between 2011 and 2017

Department	The number of departments			The number of enrolled students		
	Undergraduate	Masters	Doctoral	Undergraduate	Masters	Doctoral
Medical treatment engineering	7.4%	5.6%	9.2%	8.0%	12.5%	11.2%
Departments in total	1.4%	0.7%	2.2%	0.3%	-1.3%	3.6%

Source: author's elaboration based on KESS (2018d)

To summarize, private universities account for 82.6% of total number of conventional four-year universities in Korea in 2017. However, they have faced challenges owing to the government plan for a reduction in the number of undergraduate entrants and to a new regulation to limit the growth rate of fees, as noted above. Thus, these polices seem to have driven Korean universities pursuing research funding through the development of their own specialised capabilities or the creation of potential and promising research areas such as the digital healthcare sector. As a consequence, collaboration between different organisations and research areas is becoming more essential for Korean universities in these environmental conditions.

4.2.3. Public research institutes (PRIs)

There are various public research entities differing in their roles and governance that are engaged in developing research capabilities and stimulating innovation in the Korean economy. Their mission (role) and governance have a critical impact on the functions of PRIs, which include conducting fundamental research or more market-oriented projects, focusing on technological knowledge dissemination, providing R&D infrastructure or the support of public policy (OECD, 2011). Here, the general characteristics of PRIs, which are mainly based on 19 institutes regulated by 'Act on the establishment, operation, and fostering government-funded science and technology research institutes in the field of science and technology', will be examined in the light of their roles in the national innovation system of Korea.

Since the first PRI, the Korea Institute of Science and Technology (KIST), was established in Korea in 1966, the number of PRIs rapidly increased during the 1970s.

During this period, ten more PRIs in diverse sectors such as energy, nuclear, machinery, chemistry, electricity, ICT, geoscience, astronomy, scientific and technical standard, and science and technology information, were established. Their main role until this period was providing technological support to Korean firms, primarily in heavy and chemical industries according to a government plan for economic development. This support was provided by PRIs through adopting, imitating, and refining advanced technologies from developed countries (MSIT, 2017a). Indeed, Korean companies should have improved their research capabilities in exploring and exploiting technological knowledge through generally learning from external sources. The reason is that there were only 47 researchers with a doctorate degree in firms while there were 534 PhD holders in the PRIs, and 56.4% of total national R&D funding was invested in PRIs while the spending by firms accounted for 34.1% of total R&D funding in 1979 (MoST, 1980; NTIS, 2018b). This important role of PRIs as national R&D centres contributed to the unprecedented economic growth of Korea (Eom, et al., 2010). However, over the 1980s and 1990s, PRIs tended to become more bureaucratised with strong government interventions which focused on efficient administrative management rather than on research autonomy and support. Even the number of researchers, their salaries, and the internal management system of PRIs have been subject to intervention by government ministries during this period (MSIT, 2017a). In addition, eight more PRIs, for instance, institutes involving construction, food, railway & train, manufacturing, bio and space technologies, were established by various ministries from the 1980s to the mid-1990s, although the governance of the rest of the PRIs was unified under a single ministry, the Ministry of Science and Technology in 1981. This trend that each ministry has increasingly intervened in their relevant PRIs, may lead PRIs to depend heavily on their relevant ministries with authority over the R&D funding distributions. Thus, conflicts of interest in terms of the emerging sectors and inter-/multi-disciplinary areas between different ministries (e.g. Ministry of Science and Technology, Ministry of Industry, Ministry of Education, and Ministry of Health and Welfare) tended to give rise to excessive competition between PRIs rather than collaborating with each other.

The role of PRIs in Korea as a supporter of firms had become very clear in the national innovation system by the 1980s, but the role has become more vague as the firms have developed their own research capabilities from the 1990s onwards. The number of research divisions in the firms was 46 in 1979, around 1,000 in 1990, and reached over

7,000 in 2000 (e-Index, 2018; Lee, 2016) [53], and the number of PhD holders in firms grew dramatically from 467 in 1987 to 6,932 in 2001, which was larger than the number of researchers holding a doctorate degree in PRIs (5,881) in 2001 (MoST, 1988, 2002). Moreover, the development of research capabilities at universities from the 1990s has led to growing competition in securing research funding from government and from the private sector. In particular, the competition in order to secure more research funding strengthened after the government introduced a 'project-based funding system' to PRIs in 1996. Under this project-based funding system, the government provides directly to PRIs around 20~30% of payroll costs and the cost of the operating institutes, and PRIs are required to win competitive research projects in order to secure at least the remainder of the budget that they need. As a consequence, the ratio of R&D spending by PRIs out of total national R&D expenditure dropped from 21.3% in 1992 to 13.8% in 2003 and remained at around 13% in 2016, whereas the ratio of R&D spending by universities and by firms has grown by 4% and 3.4%, respectively, between 1992 and 2003 (NTIS, 2018b). Moreover, this project-based funding system unintendedly gave rise to increasing ambiguity in PRIs' roles because both researchers and PRIs were more likely to be forced to rely on external funding sources and to focus on short-term outputs that are less relevant to their roles. Consequently, the government has needed to set more articulated roles of PRIs with less intervention from different government ministries. Thus, government classified PRIs by their missions into three research groups, and put them in under three research councils (i.e. the council of basic science, industrial technology, and science & technology for public infrastructure), and the three councils were transferred to come under the Prime Minister, according to 'Act on the establishment, operation and fostering of government-funded research institutions' in 1999.

However, authority over R&D funding distribution was not given to the research councils, and instead was left in the hands of government ministries (MSIT, 2017a). Hence, the functions and role of the research councils were very limited and still rather vague in these circumstances, although the government has tried to transform the governance structure of the research councils in order to articulate PRIs' role in the national innovation system. In the end, the research councils were unified in 2014 to a single council, namely the National Research Council of Science and Technology (NST) in order to overcome the low level of collaboration between PRIs after the three research councils merged into two

[53] The number of research divisions in firms was 39,313 in 2017.

(i.e. the councils of basic science and industrial technology) in 2008 (NARS, 2014). This may be explained by the fact that the government views the weak level of collaborative activities among PRIs as arising from their different governance systems. Furthermore, the national R&D policy of Korea has shifted from a 'catch-up (or fast-follower)' to a more 'creative (or first-mover)' mode of development since the early 2010s (Keenan, 2012), and demands to address social issues utilising R&D activities have increased as well (MSIT, 2017a)[54]. In order to attain a more creative mode of development and to deal with complicated social issues, collaboration between PRIs and other players such as universities, firms and hospitals may play a pivotal role because collaboration among diverse participants often enhances idea quality that contributes to effective implementation of the idea and hence to better outcomes (Blohm, et al., 2010). Therefore, the Korean government has encouraged PRIs to collaborate with each other and to collaborate with other organisational type in the innovation system. Simultaneously, the government is making an effort to mandate a new role of PRIs as R&D centres for small and medium-sized enterprises (SMEs) (NSTC, 2014, 2015). Given that the digital healthcare sector in Korea is an infant or emerging industry, and PRIs including national research institutes still accounted for around 48% ~ 50% of government R&D funding between 2014 and 2017, the policies for encouraging collaboration and for becoming R&D centres for SMEs could contribute positively to the vast number of SMEs in this sector.

4.2.4. Hospitals

Healthcare services and healthcare service providers in Korea are generally regarded as public goods, and thus healthcare service providers tend to pay far more attention to achieving universal health coverage than to obtaining financial benefits, although 94.6% of them are under private ownership in Korea in 2018 (KOSIS, 2018a). However, this notion has weakened since the Korean government started to consider it as less of 'a healthcare sector (a public good)' and more as 'a healthcare industry (a commercial good)' following the establishment of the Presidential Commission on Healthcare Industry Innovation in 2005. This policy was part of the national development strategy that puts more emphasis on service industries (including the healthcare industry) than

[54] At the same time, Korean PRIs expanded their role into higher education in the middle of losing their clear role in the national innovation system, and the Korean government wanted to utilise well-established public resources such as research facilities and human resources in the PRIs in order to cultivate young researchers without any additional investment in the Korean education system (Han, 2012).

manufacturing industries because the Korean government has learned a lesson, namely, the need for industrial development in diverse sectors such as services industries and knowledge-intensive industries rather than focusing solely on manufacturing industries when it comes to dealing with the emergence of China in manufacturing industries, after experiencing the Asian financial crisis in 1997. In addition, lowering trade barriers in service industries has been negotiated as part of the Doha Development Agenda (DDA) under the World Trade Organisation (WTO) regime since 2001 (Park, 2003). Thus, the government needed to develop appropriate strategies for promoting service industries, and the strategy for facilitating a healthcare industry together with the pharmaceutical, medical device, and digital healthcare industries was introduced by the Presidential Commission on Healthcare Industry Innovation in 2006 (CHII, 2006). In this strategy, the role of healthcare service providers was considered as absolutely essential in establishing medical clusters collaborating with bio-tech/pharmaceutical /medical device companies, universities, and research institutes, and in conducting translational research[55] in order to facilitate healthcare industry development. As a result, the role of healthcare service providers has become increasingly important in the national R&D system, even though they are not still regarded as one of the main actors in the system like a university, PRI or firm.[56] In order to develop the healthcare industry through taking advantage of the distinctive features of hospitals such as utilising their patient population as a living laboratory and addressing the broad innovation process across the various stages of discovery, development, verification, and implementation, government began investing R&D funding in the establishment of medical clusters and in translational research in 2006 (Lee, 2008).

However, there have been several limitations in the R&D programs. For the medical cluster establishment program, which was later changed to the R&D program for the establishment of research-based hospitals in 2009, the government has made far less investment than the actual investment plan specified (only 29.2% of the actual investment plan) between 2012 and 2017[57] (KDI, 2013; NTIS, 2018a). In addition, the R&D funding

[55] Translational research refers to "the process of taking the findings from basic (bench-to-bedside) or clinical (bedside-to-bench) research and using them bi-directionally to produce innovation in healthcare settings." Hence, investigations made in the laboratory (at the bench) may lead to a better understanding of the disease and clinical practice in clinical settings (at the bedside). At the same time, clinical research may provide insights and information which can be feed back into the laboratory (Cooksey, 2006, p. 15; Iyngkaran, et al., 2015).

[56] Only these three organisational types are classified in the national R&D statistics used for the development of R&D policies.

[57] In 2011, government had a plan to invest £673.3 million for the establishment of medical clusters between 2012 and

has been distributed to eight different hospitals out of ten research-based hospitals,[58] and researchers in the research-based hospitals have identified the issue of low levels of government R&D investment as the top priority to be resolved for achieving the aims of the program in a survey (KISTEP, 2017). For the translational research program, a majority of the research projects have been conducted based on a single institute and on basic (bench-side) research (KISTEP, 2009), although government R&D funding has actually been invested in translational research programs in order to exploit the distinctive characteristics of hospitals, namely performing multiple roles such as the hub at a key intersection or a core actor in both bedside-to-bench and bench-to-bedside research of the healthcare system. Hence, the government reformed this R&D program in 2013, focusing more on collaborating with different organisations and on addressing applied (bedside) research (MoHW, 2014).

In spite of these limitations, healthcare service providers have played an increasingly important role in the healthcare industry. Thus, the number of approved clinical trials for drugs has risen from 282 in 2007 to 1,023 in 2015, and the number for medical devices has also increased sharply from 13 in 2007 to 141 in 2016 (MFDS, 2018). The number of patent applications by research-based hospitals has grown rapidly by 84.8% between 2013 and 2017, and the number of start-up companies linked to research-based hospitals has increased from one firm in 2013 to 47 firms in 2017 (KHIDI, 2018). Moreover, the government released a plan for establishing an 'Industry and Research-based hospitals Cooperation Centre (IRCC)' which can possess its own intellectual property (IP) holding companies in 2018 (MoHW, et al., 2018). This implies that the research-based hospitals (non-profit organisations) can establish a firm internally via the IRCC, and the firm is then able to invest in other firms or technologies as well as to attract investment from external entities. Through the policies described above, the government seems to have an expectation that hospitals will become a main actor in healthcare R&D and a core hub in medical clusters where diverse actors take part in developing healthcare innovation. However, hospitals in Korea do not have enough experience in research and development because the Korean government just perceived them as one of the main actors in the

2024 but government has so far invested only £ 98.3 million between 2012 and 2017 (KDI, 2013).

[58] The Korean government designated ten research-based hospitals in 2013, which are Seoul National University Hospital, Yonsei University Severance Hospital, Samsung Seoul Hospital, Asan Medical Centre, Gachon University Gil Medical Centre, Korea University Anam Hospital, Korea University Guro Hospital, Kyungpook National University Hospital, Ajou University Hospital, and CHA Bundang Medical Centre, and only the research-based hospitals are qualified to apply to the R&D program.

national innovation system, rather than a healthcare service provider. Thus, there are likely to be considerable gaps to fill in transforming research-oriented hospitals in that they may be suffering from a shortage of absorptive capabilities in digital healthcare research and in research management as well.

4.3. Conclusion

This chapter aims to understand the contextual characteristics of the Korean digital healthcare section. In order to identify the contextual characteristics, this chapter contains two parts.

The first part focuses on the important role of the digital healthcare sector and of collaboration in this sector of Korea in dealing with the burden of healthcare expenditure and the expectation of universal healthcare coverage. This part also shed light on diverse barriers to be resolved in order to achieve innovation in this context of the Korean digital healthcare sector such as fragmented healthcare data, incomplete de-identification technology, and an unclearly defined issue in terms of 'who pays for' and 'who benefits from' the implementation of the digital healthcare service.

In the second part of this chapter, the characteristics of the main actors in the innovation system in the Korean digital healthcare sector such as a firm, university, PRI, and hospital were explored to illuminate the important role of inter-organisational collaboration in the Korean digital healthcare sector by considering the actors' own characteristics and the environment embracing them.

The following chapter will discuss what are strategic motives influencing the establishment of inter-organisational collaboration in public R&D projects of the Korean digital healthcare sector by analysing both quantitative and qualitative data collected through a survey, desk-based research and interviews in order to address the first research question in this thesis. Additionally, the request for proposals (RFPs) will be used to provide institutional influences of the national R&D system that affect the motives in establishing inter-organisational collaboration.

Chapter 5. Characteristics of Strategic Motives in Establishing Collaboration

This chapter aims to address the first research question, what strategic motives influence the establishment of inter-organisational collaboration in public R&D projects in the Korean digital healthcare sector. In order to deal with this question, both quantitative and qualitative data collected through a survey and interviews were analysed, and they are employed for the cross-validation concerning what strategic motives affect the establishment of inter-organisational collaboration in public R&D projects. The quantitative data collected by a survey show how much specific motives based on the three theoretical approaches, namely, the NIS, TCE, and the RBV, influence the establishment of the collaboration. Later, it will be revealed which specific motives and which theoretical approaches linking to the motives are most influential on the establishment of the collaboration through comparing the means of each motive as measured on a seven-point Likert scale. This finding will also be validated with qualitative data collected through open-ended interview questions about the motives involved in establishing the collaboration. In addition, an analysis of variance (ANOVA) test is conducted to compare the three theoretical groups involving the motives, and this indicates which theoretical approach is more influential among three theoretical perspectives in establishing collaboration. Additionally, the findings from analysing qualitative data on the RFPs will be used to provide additional coverage of the motives relating to the institutional influences of the national R&D system. The RFPs will be analysed in the light of factors that might affect the establishment of collaboration, such as any words related to compelling or facilitating the establishment of the collaboration. This chapter begins with the general characteristics of R&D projects collected for analysis in this thesis.

5.1. General Characteristics of the Selected R&D Projects

Prior to conducting the analysis for addressing the research questions, the general characteristics of selected R&D projects will be illustrated to provide background information on the projects in the digital healthcare sector. These general characteristics of selected R&D projects will be identified from the perspective of funding size, funding source, focal organisation's type, organisational type of collaborating partners, and research stage based on technology readiness. As noted in chapter 3, there are 207 public R&D projects involving 484 collaborating partners, collected for the analysis from the

national R&D information service, in the digital healthcare sector between 2012 and 2015. First of all, the selected R&D projects of different funding sizes are classified by the focal organisation's type. According to this analysis, hospitals and universities were more likely to focus on projects with a low level of funding, given that R&D projects with less than £100,000 research funding account for 30.0% and 47.5% of the R&D projects led by hospitals and universities, respectively, although only 18.8% of all selected R&D projects are less than £100,000 research funding, as illustrated in *Table 5.1*. In contrast, PRIs tended to conduct R&D projects with more substantial research funding in that R&D projects with between £700,000 and £1,000,000 and with over £1,000,000 led by PRIs account for 20.8% and 16.7%, respectively, although only 7.7% of the total selected R&D projects are between £700,000 and £1,000,000, and R&D projects with over £1,000,000 account for 11.1% (see *Table 5.1*). Moreover, no firm conducted R&D projects with annual funding less than £100,000. Firms are likely to focus on medium-size R&D projects, given that the number of R&D projects led by firms in the range between £200,000 and £700,000 accounts for 52.1%, while the proportion of that in total is only 37.5% (see *Table 5.1*).

Table 5.1 The funding sizes of R&D projects by focal organisation's types

Annual funding bands (£)	The ratio of the R&D projects by focal organisation's types				
	Firms	Universities	PRIs	Hospitals	Total
< 100,000	**0.0% (0)**	**47.5% (28)**	4.2% (1)	**30.0% (9)**	18.4% (38)
100,000 ~ 200,000	27.7% (26)	22.0% (13)	12.5% (3)	33.3% (10)	25.1% (52)
200,000 ~ 400,000	**31.9% (30)**	11.9% (7)	29.2% (7)	20.0% (6)	24.2% (50)
400,000 ~ 700,000	**20.2% (19)**	6.8% (4)	16.7% (4)	3.3% (1)	13.5% (28)
700,000 ~ 1,000,000	9.6% (9)	0.0% (0)	**20.8% (5)**	6.7% (2)	7.7% (16)
1,000,000 ≤	10.6% (10)	11.9% (7)	**16.7% (4)**	6.7% (2)	11.1% (23)
Total	100.0% (94)	100.0% (59)	100.0% (24)	100.0% (30)	100.0% (207)

Source: author's elaboration

When it comes to funding sources, the funding size of most projects funded by MoHW (90.3%) and MSS (81.2%) is less than £200,000, whereas MSIT and MoTIE were more likely to invest in the size of R&D projects with over £200,000, which account for 87.1% and 76.7%, respectively (see *Table 5.2*). Furthermore, the MoTIE has played a dominant role in R&D projects in the digital healthcare sector between 2012 and 2015, and 41.5% of the total R&D projects were funded by this ministry. More specifically, 55.3%, 43.3%, and 41.7% of R&D projects were, respectively, led by firms, hospitals, and PRIs, and they received the most support from the MoTIE research programs, although the MoHW

invested the most into R&D projects led by universities (42.4%) (see *Table 5.3*). In addition, all ministries invested most in the 'development' research phase in the digital healthcare sector, which accounts for 69.6% of selected R&D projects in total. Particularly, the MSS spent all of their R&D funding in the digital healthcare sector on the 'development' research phase (see *Table 5.4*).

Table 5.2 The funding sizes of R&D projects by funding sources

Annual funding bands (£)	The ratio of the R&D projects by funding sources					
	MSIT	MoHW	MoTIE	MSS	Others	Total
< 100,000	2.6% (1)	**48.8% (20)**	9.3% (8)	**28.1% (9)**	0.0% (0)	18.4% (38)
100,000 ~ 200,000	10.3% (4)	**41.5% (17)**	14.0% (12)	**53.1% (17)**	22.2% (2)	25.1% (52)
200,000 ~ 400,000	**23.1% (9)**	4.9% (2)	**32.6% (28)**	18.8% (6)	55.6% (5)	24.2% (50)
400,000 ~ 700,000	**20.5% (8)**	2.4% (1)	**19.8% (17)**	0.0% (0)	22.2% (2)	13.5% (28)
700,000 ~ 1,000,000	**17.9% (7)**	2.4% (1)	**9.3% (8)**	0.0% (0)	0.0% (0)	7.7% (16)
1,000,000 ≤	**25.6% (10)**	0.0% (0)	**15.1% (13)**	0.0% (0)	0.0% (0)	11.1% (23)
Total	100.0% (39)	100.0% (41)	100.0% (86)	100.0% (32)	100.0% (9)	100.0% (207)

* The names of funding sources are adopted with the latest ones, which are MoTIE (Ministry of Trade, Industry, and Energy), MSS (Ministry of SMEs and Start-ups), MoHW (Ministry of Health and Welfare), and MSIT (Ministry of Science and ICT). Others include MoE (Ministry of Education) and MoLIT (Ministry of Land, Infrastructure, and Transport).

Sources: author's elaboration

Table 5.3 Characteristics of focal organisation's types and funding sources

Types of focal organisations	The ratio of the R&D projects by funding sources					
	MSIT	MoHW	MoTIE	MSS	Others	Total
Firm	18.1% (17)	4.3% (4)	**55.3% (52)**	22.3% (21)	0.0% (0)	100.0% (94)
Hospital	13.3% (4)	30.0% (9)	**43.3% (13)**	6.7% (2)	6.7% (2)	100.0% (30)
Public research institute	37.5% (9)	12.5% (3)	**41.7% (10)**	8.3% (2)	0.0% (0)	100.0% (24)
University	15.3% (9)	**42.4% (25)**	18.6% (11)	11.9% (7)	11.9% (7)	100.0% (59)
Total	18.8% (39)	19.8% (41)	**41.5% (86)**	15.5% (32)	4.8% (9)	100.0% (207)

* The names of funding sources are adopted with the latest ones, which are MoTIE (Ministry of Trade, Industry, and Energy), MSS (Ministry of SMEs and Start-ups), MoHW (Ministry of Health and Welfare), and MSIT (Ministry of Science and ICT). Others include MoE (Ministry of Education) and MoLIT (Ministry of Land, Infrastructure, and Transport).

Sources: author's elaboration

Table 5.4 Characteristics of research phases by funding sources

Research phases	The number of the R&D projects by funding sources					
	MSIT	MoHW	MoTIE	MSS	Others	Total
Basic research	17.9% (7)	22.0% (9)	7.0% (6)	0.0% (0)	0.0% (0)	10.6% (22)
Applied research	15.4% (6)	22.0% (9)	5.8% (5)	0.0% (0)	33.3% (3)	11.1% (23)

Research phases	The number of the R&D projects by funding sources					
	MSIT	MoHW	MoTIE	MSS	Others	Total
Development research	66.7% (26)	53.7% (22)	67.4% (58)	100.0% (32)	66.7% (6)	**69.6% (144)**
Etc.	0.0% (0)	2.4% (1)	19.8% (17)	0.0% (0)	0.0% (0)	8.7% (18)
Total	100.0% (39)	100.0% (41)	100.0% (86)	100.0% (32)	100.0% (9)	100.0% (207)

* The names of funding sources are adopted with the latest ones, which are MoTIE (Ministry of Trade, Industry, and Energy), MSS (Ministry of SMEs and Start-ups), MoHW (Ministry of Health and Welfare), and MSIT (Ministry of Science and ICT). Others include MoE (Ministry of Education) and MoLIT (Ministry of Land, Infrastructure, and Transport).
** Etc. in the research phases mostly include R&D projects related to standard technology and building strategic planning for new R&D programs.

Sources: author's elaboration

Now, the selected R&D projects are analysed from the perspective of research phases according to the focal organisational types. For every type of focal organisations, a 'development' phase was most heavily invested, and over 87% of the projects led by firms focused on the 'development' stage of research. Nevertheless, hospitals and universities put high emphasis on the 'basic' and 'applied' research phases in comparison with R&D projects led by firms and PRIs, in that both invested over 35% of their R&D in projects including 'basic' and 'applied' research (see *Table 5.5*).

Table 5.5 Focal organisation's types and research phases

Types of focal organisations	The ratio of R&D projects by research phases				
	Basic	Applied	Development	Etc.	Total
Firm	2.1% (2)	7.4% (7)	**87.2% (82)**	3.2% (3)	100.0% (94)
University	**18.6% (11)**	**16.9% (10)**	59.3% (35)	5.1% (3)	100.0% (59)
Public research institute	8.3% (2)	8.3% (2)	70.8% (17)	12.5% (3)	100.0% (24)
Hospital	**23.3% (7)**	**13.3% (4)**	33.3% (10)	30.0% (9)	100.0% (30)
Total	10.6% (22)	11.1% (23)	69.6% (144)	8.7% (18)	100.0% (207)

* Etc. in the research phases mostly include R&D projects related to standard technology and building strategic planning for new R&D programs.

Sources: author's elaboration

Finally, we identify which type of collaborating partner is preferred by each focal organisation type. Hospitals and universities had more opportunity to collaborate with firms, and 61.7% of hospitals' collaborating partners and 44.9% of universities' collaborating partners are firms. In addition, hospitals were proposed the most by firms as a collaborating partner (33.0%), while PRIs preferred to collaborate with universities and hospitals the most at the same ratio (35.6%) (see *Table 5.6*).

Table 5.6 Focal organisation's types and their collaborating partner's types

Types of focal organisations	The ratio of collaborating partners by their types					
	Firm	Univ.	PRI	Hospital	Etc.	Total
Firm	27.7% (57)	22.3% (46)	12.1% (25)	**33.0% (68)**	4.9% (10)	100.0% (206)
University	**44.9% (62)**	24.6% (34)	8.0% (11)	18.1% (25)	4.3% (6)	100.0% (138)
Public research institute	8.5% (5)	**35.6% (21)**	10.2% (6)	**35.6% (21)**	10.2% (6)	100.0% (59)
Hospital	**61.7% (50)**	13.6% (11)	7.4% (6)	12.3% (10)	4.9% (4)	100.0% (81)
Total	36.0% (174)	23.1% (112)	9.9% (48)	25.6% (124)	5.4% (26)	100.0% (484)

Sources: author's elaboration

5.2. Strategic Motives in the Establishment of Collaboration

As noted previously in the methodology chapter, we will identify specific strategic motives based on three theoretical approaches, namely, the NIS, TCE, and the RBV that influence the establishment of inter-organisational collaboration in public R&D projects in this section. In order to reveal the characteristics of the motives, quantitative data collected through a survey will be analysed and qualitative data collected through interviews will be utilised for the validation.

5.2.1. Quantitative Analysis of Strategic Motives

This section aims at identifying the descriptive characteristics of strategic motives in the establishment of inter-organisational R&D collaboration. In this section, we will indicate which strategic motives based on three theoretical approaches (the NIS, TCE and the RBV perspectives) are more influential in building the R&D collaboration from the perspective of all organisations. However, further investigation about how different organisational types were affected by strategic motives and how the motives influence the development of different collaborative structures will be conducted in chapter 6.

The data collected through the survey consist of 57 different research topics in the digital healthcare sector. These research topics include 20 research topics led by firms, 10 research topics driven by hospitals, 13 research topics led by PRIs, and 14 research topics led by universities. Principal investigators (PIs) in the R&D projects were asked about 23 different motives, based on the NIS (6 motives), the RBV (11 motives), and TCE (6 motives) approaches in the establishment of inter-organisational collaboration. As described in section 3.3.2, the 23 motives were generally selected based on Todeva, et al. (2005), Veugelers (1998), Dachs, et al. (2008), Hagedoorn (1993), Lee, et al. (2005), and Radas (2006). Then, they were classified into the three different theoretical approaches according to their characteristics. More specifically, motives that are imposed by or

relevant to meeting institutions such as government policies, regulations, organisational roles, and technical standards, are classified as coming under the NIS approach. Motives related to "minimising the sum of production and transaction costs" in order to achieve economic efficiency such as economising or minimising any costs, time, and risks are allocated to the TCE perspective (Kogut, 1988, p. 322). Lastly, the RBV approach includes motives which are relevant to obtaining or accessing partners' resources or capabilities and to retaining or developing individual organisations' own resources or capabilities through combining partners' resources or capabilities (Das, et al., 2000) (see *Table 3.3*).

Moreover, we have carried out reliability analyses in order to assess the internal consistency of questionnaires involving each theoretical perspective. According to the results, Chronbach's alphas show that the all questionnaires about motives in establishing collaboration reach acceptable reliability ($\alpha \geq 0.70$), because $\alpha_{RBV} = 0.81$, $\alpha_{TCE} = 0.73$, and $\alpha_{NIS} = 0.75$, respectively (Cortina, 1993). In addition, all motives appeared to be worth retaining in that all 'corrected item-total correlations' are higher than 0.30 and there is no motive that increases the Chronbach's α value if the motive is removed (see *Table 5.7*). Thus, we can say that all variables in the three theoretical groups involving the NIS, the RBV, and TCE approaches are internally consistent.

Table 5.7 Items-total statistics by three theoretical approach regarding strategic motives in establishing collaboration

Items based on the RBV ($\alpha_{RBV} = 0.81$)	Corrected-item-total correlation	Chronbach's alpha if item delected
To have priority over intellectual property rights	.46	.80
To obtain help for R&D commercialisation	.52	.79
To gain access to new technologies or markets	.38	.80
To develop existing Technologies or products	.43	.80
For learning and internalisation of embedded skills from partners	.58	.79
To access human resources	.54	.79
To understand demand-side needs	.43	.80

Items based on TCE ($\alpha_{TCE} = 0.73$)	Corrected-item-total correlation	Chronbach's alpha if item delected
To minimize research expenses through developing economies of scale	.43	.70
To minimize research expenses through developing economies of scope	.41	.70
To minimize research expenses through costs sharing/reduction in research	.57	.65
For sharing any risks and losses	.63	.64
To shorten lead time	.42	.70
To reduce administrative costs	.32	.73

Items based on the RBV (α_{RBV} = 0.81)	Corrected-item-total correlation	Chronbach's alpha if item delected
To gain access to complementary resources and capabilities	.49	.80
To gain help from a partner's administrative division	.32	.81
To utilise partner's research facilities	.62	.78
To get benefits from partner's reputation	.52	.79

Items based on the NIS (α_{NIS} = 0.75)	Corrected-item-total correlation	Chronbach's alpha if item delected
To get help with overcoming legal or regulatory barriers	.58	.69
To get information on current trends of government policies and regulations	.60	.69
To pursue certain missions mandated from the government/agency or society	.56	.70
Enforced by funding agencies or government	.46	.73
To develop technical standards	.39	.75
To achieve benefits from grants round	.37	.75

Source: author's elaboration

The question to answer on a seven-point Likert scale was 'how much do you agree or disagree that each motive influenced the establishment of collaboration with other collaborating partners?' For example, respondents were offered a choice of seven pre-coded responses, which are 'strongly disagree', 'disagree', 'slightly disagree', 'neither disagree nor agree', 'slightly agree', 'agree', and 'strongly agree' from the lowest point one to the highest point seven. *Table 5.8* below shows how much impact each motive has on establishing inter-organisational collaboration in the public R&D projects of the digital healthcare sector. According to the results, there are 14 out of 23 motives where respondents agreed (i.e. generated a score of over 4.00) that the motives influenced the establishment of the collaboration. Seven motives were marked 5.00 or over (i.e. at least slightly agree), which consist of six motives related to the RBV perspective and one motive based on TCE perspective. The most influential motive in establishing collaboration is '*to gain access to complementary resources and capabilities* (5.81)', followed by 'to gain access to new technologies or markets' with 5.75. Moreover, the next most influential motives are 'to develop existing technologies or products (5.63)' and 'to obtain help for R&D commercialisation (5.53).' In particular, only one motive which is not based on the RBV, '*to minimise research costs through developing economies of scope* (5.23)', ranks in a relatively high place (see *Table 5.8*). On the other hand, there are nine motives that did not positively affect the establishment of collaboration, which include three motives for each theoretical perspective, respectively (see *Table 5.8*).

Table 5.8 A result of the survey regarding strategic motives in establishing collaboration

Codes	Strategic motives	Theoretical approaches	Agreement level[a]	Relative Important Index (Rank)
V14	To gain access to complementary resources and capabilities	RBV	5.81	0.83 (1st)
V09	To gain access to new technologies or markets	RBV	5.75	0.82 (2nd)
V10	To develop existing technologies or products	RBV	5.63	0.80 (3rd)
V08	To obtain help for R&D commercialisation	RBV	5.53	0.79 (4th)
V02	To minimise research costs through developing economies of scope	TCE	5.23	0.75 (5th)
V13	To understand demand-side needs	RBV	5.11	0.73 (6th)
V11	For learning and internalisation of embedded skills from partners	RBV	5.00	0.71 (7th)
V12	To access human resources	RBV	4.98	0.71 (8th)
V22	To develop technical standards	NIS	4.91	0.70 (9th)
V23	To achieve benefits from potential grants	NIS	4.81	0.69 (10th)
V01	To minimise research costs through developing economies of scale	TCE	4.74	0.68 (11th)
V20	To pursue certain missions mandated from the government/agency or society	NIS	4.67	0.67 (12th)
V05	To shorten lead time	TCE	4.58	0.65 (13th)
V16	To utilise partner's research facilities	RBV	4.28	0.61 (14th)
V17	To get benefits from partner's reputation	RBV	3.98	0.57 (15th)
V04	For sharing any risks and losses	TCE	3.84	0.55 (16th)
V18	To get help with overcoming legal or regulatory barriers	NIS	3.77	0.54 (17th)
V19	To get information on current trends of government policies and regulations	NIS	3.68	0.53 (18th)
V21	Enforced by funding agencies or government	NIS	3.47	0.50 (19th)
V15	To gain help from a partner's administrative division	RBV	3.44	0.49 (20th)
V03	To minimise research expenses through costs sharing/reduction in research	TCE	3.32	0.47 (21st)
V07	To gain priority over intellectual property right	RBV	3.05	0.44 (22nd)
V06	To reduce administrative costs	TCE	2.72	0.39 (23rd)
Overall average			4.45	

* 1: Strongly disagree; 2: Disagree; 3: Slightly disagree; 4: Neither agree nor disagree; 5: Slightly agree; 6: Agree; 7: Strongly agree

a. This is the mean value of PIs' agreement level with each motive in establishing R&D collaboration

Source: author's elaboration

In addition, the relative important index analysis was conducted according to the equation below in order to calculate the relative importance of strategic motives. *Table 5.8* shows the relative important index of the strategic motives, and the results is consistent with the results of the mean value of the agreement levels in all strategic motives.

$$Relative\ Important\ Index = \frac{7n_7 + 6n_6 + 5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{A * N}$$

n_7 = Number of respondents for 'Strongly Agree'

n_6 = Number of respondents for 'Agree'

n_5 = Number of respondents for 'Slightly agree'

n_4 = Number of respondents for 'Neither agree nor disagree'

n_3 = Number of respondents for 'Slightly disagree'

n_2 = Number of respondents for 'Disagree'

n_1 = Number of respondents for 'Strongly disagree'

A = Highest Weight (=7)

N = Total number of respondents (=57)

The average level of agreement on the motives based on the NIS approach in the establishment of collaboration is 4.22, which is in the range between 'neither agree nor disagree' and 'slightly agree', although the degree is closer to the 'neither agree nor disagree' level. Nonetheless, the figures in terms of the motives, '*to develop technical standards* (4.91)' and '*to achieve benefits from potential grants* (4.81)', are much closer to the 'slightly agree' level. In addition, only half of the motives (3 out of 6) based on the NIS approach have a positive influence on developing collaboration (see *Table 5.9*).

Table 5.9 Strategic motives based on the NIS in establishing collaboration

No.	Strategic motives	Agreement level[a]
V22	To develop technical standards	4.91
V23	To achieve benefits from potential grants	4.81
V20	To pursue certain missions mandated from the government/agency or society	4.67
V18	To get help with overcoming legal or regulatory barriers	3.77
V19	To get information on current trends of government policies and regulations	3.68
V21	Enforced by funding agencies or government	3.47
Overall average		4.22

* 1: Strongly disagree; 2: Disagree; 3: Slightly disagree; 4: Neither agree nor disagree; 5: Slightly agree; 6: Agree; 7: Strongly agree

a. This agreement level is the mean value of PIs' agreement with each motive

Source: author's elaboration

With regard to the RBV, the average degree of motives' impact on the development of collaboration is 4.78, which is in the range between 'neither agree nor disagree' and 'slightly agree' as well, although this degree is much higher than the average degree based on the NIS approach, which is 4.22. Eight out of eleven motives involving the RBV approach positively influence the establishment of collaboration with the range being from 5.81 to 4.28 (see *Table 5.10*). There are six motives which are in the range between the 'slightly agree' and 'agree' level in particular. The most influential motive related to the RBV is '*to gain access to complementary resources and capabilities* (5.81)', followed by 'to gain access to new technologies or markets (5.75)' and by 'to develop existing technologies or products (5.63)' (see *Table 5.10*).

Table 5.10 Strategic motives based on the RBV in establishing collaboration

No.	Strategic motives	Agreement level[a]
V14	To gain access to complementary resources and capabilities	5.81
V09	To gain access to new technologies or markets	5.75
V10	To develop existing technologies or products	5.63
V08	To obtain help for R&D commercialisation	5.53
V13	To understand demand-side needs	5.11
V11	For learning and internalisation of embedded skills from partners	5.00
V12	To access human resources	4.98
V16	To utilise partner's research facilities	4.28
V17	To get benefits from partner's reputation	3.98
V15	To gain helps from a partner's administrative division	3.44
V06	To gain priority over intellectual property right	3.05
Overall average		4.78

* 1: Strongly disagree; 2: Disagree; 3: Slightly disagree; 4: Neither agree nor disagree; 5: Slightly agree; 6: Agree; 7: Strongly agree

a. This agreement level is the mean value of PIs' agreement with each motives

Source: author's elaboration

The average degree of the motives involving TCE is 4.07, which means respondents on average more or less neither agree nor disagree with the impact of such motives on establishing collaboration. Moreover, the influence of the motives based on this theoretical approach is the lowest compared with the average level of the motives linked to the NIS approach (4.22) and to the RBV approach (4.78). However, there are three motives that do have a positive influence on developing collaboration, which are '*to minimise research costs through developing economies of scope* (5.23)', 'to minimise research costs through developing economies of scale (4.74)', and 'to shorten lead time (4.58).' In particular, the degree of the most influential motives based on TCE, 'to

minimise research costs through developing economies of scope', is 5.23, which is a relatively high figure considering the average. Interestingly, for only one motive out of 23 motives in total, is the figure below the 3.00 between disagreement and slight disagreement with the motive, 'to reduce administrative costs (2.72)', which is related to TCE (see *Table 5.11*).

Table 5.11 Strategic motives based on TCE in establishing collaboration

No.	Strategic motives	Agreement level[a]
V02	To minimise research costs through developing economies of scope	5.23
V01	To minimise research costs through developing economies of scale	4.74
V05	To shorten lead time	4.58
V04	For sharing any risks and losses	3.84
V03	To minimise research expenses through costs sharing/reduction in research	3.32
V06	To reduce administrative costs	2.72
Overall average		4.07

* 1: Strongly disagree; 2: Disagree; 3: Slightly disagree; 4: Neither agree nor disagree; 5: Slightly agree; 6: Agree; 7: Strongly agree

a. This agreement level is the mean value of PIs' agreement with each motives

Source: author's elaboration

Lastly, a statistical test, one-way ANOVA, is conducted in SPSS to compare the three theoretical groups involving the motives, and this test can indicate which theoretical approach is the more influential among three theoretical perspectives in establishing collaboration. Before conducting this test, a normality test is carried out to meet an assumption of the ANOVA test, although it could be skipped according to the central limit theorem because the number of samples is more than 30 (c.f. n=57). *Table 5.12* below shows all three groups are normally distributed with a 95% confidence level because all the p-values of the test are higher than a significance level of 0.05 in both Kolmogorov-Smirnov and Shapiro-Wilk tests, and the null hypothesis that the samples in each group are normally distributed, is not rejected. Then, Levene's test for homogeneity of variances is conducted, and this result shows the variances are homogenous across the three groups (see *Table 5.13*). The reason is that we fail to reject the null hypothesis, the variance is equal across groups, at the 0.05 significance level.

Table 5.12 Normality tests of the degree of motives by theoretical approaches

Motive	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
NIS	.084	57	**.200***	.979	57	**.433**
RBV	.078	57	**.200***	.963	57	**.082**
TCE	.088	57	**.200***	.981	57	**.491**

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Source: author's elaboration

Table 5.13 The Levene's test for homogeneity of variances

Levene Statistic	df1	df2	Sig.
2.059	2	168	**.131**

Source: author's elaboration

Now, all the assumptions for the ANOVA test are met and the ANOVA test is able to proceed. According to the result of the test, the omnibus test result below indicates that there is at least a significant mean difference across the groups at less than the 0.01 significance level. Thus, multiple comparison analysis with a post-hoc *Bonferroni* test[59] is used to determine which means are significantly different. According to the result in *Table 5.14*, we can presume with a 95% confidence level that the group of the motives based on the RBV approach is significantly different from the group based on the NIS and TCE approaches by rejecting the null hypothesis, that the mean difference is zero across the groups. Thus, this result can be interpreted to mean that the motives linked to the RBV approach are more influential in the establishment of collaboration than the motives based on the NIS and TCE approaches (i.e. 0.56 more and 0.71 more, respectively).

Table 5.14 The result of multiple comparisons with a Bonferroni test

(I) Motive	(J) Motive	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
RBV	NIS	**.55912***	.20021	**.018**	.0750	1.0433
	TCE	**.70789***	.20021	**.002**	.2237	1.1920

*. The mean difference is significant at the 0.05 level.
Source: author's elaboration

5.2.2. Qualitative Analysis for Strategic Motives

This section aims at validating the quantitative findings from section 5.2.1 through dealing with the analysis of motives based on the interview data. Hence, an open-ended

[59] This can control for the overall type-one error (i.e. false positive) and tends to be conservative and powerful (Frane, 2015).

question, 'What were your motives in establishing collaboration with partners in the project?', was asked to interviewees for cross-validation of the finding from the quantitative analysis above. As noted in the previous section, the five most influential motives in the establishment of collaboration were identified with motives mainly involving the RBV, which are 'to gain access to complementary resources and capabilities (5.81)', 'to gain access to new technologies or markets (5.75)', 'to develop existing technologies or products (5.63)' and 'to obtain help for R&D commercialisation (5.53).' Only one motive based on TCE, 'to minimise research costs through developing economies of scope (5.23)', follows the former four motives related to the RBV perspective. Moreover, the motives linked to the RBV perspective overall (4.78) have significantly more impact on the establishment of collaboration than the motives connected with the NIS (4.22) and TCE (4.07) approaches.

For the interviews, there are 35 interviewees taking part in the course of interviews, and 34 interviewees (covering 37 research topics)[60] responded to the question mentioned above. According to the results, a primary motive in establishing collaboration seems to be that focal organisations established the collaboration '*for seeking complementary capabilities and resources from their collaborating partners in order to achieve their research aims*'. The reason for responding with this motive as a primary motive is because they cannot solely cover all the diverse research tasks or sectors due to either a lack of internal resources or capabilities, or because of the characteristics of the digital healthcare sector where interactions between diverse specialised capabilities and resources based on bio-medical technology, healthcare services, and ICT are essential. Indeed, 30 interviewees (covering 33 research topics) out of a total of 34 interviewees (with 37 research topics) answered that their motive is *to obtain complementary capabilities or resources* through collaborating with their partners involved in the RBV perspective (see the motives of interviewees F01~13, H01~08, P01, P02, P04, and U01~06 in *Appendix 5*). For instance, interviewee F02 from a firm responded that "diverse core capabilities are needed … given the feature of the digital healthcare sector … such as information security, data mining, and clinical validation" as a motive in establishing collaboration. Another interviewee F13 from a firm answered that a motive is "to access specialised human capabilities in diverse technological areas due to a lack of internal resources." In addition, interviewee H04 from a hospital collaborated with other organisational partners

[60] The number of interviewees accounts for 27.5% of PIs in total.

in order to "gain complementary capabilities that we do not have or have insufficient capabilities such as hardware development and sensing technology." Another interviewee (P01) from a PRI responded that "collaborating partners' capabilities and resources are considered in order to achieve the research aim" was her motive for establishing inter-organisational collaboration. Finally, a university professor (U04) responded that his motive to establish collaboration is "to gain complementary capabilities and resources that we do not have such as clinical data and capabilities."

There were only four interviewees who responded differently from the majority of the interviewees about their motives in establishing collaboration, which are linked to the NIS perspective. The four are interviewees ID P03, P05, P06, and U07. Both P03 and P05 answered that their motives were to contribute to the refinement of the service model owned by an SME and to create a new market in the digital healthcare sector for performing their role as a PRI. Moreover, the other two interviewees (i.e. P06 and U07) responded that they established collaboration on account of pressure from funding agencies (see the motives of ID P03, P05, P06, and U07 in *Appendix 5*). Interestingly, the response of interviewee F01 is mixed with various motives such as to access core and specialised capabilities that they do not have, and enforced by institutional pressure (see interviewee F01' comment in *Appendix 5*).

5.3. Implications of R&D Policy Instruments for Establishing Collaboration

As mentioned previously in section 3.2, researchers in R&D projects tend to have bounded information, or might not even perceive the institutional properties of the national innovation system, because these institutional pressures[61] are likely to be 'taken-for-granted' within the R&D system, being accepted without question (Lu, 2002). Thus, an additional investigation of the institutional pressures affecting the establishment of collaboration is needed in order to arrive at a better understanding of the motives in establishing collaboration in the public R&D projects in the digital healthcare sector. This investigation was performed through analysing 82 'requests for proposals' (RFPs) of the R&D projects shown in *Table 3.2* in section 3.3.1 because an RFP in a public R&D program plays a crucial role in the national innovation system as one of the R&D policy instruments. For instance, R&D funding agencies and government ministries employ

[61] Here, institutional pressure is defined as the conditions that are required or encouraged by funding agencies or government ministries in order to establish inter-organisational R&D collaboration.

RFPs as an R&D policy instrument in order to meet the objectives of the public R&D program with various conditions such as the eligibility of organisations, establishing collaboration, collaborating with specific types of partners, a royalty payment regulation, and a matching funding request. Hence, this section aims to explore how funding agencies or government ministries compel or encourage the establishment of collaboration, how the characteristics of RFPs differ by institutional pressure types on establishing collaboration, and how different organisational types are affected differently by institutional pressure in establishing collaboration.

Before conducting the exploration, the descriptive characteristics of selected RFPs involving the R&D collaboration projects in the digital healthcare sector are identified. There are 82 RFPs which account for a total of 207 R&D collaboration projects in the digital healthcare sector between 2012 and 2015. Forty-two out of the 82 RFPs (51.2%) include information on the enforcement of establishing inter-organisational collaboration, and funding agencies or government ministries promote research collaboration with various incentives in an additional 16 RFPs (19.5%). Thus, the establishment of the inter-organisational collaboration was affected by institutional pressure in 58 out of the 82 RFPs in total (70.7%), and these account for 153 R&D (73.9%) projects out of a total of 207 collaboration R&D projects. These ratios seem to be relatively high, given that the agreement level regarding the ‘enforced by funding agencies or government’ in establishing collaboration is rated 3.47 on a seven-point scale, as described in Table 5.8 in section 5.2.1, which corresponds to a level somewhere between ‘slightly disagree’ and ‘neither disagree nor agree’. This may be due to the fact that PIs (principal investigators) in the R&D projects did not seem to regard the institutional pressure as a crucial factor; they may be more concerned with other motives engaging TCE and the RBV perspectives than the institutional pressure in developing collaboration, or they might not even perceive the institutional pressure in establishing collaboration.

As noted previously, the first exploration of the RFPs is how funding agencies or government ministries compel or encourage the establishment of inter-organisational collaboration in the public R&D projects. Thus, the institutional pressure to enforce or promote the establishment of inter-organisational collaboration is classified by its distinctive attributes. The institutional pressure that requires the establishment of collaboration is categorised into two kinds of RFPs. In one kind of RFPs, a particular

organisational type was assigned to a focal organisation, and a particular organisational type of collaborating partners was also designated at the same time. For instance, only SMEs can apply as a focal organisation for specific R&D programs such as the 'healthcare management system development based on the personal health records', 'biomedical device development', and the 'development of smart patches for monitoring patients and of a homecare service solution', and the focal SMEs are required to collaborate with at least one hospital in those programs. In the other type of RPFs, funding agencies require the establishment of collaboration as a mandatory condition in the RFPs, although they do not designate a particular organisational type for the focal organisation or collaborating partner (see *Table 5.15*). These RFPs include the 'healthcare platform establishment for wellness', the 'industrial convergence promotion', 'international cooperation R&D for acquiring technology', 'software convergence technology development', 'medical device integrated digital hospital development', and so on.

To facilitate the establishment of R&D collaboration in the RFPs, there are 16 RFPs such as 'cutting-edge core technology development in medical information and systems', 'cooperation development for the economic belt promotion', 'globally specialised technology development and IT related new industry', and 'strategic technology development – next-generation medical devices development.' In the 'cutting-edge core technology development in medical information and systems' research program, University-Industry-Public research institute (U-I-P) collaboration was facilitated by a funding agency, and also the participation of a medical doctor in the research team was required in order to enhance clinical usability. A research team can receive additional points in the grant round assessment if they establish collaboration with another partner organisation in the R&D program on the 'Cooperation development for the economic regional belt promotion.' In addition, in the program of 'globally specialised technology development and IT related new industry', a funding agency provided researchers with an opportunity to find the best collaborating partner among R&D funding candidates through sharing candidates' information and holding an off-line information exchange event. Meanwhile, the government provided a higher rate of government funding for research teams with collaboration than non-collaborative research teams in the program on the 'strategic technology development – next-generation medical devices development' (see *Table 5.15*). Through these inducements, either in the form of enforcement or facilitation, funding agencies and the Korean government put institutional pressure on

researchers in the digital healthcare sector to establish inter-organisational R&D collaboration in order to achieve their policy goals.

Table 5.15 Requests for proposals and institutional pressure in establishing collaboration

Institutional pressure types	The attributes of institutional pressure
Enforcement of collaboration (42 RFPs)	- particular organisational types of focal and/or collaborating partner organisations are designated, and inter-organisational collaboration is required at the same time (31 RFPs) - inter-organisational collaboration is obligated without additional mandatory conditions in establishing collaboration (11 RFPs)
Facilitation of collaboration (16 RFPs)	- particular organisational types are encouraged to participate in R&D projects as a collaborating partner organisation (6 RFPs) - particular experts in specialised areas are required to take part in R&D projects (4 RFPs) - additional points in the grant round assessment are applied (3 RFPs) - a higher rate of government funding is provided for research teams with collaboration than non-collaborative research teams (2 RFPs) - an off-line information exchange event is held to promote the establishment of collaboration (1 RFPs)

Source: author's elaboration

Now, we will indicate how the characteristics of RFPs differ according to the types of institutional pressure on establishing collaboration. Through this investigation, we can understand why the institutional pressure to build a collaboration is introduced in a particular RFP. In order to conduct this investigation, a total of 82 RFPs are classified according to two characteristics by the R&D policy goal of the RFPs – the development of particular technologies or products, and the improvement of the national or regional innovation system (through developing the capacity of the main actors, mainly SMEs, and promoting collaboration between the actors). As you can see in *Table 5.16*, funding agencies or government ministries tend to compel or encourage the establishment of inter-organisational collaboration if the goal of R&D programs is related to the development of particular technologies or products. It would seem that combinations with a variety of technologies in diverse technological areas such as ICT, bio, and medical technologies through inter-organisational collaboration play an essential role in developing particular technologies or products in the digital healthcare sector.

Meanwhile, those RFPs free from institutional pressure to establish collaboration are more involved in the R&D policy goal of improvement of the innovation system (see *Table 5.16*). Interestingly, there are 18 RFPs requiring the building of inter-organisational collaboration with institutional enforcement, although the goal of the R&D programs is

to improve the innovation system (see *Table 5.16*). However, 15 out of these 18 RFPs aim to improve the innovation system through promoting collaboration between actors such as a firm, university, PRI, and hospital. As a consequence, this investigation shows funding agencies or government ministries are more likely to require or encourage the establishment of inter-organisational collaboration in the digital healthcare sector *if the goal of the R&D programs is to develop particular technologies or products*. In addition, if the R&D policy goal to improve the national or regional innovation system via promoting collaboration between actors, the R&D programs tend to be forced to build collaboration by institutional pressure.

In contrast, institutional pressure on establishing collaboration is less likely to be involved in R&D programs to improve the innovation system through developing main actors' capacity at the national or regional level. Accordingly, the R&D projects forced or facilitated by institutional pressure to build collaboration are those projects that should be implemented with other collaborating partners in order to achieve the research aims of the R&D projects. Hence, PIs may overlook the motives related to institutional pressure for the establishment of inter-organisational collaboration in the digital healthcare sector, as noted earlier in this section with the survey result.

Table 5.16 The characteristics of RFPs by institutional pressure types

Institutional pressure types	The number of RFPs by R&D Policy goal		Total
	Developing particular technologies or products	Improving the innovation system	
Enforcement of collaboration	**24 (55.8%)**	**18 (46.2%)**	42 (51.2%)
Facilitation of collaboration	**14 (32.6%)**	2 (5.1%)	16 (19.5%)
Free from institutional pressure	5 (11.6%)	**19 (48.7%)**	24 (29.3%)
Sum	43 (100%)	39 (100%)	82 (100%)

Source: author's elaboration

Finally, we are going to explore how different organisational types are affected differently by the institutional pressure types in the establishment of inter-organisational collaboration in the digital healthcare sector. As described in *Table 5.17*, 45.9% of all collaborative R&D projects were influenced to establish collaboration (i.e. 95 out of 207 R&D projects) by the pressure of the institutional enforcement, while 58 out of 207 R&D projects (i.e. 28.0%) were encouraged to build collaboration. Conversely, there are 26.1% of the collaborative R&D projects (i.e. 50 out of 207 projects) in which collaboration was not enforced or encouraged by anyone, and those 50 R&D projects were more likely to focus on their own motives without considering institutional pressure in establishing

collaboration (see *Table 5.17*).

Interestingly, universities were less likely to build collaboration, judging from its collaboration ratio of 17.9% compared with 30.5% on average (see *Table 5.17*). In addition, *Table 5.17* shows that if there is no institutional pressure to establish R&D collaboration in the RFPs, universities are less likely to establish collaboration (i.e. 15.3%) than other organisational types, particularly a firm (35.1%) and PRI (29.2%). Under this condition (i.e. free from institutional pressure), universities may tend to act as a knowledge producer more than as a knowledge disseminator in the digital healthcare sector of the Korean innovation system.

Meanwhile, private companies were more likely to build collaboration voluntarily without any influence in the form of institutional pressure (i.e. 35.1%) than any other organisational types. This could explain why private firms tend to depend on collaborating partners in order to achieve their research aims, to develop their technological capabilities, and to minimise research expenses, given that more than 91.5% of private firms taking part in the R&D projects in the digital healthcare sector are SMEs. This explanation is also supported by the collaboration ratio of R&D projects led by firms at 49.2%, which is much higher than the average ratio of 30.5% (see *Table 5.17*).

In addition, the overall collaboration ratio of PRIs is at the highest level, 57.1%, among the four different focal organisational types (see *Table 5.17*). This might be due to the role of PRIs in the Korean national innovation system in dealing with complicated social issues and challenging a more creative mode of technology development, as described earlier in section 4.2.3. Thus, collaboration with other actors enables researchers in PRIs to contribute to meeting the PRIs' role in the Korean innovation system.

Table 5.17 R&D projects based on focal organisational types by institutional pressure types

Institutional pressure types	Focal organisation types				Total
	Firm	Univ.	PRI	Hospital	
Enforcement of collaboration	47 (50.0%)	25 (42.4%)	10 (41.7%)	13 (43.3%)	95 (45.9%)
Facilitation of collaboration	14 (14.9%)	25 (42.4%)	7 (29.2%)	12 (40.0%)	58 (28.0%)
Free from institutional pressure	33 (**35.1%**)	9 (**15.3%**)	8 (**29.2%**)	5 (16.7%)	50 (26.1%)
R&D collaboration projects in total (A) *	94 (100%)	59 (100%)	24 (100%)	30 (100%)	207 (100%)
R&D projects in total (B) *	191	330	42	97	660
Collaboration ratio of R&D projects (A/B)	**49.2%**	**17.9%**	**57.1%**	30.9%	30.5%

* While the R&D collaboration projects (A) explain the projects building R&D collaboration in the digital healthcare sector between 2012 and 2015, a total of R&D projects (B) account for all public R&D projects in the digital healthcare sector during the same period. However, there are 12 security projects and 10 projects, where the focal organisational type is neither a firm, hospital, PRI, or university, which are excluded in the total numbers of R&D projects.

Source: author's elaboration

5.4. Conclusion

This chapter addressed the first research question in terms of identifying strategic motives influencing the establishment of inter-organisational collaboration in public R&D projects of the Korean digital healthcare sector. There are mainly three parts to answer this question, and they were carried out by mixed methods analysis based on a survey, interviews, and desk research.

First, the most influential motive in the establishment of inter-organisational R&D collaboration in the digital healthcare sector turns out to be '*to gain access to complementary resources and capabilities*' involving the RBV perspective, and strategic motives involved in this theoretical perspective influence the establishment of collaboration significantly more than motives involved in the other theoretical perspectives based on TCE and the NIS perspectives. This finding is consistent with the results from Yasuda (2005), Odagiri (2003) and Hagedoorn, et al. (1991), who suggested that technological complementarity is reported as a major motive, while sharing of costs and of risks are only of relatively minor importance.

Second, this result from quantitative analysis was cross-validated with an open-ended question regarding the strategic motives in establishing collaboration in the course of interviews. The reason is that a primary motive in establishing collaboration seems to be

‘*for seeking complementary capabilities and resources from their collaborating partners in order to achieve their research aims*’, according to the qualitative analysis.

Lastly, we found that funding agencies or government ministries are more likely to require or encourage the establishment of inter-organisational collaboration *if the goal of the R&D programs is to develop particular technologies or products*. We also found that *universities were less likely to build collaboration* than other organisational types if there is no institutional pressure, whilst private firms were more likely to establish collaboration voluntarily without any influence in the form of institutional pressure than other organisational types. In order words, the institutional influences on the establishment of R&D collaboration are likely to be affected by the goal of R&D programs, and organisations of different types behave differently in response to the institutional influences.

The following chapter will discuss how different collaborative structures categorized by types of focal and collaborating partner organisations, which reflect differing motives in establishing collaboration, are developed in public R&D projects in the digital healthcare sector. This is because each type of organisation, whether a firm, university, PRI, or hospital, has its own attributes contingent upon internal and external factors.

Chapter 6. Strategic motives and Different Collaborative Structures

In chapter 5, we have dealt with what are the motives influencing the establishment of inter-organisational collaboration in public R&D projects in the Korean digital healthcare sector. However, each type of organisation, whether a firm, university, PRI, or hospital, has its own attributes contingent upon internal and external factors such as strategic organisational goals, institutions, organisational missions, its own motivations and priorities, and the manager's role (Isaksen, et al., 2017; Rainey, 1989). In addition, given that both managerial leadership and technical leadership have a substantial impact on R&D and innovative performance (DiBella, 1995; Pelz, et al., 1966; Shim, et al., 2001), the coordination role of focal organisations, who launch initiatives with the strategic purpose of establishing collaboration in the R&D projects, is crucial. Hence, the features of R&D collaboration between those four types of organisations vary from the point of view of the focal organisation (Groenewegen, 1992). Consequently, the objective of this chapter is to identify how different collaborative structures categorized by types of focal and collaborating partner organisations, which reflect differing strategic motives in establishing collaboration, are developed in public R&D projects in the digital healthcare sector.

In order to address the research aim set out in section 6.1, quantitative data collected by a survey are used to reveal how much each motive based on the three theoretical approaches – namely, the NIS, TCE, and the RBV - influences the development of different R&D collaborative structures. The different R&D collaborative structures are categorised in terms of the focal organisation's funding features (i.e. for-profit and not-for-profit organisations). Then, an Mann-Whitney U test will be employed to determine whether there are any significant differences between the two groups of collaborative structures on the agreement level for each motive as measured on a seven-point Likert scale. Thus, this analysis will identify how each motive influences the development of different collaborative structures, according to the funding features of the focal organisations. Additionally, we will take a closer look at for-profit firms on the basis of their size (i.e. small vs medium-sized and large firms) to see if and how they are affected by different theoretical approaches in the establishment of R&D collaboration.

Next, we will focus on exploring how much each motive influences the development of different collaborative structures categorised by focal organisational type (i.e. a firm,

university, public research institute, and hospital) based on the survey data in section 6.2. Here, an analysis of variance (ANOVA) test is utilised to determine whether there are any significant differences between the different collaborative structures on the agreement level for each motive as measured on a seven-point Likert scale. For the additional coverage, we will investigate how strategic motives influence the development of different collaborative structures by focal organisational type based on interview data. This investigation is also carried out to validate the novel conceptual framework of this thesis by asking an open-ended question to PIs in the different types of focal organisations (i.e. a question without any theoretical restrictions). Through this integration based on both quantitative and qualitative analysis, we expect to reach a better understanding of how different collaborative structures are developed by the various focal organisational types.

In section 6.3, we will address how strategic motives affect focal organisations in their choice of collaborating partner types. This investigation is carried out through classifying a total of 207 R&D projects in the digital healthcare sector in terms of collaborating partners' organisational types, and these classified groups are then employed to analyse the agreement level of different motives from the perspective of focal organisational types (using the Kruskal-Wallis test), as noted previously. Hence, we can identify how each motive has a different impact on each type of focal organisations in establishing different collaborative structures with a particular collaborating partner type. For the additional coverage, interview data will be employed to disclose how strategic motives affect each type of focal organisations in the choice of a particular collaborating partner type in section 6.4. Thus, this analysis may help provide a better understanding of how motives influence the development of different R&D collaborative structures.

Finally, we will discuss the expectations of collaborating partners with regard to the focal organisations in the development of R&D collaboration in *Appendix 13* for those readers who are interested in these findings. The reason for carrying out this analysis is that any form of R&D collaborations requires a mutual agreement whereby both the partners and focal organisations have to be motivated at the same time to enter into the R&D collaboration (Sytch, et al., 2008). In addition, the motives of organisations for participating in R&D collaboration may differ according to their specific expectations in the R&D collaboration (i.e. a focal or partner organisation). However, we decided not to

include these findings in this chapter because the evidence we found seems not to be robust enough due to the fact that we have investigated these expectations of collaborating partners by asking PIs in focal organisations, not by directly asking the main researchers in collaborating partners.

6.1. Characteristics of Strategic Motives and Collaborative Structures by Focal Organisational Funding Features (For-Profit *vs* Not-for-Profit)

The purpose of this section is to indicate how the development of different collaborative structures by for-profit compared with not-for-profit focal organisations is affected by the motives involved in the establishment of collaboration. Thus, the motives in developing different collaborative structures are analysed for different types of focal organisations based on survey data. Hence, this investigation of the motives in establishing R&D collaboration may be useful in understanding how different collaborative structures are developed along with the features of focal organisations. *Table 6.1* provides a basic description with regard to the characteristics of the motives of for-profit and not-for-profit focal organisations. According to this, for-profit organisations tend to be more concerned with motives reflecting TCE and the RBV theoretical perspectives than not-for-profit organisations. Conversely, not-for-profit organisations are more likely to be influenced by motives linked to the NIS perspective than for-profit organisations in developing their R&D collaborations.

Table 6.1 Descriptive characteristics of motives broken down by the feature of focal organisations

Theoretical approaches	Strategic motives	For-profit	Not-for-profit	Overall
TCE	(V01) To economise research and administrative expenses through developing economies of scale	5.50	4.32	4.74
	(V02) To minimise research costs through developing economies of scope	5.55	5.05	5.23
	(V03) To minimise research expenses through costs sharing/reduction in research	4.25	2.81	3.32
	(V04) For sharing any risks and losses	4.40	3.54	3.84
	(V05) To shorten lead time	4.70	4.51	4.58
	(V06) To reduce administrative costs	3.40	2.35	2.72
	Average	4.63	3.77	4.07
RBV	(V07) To gain priority over intellectual property right	4.20	2.43	3.05
	(V08) To obtain help for R&D commercialisation	5.80	5.38	5.53
	(V09) To gain access to new technologies or markets	5.85	5.70	5.75
	(V10) To develop existing technologies or products	6.05	5.41	5.63
	(V11) For learning and internalisation of embedded	5.35	4.81	5.00

Theoretical approaches	Strategic motives	For-profit	Not-for-profit	Overall
	skills from partners			
	(V12) To access human resources	5.05	4.95	4.98
	(V13) To understand demand-side needs	4.85	5.24	5.11
	(V14) To gain access to complementary resources and capabilities	5.70	5.86	5.81
	(V15) To gain helps from a partner's administrative division	3.65	3.32	3.44
	(V16) To utilise partner's research facilities	4.75	4.03	4.28
	(V17) To get benefits from partner's reputation	4.20	3.86	3.98
	Average	**5.04**	**4.64**	4.78
NIS	(V18) To get help with overcoming legal or regulatory barriers	3.85	3.73	3.77
	(V19) To get information on current trends of government policies and regulations	4.00	3.51	3.68
	(V20) To pursue certain missions mandated from the government/agency or society	4.35	4.84	4.67
	(V21) Enforced by funding agencies or government	3.20	3.62	3.47
	(V22) To develop technical standards	4.60	5.08	4.91
	(V23) To achieve benefits from potential grants	4.35	5.05	4.81
	Average	**4.06**	**4.31**	4.22

Source: author's elaboration

For a more detailed investigation, statistical analysis with a Mann-Whitney U test, which can identify the mean differences of each motive between the two different organisational groups (i.e. for-profit and not-for-profit), is conducted using SPSS. The Mann-Whitney U test, a non-parametric test, is adopted because the normality test of the not-for-profit group in all motives shows that the data are statistically different from a normal distribution at a significance level of 0.05. Moreover, the data of the for-profit group in many motives (e.g. V01, V02, V04, V07, V08, V09, V10, V11, V13, V14, V15, V17, V22 and V23) shows that they are not normally distributed as well, and a nonparametric test (a Mann-Whitney U test) is therefore carried out.

According to the result of the Mann-Whitney U test, there are significant differences between the two organisational groups in the motives 'to minimise research costs through developing economies of scale' (V01), 'to minimise research expenses through costs sharing/reduction in research' (V03), 'for sharing any risks and losses' (V04), 'to reduce administrative costs' (V06), and 'to gain priority over intellectual property right'(V07) at a 95% confidence level (see *Table 6.2 and Appendix 7*). This result reveals that those motives have a more significant impact on for-profit organisations (i.e. firms) than not-for-profit organisations (i.e. universities, PRIs, and hospitals) in developing R&D

collaboration. More specifically, firms are more concerned with motives involving a cost-economising perspective such as 'to minimise research costs through developing economies of scale (V01)', 'to minimise research expenses through costs sharing/reduction in research (V03)', 'for sharing any risks and losses (V04)', and 'to reduce administrative costs (V06)' than not-for-profit organisations when developing inter-organisational R&D collaboration. In addition, private firms pay more attention to securing strategic assets like intellectual property rights through developing R&D collaboration than not-for-profit organisations, making up the rest of the knowledge infrastructure in the national innovation system.

Table 6.2 The result of the Mann-Whitney U test on agreement levels of strategic motives by organisational funding features

Organisational funding features	Strategic motives	N	Mean Rank	Agreement levels	Asymp. Sig. (2-tailed)
For-profit		20	35.33	5.50	
Not-for-profit	V01	37	25.58	4.32	0.030
Total	(TCE)	57			
For-profit		20	36.88	4.25	
Not-for-profit	V03	37	24.74	2.81	0.007
Total	(TCE)	57			
For-profit		20	33.95	4.40	
Not-for-profit	V04	37	26.32	3.54	0.086
Total	(TCE)	57			
For-profit		20	35.93	3.40	
Not-for-profit	V06	37	25.26	2.35	0.018
Total	(TCE)	57			
For-profit		20	39.25	4.20	
Not-for-profit	V07	37	23.46	2.43	0.000
Total	(RBV)	57			

Source: author's elaboration

Furthermore, we will deal with the characteristics of theoretical perspectives linked to motives based on the focal organisational features through an independent samples t-test. This test can point out which theoretical perspective is more influential in developing different collaborative structures when comparing for-profit and not-for-profit focal organisations. *Appendix 8* shows brief statistics of the average values of theoretical approaches-related motives by the focal organisational feature, and the normality test for these data, which indicates a failure to reject the null hypothesis at a 95% confidence level. Therefore, we can say the data are normally distributed, and the independent-samples t-test, a parametric test, is carried out.

According to the result of the t-test (see *Table 6.3*), we can presume that the mean of the

agreement level for the motives linked to a cost economising perspective in developing R&D collaboration between for-profit and not-for-profit focal organisations is significantly different at a 99% confidence level. This result is based on the Levene's test showing the variances between the two groups are homogenous by failing to reject the null hypothesis in all three theoretical perspectives. In other words, *for-profit firms* are more concerned with *cost-economising motives* in developing collaborative structures than not-for-profit organisations. In this regard, Coles, et al. (1998) suggested that not-for-profit organisations face less severe efficiency pressures than private organisations from the perspective of TCE because other incentives such as political or other non-economic forces may induce distinctive strategic decisions from not-for-profit organisations.

Table 6.3 The result of the independent t-test in terms of theoretical perspectives in establishing collaboration between for-profit and not-for-profit organisations

Theoretical approaches		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
NIS	Equal variances assumed	.793	.377	-.775	55	.442	-.24772	.31954	-.88809	.39266
	Equal variances not assumed			-.809	44.12	.423	-.24772	.30605	-.86447	.36904
RBV	Equal variances assumed	1.588	.213	1.623	55	.110	.40528	.24978	-.09529	.90586
	Equal variances not assumed			1.713	45.44	.094	.40528	.23665	-.07123	.88180
TCE	Equal variances assumed	.998	.322	2.949	55	.005	.86728	.29414	.27782	1.45675
	Equal variances not assumed			3.141	46.53	.003	.86728	.27616	.31158	1.42299

Source: author's elaboration

Next, we are going to take a closer look at for-profit firms in that they have a significantly different theoretical perspective in developing collaboration than other organisational types. As described in section 4.2.1, there are different sizes of firms participating in public R&D projects in the digital healthcare sector of Korea. Thus, it may be helpful to analyse the characteristics of theoretical approaches in developing collaborative structures according to the size of for-profit firms. There are 20 firms responding to our survey study, and they are classified into two groups, 11 small-sized firms (i.e. an annual

turnover of less than €10 million) and nine medium & large-sized firms[62] (i.e. an annual turnover of more than €10 million), based on their annual turnovers.

The data for the two different size groups of firms are normally distributed in the RBV and TCE related motives at a 95% confidence level according to Kolmogorov-Smirnov and Shapiro-Wilk tests. Nonetheless, the motives involving the NIS are not normally distributed at a significant level of 0.05 (see *Appendix 9*). Thus, a parametric test such as an independent-samples t-test is conducted for the RBV and TCE perspectives-related motives, whereas a non-parametric test is performed for the theoretical motives related to the NIS. As noted above, both those tests are for appreciating the mean difference of the agreement level of the three theoretical approaches in developing R&D collaboration for the two different firm sizes.

The result of the Mann-Whitney U test for the NIS-related motives in developing R&D collaboration shows that *small firms are more influenced by the motives linked to the NIS* at a 95% confidence level than medium and large firms (see *Table 6.4 and Appendix 9*). This may be on account of the shortage of internal resources and capabilities of small firms compared with medium and large firms, and the small firms are more likely to rely on external factors to cope with institution-related issues such as accessing knowledge or information on the change of government policies and regulations, and obtaining benefits from potential grants. Meanwhile, there are no significant differences between small and medium or large firms in TCE- and the RBV-related motives because we fail to reject the null hypothesis of the independent-samples t-test that the means of the data between small and medium or large firms are homogenous (see *Appendix 9*).

Table 6.4 The statistical result of the Mann-Whitney U test for the NIS perspective-related motives by firm size

Theoretical motive	Firm sizes	N	Mean Rank	Agreement levels of motives	Exact Sig. [2*(1-tailed Sig.)]
NIS	Small-sized	11	12.95	4.42	0.038[a]
	Medium & large-sized	9	7.50	3.61	
	Total	20		4.06	

a. Not corrected for ties.

Source: author's elaboration

[62] These firms consist of eight medium-sized firms and one large-sized firm.

6.2. Characteristics of Motives and Collaborative Structures by Type of Focal Organisations (a Firm, University, PRI, and Hospital)

The purpose of this section is to indicate how the development of different collaborative structures by focal organisational types is affected by the motives involved in the establishment of collaboration. Thus, the characteristics of motives in developing different collaborative structures are analysed from the perspective of the focal organisational types based on survey data in section 6.2.1. The different organisational types, namely, a firm, hospital, PRI, and university, each with their own roles and characteristics, play a pivotal role in the innovation system as core actors. Thus, the attributes of their motives should be considered in terms of each type of focal organisation in order to identify how the various motives affect the development of different collaborative structures.

In addition, we will investigate how strategic motives influence the development of different collaborative structures by focal organisational type based on interview data in order to provide the additional coverage in section 6.2.2. This investigation is also carried out to validate the novel conceptual framework of this thesis by asking an open-ended question to PIs in the different types of focal organisations (i.e. a question without any theoretical restrictions). Through the integration of the both quantitative and qualitative analysis, we can reach a better understanding of how different collaborative structures are developed by the various focal organisational types.

6.2.1. Characteristics of Motives and Collaborative Structures by Type of Focal Organisations (a Firm, University, PRI, and Hospital) based on Quantitative Analysis

This section aims to understand how different focal organisational types are influenced by motives in the development of collaboration based on survey data. Through this investigation, we expect to reach a better understanding of how different collaborative structures are developed by the various types of focal organisations. To understand the motives based on focal organisational types in developing R&D collaboration is very important because the different organisational types have their own roles and characteristics in the innovation system as core actors. In addition, both managerial leadership and technical leadership of focal organisations have a substantial impact on R&D and innovative performance, as explained previously. Hence, the analysis of the characteristics of motives in developing different collaborative structures through the lens of the focal organisational types would be helpful in meeting the aim of this section.

The analysis begins by showing a general description of the characteristics of motives by focal organisational types based on survey data. According to the analysis in section 5.2 to figure out the most influential motives in establishing R&D collaboration, the motives linked to securing strategic resources for value maximisation (i.e. the RBV) were the most influential in establishing R&D collaboration. Hence, six out of seven motives, marked 5.00 or above (i.e. at least slightly agree), are involved in this perspective (see *Table 5.8*).

However, the analysis in this section indicates that the characteristics of the most influential motives in establishing R&D collaboration are distinctive according to focal organisational types. Although the motive 'to gain access to complementary resources and capabilities' is generally the most significant motive, this motive is the most influential in establishing R&D collaboration only for universities. For firms, the motive 'to develop existing technologies or products' is the most important reason to establish R&D collaboration, while the motive 'to gain access to new technologies or markets' has most effect on the development of collaborative structures led by hospitals and PRIs (see *Table 6.5*). These results show that firms in the digital healthcare sector are more likely to have an interest in developing existing technologies or products through R&D collaboration, while universities tend to be affected by the motive about gaining access to complementary resources and capabilities. Meanwhile, PRIs and hospitals tend to focus more on creating new technologies or markets through collaborating with external partners.

Furthermore, the agreement level for the motive 'to understand demand-side needs' in establishing collaboration is over the 'slightly agree' level for hospitals, PRIs, and universities, although not for private firms. The agreement levels of the motives 'to minimise research costs through developing economies of scope' and 'for learning and internalisation of embedded skills from partners' are between the 'agree' and the 'slightly agree' level in the development of R&D collaboration led by firms and hospitals. Nevertheless, these two motives are below the 'slightly agree' level for PRIs and universities on establishing R&D collaboration (see *Table 6.5*). In other words, PRIs and universities are less likely to be concerned with cost minimisation and learning issues through collaboration than firms and hospitals. Firms seem to be less concerned about understanding demand-side needs compared with the other organisational types.

Table 6.5 The characteristics of most influential motives by focal organisational type

Motives	Theoretical approaches	Ranks by agreement level (agreement levels)				
		Overall	Firm	Univ.	PRI	Hosp'l
To gain access to complementary resources and capabilities	RBV	1 (5.81)	4 (5.70)	1 (5.64)	2 (5.85)	2 (6.20)
To gain access to new technologies or markets	RBV	2 (5.75)	2 (5.85)	7 (5.07)	1 (5.92)	1 (6.30)
To develop existing technologies or products	RBV	3 (5.63)	1 (6.05)	5 (5.21)	5 (5.23)	3 (5.90)
To obtain help for R&D commercialisation	RBV	4 (5.53)	3 (5.80)	2 (5.43)	6 (5.15)	5 (5.60)
To minimise research costs through developing economies of scope	TCE	5 (5.23)	5 (5.55)	-	-	5 (5.60)
To understand demand-side needs	RBV	6 (5.11)	-	6 (5.14)	4 (5.38)	10 (5.20)
For learning and internalisation of embedded skills from partners	RBV	7 (5.00)	7 (5.35)	-	-	10 (5.20)

Variables at least the slightly agreed level (i.e. 5.00) by each organisational type are as follows

*Firm: TCE – 'to minimize research expenses through developing economies of scale (5.50)' and the RBV – 'to access human resources (5.05)'

*University: the NIS – 'to develop technical standards (5.29)' and 'to achieve benefits from potential grants (5.29)'

*PRI: the NIS – 'to pursue certain missions mandated from the government/agency or society (5.69)' and the RBV – 'to access human resources (5.15)'

*Hospital: TCE – 'to shorten lead time (5.90)'; the NIS – 'to develop technical standards (5.40)' and 'to achieve benefits from potential grants (5.40)', and the RBV – 'for learning and internalisation of embedded skills from partners (5.00)'

* 1: Strongly disagree; 2: Disagree; 3: Slightly disagree; 4: Neither agree nor disagree; 5: Slightly agree; 6: Agree; 7: Strongly agree

** The more information on all the motives influencing the establishment of R&D collaboration by focal organisational types is provided in *Appendix 6*.

Source: author's elaboration

Here, we are going to analyse the survey data to show statistical differences in the agreement levels on particular motives in establishing collaboration across the different focal organisational types (a firm, university, PRI, and hospital). This analysis is carried out through an independent-samples Kruskal-Wallis test, a non-parametric test, because the survey data by organisational types are not normally distributed according to the normality tests at a significance level of 0.05. The results of the test shows that motives between at least one pair of groups across focal organisational types are significantly different for six variables - V01, V03, V05, V06, V07, and V20 - at a 95% confidence level (see *Appendix 10*).

Then, Dunn's post-hoc tests are carried out on each pair of groups. For more conservative analysis via minimising type-one error, Bonferroni adjustment to the p-values is conducted. According to the result, focal firms are significantly more affected (at a 0.05 significance level) by motives such as 'to economise research and administrative

expenses through developing economies of scale', 'to gain priority over intellectual property rights', and 'to reduce administrative costs' in establishing collaboration than public research institutes (PRIs). Meanwhile, motives such as 'to minimise research expenses through costs sharing/reduction in research' and 'to gain priority over intellectual property rights' influence significantly more the establishment of R&D collaboration led by firms than by universities at a 0.05 significance level (see *Table 6.6*). These results can be explained by presuming that private firms are more concerned with intellectual property rights (IPRs) and cost-economising motives involving TCE in establishing R&D collaboration than PRIs and universities.

Table 6.6 The result of post hoc tests on strategic motives by focal organisational type

Variables	Strategic motives	Focal organisations 1 - 2	Sig.	Adj. Sig.
V01 (TCE)	To economise research and administrative expenses through developing economies of scale	Firm-PRI	0.006	0.034
V03 (TCE)	To minimise research expenses through costs sharing/reduction in research	Firm-University	0.08	0.046
		Firm-PRI	0.032	0.193
V05 (TCE)	To shorten lead time	Hospital-PRI	0.009	0.056
		Hospital-University	0.014	0.086
V06 (TCE)	To reduce administrative costs	Hospital-PRI	0.029	0.172
		Firm-PRI	0.004	0.022
		Firm-University	0.045	0.273
V07 (RBV)	To gain priority over intellectual property rights	Firm-University	0.001	0.005
		Firm-PRI	0.003	0.016
V20 (NIS)	To pursue certain missions mandated from the government/agency or society	PRI-University	0.014	0.087
		PRI-Firm	0.012	0.073

* Each row tests the null hypothesis that the distributions of the motives in the establishment of different collaborative structures by focal organisations 1 and 2 are the same.

Source: author's elaboration

We will deal with the characteristics of theoretical perspectives linked to motives based on the focal organisational types in this paragraph. The analysis is carried out with a one-way ANOVA test to determine whether there are any significant differences between the means of the degree of motives by focal organisational types based on the three theoretical perspectives of the NIS, the RBV and TCE. Each group of theoretical approaches by focal organisational type are normally distributed at a 0.05 significance level while the variances across the groups of theoretical approaches by focal organisational type are also homogenous, according to normality tests and Levene's test (see *Appendix 11*). Hence, the one-way ANOVA test can be conducted based on meeting both these assumptions, the normal distribution and the homogeneity of variances of the data.

According to the result of the ANOVA test, there are significant differences between focal organisational types in the means of the agreement level of motives involving a cost-minimisation approach (i.e. TCE) at a confidence level of 99%. More specifically, the Bonferroni post hoc tests on pair comparisons between focal organisational types show that the motives based on the cost-minimising approach exercise significantly more influence on the establishment of R&D collaboration led by firms than those led by PRIs at a 0.01 significant level. Similarly, these post hoc tests indicate firms are significantly more affected by motives linked to a cost-minimising approach in developing collaboration than universities (at a 0.05 significance level) (see *Table 6.7 and Appendix 12*).

Table 6.7 The summary of post-hoc tests on theoretical approaches by focal organisational type

Dependent Variable	(I) Focal organisational types	(J) Focal organisational types	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
TCE	Firm	Hospital	.16667	.39296	1.000	-.9104	1.2437
		PRI	1.27436*	.36147	.005	.2836	2.2651
		University	.99048*	.35356	.043	.0214	1.9596

* The mean difference is significant at the 0.05 level.

** The Bonferroni test can control the overall type-one error (i.e. false positive) and tend to be conservative and powerful (Frane, 2015).

Source: author's elaboration

6.2.2. Characteristics of Strategic Motives and Collaborative Structures by Type of Focal Organisations (a Firm, University, PRI, and Hospital) based on Qualitative Analysis

The purpose of this section is to explore how different focal organisational types are influenced by motives in the development of R&D collaboration based on interview data. In addition, this section aims to validate the novel conceptual framework of this thesis by asking an open-ended question to the different types of focal organisations (i.e. a question without any theoretical restrictions). As noted in the previous section, understanding the motives based on focal organisational types in developing R&D collaboration is crucial because the different organisational types have their own roles and characteristics in the innovation system and they may have distinctive motives in the establishment of R&D collaboration with other partners. Through the integration of this exploration along with the investigation performed in section 6.2.1 based on survey data, we can perhaps reach a better understanding of how different collaborative structures are developed by the various focal organisational types. Thus, the analysis of the characteristics of motives based on the interview data in developing different collaborative structures categorised

by focal organisational type should provide additional coverage for arriving at a better understanding of how different collaborative structures are developed.

When it comes to the development of a collaborative structure *led by focal firms*, focal firms tend to establish collaboration 'to access complementary capabilities or resources' in order 'to develop existing technologies', 'to gain access to new technologies or markets', and 'to gain help for R&D commercialisation'. As described in *Appendix 5*, all interviewees in focal firms taking part in the interview course answered that their motive is basically 'to obtain complementary capabilities or resources' through collaborating with their partners.

However, the specific objectives of accessing complementary capabilities or resources through the development of collaboration are diverse, according to the interview data. Indeed, interviewee F05 (CTO) said that the reason for establishing R&D collaboration is "to add core algorithm technology to our own technology in order for the commercial use." Similarly, interviewee F05 expected to develop their existing technology for the achievement of R&D commercialisation through obtaining complementary capabilities from their collaborating partner. Interviewee F10 (Founder/CEO) also responded that they needed to gain complementary capabilities "for their existing healthcare platform." In addition, interviewees F06 (CTO/Executive Director) and F08 (CTO) mentioned that they wanted to acquire complementary capabilities and resources in order "to deal with new technology" and "to cover all needed technological areas" (i.e. to access new technologies) for achieving their research aims, respectively. Meanwhile, interviewees F02 (Founder/CEO) and F09 (CTO) said complementary capabilities were necessary in order "to launch their product to the market" and "to cover all the process of product development from technological development to commercialisation", respectively (see *Appendix 5*). In order words, interviewees F02 (Founder/CEO) and F09 (CTO) established R&D collaboration with motives 'to access complementary capabilities' in order 'to obtain help for R&D commercialisation'.

The result of this qualitative analysis is consistent with the previous finding regarding the most influential motives in the establishment of R&D collaboration by type of focal organisation based on survey data in section 6.2.1. For instance, the agreement level of focal firms on the motive 'to develop existing technologies' is highest, followed by motive 'to gain access to new technologies or markets', while the motive 'to obtain help

for R&D commercialisation' is ranked third, and the motive 'to access complementary capabilities or resources' is placed fourth among the 23 different motives (see *Table 6.5*).

In the light of the development of a collaborative structure *by focal universities*, focal universities tend to establish R&D collaboration with the motives 'to obtain help for R&D commercialisation' through 'accessing complementary capabilities', and 'to achieve benefits from potential grants'. For example, interviewee U01 (Full professor) said they expected "to obtain complementary capabilities from private firms regarding the commercialisation of the existing technology." Meanwhile, interviewee U05 (Full professor) responded that they established R&D collaboration in order to apply their healthcare service platform "to clinical practice" to be utilised in the healthcare service market. In addition, interviewee U07 (Assistant professor) said that their collaborating partner asked him to collaborate together for the purpose of "winning the research grant" (see *Appendix 5*). This result based on interview data is coherent with the result based on survey data, given that the motive 'to access complementary capabilities' in the establishment of R&D collaboration is the most influential motive, followed by the motive 'to obtain help for R&D commercialisation'. The motive 'to achieve benefits from potential grants' is also placed in third from the perspective of the average agreement level of motives in the development of R&D collaboration (see *Table 6.5*).

Here, we will move our attention to the development of a collaborative structure *led by focal PRIs*. They are likely to develop R&D collaboration 'to access complementary capabilities or resources' in order 'to gain access to new technologies or markets', and 'to pursue certain missions mandated from the government/agency or society' in the innovation system. Indeed, interviewee P02 (Principal researcher) said that "we cannot internally hold every capability and resource for attaining the research goal …" and need to collaborate with external partners to access new technologies or markets. Moreover, interviewee P05 (Team head/Senior researcher) responded that they developed R&D collaboration "in order to create a new market …." Meanwhile, interviewee P03 (Principal researcher) mentioned they wanted "to contribute to the refinement of the healthcare service model owned by a SME" by carrying out the role mandated from government or society as a PRI in the innovation system (see *Appendix 5*). In addition, this result is consistent with findings from survey data in section 6.2.1. According to the survey data, the motive 'to gain access to new technologies or markets' is evaluated as

the most influential motive, and the motives ‘to access complementary capabilities’ and ‘to pursue certain missions mandated from the government/agency or society’ are placed second and third, respectively (see *Table 6.5*).

Lastly, we will focus on a collaborative structure developed *by focal hospitals*. According to interview data, focal hospitals tend ‘to access complementary capabilities’ and ‘to gain access to new technologies or markets’. For example, interviewees H02 (Full professor/Director, MD), H03 (Full professor, MD), H04 (Full professor), H05 (Principal researcher), and H08 (Full professor, MD) said they expected ‘to gain access to new technologies’ such as the development of mobile applications, sensing technology, hardware development, and IT security through establishing R&D collaboration. The rest of interviewees in hospitals, H01 (Research assistant professor), H06 (Full professor/Vice Dean, MD), and H07 (Full professor, MD), also commented that they needed to collaborate with external partners in order to obtain complementary capabilities that are new to them and they cannot cover with their own capabilities (see *Appendix 5*). Furthermore, this result is consistent with the result from the previous section based on survey data, in that the motive ‘to gain access to new technologies or markets’ is assessed as the most influential motive in the establishment of R&D collaboration, followed by the motive ‘to access complementary capabilities’ (see *Table 6.5*).

Table 6.8 below summarises the main motives in the development of different R&D collaborative structures by focal organisational type (a firm, university, PRI, and hospital) in public R&D collaboration in the digital healthcare sector of Korea. These main strategic motives resulting from interviews with PIs in different types of focal organisations by asking an open-ended question (without any theoretical restrictions) are well covered within the conceptual framework of this thesis. Hence, we can say that the conceptual framework can cope suitably with various determinants affecting the formation of strategic motives in establishing collaborations (i.e. value-maximising determinants and institutional influences) among different types of organisations (see *Table 6.8*). In addition, this conceptual framework is useful to deal with cost-minimising determinants in the formation of strategic motives (linked to a TCE perspective), which are significantly distinctive motives affecting the development of inter-organisational collaboration between for-profit and not-for-profit organisations (in particular such as universities and PRIs) (see *Table 6.3* and *6.7*).

Table 6.8 Main motives in the development of different R&D collaborative structures by focal organisational type

Main motives in the establishment of R&D collaboration	Collaborative structures
'To access complementary capabilities or resources (RBV, 4)' in order 'to develop existing technologies (RBV, 1)', 'to gain access to new technologies or markets (RBV, 2)', and 'to obtain help for R&D commercialisation (RBV, 3)'	Led by focal firms
'To obtain help for R&D commercialisation (RBV, 2)' through 'accessing complementary capabilities (RBV, 1)', and 'to achieve benefits from potential grants (NIS, 3)'	Led by focal universities
'To access complementary capabilities or resources (RBV, 2)' in order 'to gain access to new technologies or markets (RBV, 1)', and 'to pursue certain missions mandated from the government/agency or society (NIS, 3)'	Led by focal PRIs
'To access complementary capabilities (RBV, 2)' 'to gain access to new technologies or markets (RBV, 1)'	Led by focal hospital

* The numbers in the parenthesis show ranks by agreement level on strategic motives in establishing collaboration based on a survey study (see *Table 6.5*).
Source: author's elaboration

6.3. Focal Organisations' Strategic Motives for the Choice of Collaborating Partners based on Quantitative Analysis

This section aims to understand how motives affect focal organisations in choosing their collaborating partner types. In order to address this question, the survey-based data are classified by collaborating partner types, and these classified groups are employed to analyse the agreement level for the motives in the light of focal organisational types. Hence, we can investigate how each motive affects a particular focal organisational type in establishing R&D collaboration with a particular partner type. *Table 6.9* shows the descriptive characteristics of collaborating partners by focal organisational type. Firms are more likely to collaborate with hospitals, and PRIs tend to collaborate more with hospitals and universities in comparison with the average ratios. Meanwhile, universities are more likely to establish R&D collaboration with firms, and hospitals also prefer to collaborate more with firms, these accounting for 47% and 65% of all collaborating partners, respectively (see *Table 6.9*).

Table 6.9 Descriptive characteristics of collaborating partners by focal organisational type

Focal organisations (No. of projects)	The number of collaborating partners (ratios)				
	Firm	Hospital	PRI	University	Total
Firm (94)	57 (29.1%)	**68 (34.7%)**	25 (12.8%)	46 (23.5%)	196 (100%)
University (59)	**62 (47.0%)**	25 (18.9%)	11 (8.3%)	34 (25.8%)	132 (100%)
PRI (24)	5 (9.4%)	**21 (39.6%)**	6 (11.3%)	**21 (39.6%)**	53 (100%)
Hospital (30)	**50 (64.9%)**	10 (13.0%)	6 (7.8%)	11 (14.3%)	77 (100%)
In total (207)	174 (38.0%)	124 (27.1%)	48 (10.5%)	112 (24.5%)	458 (100%)

* Twenty-five collaborating partners, which are not one of the four organisational types, are excluded.

Source: author's elaboration

Next, we will explore mean differences in the agreement level of the motives by collaborating partner types across the four different focal organisational types. Through this analysis, we can arrive at a better understanding of how motives affect the four different leading organisational types in choosing a particular partner type in an R&D collaboration. This analysis is conducted using the Kruskal-Wallis test, a non-parametric test because the dependent variables are not normally distributed. *Table 6.10* below shows the results of the Kruskal-Wallis tests, and of the Dunn post hoc tests. These post hoc tests are carried out to identify significant mean differences between each pair of focal organisational types, and a Bonferroni adjustment to p-values is performed for more conservative analysis through minimising type-one errors.

According to the results, the motive to shorten lead time influences focal hospitals to establish R&D collaboration with partner firms significantly more so than focal universities, while focal firms are significantly more concerned with minimising research expenses in the development of R&D collaboration with partner hospitals than focal universities. Moreover, focal firms are significantly more affected by the motive to gain priority over IPR in establishing R&D collaboration with partner universities than focal universities. Focal firms are also more concerned about the motive of reducing administrative costs in developing R&D collaboration with partner universities than focal universities and PRIs, respectively. However, focal firms are significantly less influenced by the motive to achieve benefits from potential grants in R&D collaboration with partner universities than focal hospitals (see *Table 6.10*).

In other words, these results seem to suggest that researchers or medical doctors in hospitals seek to shorten the lead-time for the materialisation of their ideas from a clinical site through collaborating with partner firms, while they collaborated with universities to gain benefits from potential grants. Furthermore, focal firms may establish R&D collaboration with partner hospitals in order to minimise research expenses such as costs of clinical trials or employing a clinical test-bed. Meanwhile, they form R&D collaborations with partner universities in the expectation that they might obtain support for research-related administrative tasks, which can be provided by the University and Industry Cooperation Centre (UICC) at universities[63]. In addition, focal firms expect to

[63] Until 2016, 77.7% of the four-year Korean universities established a UICC as noted in section 4.2.2.

gain priority over IPR such as patenting and licensing-in through collaborating with partner universities.

Table 6.10 The results of statistical analysis on the influence of different strategic motives on a focal organisation to choose a particular collaborating partner

Collaborating partner types	Strategic motives	Sig.[a]	The Dunn's post-hoc tests		
			Sample 1–Sample 2[b]	Sig.	Adj. Sig.
Firm	**(V05) To shorten lead time**	0.03	University-**Hospital**	0.00	**0.02**
	(V06) To reduce administrative costs	0.02	PRI-Firm;	0.02	0.14
			PRI-Hospital;	0.03	0.20
			University-Firm;	0.02	0.13
			University-Hospital	0.04	0.23
	(V07) To gain priority over intellectual property right	0.04	University-Hospital;	0.05	0.29
			University-Firm	0.02	0.12
	(V18) To get help with overcoming legal or regulatory barriers	0.01	PRI-Firm;	0.03	0.17
			PRI-Hospital;	0.01	0.06
			University-Firm;	0.04	0.25
			University-Hospital	0.01	0.08
University	**(V06) To reduce administrative costs**	0.01	University-**Firm;**	0.00	**0.02**
			PRI-**Firm**	0.01	**0.03**
	(V07) To gain priority over intellectual property right	0.03	University-**Firm**	0.00	**0.02**
	(V23) To achieve benefits from potential grants	0.03	Firm-University;	0.02	0.15
			Firm-**Hospital**	0.01	**0.03**
Hospital	**(V03) To minimise research expenses through costs sharing/reduction in research**	0.01	University-**Firm;**	0.00	**0.01**
			University-Hospital	0.04	0.22
	(V22) To develop technical standards	0.04	Firm-Hospital;	0.03	0.19
			Firm-PRI	0.03	0.16

a. This indicates the significance level of the Kruskal-Wallis tests
b. The agreement level of motives on establishing collaboration of Sample 2 is higher than the degree of Sample 1
* The null hypothesis for the Dunn's post-hoc tests are that the Sample 1 and Sample 2 distributions are the same.

Source: author's elaboration

6.4. Focal Organisations' Strategic Motives for their Choice of Collaborating Partners based on Qualitative Analysis

This section aims to identify focal organisations' expectations with regard to their collaborating partners in the development of R&D collaboration in the digital healthcare sector. Through this investigation, we aim to arrive at a better understanding of the motives of focal organisations because the organisational strategic expectations of collaborating partners are vital elements in the motives by which different collaborative structures are developed. Data for this investigation are based on interviews with 35 principal investigators (PIs) of 39 research topics. The focal organisations of these 39 research topics include 14 firms, nine hospitals, six PRIs, and 10 universities. Thus, this

section includes four sections which consider the expectations of four different focal organisational types with regard to particular collaborating partner' types, namely firms, universities, PRIs, and hospitals.

Before undertaking the investigation to understand focal organisation's motives in choosing a particular organisational type of collaborating partners, we will first explore the general characteristics of different R&D collaborative structures. In order to understand the general characteristics of R&D collaborative structures, the R&D projects involving collaboration with a particular type of partner are classified by focal organisational type. Hence, we can identify to what extent each type of focal organisations is likely to collaborate with a particular type of partner organisation. Those R&D projects led by a firm are most likely to involve the establishment of R&D collaboration with different collaborating partner types, and focal firms have developed R&D collaboration with 1.62 different collaborating partner types for each R&D project on average, as described in *Table 6.11*. In contrast, for R&D projects led by PRIs there was only collaboration with 1.25 different partner types for each project on average (see *Table 6.11*).

Furthermore, more than 56% of focal firms established an R&D collaboration with partner hospitals, and 70% of focal hospitals developed an R&D collaboration with partner firms, these being much higher rates compared with the overall rate of around 44%. Conversely, focal hospitals were less likely to collaborate with partner universities, (by 12 percentage points less than an overall rate). When it comes to focal PRIs, more than 58% of R&D projects led by PRIs established an R&D collaboration with partner universities while only around 20% and 25% of them developed R&D collaboration with partner firms and hospitals, respectively. Lastly, focal universities are less likely to build R&D collaboration with partner PRIs (13.6%) than the average for all R&D projects involving collaboration with partner PRIs (20.3%) (see *Table 6.11*).

Table 6.11 The number of R&D projects collaborating with a particular type of collaborating partners by focal organisational type

The number of R&D projects by focal organisational type (A)	The number of R&D projects collaborating with a particular type of partners*				
	Firm (F/A)	University (U/A)	PRI (P/A)	Hospital (H/A)	Total (T/A)
Firm (94)	37 (39.4%)	39 (41.5%)	23 (24.5%)	**53 (56.4%)**	**152 (1.62)**
University (59)	28 (47.5%)	25 (42.4%)	**8 (13.6%)**	23 (39.0%)	84 (1.42)
PRI (24)	**5 (20.8%)**	**14 (58.3%)**	5 (20.8%)	**6 (25.0%)**	**30 (1.25)**
Hospital (30)	**21 (70%)**	**9 (30.0%)**	6 (20.0%)	10 (33.3%)	46 (1.53)
Overall (207)	**91 (44.0%)**	**87 (42.0%)**	**42 (20.3%)**	**92 (44.4%)**	312 (1.51)

* 'F' is the number of R&D projects involving collaboration with a partner in the form of a firm. In the same way, 'H', 'P', and 'U' indicate the number of R&D projects involving R&D collaboration with a partner hospital, PRI, and university, respectively. In addition, 'T' indicates the total number of R&D projects involving collaboration with the four different partner types.

Source: author's elaboration

6.4.1. Focal Firms' Expectations with regard to their Collaborating Partners

As noted above, we will analyse focal organisations' expectations of particular collaborating partner types in the establishment of R&D collaboration based on the interview data. This analysis can help arrive at a better understanding of how different collaborative structures are developed among four different core actors in the innovation system. In this section, we will first focus on the expectations of focal firms with regard to particular collaborating partner types in developing R&D collaboration.

According to our investigation, *focal firms* are likely to build an R&D collaboration with collaborating *partner firms* with the expectations of component technologies/items held by the partner firms being used to develop the focal firm's products or services. For instance, interviewee F02 (Founder/CEO) said "the R&D project we are undertaking is to establish a personalised healthcare server platform for the whole life-cycle healthcare by utilising life-logs and government healthcare data … and start-ups and venture firms, which may be unable to launch their digital healthcare services with their limited resources and capabilities, will be able to access this platform without additional efforts for data security and collection … we needed to collaborate with other partner firms to help them in dealing with component technologies about data and systems security, data analysis, and the development of algorithms …." Interviewee F04 (Founder/CEO) has taken part as a PI in two different R&D projects in the digital healthcare sector. The

objectives of the R&D projects are to develop IT service solutions for smart healthcare[64] and wellness. This interviewee mentioned the reason for building collaboration with partner firms as being "to acquire the partner's technological capabilities regarding the development of the remote healthcare monitoring system such as the Internet of Things (IoT) technology and a platform of mobile applications", which are core elements in the development of the smart healthcare service solutions.

Likewise, interviewees F06 (CTO/Executive Director) and F13 (CTO and Full professor) responded that they expected partner firms to take care of component technological capabilities in terms of their developing services and products in the R&D projects. Interviewee F06 said, "we expected our partner firm to deal with integrating the bio-signal measurement technology the partner's firm has with the blood sugar measurement technology possessed by our company" in order to develop a new healthcare service model. In addition, interviewee F13 responded "… we expected partner firms to play diverse roles in coping with the user interface design of the mobile application, managing the server system of the wellness care platform, and commercialising developed devices from the R&D project …." Interviewee F03 (CTO) also said "we looked for a partner firm possessing the technological capabilities about batteries to develop an advanced automated external defibrillator (AED), although the R&D collaboration was established by the enforcement" of a funding agency according to a requirement condition in the call for proposals.

These collaborations between focal and partner firms in the R&D projects in the digital healthcare sector may be associated with 'supply chain collaboration'. Many scholars have argued that this kind of collaboration with suppliers tends to contribute to focal firms' innovative performance via lowering production costs (e.g. Hagedoorn, 1993; Scannell, et al., 2000), reducing the costs of opportunism and monitoring (Croom, 2001), and thus reducing transaction costs (Johnson, et al., 2003; Sheu, et al., 2006).

When it comes to *focal firms*' expectations from collaborating *partner universities*, focal firms are likely to collaborate with partner universities in order to acquire highly

[64] Smart healthcare is defined by the technology that leads to better diagnostic tools, better treatment for patients, and devices that improve the quality of life for anyone and everyone. The key concept of smart health includes eHealth and mHealth services, electronic record management, smart home services and intelligent and connected medical devices (BlueStream, 2015).

specialised technology and to develop technical standards. Interviewee F02 (Founder/CEO) responded to a question about their expectations regarding collaborating partner universities in an R&D collaboration by stating that "we expected to learn about the development of technical standards and to gain benefits from feasibility studies on developing a personalised healthcare server platform …., and we also wanted universities to be responsible for data analysis." In the same vein, interviewees F04 (Founder/CEO) and F05 (CTO) said that they expected to acquire "highly specialised technical capabilities involved in the development of algorithms based on mental diseases and in the fine measurement of electrocardiograms (ECGs)" through establishing R&D collaboration with universities, respectively. Similarly, interviewee F03 (CTO) said that "collaboration with two universities was to obtain specialised technical capabilities in terms of an electric motor and high-voltage technology" because the R&D project led by F03 is to develop an advanced automated external defibrillator (AED) incorporating the function of automated cardiopulmonary resuscitation (CPR). In addition, "collaboration with the other university was to get benefits from the UICC (University and Industry Cooperation Centre) at the university in terms of technology licensing-ins." Meanwhile, interviewee F06 (CTO/Executive Director) mentioned what their firm expected was "to get help with the development of technical standards from R&D collaboration with a university."

This paragraph focuses on *focal firms'* expectations with regard to *partner PRIs* in an R&D collaboration. According to interviewees, focal firms tend to establish R&D collaboration with PRIs in order to obtain benefits from PRIs' research capabilities and to overcome institutional barriers such as approval information on new products. For instance, interviewees F04 (Founder/CEO) and F09 (CTO) said their expectations from the partner PRIs were "to gain research capabilities for the development of advanced algorithms based on mental diseases", and "for the development of a new form of AED which is smaller and can be installed outdoors." Interviewee F03 (CTO) said that "we expected to obtain government approval information and testing procedures for the approval of new products in the domestic and overseas markets" through working with a PRI.

Lastly, *focal firms'* expectations from *partner hospitals* in an R&D collaboration are mainly to employ hospitals as testbeds for the clinical validation of the focal firm's

products or services. They also tried to gain clinical insights or establish demand-side needs from collaborating with hospitals. Many interviewees, for example F01 (Founder/CEO), F02 (Founder/CEO), F03 (CTO), F06 (CEO/Executive Director), and F10 (Founder/CEO), said that their expectation from collaboration with hospitals was "to get help in terms of clinical validations of their products or services" through clinical trials in their partner hospitals. In a similar vein, interviewee F04 (Founder/CEO) mentioned they expected "to obtain specialised capabilities in clinical and medical knowledge" from their collaborating partner hospital. In addition, interviewee F01 (Founder/CEO) commented that he wanted "to obtain clinical insights regarding physical rehabilitation of the disabled owing to a stroke", which contributed to the development of a home rehabilitation device called smart gloves and of various rehabilitation games. Meanwhile, interviewee F12 (Team head) noted that the reason for the establishment of R&D collaboration with a hospital was "to understand demand-side needs and to gain benefits from the reputation of the partner hospital and the role of the partner hospital as a clinical test bed."

Table 6.12 below provides a summary of focal firms' expectations from each partner organisational type in public R&D collaboration in the digital healthcare sector of Korea.

Table 6.12 Summary of focal firms' main expectations from their partners

Focal firms' main expectations	Collaborating partners' type
To secure component technologies or specific items held by partner firms for developing the focal firm's products or services with the expectation of a reduction in transaction costs	Firm
In order to gain highly specialised technology and to develop technical standards	University
To obtain benefits from PRIs' research capabilities and to overcome institutional barriers such as approval information on new products	PRI
To employ hospitals as testbeds for the clinical validation of focal firms' products or services and to obtain clinical insights	Hospital

Source: author's elaboration

6.4.2. Focal Universities' Expectations with regard to their Collaborating Partners

This section aims to identify focal universities' expectations with regard to each type of collaborating partners in public R&D projects in the digital healthcare sector. In contrast to the expectations of focal organisations from the not-for-profit sector, the expectations of *focal universities* with regard to their *partner firms* cannot be easily grouped together under several main headings. This may be because the characteristics of private firms are more diverse, compared with attributes of the not-for-profit organisations. The

characteristics of the firms range from manufacturers, to service providers, and to outsourcing firms. In this regard, interviewee U01 (Full professor) said that "we expected to benefit from licensing-outs[65] and technology commercialisation, and we also wanted to develop our existing technology to examine its compatibility and interoperability in diverse technological environments, and to get complementary capabilities such as the development of digital healthcare contents related to chronic diseases" through the establishment of R&D collaboration with firms. The expectations of interviewee U02 (Full professor, MD) with regard to partner firms reflect a particular research goal to be achieved via the R&D project they conducted, namely to develop a customised cyber-doctor to monitor bio-signals for providing personalised healthcare information to users. Hence, their expectation of partner firms was "to gain help from the development of the user interface (UI) based on patients' and healthcare service providers' demands (because particular firms in this project work very closely with patients and service providers), from technology licensing-outs, and from specialised technologies such as the development of mobile applications and of mobile networking systems."

Meanwhile, interviewee U03 (Full professor, MD) said the purpose of the R&D project was to build a data supply chain, namely in terms of a clinical data warehouse (CDW) that integrates real-time clinical data from a variety of healthcare service providers to present a unified view for an individual patient. Hence, they expected "to get help from the development of the CDW system" by collaborating with a partner firm. Finally, interviewee U07 (Assistant professor) observed that "we wanted to gain benefits from the demonstration and implementation of our ideas and concepts through collaborating with a partner firm."

With regard to *focal universities'* expectations of their *partner universities*, focal universities are likely to expect to benefit from particular specialised technologies of their partner universities. For example, interviewee U02 (Full professor, MD) said that "we collaborated with other universities in order to acquire their specialised technologies such as the development of optical bio-sensors and immunological detection technology." Likewise, interviewee U03 (Full professor, MD) mentioned that they expected their partner universities to deal with "the development of algorithms for the proper

[65] Technology licensing-out can be defined as the activity of a technology holder to transfer it to another company in return for a fee, while licensing-in is the way to adopt external technology to develop your own business and products.

anonymization of electronic medical records (EMRs)", while another reason to develop R&D collaboration with a university was "to access a talented researcher" in their research topic. Moreover, interviewee U06 (Full professor, MD) had a similar expectation with regard to their collaborating partner universities, in that "we needed to acquire specialised technologies from our partner universities such as syntactic analysis technology based on EMRs and the development of a biomarker analysis system for diagnostic and prognostic prediction of cancers."

There is only one *focal university* collaborating with *partner PRIs* in the interview data. Interviewee U02 (Full professor, MD) said that he expected "to receive help in the development of software-related to biosensors and the system integration of sensors, software packages, and a variety of hardware" through collaboration with PRIs. Thus, it may be concluded that focal universities tend to collaborate with PRIs in order to acquire specialised capabilities, although this is based on just a single observation.

When it comes to the expectations of *focal universities with regard to partner hospitals* in an R&D collaboration, focal universities may seek to secure medical data and to carry out a clinical validation by collaborating with partner hospitals. Thus, interviewee U03 (Full professor, MD) said "we expected to build a medical data supply chain in the first R&D project, and to build an evidence supply chain in the second R&D project through collaborations with partner hospitals" (the focal university has conducted two different R&D projects in the digital healthcare sector). Similarly, interviewee U04 (Full professor) said that "we established R&D collaboration with a partner hospital in order to access medical data collected from patients." Meanwhile, interviewee U05 (Full professor) said "we expected to apply an individualised drug use system for appropriate medication therapy on a clinical site" of the partner hospital through collaboration with that partner hospital. Finally, interviewee U06 (Full professor, MD) mentioned that "we wanted to collect medical data as well as to benefit from the development of the biomarker analysis system for the diagnostic and prognostic prediction of cancers from a clinical perspective" by collaborating with a partner hospital.

Table 6.13 below provides a summary of focal universities' expectations with regard to each partner organisational type.

Table 6.13 Summary of focal universities' main expectations with regard to their partners

Focal universities' main expectations	Collaborating partners' type
- To benefit from licensing-out and technology commercialisations - In order to understand end-users' demands and to check the compatibility and interoperability of their existing technology with other similar technology - To gain help in the implementation of research concepts and developing technologies	Firm
To benefit from specialised capabilities such as optical bio-sensors and immunological anonymization, and syntactic analysis technology.	University
To acquire highly specialised capabilities such as biosensor-related software and the system integration	PRI
In order to secure medical data and to carry out the clinical validation of developing technologies	Hospital

Source: author's elaboration

6.4.3. Focal PRIs' Expectations with regard to their Collaborating Partners

In this section, we will shed light on the expectations of focal PRIs with regard to particular collaborating partner types in the development of R&D collaboration. First, we will analyse the expectations of *focal PRIs* with regard to collaborating *partner firms*. According to interviewees, focal PRIs are likely to establish an R&D collaboration with partner firms in order to implement their research concepts and technologies and to support private sector firms. Thus, interviewee P02 (Principal researcher) said that "we asked a firm to address the materialisation of the ontology-based knowledge system involving traditional Korean medicine" in the R&D project. Meanwhile, interviewee P03 (Principal researcher) said that "the purpose of the R&D project we carried out is to support SMEs in improving their technological capabilities, and we helped one firm to advance its existing healthcare service platform". This can be interpreted as implying that this focal PRI carried out its mandated role as one of the public organisations in the innovation system.

However, *focal PRIs* are likely to collaborate with *partner universities* with the expectation of benefiting from the development of highly specialised technologies. Thus, interviewee P01 (Principal researcher/Team head) responded that "we intended to obtain specialised technological information on the security technology of EMR data exchange and state-of-the-art information on healthcare information management for the establishment of the national health information strategy." In a similar vein, interviewee P04 (Principal researcher/Assistant vice president) expected "to acquire exploratory

research capabilities based on diverse bio-signals", while interviewee P06 (Principal researcher/Director) said they hoped "to develop diagnostic chips for respiratory infections" through establishing collaboration with partner universities.

When it comes to *focal PRIs*' expectations from other *partner PRIs* in R&D collaboration, focal PRIs tend to develop R&D collaboration with other PRIs in order to benefit from partners with component technologies for attaining their research goals. Therefore, interviewee P06 (Principal researcher, Director) mentioned that "we expected to get help with the development of bio-chips based on immunodiagnostic analysis and with the communication and network technology" between bio-chips and a server.

Regarding the expectations of *focal PRIs* with respect to *partner hospitals* in R&D collaboration in the digital healthcare sector, they may be likely to establish collaboration with partner hospitals to get help with the clinical validation for targeted technologies and to obtain clinical insights and knowledge on their research. Thus, interviewee P01 (Principal researcher/Team head) commented that "we expected to get help with doing pilot studies on medical information exchange between hospitals", and "to gain access to clinical knowledge" in order to establish the appropriate national health information strategy. Similarly, interviewee P02 (Principal researcher) said "we needed to get help with the practical validation" for their developed IT solution in diverse clinic sites through collaborating with partner hospitals. On the other hand, interviewee P03 (Principal researcher) responded that "we expected to acquire clinical knowledge and insights on our research."

Table 6.14 below shows a summary of focal PRIs' expectations with regard to each partner organisational type.

Table 6.14 Summary of focal PRIs' main expectations with regard to their partners

Focal PRIs' main expectations	Collaborating partners' type
In order to implement the research concepts and technologies they have and to support SMEs as a public research organisation	Firm
To benefit from the development of specialised technologies based on their research	University
In order to benefit from partners with component technologies for their research	PRI
To get help with the clinical validation for targeted technologies and to obtain clinical insights and knowledge on their research	Hospital

Source: author's elaboration

6.4.4. Focal Hospitals' Expectations with regard to their Collaborating Partners

Here, we will focus on the expectations of focal hospitals with regard to their different collaborating partners in the digital healthcare sector. First of all, we aim to shed light on *focal hospitals*' expectations with regard to *partner firms* in R&D collaborations. According to interviewees, focal hospitals expected the benefits of complementary capabilities from their partner firms such as existing technologies or platforms of the partner firms in relation to ICT and digital services in order to implement their ideas derived from clinical practice.

For instance, interviewee H02 (Full professor/Director, MD) said "we needed to obtain complimentary capabilities that we do not have in our hospital, in particular the development of a mobile rehabilitation service platform and mobile applications" in order to provide better health services for patients after cochlear implantation. Interviewee H03 (Full professor, MD) responded that "we expected to benefit from the measurement technology of sodium levels[66], from the implementation of hardware" about a medical device for arrhythmia diagnosis and therapy, and from "the utilisation of partners' existing technology regarding a wearable AED and a portable electrocardiogram." In addition, interviewee H04 (Full professor, MD) said that "we wanted to develop an open source-based personal health information management system for patients with a cleft palate who need a series of operations from a very early age." For the development of this system, we expected "to get help with the development of mobile applications and the technical integration between electronic medical records and personal health records" from partner firms "because the interviewee said the partner firms have much experience in managing the health information system."

Furthermore, interviewee H07 (Full professor, MD) said that "we wanted to utilise an existing mobile platform of a partner firm and its contents", and "to access health information collected from different hospitals" from the partner firm managing health information systems of many hospitals. Hence, R&D collaboration with the partner firm may enable the focal hospital to establish a multi-platform-based health information system for patients with chronic diseases. Interviewee H07 also said "we collaborated with another partner firm to get dietary and restaurant information to suggest suitable menu and restaurants for patients with chronic diseases such as diabetes." The

[66] Sodium levels are used as an important indicator for cardiac arrhythmia diagnosis.

expectations of interviewee H08 (Full professor, MD) with regard to partner firms were "to obtain help with the development of user interface technology to provide health management services" for people who have chronic diseases, obesity, and infection diseases, and "for the development of sensors and a platform for monitoring them and collecting data from them." Lastly, interviewee H06 (Full professor/Vice Dean, MD) responded that "we expected to get benefits from the service design capabilities" of the partner firm in order to develop patients-centred medical contents.

Next, we will focus on the expectations of *focal hospitals* in connection with their *partner universities* in R&D collaboration. Interviewee H01 (Research assistant professor) observed that they wanted to collaborate with the university "to get help with technical standards because the professor at the university is renowned for his research capabilities in the technical standards of medical information." Interviewee H05 (Principal researcher) also mentioned that "we expected to benefit from technical standard capabilities to facilitate the exchange of personal health records" by collaborating with a partner university. On the other hand, interviewee H08 (Full professor, MD) said "we expected to obtain information and knowledge on the latest trend in rehabilitation technology for the elderly, and on demands of healthcare service contents for apartment complexes" based on ambient assisted living (AAL) from partner universities in order to obtain benefits from technical standards based on medical information and from the exploratory research capabilities of partner universities.

With regard to the expectations of *focal hospitals* with respect to *partner PRIs* in R&D collaborations, focal hospitals tend to gain help with institutional issues and technological capabilities from their partner PRIs. Hence, interviewee H03 (Full professor, MD) said "we wanted to benefit from how to develop research concepts into practical research projects, and from information on the process of technology transfer and medical device approval" by collaborating with a partner PRI. Meanwhile, interviewee H07 (Full professor, MD) said "we expected to utilise a mobile healthcare management platform" developed by our partner PRI through the R&D collaboration.

When it comes to the expectations of *focal hospitals* with regard to their *partner hospitals* in R&D collaboration, focal hospitals are likely to develop R&D collaboration with other hospitals in order to employ them as additional clinical test-beds. For instance, interviewee H01 (Research assistant professor) said that "our hospital is too big and the

structure of healthcare information is also very complicated …. Thus, it would be very difficult to codify health information to build a general model based on clinical contents within our hospital … and we needed a smaller-sized hospital to proceed with our research." Moreover, interviewee H08 (Full professor, MD) responded that "we wanted to use another hospital as a test bed for clinical trials for chronic disease management" by collaborating with that partner hospital.

Table 6.15 below provides a summary of focal hospitals' expectations with regard to each partner organisational type.

Table 6.15 Summary of focal hospitals' main expectations with regard to their partners

Focal hospitals' main expectations	Collaborating partners' type
To benefit from complementary capabilities such as existing technologies or platforms of the partner firms in relation to ICT and digital services in order to implement their ideas derived from clinical practice	Firm
In order to get benefits from technical standards based on medical information and exploratory research capabilities	University
To gain help with institutional and technological capabilities	PRI
To employ partner hospital(s) as additional clinical test-beds	Hospital

Source: author's elaboration

6.5. Conclusion

This chapter focused on investigating the characteristics of strategic motives in establishing collaboration for different collaborative structures categorised by focal organisational type. The strategic motives of the focal organisations in the choice of the particular type of collaborating partners were also explored.

According to the analysis, collaborative structures led by focal firms are significantly more affected by motives in terms of '*cost-economising* (e.g. through developing economies of scale, costs sharing/reduction in research, and reducing administrative costs) and *gaining IPRs*' in establishing collaboration than not-for-profit organisations such as universities and PRIs (see *Table 6.6*). In addition, we found that strategic motives engaged in *a TCE perspective* affect *focal firms* significantly more than not-for-profit organisations like universities and PRIs in developing collaboration than strategic motives linked to the RBV and NIS perspectives (see *Table 6.7*). This may be because the not-for-profit organisations face less severe efficiency pressures than private organisations from the perspective of TCE because other incentives such as political or

other non-economic forces may induce distinctive strategic decisions from the not-for-profit organisations (Brody, 1996; Coles, et al., 1998).

Moreover, the qualitative analysis based on interviews in order to achieve additional coverage shows that each type of focal organisations (i.e. firms, universities, PRIs, and hospitals) is extensively affected by distinctive motives[67], although all types of focal organisations are greatly influenced by the motive 'to access complementary capabilities or resources'. For instance, *focal firms* tend to focus on '*developing existing technologies*' (an RBV perspective), while *focal universities* are likely to be concerned with '*achieving benefits from potential grants*' (a NIS perspective) in establishing R&D collaboration. The strategic motive '*to pursue certain missions mandated from the government, funding agency, or society*' (a NIS perspective) is likely to affect the establishment of R&D collaboration *led by PRIs* (see *Table 6.8*). This qualitative analysis also validated the conceptual framework of this thesis because the various determinants (collected through an open-ended question without any theoretical restrictions) forming the strategic motives of all types of focal organisations in the establishment of collaboration were well covered within this conceptual framework.

Then, we analysed how strategic motives affect focal organisations in choosing their collaborating partner types in section 6.3. According to the results in *Table 6.10*, focal firms are significantly more concerned with '*minimising research expenses'* in the choice of hospitals as their collaborating partner than focal universities, while the motive '*to shorten lead time*' influences focal hospitals in choosing collaborating partner firms significantly more so than focal universities. In addition, the choice of collaborating partner universities is relevant to diverse strategic motives by focal organisational type. For instance, focal firms are significantly more influenced by the motive '*to have priority over IPR*' and of '*reducing administrative costs*' in establishing R&D collaboration with partner universities than focal universities and focal universities and PRIs, respectively. However, focal firms are significantly less influenced by the motive '*to achieve benefits from potential grants*' for an R&D collaboration with partner universities than focal hospitals.

Furthermore, interview data provided additional information for understanding the

[67] PIs in hospitals did not respond different motives from ones in other types of focal organisations (firms, universities, and PRIs), although their main strategic motives in establishing collaboration are 'to access complementary capabilities' 'to gain access to new technologies or markets' (RBV perspectives) (see *Table 6.8*).

characteristics of focal organisations in the choice of a particular type of collaborating partners in section 6.4. For instance, focal firms are likely to expect '*securing component technologies or specific items*' to develop their own products or services with the expectation of '*a reduction in transaction costs*' by collaborating with partner firms, while not-for-profit focal organisations including universities, PRIs, and hospitals tend to collaborate with partner firms '*to gain help in the implementation of research concepts and their technologies*'. In addition, most focal organisations are likely to expect '*to obtain highly specialised capabilities or technologies*' with regard to their university partners, except for focal hospitals being likely to focus on '*benefits from technical standards and exploratory research capabilities*'. Meanwhile, all types of focal organisations tend to '*look for technological capabilities*' from their PRI partners, while focal firms and hospitals are also likely to expect '*to gain help in dealing with institutional issues*' by choosing PRIs as their collaborating partners. When it comes to hospital partners, all types of focal organisations are likely to employ hospitals in order '*to secure the clinical validation*' of their technologies, products, or services.

The following chapter will analyse what effects the different collaborative structures categorised by focal and collaborating organisational type have on various aspects of R&D performance. Additionally, unrevealed benefits and outcomes involved in the establishment of inter-organisational collaboration will be identified by focal organisational type.

Chapter 7. Different Collaborative Structures and their R&D Performance[68]

In the previous chapter, we examined how different collaborative structures categorised by focal organisational type and by their choice of collaborating partner types are developed, based on mixed methods research. Through dealing with this research question, we can arrive at a better understanding of how the motives of focal organisations influence the development of these different R&D collaborative structures. Meanwhile, the purpose of this chapter is to consider what effects the different collaborative structures have on various aspects of R&D performance, namely, SCI papers, patent applications, patents-granted, and technology licensing[69]. Hence, we will primarily investigate the characteristics of the R&D performance according to different collaborative structures in comparison with the R&D performance of non-collaboration R&D projects in the digital healthcare sector.

This chapter is divided into four main sections. The first will begin with an analysis of the general characteristics of R&D performance across different collaborative structures. In addition, the R&D productivity levels of the various different collaborative structures will be compared with those of non-collaboration R&D projects to provide a clearer understanding of the influence of different collaborative structures on the various aspects of R&D performance. In section 7.2, we will carry out a more in-depth statistical analysis (binary logistic regressions) in terms of the four different R&D performance aspects (i.e. SCI papers, patent applications, patents-granted, and technology licensing) from the perspective of the different collaborative structures. Then, we will conduct an investigation of how institutional characteristics such as R&D policy instruments have an effect on the various aspects of R&D performance of different collaborative structures in section 7.3. Lastly, in section 7.4, using interview data we will attempt to identify unrevealed benefits and outcomes involved in the establishment of inter-organisational collaboration.

[68] As noted previously in section 3.3.1, R&D performance here means the output or outcome of R&D projects, and indicators for the outputs include SCI papers, patent applications, and patents-granted while an indicator for the outcome comprises technology licensing, because new technologies generally go through the process of scientific, technological, and economic development and the future potential of new technologies can often be anticipated with these indicators (Hullmann, et al., 2003).

[69] Here, technology licensing is used as a means of exploiting intellectual property by the way of use, transfer, or loan.

7.1. General R&D Performance and Different Collaborative Structures

As noted earlier, the objective of this section is to identify the general characteristics of R&D performance from the perspective of different collaborative structures. In order to achieve this objective, we will carry out an analysis of the general characteristics of the R&D performance of different collaborative structures based on organisational types in line with the analysis in previous chapters. Moreover, the R&D performance associated with different collaborative structures of R&D collaboration projects will be compared with the R&D performance of non-collaboration R&D projects in order to provide a better understanding of the characteristics of the R&D performance of each of the different collaborative structures.

First of all, we will focus on the general characteristics of R&D performance according to different collaborative structures categorised by the type and funding feature of focal organisations. *Table 7.1* shows that the proportions of research funding are more or less similar for the two collaborative structures categorised by the funding feature of focal organisations, with R&D projects led by for-profit (hereafter 'FP') organisations accounting for 51.7% of research funding, while 48.3% of research funding is accounted for the R&D projects with not-for-profit (hereafter 'NFP') focal organisations.

Given that the share of SCI papers from collaborations led by FP organisations is only 23.0%, even though they accounted for more than a half of R&D collaboration research funding, R&D collaboration projects involving FP focal firms exhibit a much lower level of SCI paper output than R&D collaboration projects led by NFP organisations. Conversely, R&D projects led by universities demonstrated a substantially higher publication level compared with R&D projects coordinated by other types of focal organisations, with the R&D collaboration projects of focal universities contributing more than half of all SCI publications while accounting for only around 20% of the total research funding (see *Table 7.1*). Moreover, the ratios of other types of R&D performance produced by R&D projects with focal universities are all higher than the proportion of research funding they accounted for (see *Table 7.1*).

Table 7.1 General characteristics of R&D performance by different collaborative structures based on focal organisational type and funding feature

Focal organisations	R&D Projects	Research funding		SCI Papers		Patent Applications		Patents-Granted		Technology licensing	
	No.	Billion KRW*	%	No.	%	No.	%	No.	%	No.	%
For-profit/Firms	94	69.58	**51.7**	29	**23.0**	141	48.8	78	49.4	33	51.6
Not-for-profit	113	63.02	**48.3**	97	**77.0**	148	51.2	80	50.6	31	48.4
Universities	59	27.45	**20.4**	64	**50.8**	69	**23.2**	45	**28.5**	19	**29.7**
PRIs	24	23.83	17.7	20	15.9	39	13.5	22	13.9	4	6.3
Hospitals	30	13.69	10.2	13	10.3	42	14.5	13	8.2	8	12.5

* Korean won

Source: author's elaboration

Second, we will also look at the characteristics of R&D performance by different collaborative structures categorised by the funding feature of both focal and collaborating partner organisations. According to *Table 7.2*, R&D collaboration between different organisational funding features (e.g. FP focal firms with NFP collaborating partners, or NFP focal organisations with partners including at least one FP firm[70]) tends to generate better productivity in terms of patent applications and patents granted as compared with the proportions of their research funding. In contrast, R&D collaboration between the same organisational funding features (e.g. FP focal firms with partners including at least one FP firm, or NFP focal organisations with NFP partners) is likely to result in lower productivity in terms of patent applications and patents granted given the portions of their research funding. In the same vein, R&D collaborations between organisations with NFP focal organisations and FP partners accounts for a higher proportion of technology licensing (43.8%) compared with the ratio of research funding (26.9%). Meanwhile, collaboration between NFP focal organisations and NFP partners accounts for a much lower share of technology licensing (4.7%), given their share of research funding, which is 21.4% (see *Table 7.2*).

However, the performance in terms of SCI papers may not be significantly affected by the funding feature of collaborating partners, and its level seems to rely on the types of focal organisations. Therefore, R&D projects led by FP firms show a much lower performance level in terms of SCI papers than those of R&D projects coordinated by NFP organisations regardless of the financial nature of their collaborating partners, although

[70] Here, the 'not-for-profit' collaborating partner means there is no for-profit collaborating partner among the partners, while the 'for-profit' collaborating partner means at least one for-profit collaborating partner is included among the collaborating partners.

they had a more or less similar share of research funding (see *Table 7.2*).

Table 7.2 General characteristics of R&D performance by different collaborative structures based on the funding feature of focal and partner organisations

Focal organisations	Collaborating partners [a]	R&D Projects	Research funding		SCI Papers		Patent Applications		Patents-Granted		Technology licensing	
		No.	Billion KRW	%	No.	%	No.	%	No.	%	No.	%
For-profit firms	For-profit	37	37.42	27.8	12	9.5	48	16.5	26	16.5	19	29.7
	Not-for-profit	57	32.17	23.9	17	13.5	93	32.0	52	32.9	14	21.9
Not-for-profit organisations	For-profit	54	36.15	26.9	44	34.9	114	39.2	55	34.8	28	43.8
	Not-for-profit	59	28.82	21.4	53	42.1	36	12.4	25	15.8	3	4.7

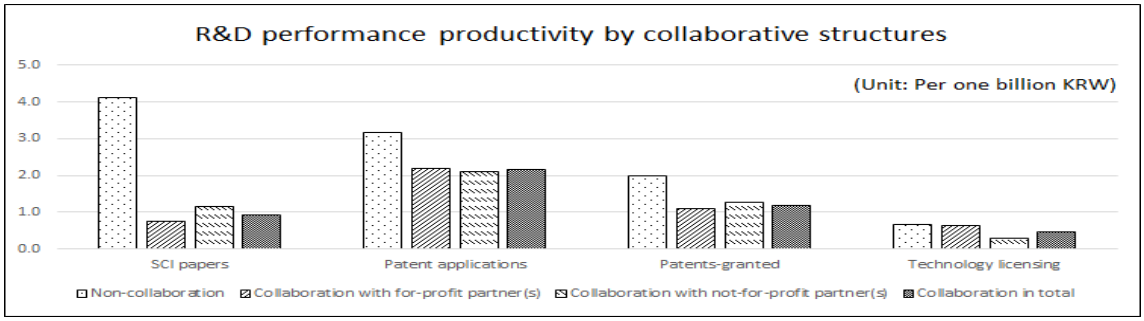
a. The 'for-profit' collaborating partner is categorised if there is at least one for-profit collaborating partner in the collaborating partners, while the 'not-for-profit' collaborating partner is defined if there is a no for-profit collaborating partner in the partners.

Source: author's elaboration

Next, we will focus on a comparison of the productivity levels of various aspects of R&D performance between R&D collaboration projects and non-collaboration R&D projects. In order to proceed, different collaborative structures are categorised by focal organisational type and the financial nature of collaborating partner, and all R&D performance estimates are calculated on the basis of research funding of one billion Korean won (KRW) for ease of comparison.

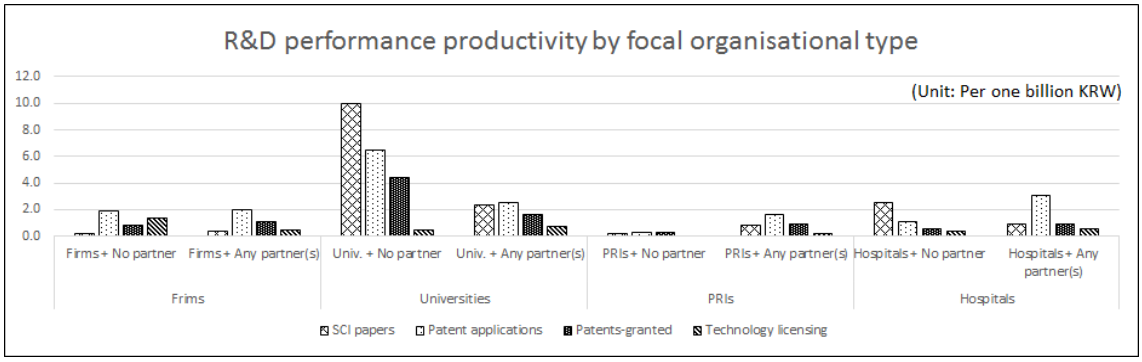
When it comes to overall R&D performance, *the productivity levels of R&D collaboration projects*, regardless of the funding feature of collaborating partners, *are lower than the productivity levels of non-collaboration R&D projects in all R&D performance aspects* including SCI papers, patent applications, patents-granted, and technology licensing. However, we find completely different patterns in R&D productivity levels when we break down collaborative structures from the perspective of the type of focal organisations (see *Figures 7.1, 7.2 and Table 7.3*).

Figure 7.1 Overall R&D performance productivity of different collaborative structures per one billion Korean won of research funding



Source: author's elaboration

Figure 7.2 Overall R&D performance productivity by focal organisational type per one billion Korean won of research funding



Source: author's elaboration

Table 7.3 Characteristics of R&D performance per one billion Korean Won (KRW) by different collaborative structures

Collaborative structures		No. of projects	Research funding (Billion KRW)	R&D performance per one billion KRW			
Focal organisations	Collaborating partners			SCI papers	Patent applications	Patents-granted	Technology licensing
Firms	No partner	84	26.15	**0.15**	**1.87**	**0.80**	1.38
	For-profit partner(s) [a]	37	37.42	0.32	1.28	0.69	0.51
	Not-for-profit partner(s) [a]	57	32.17	**0.53**	**2.89**	**1.62**	0.44
	Collaboration with any partner(s)	94	69.58	0.42	2.03	1.12	0.47
Universities	No partner	257	30.58	9.97	6.48	4.38	**0.46**
	For-profit partner(s) [a]	28	21.26	1.36	3.15	1.93	**0.89**
	Not-for-profit partner(s) [a]	31	6.19	5.65	0.32	0.65	0.00
	Collaboration with any partner(s)	59	27.45	2.33	2.51	1.64	0.69
PRIs	No partner	16	14.86	**0.20**	**0.27**	**0.27**	**0.00**
	For-profit partner(s) [a]	5	3.30	**1.52**	**2.12**	**0.61**	**0.30**
	Not-for-profit partner(s) [a]	19	20.53	**0.73**	**1.56**	**0.97**	**0.15**
	Collaboration with any partner(s)	24	23.83	0.84	1.64	0.92	0.17
Hospitals	No partner	44	11.52	2.52	**1.13**	**0.52**	**0.35**
	For-profit partner(s) [a]	21	11.59	0.86	**3.45**	**1.04**	**0.69**
	Not-for-profit partner(s) [a]	9	2.09	1.43	0.95	0.48	0.00
	Collaboration with any partner(s)	30	13.69	0.95	3.07	0.95	0.58
Overall	Non-collaboration	401	83.11	**4.10**	**3.18**	**1.99**	**0.65**
	Collaboration with for-profit partner(s)	91	73.57	0.76	2.20	1.10	0.64
	Collaboration with not-for-profit partner(s)	116	60.99	1.15	2.12	1.26	0.28
	Collaboration in total	207	134.55	**0.94**	**2.16**	**1.17**	**0.48**

a. A 'for-profit' collaborating partner means there is at least one for-profit collaborating partner among the collaborating partners, while a 'not-for-profit' collaborating partner means there is no for-profit collaborating partner among the partners.

Source: author's elaboration

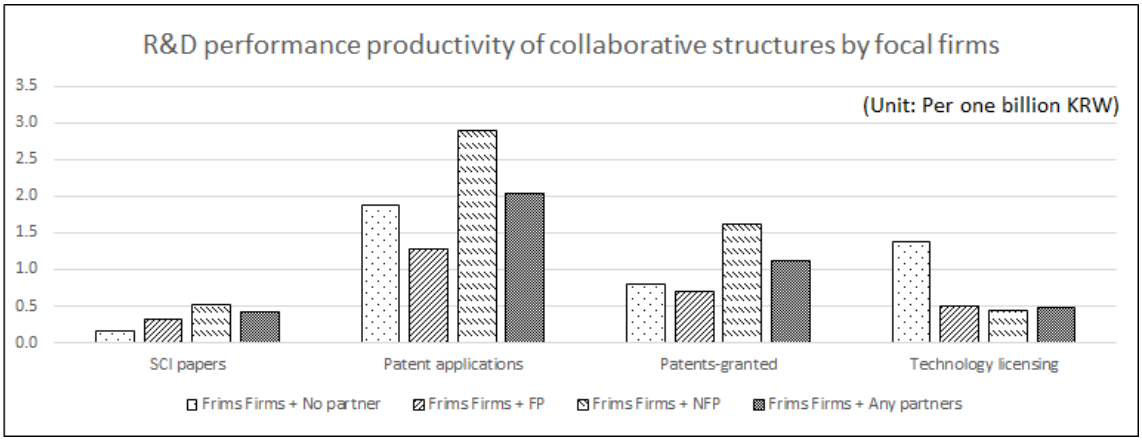
R&D collaboration projects led by focal firms achieved higher levels of R&D performance than non-collaboration R&D projects carried out by firms, by 0.3 papers for SCI papers, 0.2 patents for patent applications, and 0.3 patents for patents-granted for every one billion KRW of research funding. In addition, the pattern of R&D performance of R&D collaboration projects between focal firms and NFP partners is similar to that for all R&D collaboration projects led by focal firms, although the former has higher productivity in terms of SCI papers, patent applications, and patents-granted than the latter (see *Figure 7.3* and *Table 7.3*). However, R&D collaboration projects led by focal firms have around three times lower productivity in terms of technology licensing, irrespective of the funding feature of their collaborating partners, than non-collaboration R&D projects carried out by firms. Interestingly, we find the opposite picture in terms of productivity level as reflected in SCI papers (see *Figure 7.3* and *Table 7.3*).

These findings may be explained by the fact that the main motives[71] of focal firms in the establishment of inter-organisational collaboration are 'to access complementary capabilities or resources' in order 'to develop existing technologies', 'to gain access to new technologies or markets', and 'to achieve R&D commercialisation', as noted in section 6.2.2. The reason is that focal firms in R&D collaboration projects may be likely to put more emphasis on learning and the development of existing or new technologies than on the immediate commercialisation of their products or services, given their most influential motives in establishing R&D collaboration. Thus, these motives may contribute to the higher research outputs of R&D collaboration projects in terms of SCI papers, patent applications and patents-granted compared with non-collaboration R&D projects. In contrast, it may take more time and funds to produce research outcomes in the form of technology licensing from R&D collaboration projects led by focal firms than non-collaboration R&D projects run by firms. The reason may be to do with a conflict of interest between focal and partner firms and a lack of willingness[72] among collaborating partners to generate technology licensing for their focal firms in the R&D collaboration projects. In addition, the lower productivity level of technology licensing for R&D collaboration projects led by focal firms than non-collaboration R&D projects run by

[71] The most influential motive of focal firms is 'to develop existing technologies' followed by 'to gain access to new technologies or markets' through the establishment of inter-organisational collaboration (see *section 6.2.1*).
[72] Indeed, interviewees F03, 04, 06, 09, 10, 11, 12, and 13 said that the main expectations of PRI and hospital partners with regard to focal firms are 'to gain research funding' and 'due to own interests in particular research topics', respectively (see *Appendix 13*).

firms may be also explained with that they do not have to deal with other collaborating partners for technology licensing because they can learn or internalise what they need by interacting with their partners.

Figure 7.3 R&D performance productivity of different collaborative structures by focal firms



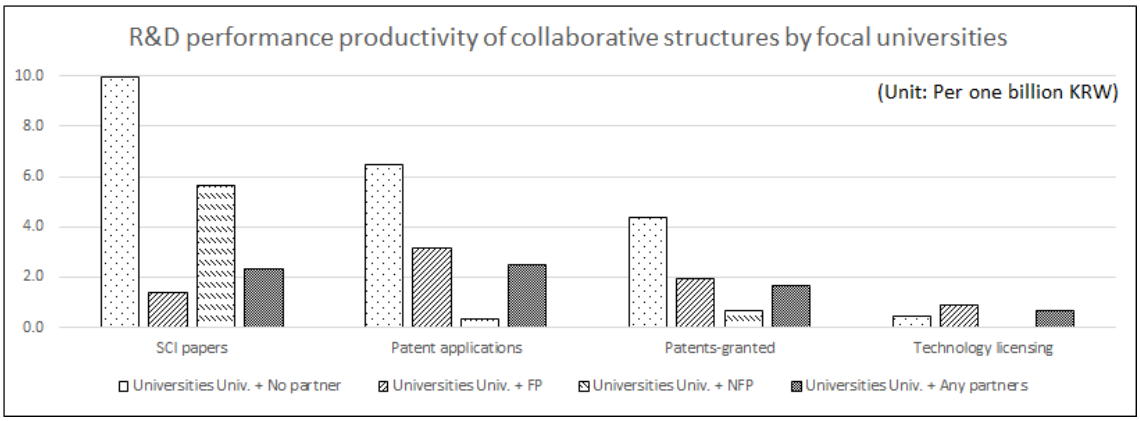
Source: author's elaboration

Here, we will shift our attention to the R&D performance of *R&D collaboration projects led by focal universities* compared with non-collaboration R&D projects run by universities. According to *Figure 7.4* and *Table 7.3*, the productivity levels in terms of SCI papers, patent applications, and patents-granted for R&D collaboration projects led by focal universities are much lower than those for non-collaboration R&D projects run by universities. More specifically, the R&D collaboration projects produced 7.6 fewer SCI papers, 4.0 fewer patent applications, and 2.7 fewer patents-granted than non-collaboration R&D projects for every one billion KRW of research funding. However, R&D collaboration projects between focal universities and FP firms generated 0.4 technology licenses more than non-R&D collaboration projects (see *Figure 7.4* and *Table 7.3*). This result may be explained by the fact that most influential motives of focal universities in the development of inter-organisational collaboration are 'to obtain help for R&D commercialisation' through 'accessing complementary capabilities' (see section 6.2). Thus, R&D collaboration projects led by focal universities tended to put more effort into technology licensing, while they paid relatively less attention to other types of R&D performance such as SCI papers, patent applications and patents-granted.

However, R&D collaborations between focal universities and NFP organisations may face difficulties in accessing end-users, leading to a lack of understanding of end-user's demands, even though this understanding is a core part of the innovation process (von

Hippel, 2005). In addition, the most influential motives of this collaborative structure in establishing collaboration with not-for-profit collaborating partners are 'to benefit from specialised capabilities' and 'to secure medical data' (see *Table 6.13*). Hence, these motives may have negatively influenced the productivity level in terms of patent applications, patents-granted, and technology licensing for the collaborative structure.

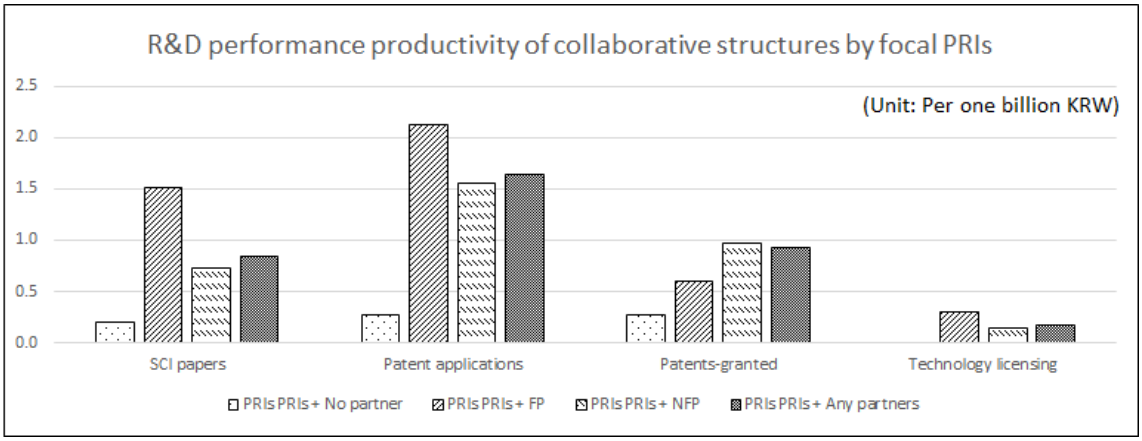
Figure 7.4 R&D performance productivity of different collaborative structures by focal universities



Source: author's elaboration

Next, we will move on to the R&D performance of *collaboration projects led by focal PRIs*. As one can see from *Figure 7.5* and *Table 7.3*, the productivity levels for all types of R&D performance in R&D collaboration projects led by focal PRIs, regardless of their collaborating partners, are higher than in non-collaboration R&D projects run by PRIs. This may be due to the fact that many non-collaboration R&D projects run by PRIs aim to create infrastructure for IT systems and databases such as 'the database establishment for the state-of-the-art healthcare industry', 'the establishment of the open database based on anonymization technology', and 'the IT system development for Korea Institute of Radiological Medical Sciences (KIRMS)'. Thus, PRIs in non-collaboration R&D projects might not be able to focus on R&D performance as much as focal PRIs in R&D collaborations.

Figure 7.5 R&D performance productivity of different collaborative structures by focal PRIs



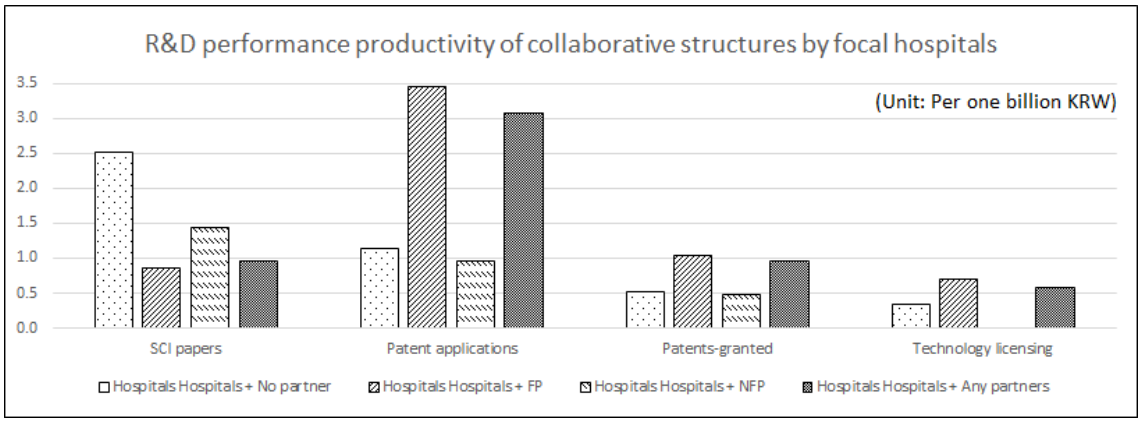
Source: author's elaboration

Moving to the R&D performance productivity of *R&D collaboration projects led by focal hospitals*, such projects produced more patent applications, patents-granted, and technology licensing than non-collaboration R&D projects run by hospitals by 1.9 patent applications, 0.4 patents-granted, and 0.2 technology licensing for every one billion KRW of research funding (see *Table 7.3*). When it comes to the financial nature of collaborating partners, R&D collaboration projects between focal hospitals and FP partners produced much higher levels of patent applications, patents-granted, and technology licensing than R&D collaboration projects between focal hospitals and NFP partners. In addition, productivity levels in all aspects for R&D collaboration projects between focal hospitals and NFP partners are less than those for non-collaboration R&D projects run by hospitals (see *Figure 7.6* and *Table 7.3*). However, the different pattern is shown in terms of productivity as reflected in SCI papers, with this productivity level for R&D collaboration projects between focal hospitals and FP partners being the lowest (0.9) followed by R&D collaborations between focal hospitals and NFP partners (1.4). The highest productivity level with regard to SCI papers is 2.5, this being the figure for non-collaboration R&D projects run by hospitals.

The result can be influenced by diverse R&D policies and programs initiated by the Korean government as described in section 4.2.4. For instance, the Korean government began investing R&D funds in the establishment of medical clusters based on research-oriented hospitals in 2006 (Lee, 2008). Through this program, the number of patent applications has rapidly increased by 85% between 2013 and 2017, and the number of start-up companies linked to research-based hospitals has increased from one firm in 2013

to 47 firms in 2017 (KHIDI, 2018). In addition, 70% of focal hospitals (21 out of 30 focal hospitals) have established R&D collaboration with FP firms, and they expected to obtain benefits in terms of ICT and digital services from their partner firms or the implementation of research concepts or ideas derived from clinical practice, as described in section 6.4. Thus, this may also allow focal hospitals in R&D collaboration projects to put more emphasis on producing patents and technology licensing rather than academic papers.

Figure 7.6 R&D performance productivity of different collaborative structures by focal hospitals



Source: author's elaboration

Lastly, we will investigate statistical differences between collaborative structures and non-collaboration projects in terms of the various aspects of R&D performance, namely SCI papers, patent applications, patents-granted, and technology licensing, per one billion KRW. This analysis is carried out on the basis of an independent-samples Kruskal-Wallis test (a non-parametric test) because the R&D performance data are not normally distributed according to normality tests at a significance level of 0.05 (see Appendix 14). *Table 7.4* below shows the results of the Kruskal-Wallis tests, and of Dunn's post hoc tests. These post hoc tests are carried out to identify significant mean differences between each pair of focal organisational types, and a Bonferroni adjustment was made to p-values for a more conservative analysis through minimising type-one errors. According to the results, the productivity levels in terms of SCI papers, patent applications and patents-granted produced by R&D collaborations led by firms with NFP partners are significantly higher than those for non-collaboration R&D projects run by firms at a 0.05 significance level. Moreover, R&D collaboration projects between focal universities and FP partners had a significantly higher productivity level with regard to technology licensing

compared with non-collaboration R&D projects run by universities at a significance level of 0.01 (see Table 7.4).

Table 7.4 Main results of post hoc tests on R&D performance by different collaborative structures

(Sample 1) – (Sample 2)	SCI papers		Patent applications		Patents-granted		Technology licensing	
	Test statistics[a]	Adj. Sig.	Test statistics[a]	Adj. Sig.	Test statistics[a]	Adj. Sig.	Test statistics[a]	Adj. Sig.
(Focal firms + NFP) – (Firms + None)	10.09	0.03	27.48	0.00	21.10	0.01	-	-
(Focal universities + FP) – (Universities + None)	-	-	-	-	-	-	19.80	0.00

a = (the average rank of Sample 1) – (the average rank of Sample 2)

Source: author's elaboration

7.2. Characteristics of R&D Performance of Particular Collaborative Structures in comparison to Non-Collaboration in R&D Projects

7.2.1. Characteristics of R&D Performance from Univariate Analysis

We focused on the general characteristics of R&D performance according to collaborative structures in the previous section. However, this section aims to carry out statistical analyses in terms of the various aspects of R&D performance (i.e. SCI papers, patent applications, patents-granted, and technology licensing) from the perspective of the different collaborative structures in comparison to non-collaboration R&D projects. Hence, these analyses will provide statistical evidence regarding how much different collaborative structures of R&D projects affects the production of each type of R&D performance compared with non-collaboration R&D projects. In order to carry out these analyses, we will employ binary logistic regressions in SPSS. For the binary logistic regressions, the dependent variables (i.e. R&D performance in terms of SCI papers, patent applications, patents-granted, and technology licensing) are coded as '0' in cases where a R&D project did not generate that particular R&D performance, whereas they are coded as '1' if a R&D project produced that particular form of R&D performance. For the independent variables, the R&D projects in the digital healthcare section are first categorised by focal organisation type. Then, each group of collaborative structures based on focal organisational types is classified into one of three categories based on the type of partners – focal organisations collaborating with FP organisations, focal organisations collaborating with NFP organisations, and focal organisations without collaborating partners (see *Table 7.5*). Hence, we can understand how much each form of collaborative

structure of R&D projects has more or less impact on the production of each type of R&D performance as compared with non-collaboration R&D projects (i.e. focal organisations without collaborating partners). In order words, each type of R&D performance generated by each collaborative structure is translated into odds ratios as compared with the performance of non-collaboration R&D projects through the analyses.

Table 7.5 A summary of independent variables (different collaborative structures)

Focal organisations	Partners	Different collaborative structures
Firms	FP partners, NFP partners, or None	Firms + FP, Firms + NFP, or Firms alone
Universities		Universities + FP, Universities + NFP, or Universities alone
PRIs		PRIs + FP, PRIs + NFP, or PRIs alone
Hospitals		Hospitals + FP, Hospitals + NFP, or Hospitals alone

Source: author's elaboration

First of all, we will focus on the characteristics of *R&D performance created by R&D collaboration projects led by firms* (focal firms + FP and focal firms + NFP) compared to the R&D performance generated by non-collaboration R&D projects run by firms as a baseline group. When it comes to chi-squared tests for any association between the collaborative structure group involving focal firms and R&D performance, these tests point to clear evidence of an association between the group and three types of R&D performance – SCI papers, patent applications, and patents-granted. The p-values for the Pearson chi-squared tests are 0.02, 0.00, and 0.01, respectively (see *Appendix 15*).

Hence, binary logistic regression analysis was adopted to predict the probability that each R&D project in the various collaborative structures would generate that form of R&D performance. Omnibus tests of our models versus each model with only intercepts are statistically significant, $\chi^2(2, N=178) = 9.2$, $P < 0.05$ for SCI papers, $\chi^2(2, N=178) = 17.2$, $P < 0.001$ for patent applications, and $\chi^2(2, N=178) = 9.7$, $P < 0.01$ for patents-granted, respectively. *Table 7.6* shows the logistic regression coefficient, Wald χ^2 test, and odds ratio for each of the predictors. By employing a 5% criterion of statistical significance, all predictors have significant effects on the three aspects of R&D performance, except for the predictor, 'focal firms + FP', on patents-granted performance. The odds ratios for different collaborative structures indicate that R&D projects with collaboration between focal firms and FP partners and between focal firms and NFP partners are respectively 10.1 times and 11.6 times more likely to produce SCI papers than our reference predictor group (i.e. non-collaboration R&D projects run by firms). Similarly, the odds ratios show

that R&D collaborations between focal firms and FP partners and between focal firms and NFP partners are 2.8 times and 4.4 times more likely to generate patent applications than our reference group, respectively. In addition, the odds ratio also illustrates that focal firms collaborating with NFP partners tend to create 3.4 times more patents-granted performance than our reference group (see *Table 7.6*).

These findings may be interpreted in the same way as noted earlier in section 7.1. The motives of focal firms in the establishment of R&D collaboration projects, 'to develop existing technologies' and 'to gain access to new technologies or markets', may encourage them to generate more research outputs such as SCI papers, patent applications, and patents-granted rather than dedicating themselves to commercialisation outcomes like technology licensing. Hence, R&D collaboration projects led by firms are likely to be affected by the motive to produce more the research outputs than non-collaboration R&D projects.

Table 7.6 Binary logistic regression predicting decision from different collaborative structures categorised by focal firms

Dependent Variable	Predictor	B	Wald χ^2	Sig.	Odds Ratio (EXP(B))	95% C. I. for EXP(B)	
						Low	High
SCI papers	Focal firms + FP	2.31	4.12	0.04	10.06	1.08	93.39
	Focal firms + NFP	2.45	5.12	0.02	11.62	1.39	97.24
Patent applications	Focal firms + FP	1.03	5.84	0.02	2.79	1.21	6.43
	Focal firms + NFP	1.48	15.39	0.00	4.37	2.09	9.14
Patents-granted	Focal firms + FP	0.70	2.18	0.14	2.02	0.79	5.16
	Focal firms + NFP	1.23	9.22	0.00	3.43	1.55	7.61

* The reference predictor group is the R&D performance generated by R&D projects only run by firms.

Source: author's elaboration

We will shift our attention in this paragraph to the characteristics of *R&D performance generated by R&D collaboration projects led by universities* (focal universities + FP partners and focal universities + NFP partners), which will again be compared with our reference group, the R&D performance produced by non-collaboration R&D projects run by universities. Before proceeding to the binary logistic regression analysis, we first carried out a chi-squared test for association between collaborative structure group in terms of focal universities and their R&D performance. These tests indicate that there is clear evidence of an association between the group and three types of R&D performance – patent applications, patents-granted, and technology licensing. The p-values for the Pearson chi-squared tests are 0.00, 0.03, and 0.00, respectively (see *Appendix 15*).

Hence, binary logistic regression analysis was employed to predict the probability that a R&D project in different collaborative structures would produce the particular form of R&D performance. Omnibus tests of our models versus each model with intercepts only are statistically significant, $\chi^2(2, N=315) = 15.9$, $P < 0.00$ for patent applications, $\chi^2(2, N=315) = 6.5$, $P < 0.04$ for patents-granted, and $\chi^2(2, N=315) = 10.4$, $P < 0.01$ for technology licensing, respectively. According to *Table 7.7*, R&D collaboration projects between focal universities and FP partners had a significant impact on the three types of R&D performance, while collaboration between focal universities and NFP partners had a significant effect on only patent applications in comparison with our reference group. More specifically, R&D collaborations between focal universities and FP partners are 3.4, 2.6, and 10.5 times more likely to generate patent applications, patents-granted, and technology licensing, respectively, than non-collaboration R&D projects by universities. In contrast, R&D collaboration between focal universities and NFP partners are 77% less likely to produce patent applications than our baseline group (see *Table 7.7*).

These results may be explained by what we found in section 6.4.2. The main expectations of focal universities with regard to for-profit partners are ‘to benefit from technology licensing-out’ and ‘to understand end-user’s demands’, this being an essential part of the innovation process because many of the important and novel products and processes in a variety of fields have been developed or modified by user firms or by individual users (von Hippel, 2005). Thus, these motives of focal universities in the establishment of collaboration with FP partners may positively affect the R&D performance in terms of patent applications, patents-granted, and technology licensing. However, focal universities are likely to expect to obtain specialised capabilities with regard to their NFP partners according to our finding in section 6.4.2. Thus, this motive might have a negative impact on focal universities in terms of applying for patents because these kinds of specialised capabilities should have been patented by their collaborating partners’ own purposes or the partners may have been reluctant to disclose their own specialised capabilities due to safeguarding issues.

Table 7.7 Binary logistic regression predicting decision from different collaborative structures categorised by focal universities

Dependent Variable	Predictor	B	Wald χ^2	Sig.	Odds Ratio (EXP(B))	95% C. I. for EXP(B)	
						Low	High
Patent applications	Focal universities + FP	1.21	8.89	0.00	3.36	1.51	7.44
	Focal universities + NFP	-1.46	3.85	0.05	0.23	0.05	1.00
Patents-granted	Focal universities + FP	0.94	4.81	0.03	2.55	1.10	5.88
	Focal universities + NFP	-0.71	1.28	0.26	0.49	0.14	1.69
Technology licensing	Focal universities + FP	2.36	10.17	0.00	10.54	2.48	44.84
	Focal universities + NFP	-17.06	0.00	1.00	0.00	0.00	-

* The reference predictor group is the R&D performance generated by R&D projects only run by universities.

Source: author's elaboration

This paragraph focuses on the *R&D performance of collaborative structures led by PRIs* (focal PRIs + FP partners and focal PRIs + NFP partners) compared with those created by non-collaboration R&D projects run by PRIs. We first conducted a chi-squared test for any association between collaborative structure and R&D performance. These tests indicate that there is clear evidence of an association between the group and patent applications. The p-value for the Pearson chi-squared test is 0.02 (see *Appendix 15*). Then, binary logistic regression analysis was employed to predict the probability that each R&D project in a different collaborative structure would create a particular R&D performance. An omnibus test of our model versus a model with intercepts only is statistically significant, $\chi^2(2, N=40) = 8.9$, $P < 0.01$ for patent applications. As one can see from the result of the logistic regression analysis shown in *Table 7.8*, R&D collaboration projects between focal PRIs and FP partners tend to produce 28 times more patent applications than non-collaboration R&D projects run by PRIs at a significance level of 0.05.

This finding can be interpreted in terms of the expectations of focal PRIs with regard to their collaborating FP partners described in section 6.4.3, which are 'to implement the research concepts and technologies they have' and 'to support SMEs as a public research organisations'. Through supporting SMEs, focal PRIs may have encouraged SMEs to codify their tacit knowledge and technologies for the patent application. In addition, focal PRIs may have developed their own technological concepts and ideas by collaborating with FP partners to reach a suitable technology readiness level for the patent application. Hence, these motives of focal PRIs in developing collaboration with FP partners might have positively influenced the production of patent applications.

Table 7.8 Binary logistic regression predicting decision from different collaborative structures categorised by focal PRIs

Dependent Variable	Predictor	B	Wald χ^2	Sig.	Odds Ratio (EXP(B))	95% C. I. for EXP(B)	
						Low	High
Patent applications	Focal PRIs + FP	3.33	6.10	0.01	28.00	1.99	394.41
	Focal PRIs + NFP	1.63	3.36	0.07	5.09	0.89	28.98

* The reference predictor group is the R&D performance generated by R&D projects only run by PRIs.

Source: author's elaboration

We have also carried out a binary logistic regression analysis in order to investigate *the R&D performance of collaboration projects led by focal hospitals* (focal hospitals + FP partners and focal hospitals + NFP partners) in comparison with non-collaboration R&D projects run by hospitals. However, there is a no significant association between collaborative structures categorised by focal hospitals and their R&D performance at a significance level of 0.05 (see *Appendix 15*). Thus, we have not proceeded further with this analysis. This would seem to suggest that the role of hospitals as a collaborating partner is very important in the achievement of innovation for other types of organisations such as a firm, PRI, and university. Hence, all the other types of focal organisations mentioned that they particularly appreciated the benefits from collaborating with their hospital partners, as will be described in section 7.4. However, hospitals in South Korea had only focused on their role as healthcare-providers until 2006 before the introduction of the strategy for facilitating a healthcare industry by the Presidential Commission on Healthcare Industry Innovation in 2006, as noted earlier in section 4.2.4. Thus, they might not have been enough time to accumulate their capabilities in the innovation system in order to lead other collaborating partners toward the achievement of their distinctive research goals.

7.2.2 Characteristics of R&D Performance from Multivariate Analysis

The previous section aims to carry out statistical analyses in terms of the various aspects of R&D performance (i.e. SCI papers, patent applications, patents-granted, and technology licensing) from the perspective of the different collaborative structures in comparison to non-collaboration R&D projects. Hence, these analyses provide statistical evidence regarding how much different collaborative structures of R&D projects affect the production of each type of R&D performance compared with non-collaboration R&D projects. However, this univariate analysis neglected other potential factors that may affect the R&D performance such as the number of partners in R&D collaboration projects, the amount of research funding, the features of funding input by participants,

and the attributes of the institutional pressure.

Hence, we have carried out multivariate analysis in order to examine whether the findings from binary logistic regressions in section 7.2.1. on the effects of different collaborative structures are robust. Here, various aspects of R&D performance, namely SCI papers, patent applications, patents-granted, and technology licensing, are statistically characterised by diverse related factors as independent variables via multivariate analyses. The independent variables include different types of collaborative structures as well as four additional factors that may have an influence on the performance, namely the number of partners in R&D collaboration projects (Partners), the amount of research funding (Funding), the features of funding input by participants (Matching), and the attributes of the institutional pressure (RFP).

More specifically, the R&D performance, i.e. the dependent variable, is allocated a binary code, where '1' indicates that a R&D project resulted in successful R&D performance, while '0' is given if not. For independent variables, there are three categorical variables - different types of collaborative structures, Matching, and RFP - and two scale variables - the number of partners (Partners), and the amount of research funding in Korean million won (Funding). For the different types of collaborative structures, '0' indicates R&D projects where each type of focal organisation (a firm, university, PRI, or hospital) does not collaborate with any other partner, while '1' is given if each type of focal organisations collaborates with partner(s) including a for-profit organisation, and R&D collaboration projects are coded as '2' in cases where R&D collaboration projects are not coded as '1'. In the Matching variable, '1' indicates that any partner(s) invest research funding matching the government funding, while '0' is given if not, and for the RFP variable '1' indicates that an RFP includes any type of institutional pressure such as encouragement or enforcement to establish R&D collaboration, while '0' is given if not.

First of all, we will focus on the characteristics of *R&D performance for R&D projects led by firms.* Here, the probit link function in the generalized linear model was conducted in order to estimate the relationships between independent variables (i.e. Partner, Matching, Funding, RFP, different types of R&D projects led by firms) and the dependent variables (i.e. four different types of R&D performance with regard to SCI papers, patent applications, patents-granted, and technology licensing). When it comes to omnibus tests, the likelihood ratios chi-square for each four different dependent variables indicates that

the model as a whole is statistically significant compared with a model with no predictors because the all p-values for the tests are lower than a significance level of 0.05 (see *Appendix 17*).

Tables 7.9 below shows the probit regression coefficient, Wald χ^2 test, and odds ratio for each of the predictors. By employing a 5% criterion of statistical significance, four predictors (i.e. Focal firms + NFP, RFP, Funding, and Partners) have significant effects on R&D performance in terms of SCI papers, while one predictor, namely Funding, has a significant impact on patent applications performance. In addition, two predictors, Focal firms + NFP and Funding, have a significant effect on patents-granted performance, while two predictors, RFP and Funding have significant impacts on the technology licensing. The odds ratios for different collaborative structures indicate that R&D collaboration projects between focal firms and not-for-profit organisations (Focal firms + NFP) are 5.06 times and 1.92 times more likely to enhance R&D performance in terms of SCI papers and patents-granted, respectively, compared to non-collaboration R&D projects run by focal firms at a significance level of 0.05. These results are consistent with the findings from univariate analysis in section 7.2.1 (see *Table 7.6*).

Furthermore, for every one additional unit (One million Korean won ≈ GBP 687) in Funding, this increases the probability of generating 0.2% more SCI papers, and the probability of producing patent applications and patents-granted performance by 0.1% more, while every one additional million Korean won in Funding decreases the probability of generating technology licensing by 0.1%. The probit regression coefficient for RFP shows that institutional pressure (encouragement or enforcement) for establishing R&D collaboration positively affects the probability of generating SCI papers, while R&D projects influenced by institutional pressure to establish R&D collaboration has a negative influence on the probability of generating technology licensing. Likewise, for every one additional partner in R&D collaboration projects, this decreases the probability of creating SCI papers by 30% (see *Table 7.9*).

Table 7.9 Results of the multivariate analysis in terms of R&D projects led by firms

Dependent Variable	Predictor	B	Wald χ^2	Sig.	Odds Ratio EXP(B)	95% C. I. for EXP(B)	
						Low	High
SCI papers	Focal firms + NFP	1.62	5.54	0.02	5.06	1.31	19.54
	RFP	2.34	4.72	0.03	10.37	1.26	85.53
	Funding	0.00	12.78	0.00	1.002	1.001	1.003

Dependent Variable	Predictor	B	Wald χ^2	Sig.	Odds Ratio EXP(B)	95% C. I. for EXP(B)	
						Low	High
	Partners	-0.36	5.37	0.02	0.70	0.52	0.95
Patent applications	Funding	0.00	13.11	0.00	1.001	1.001	1.002
Patents-granted	Focal firms + NFP	0.65	5.77	0.02	1.92	1.13	3.28
	Funding	0.00	11.16	0.00	1.001	1.000	1.001
Technology licensing	RFP	-0.72	8.26	0.00	0.49	0.30	0.80
	Funding	-0.00	5.06	0.02	0.999	0.999	1.000

Source: author's elaboration

We will shift our attention in this paragraph to the characteristics of *R&D performance generated by R&D collaboration projects led by universities*. Here, the probit link function in the generalized linear model was investigated in order to estimate the relationships between independent variables (i.e. Partner, Matching, Funding, RFP, different types of R&D projects led by universities) and the dependent variables (i.e. four different types of R&D performance in terms of SCI papers, patent applications, patents-granted, and technology licensing). Regarding omnibus tests, the likelihood ratios chi-square for each four different dependent variables shows that the model as a whole is statistically significant compared with a model with no predictors because the all p-values for the tests are lower than a significant level of 0.05 (see *Appendix 17*).

Tables 7.10 below shows the probit regression coefficient, Wald χ^2 test, and odds ratio for each of the predictors. By employing a 5% criterion of statistical significance, we find that two predictors (i.e. Matching and Funding) have significant effects on producing SCI papers, while three predictors (i.e. Focal Universities + NFP, RFP, and Funding) have a significant impact on patent applications. Additionally, two predictors, Focal universities + NFP and Funding, and Matching and Funding, have a significant effect on patents-granted. The odds ratios for different collaborative structures indicate that R&D projects with collaboration between focal universities and not-for-profit organisations (Focal universities + NFP) are 76% and 64% less likely to produce patent applications and patents-granted performance, respectively, compared to non-collaboration R&D projects run by focal universities at a significance level of 0.05. The results are consistent with the findings from univariate analysis in section 7.2.1, although the results from multivariate analysis do not show that R&D collaboration projects between focal universities and for-profit partners (Focal universities + FP) have statistically positive effects on the generation of patent applications, patents-granted, and technology licensing, compared to

non-collaboration R&D projects led by focal universities (see *Table 7.7*).

Moreover, if any participants in R&D projects invest research funding in order to match government research funding, the probability of producing SCI papers is 42% lower than when there is no matching funding from participants. In contrast, the inputs from any participants in R&D projects have 3.33 times greater the probability of creating technology licensing than R&D projects with no input from any participants. The odds ratios for RFP show that institutional pressure (encouragement or enforcement) to establish R&D collaboration increases the probability of generating patent applications by 2.21 times. Lastly, for each one additional unit (One million Korean won ≈ GBP 687) in Funding, this results in increasing all four types of R&D performance by 0.1% (see *Table 7.10*).

Table 7.10 Results of the multivariate analysis in terms of R&D projects led by universities

Dependent Variable	Predictor	B	Wald χ^2	Sig.	Odds Ratio EXP(B)	95% C. I. for EXP(B)	
						Low	High
SCI papers	Matching	-0.55	5.33	0.02	0.58	0.36	0.92
	Funding	0.00	10.89	0.00	1.001	1.000	1.001
Patent applications	Focal Universities + NFP	-1.42	8.26	0.00	0.24	0.09	0.64
	RFP	0.793	12.76	0.00	2.21	1.43	3.41
	Funding	0.00	6.61	0.01	1.001	1.000	1.001
Patents-granted	Focal universities + NFP	-1.02	4.71	0.03	0.36	0.14	0.91
	Funding	0.00	8.88	0.00	1.001	1.000	1.002
Technology licensing	Matching	1.20	6.02	0.01	3.33	1.27	8.71
	Funding	0.00	5.55	0.02	1.001	1.000	1.002

Source: author's elaboration

In this paragraph, we will focus on the characteristics of *R&D performance generated by R&D collaboration projects led by PRIs*. Here, the probit link function in the generalized linear model was investigated in order to estimate the associations between independent variables (i.e. Partner, Matching, Funding, RFP, different types of R&D projects led by PRIs) and the dependent variables (i.e. the four different types of R&D performance in terms of SCI papers, patent applications, patents-granted, and technology licensing). When it comes to omnibus tests, the likelihood ratios chi-square for each of the four different dependent variables indicates that the model as a whole is not statistically significant compared with a model with no predictors because the all p-values for the tests are higher than a significant level of 0.05 (see *Appendix 17*). Hence, this particular result

from the multivariate analysis does not support the finding from the univariate analysis in *Table 7.8,* showing that R&D collaboration projects between focal PRIs and any type of partners tend to produce more patent applications than non-collaboration R&D projects run by PRIs at a significance level of 0.05.

Our focus in this paragraph will be on the characteristics of *R&D performance generated by R&D collaboration projects led by hospitals*. Here, the probit link function in the generalized linear model was investigated in order to estimate the relationships between independent variables (i.e. Partner, Matching, Funding, RFP, different types of R&D projects led by hospitals) and the dependent variables (i.e. the four different types of R&D performance). When it comes to omnibus tests, the likelihood ratios chi-squares for two dependent variables, namely patent applications and patents-granted, indicate that the models as a whole are statistically significant compared with a model with no predictors because the p-values for the tests are 0.00 and 0.01, respectively, which are lower than a significance level of 0.05 (see *Appendix 17*). However, the omnibus tests for the other dependent variables of SCI papers and technology licensing do not rule out the null hypothesis since there is no difference between the model as a whole with predictors and a model with no predictors with a 95% confidence level (see *Appendix 17*).

Tables 7.11 below shows the probit regression coefficient, Wald χ^2 test, and odds ratio for each of the predictors. By employing a 5% criterion of statistical significance, only one predictor, Partners, has a significant effect on the probability of producing patent applications and patents-granted. For every one additional partner in R&D collaboration projects, this increases the probability of generating patent applications and patents-granted by 1.47 times and 1.38 times, respectively. Furthermore, in line with the finding from the univariate analysis in section 7.2.1, there is no significant difference in terms of all types of R&D performance between R&D collaboration projects led by hospitals and R&D projects led by hospitals without a partner.

Table 7.11 Results of the multivariate analysis in terms of R&D projects led by hospitals

Dependent Variable	Predictor	B	Wald χ^2	Sig.	Odds Ratio EXP(B)	95% C. I. for EXP(B)	
						Low	High
Patent applications	Partners	0.39	5.14	0.02	1.47	1.05	2.06
Patents-granted	Partners	0.32	4.45	0.04	1.38	1.02	1.86

Source: author's elaboration

Lastly, we will try to interpret the findings related to control variables in this section. The amount of research funding has positive influence on all types of R&D performance of R&D projects led by firms and universities with only one exception (see *Table 7.9 and 7.10*). This finding may be interpreted as meaning that researchers with more research funding, which can be easily transferred to other resources such as human resources and research facilities in order to produce more research outputs or outcomes for meeting their goals, tend to have higher probability to produce R&D performance.

Next, R&D projects led by for-profit firms with institutional pressure to establish R&D collaboration are more likely to produce SCI papers, while R&D projects run by not-for-profit (i.e. universities) organisations with the institutional pressure tend to generate more patent applications (see *Table 7.9 and 7.10*). These findings may be explained by as noted later in *section 7.3*. For-profit-firms under the institutional pressure tend to improve their technological capabilities by learning from their collaborating partners in order to develop their own particular technologies or products. This may lead to concentrating more on the production of SCI papers. In contrast, not-for-profit organisations such as universities affected by institutional pressure are likely to obtain benefits from understanding different perspectives to technologies including the demands of end-users. Hence, this may bring about more opportunities for not-for-profit organisations to generate IPR or commercialisation possibilities.

For the features of funding input by participants (Matching), R&D projects led by universities are more likely to produce technology licensing, while they are less likely to create SCI papers if there is any inputs, matching funding, from participants in R&D projects. These findings may be interpreted to mean that for-profit organisations (i.e. firms) tend to more invest their own resources into the R&D project than not-for-profit organisations. Indeed, there are 216 R&D projects that include at least a firm in their research teams out of a total of 280 R&D projects with matching government funding, while there are only 16 R&D projects that comprise at least a firm out of a total of 328 R&D projects without matching government funding. Hence, universities with for-profit organisations may benefit from understanding different perspectives to technologies including the demands of end-users, which may lead to more opportunities to generate IPR or commercialisation possibilities. Conversely, firms may not contribute to universities to improve their technologically specialised capabilities to create SCI papers

although there must be coordination costs to manage R&D collaboration projects.

In this section, we have found that R&D projects led by firms are less like to produce SCI papers while R&D projects led by hospitals are more likely to generate patent applications and patents-granted, for one additional partner in R&D projects (see *Tables 7.9 and 7.10*). These results can be explained with leadership styles of PIs, because PIs coordinate their research teams with detailed management are higher productivity levels in terms of all types of R&D performance than PIs do not lead their research teams with detailed management (see *Appendix 16*). Indeed, just 45.0% of PIs in focal firms coordinate their research teams with detailed management, while 62.5% of PIs in focal hospitals deal with their research teams with the detailed management.

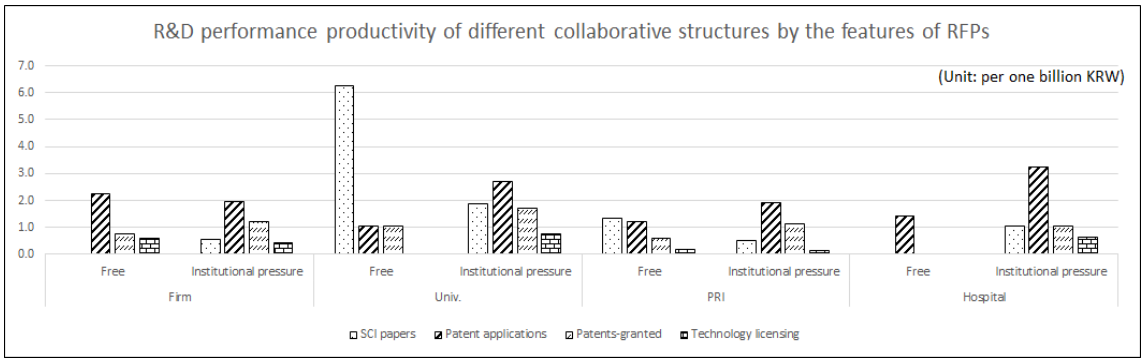
7.3. Institutional Implications for R&D performance

In section 7.2, we investigated the characteristics of R&D performance of particular collaborative structures compared with non-collaboration R&D projects based on statistical analyses. In addition, we discussed how the strategic motives of individual organisations in R&D collaborations may affect the R&D performance. On the other hand, we will focus on institutional implications for R&D performance in this section. The reason is that researchers in R&D projects are likely to have bounded information, or might not even recognise certain institutional properties of the national innovation system, because these institutional properties tend to be 'taken-for-granted' within the R&D system, being accepted without question (Lu, 2002) as noted in sections 3.2 and 5.3. In fact, the agreement level for motives regarding the 'enforced by funding agencies or government' in establishing collaboration is rated 3.5 on a seven-point scale, as described in *Table 5.8* in section 5.2.1, which corresponds to a level somewhere between 'slightly disagree' and 'neither disagree nor agree'. Hence, an additional investigation of the institutional implications for R&D performance is needed in order to arrive at a better understanding of how different collaborative structures have an effect on various aspects of R&D performance. In this regard, this section aims to explore the institutional implications for the various aspects of R&D performance, namely SCI papers, patent applications, patents-granted, and technology licensing. With regard to the institutional implications, we will deal in particular with R&D policy instruments (i.e. requests for proposals) discussed in section 5.3. Thus, we can address the implications of the attributes of RFPs as an R&D policy instrument for the R&D performance of different collaborative

structures based on focal organisational types in this section.

When it comes to the features of RFPs, institutional pressure by way of enforcement or various incentives influenced the establishment of the inter-organisational collaboration in 58 out of the a total of 82 RFPs (70.7%), and these account for 153 R&D (73.9%) projects out of a total of 207 collaboration R&D projects, as described in section 5.3. Meanwhile, there were 24 out of 82 RFPs (29.3%) without any conditions being attached by funding agencies or government ministries in terms of the establishment of collaboration. According to the *Figure 7.7* and *Table 7.12*, for-profit firms in the R&D projects from RFPs affected by institutional pressure to develop collaboration tended to show better productivity in terms of SCI papers and patents-granted than the firms in R&D projects from RFPs free from institutional pressure. However, the firms taking part in R&D collaborations voluntarily (without any institutional implications) were likely to produce better R&D performance in terms of technology licensing for every one billion KRW than firms influenced by institutional pressure. In addition, not-for-profit organisations (hospitals, PRIs, and universities) affected by institutional pressure to establish collaboration were more likely to enhance their R&D performance in terms of patent applications, patents-granted, and technology licensing for every one billion KRW. On the other hand, not-for-profit organisations participating in R&D collaborations without any institutional pressure in RFPs tended to generate higher productivity in terms of SCI papers per one billion KRW than their peer groups, except for hospitals[73].

Figure 7.7 The R&D performance productivity of different collaborative structures by the features of RFPs



* The 'Free' in the figure means that RFPs do not have any conditions in terms of establishing collaboration, while the 'Institutional pressure' points out that some conditions of enforcement or encouragement regarding the establishment of collaboration are included in the RFPs.

[73] This exception may be influenced by the small size of sample, which is only four (see *Table 7.12*).

Source: author's elaboration

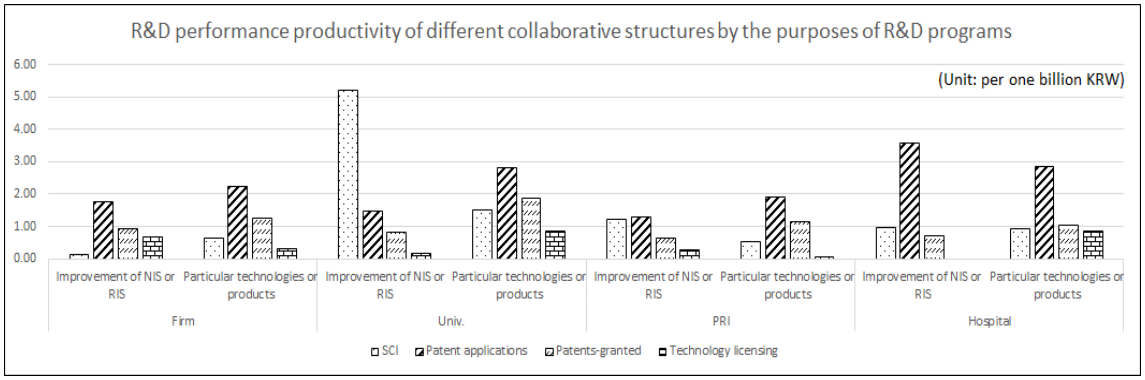
Table 7.12 The R&D performance productivity of different collaborative structures by the features of RFPs for every one billion KRW

Focal organisational type	Features of RFPs	No. of projects	SCI papers	Patent applications	Patents-granted	Technology licensing
Firm	Free from institutional pressure	57	0.0	2.2	0.8	**0.6**
	Institutional pressure	37	**0.6**	2.0	**1.2**	0.4
Hospital	Free from institutional pressure	**4**	0.0	1.4	0.0	0.0
	Institutional pressure	26	**1.1**	**3.3**	**1.1**	**0.7**
PRI	Free from institutional pressure	10	**1.3**	1.2	0.6	0.2
	Institutional pressure	14	0.5	**1.9**	**1.1**	0.1
Univ.	Free from institutional pressure	17	**6.3**	1.0	1.0	0.0
	Institutional pressure	42	1.9	**2.7**	**1.7**	**0.8**

Source: author's elaboration

These patterns may be explained by what we found in section 5.3. According to that finding, funding agencies or government ministries tend to compel or encourage the establishment of inter-organisational collaboration if the goal of R&D programs is related to the development of particular technologies or products. Meanwhile, those RFPs free from institutional pressure to establish collaboration are more involved in the R&D policy goal of improvement of the national or regional innovation system (see *Table 5.16*). Indeed, the pictures of R&D performance generated by R&D projects from R&D programs aiming to develop particular technologies or products are similar to the patterns produced by R&D projects influenced by institutional pressure to establish R&D collaboration (see *Figures 7.7 and 7.8*). For instance, for-profit firms taking part in R&D collaborations to develop particular technologies or products were more likely to produce SCI papers, patent application, and patents-granted while they were less likely to generate technology licensing than those in R&D programs with other goals. On the other hand, not-for-profit organisations participating in R&D collaboration with the purpose of developing particular technologies or products tended to produce rather more patent applications, patents-granted, and technology licensing while they were less likely to generate SCI papers than those in R&D programs with other goals (see *Figure 7.8* and *Table 7.13*).

Figure 7.8 The R&D performance productivity of different collaborative structures by the purposes of R&D programs



Source: author's elaboration

Table 7.13 The R&D performance productivity of different collaborative structures by the purposes of R&D programs for every one billion KRW

Focal organisational type	Purposes of RFPs	SCI papers	Patent applications	Patents-granted	Technology licensing
Firm	Improvement of NIS or RIS	0.13	1.77	0.95	**0.66**
	Particular technologies or products	**0.66**	**2.24**	**1.26**	0.32
Hospital	Improvement of NIS or RIS	0.95	3.57	0.71	0.00
	Particular technologies or products	0.95	2.85	**1.05**	**0.84**
PRI	Improvement of NIS or RIS	**1.21**	1.30	0.65	0.28
	Particular technologies or products	0.54	**1.91**	**1.15**	0.08
Univ.	Improvement of NIS or RIS	**5.21**	1.47	0.81	0.16
	Particular technologies or products	1.50	**2.82**	**1.88**	**0.84**

Source: author's elaboration

This would seem to suggest that combinations through inter-organisational collaboration with a variety of technologies and knowledge in diverse areas such as ICT, bio/medical technologies, and healthcare services play a pivotal role in developing particular technologies or products in the digital healthcare sector. Hence, funding agencies or government ministries are more likely to require or encourage the establishment of inter-organisational collaboration in this sector if the goal of the R&D programs is to develop particular technologies or products. As a consequence, for-profit-firms tend to improve their technological capabilities by learning from their collaborating partners in order to develop their own particular technologies or products, which may lead to producing SCI papers, patent applications and patents-granted, rather than emphasising immediate commercialisation aspects like technology licensing. In contrast, not-for-profit organisations are likely to obtain benefits from understanding different perspectives to

technologies including the demands of end-users, bringing about more opportunities to generate IPR or commercialisation possibilities through the process of inter-organisational collaborations, rather than focusing more specifically on scientific knowledge creation.

7.4. Additional Benefits and Unrevealed Outcomes from Inter-organisational R&D Collaboration

In sections 7.1, 7.2, and 7.3, we focused on the codified R&D performance – in terms of SCI papers, patent applications, patents-granted, and technology licensing – associated with inter-organisational R&D collaborations in order to explore the characteristics of the R&D performance according to different collaborative structures. The purpose of this section, in contrast, is to explore additional benefits and unrevealed outcomes from the establishment of inter-organisational R&D collaboration based on interview data from PIs in the focal organisations leading R&D collaborative projects. Here, the unrevealed outcomes mean that R&D performance which is not captured as research outputs or outcomes through Korean National Science and Technology Information System (NTIS: https://www.ntis.go.kr/ThMain.do)[74], because this system predominantly focuses on codified R&D performance such as academic papers, patent applications, patents-granted, and technology licensing. During these interviews, all interviewees were asked open-ended questions regarding any benefits from the establishment of R&D collaboration, and any undisclosed outcomes from inter-organisational collaboration which are not reported to funding agencies as their outputs or outcomes after finishing their R&D projects. Through this investigation, we can perhaps arrive at a fuller understanding of how different collaborative structures have an effect on various aspects of R&D performance.

First of all, we will deal with the benefits and unidentified outcomes from *R&D collaborations led by focal firms*. According to interviewees in focal firms, they particularly appreciated the benefits from collaborating with hospital partners in terms of acquiring medical and clinical knowledge from them, employing them as a test-bed, and securing medical data. This may be because more than 56% of focal firms developed R&D collaborations with hospital partners, which is a much higher proportion compared with collaboration with other partner types (a firm (39%), university (42%), or PRI

[74] As mentioned in section 3.3.1, the data in terms of public R&D projects collected, managed and verified by the Ministry of Science and ICT (MSIT), the Korea Institute of Science and Technology Evaluation and Planning (KISTEP), and the Korea Institute of Science and Technology Information (KISTI) are released via this NTIS for the only purpose of the public research.

(25%)), according to *Table 6.11* in section 6.4.

All eight interviewees in focal firms collaborating with hospital partners mentioned acquiring significant benefits from their hospital partners. For instance, interviewee F01 (Founder/CEO) said that "we have had a chance to improve our insight into the clinical sector through collaborating with hospitals", and interviewees F03 (CTO) also said that "we have learned many things in the process of a clinical trial" via R&D collaboration with a hospital partner. In the same vein, interviewees F04 (Founder/CEO), F05 (CTO), and F06 (CTO/Executive Director) mentioned that "we have obtained specialised medical and clinical knowledge …", "we have developed medical and clinical knowledge …", and "We have had a chance to acquire capabilities including … clinical knowledge", respectively, from the development of inter-organisational collaboration. Similarly, interviewee F08 (CTO) said "we have obtained complementary assets from our hospital partners such as medical data", and interviewees F02 (Founder/CEO) and F12 (Team Head) responded that "we have been able to carry out clinical trials at a very low cost through collaborating with hospitals", and "thanks to collaborating with a hospital, we have secured a clinical test-bed …", respectively. These benefits from establishing R&D collaboration are very similar to the main expectation of focal firms with regard to hospital partners in the development of collaboration, which is 'to employ hospitals as testbeds for the clinical validation of focal firms' products or services and to obtain clinical insights', as noted earlier in section 6.4.1.

With regard to unrevealed outcomes from R&D collaboration led by firms, interviewees in focal firms said that the technologies they developed together with their collaborating partners were adopted to apply in their own products or services in order to advance those products or services. For example, interviewee F01 (Founder/CEO) said that "several technologies developed through this collaboration project were applied to our own commercial good", namely a smart glove for the purpose of the physical rehabilitation of the disabled following a stroke. Interviewee F09 (CTO) also responded that "we have applied the technology we developed (in this R&D collaboration) to our existing AED (Automated External Defibrillator), and we can remotely monitor the condition of the new version of AEDs" installed in public areas, while interviewee F12 (Team Head) said that "we have made around three to four billion KRW (more than £ 2 million) sales through the network-based medical monitoring system we developed in this R&D

collaboration project". Moreover, interviewee F06 (CTO/Executive Director) replied that "we have launched a new business, a mobile healthcare diagnostic service, in the US based on the technology we developed through the R&D collaboration project", overcoming a regulatory barrier regarding telemedicine in Korea. Interviewee F08 also mentioned that "we have achieved an upgrade version of our existing health information system (HIS) through this R&D collaboration, and we were able to launch this new version of the system in Saudi Arabia and in US hospitals"

This may show that R&D collaborations led by focal firms are likely to have a positive impact on the focal firm's commercialisation activities, although these outcomes are not revealed in terms of technology licensing as discussed in previous sections. This finding may be explained by the fact that focal firms may be likely to put more emphasis on learning from their collaborating partners in order to develop their existing or new technologies, which could be influenced by their main motives in establishing the collaborations, as explained earlier in section 7.1. Therefore, R&D collaborations led by focal firms may have achieved higher levels of R&D outputs in terms of SCI papers, patent applications, and patents-granted than non-collaboration R&D projects run by firms, as discussed in sections 7.1 and 7.2. Interestingly, however, the level of R&D performance in terms of technology licensing of R&D collaborations led by focal firms is lower than that for non-collaboration R&D projects run by firms, as shown in section 7.1. This may be due to the fact that focal firms in R&D collaborations do not have to go through the technology licensing process when they employ the technologies they needed, because the technologies might be internalised through learning by collaborating with other partners and are not owned by collaborating partners with the relevant IPR.

Second, let us shift our attention to the additional benefits and undisclosed outcomes from inter-organisational *R&D collaborations led by universities*. We will first focus on the benefits from the R&D collaborations. According to interviewees, the benefits are generally categorised under two headings – obtaining advantages from collaborating with particular organisational types such as hospitals and firms, and perceiving the weaknesses of their own capabilities or technologies that can be filled in the future. For example, interviewees U03 (Full Professor, MD) and U04 (Full Professor/Dean) said that they "have collected clinical data through collaborating with hospitals, which was a most beneficial advantage from the establishment of R&D collaboration". Interviewee U05

(Full Professor) mentioned as a benefit the fact that "we have had an opportunity to understand a health information system in a hospital through this project". In addition, interviewee U02 (Full Professor, MD) responded that "we have obtained many insights, in particular, in terms of the marketplace … from diverse collaborating partners", and interviewee U07 (Assistant Professor) said that "we have had a chance to understand the market-side perspective by collaborating with a firm". Furthermore, interviewees U01 (Full Professor), U03 (Full Professor, MD) and U04 (Full Professor/Dean) all mentioned that they appreciated seeing the weaknesses of their own technologies and capabilities in order to fill any gaps in the development of their capabilities and technologies. More specifically, interviewee U01 said that "we have perceived and corrected a weak point of our technology via collaborating with our partners", and both interviewees U03 and U04 answered that "we have had a chance to perceive the weaknesses of our capabilities and technologies" through collaborating with other partners.

Moving to the unrevealed outcomes of R&D collaborations led by focal universities, these universities may be likely to develop human resources and evolve their technologies to a higher level of technological maturity[75]. For example, interviewee U01 (Full Professor) responded that "we have achieved the development of human resources particularly by collaborating with partners in the industrial sector", and interviewee U02 (Full Professor, MD) said that "we have achieved the development of human resources" through R&D collaboration research. In addition, interviewee U02 (Full Professor, MD) also said that "we have launched two spin-off companies in Korea and the US on the basis of the technology we developed with diverse collaborating partners [from one university and one PRI], and we have also contributed to launching the spin-off companies of our collaborating partners". In this regard, interviewee U05 (Full Professor) also mentioned that "the technology we developed through collaborating with a hospital partner in terms of 'an individualized drug use process' has been applied to the health information system of our collaborating hospital". Moreover, interviewee U07 (Assistant Professor) said that "we have managed to make a proto-type device for monitoring the habits of eating and sleeping" through collaborating with our partner firm. These unrevealed outcomes may be influenced by the main motives of focal universities in establishing R&D collaboration, which are 'to obtain help for R&D commercialisation' through 'accessing complementary

[75] According to Albert, et al. (2015, p. 197), "the maturity can be represented as the technology's position within a technology life cycle".

capabilities', as noted previously in section 6.2.2. In addition, the motives may influence the development of the capabilities of students or researchers at universities through carrying out research with different types of collaborating partners. As a consequence, focal universities in R&D collaborations are more likely to place an emphasis on the later, more mature stages of technologies leading to technology licensing or IPR rather than them those engaged in non-collaboration R&D projects, a result which is line with the finding from section 7.2.

In this paragraph, we will focus on understanding the additional benefits and unidentified outcomes from *inter-organisational R&D collaborations led by PRIs*. With regard to the benefits from these R&D collaborations, focal PRIs tend to obtain benefits from accessing complementary capabilities through research with firm and hospital partners in particular, according to interviewees. For instance, interviewee P02 (Principal Researcher) responded that "we have learned about the development of software from our collaborating ICT firm and collected clinical data from our collaborating hospitals". Interviewee P04 (Principal Researcher/Assistant Vice President) also said that "we have gained benefits from complementary capabilities and had a chance to understand our research topic from the perspectives of a hospital and a firm". In addition, interviewee P03 (Principal Researcher) mentioned that "we have acquired some know-how in terms of how to optimally combine diverse elements such as technologies, content, and services in order to launch a product in the marketplace through collaborating with our partner firm".

When it comes to unidentified outcomes from R&D collaborations led by focal PRIs, such collaborations are likely to contribute to the establishment of better infrastructure in the digital healthcare sector. The reason given by interviewee P01 (Principal Researcher/Team Head) is that "we have contributed to an official government announcement for the standardised exchange of medical information based on this R&D collaboration project with diverse partners. Based on this government announcement, we are now carrying out a pilot project to implement the standardised exchange of medical information between several core hospitals and many clinics". Interviewee P05 (Senior Research/Team Head) also said that "we have put efforts into fostering an effective research environment between the health and ICT sectors" through the R&D collaboration project. Interestingly, the benefits and unrevealed outcomes of R&D

collaborations led by PRIs may be substantially affected by their motives in the establishment of R&D collaboration, because the benefits (gaining complementary capabilities or resources from hospital or firm partners to develop technologies or products) and outcomes (contributing to the promotion of the digital healthcare sector) are similar to the motives underpinning the collaboration. In fact, the motives of focal PRIs in establishing collaboration are 'to access complementary capabilities or resources' in order 'to have access to new technologies or markets', and 'to pursue certain missions mandated from the government/agency or society', as noted earlier in section 6.2.2.

Lastly, we will shift our attention to additional benefits and unrevealed outcomes from inter-organisational *R&D collaborations led by hospitals*. We will first attempt to shed some light on the benefits from R&D collaborations led by hospitals. According to interviewees in hospitals, they are likely to appreciate the benefits from ICT-related technologies, which help to implement their ideas or concepts derived from clinical practice, with support from their partner firms. For example, interviewee H02 (Full Professor/Director, MD) said that "we have learned a lot of things regarding ICT technologies …" via collaborating with an ICT firm, while interviewee H03 (Full Professor, MD) responded that "having an opportunity to understand ICT-related technologies … is a meaningful benefit" from collaborating with a partner firm. In addition, interviewee H06 (Full Professor/Vice Dean, MD) said "we have learned … essential capabilities and elements to develop mobile applications" to provide a patient-centred medical content service by collaborating with a partner firm. This benefit would seem to have been affected by the motives in the establishment of R&D collaboration led by focal hospitals, given that the main motives are 'to access complementary capabilities' in order 'to gain access to new technologies or markets' (e.g. ICT-related areas).

With regard to the unrevealed outcomes of R&D collaboration led by hospitals, they tended to generate R&D performance linked to a technical standard through R&D collaboration projects. For instance, interviewee H01 (Research Assistant Professor) responded that "most genetic firms in Korea are about to adopt a technical standard in terms of human genome sequencing in EMRs (Electronic Medical Records) that we developed in this collaboration project". Interviewee H05 (Principal Researcher) also said that "a technical standard we developed in the R&D collaboration has been adopted as an international standard", which would represent a major achievement for their research

team.

Table 7.14 below summarise the additional benefits and unrevealed outcomes from the establishment of inter-organisational R&D collaboration in the digital healthcare sector.

Table 7.14 A summary of additional benefits and unrevealed outcomes from the establishment of inter-organisational collaboration

Focal organisational type	Additional benefits	Unrevealed outcomes
Focal firms	Learning medical and clinical knowledge, employing a clinical test-bed, and securing medical data through Collaborating with hospital partners	The technologies they developed together with their collaborating partners were adopted to apply into focal firms' own products or services.
Focal universities	Obtaining medical- and market-sides knowledge, and perceiving the weaknesses of their own capabilities or technologies that can be filled in the future	Achieving the development of human resources and a higher level of technological maturity in terms of focal universities' technologies
Focal PRIs	Obtaining benefits from complementary capabilities through particular collaborating with firm and hospital partners	The establishment of better infrastructure in the Korean digital healthcare sector
Focal hospitals	Learning ICT-related technologies, which help to implement their ideas or concepts derived from clinical practice	Generating R&D performance regarding a technical standard through collaboration research

Source: author's elaboration

7.5. Conclusion

The purpose of this chapter has been to examine what effects different collaborative structures have on various aspects of R&D performance, namely, SCI papers, patent applications, patents-granted, and technology licensing. Hence, we primarily focused on the characteristics of the R&D performance according to different collaborative structures in comparison with the R&D performance of non-collaboration R&D projects in the digital healthcare sector. Through the analysis process, we found very interesting features concerning R&D performance of R&D collaboration projects compared with that of non-collaboration R&D projects. The productivity levels of R&D collaboration projects are generally lower than those of non-collaboration R&D projects in all aspects of R&D performance.

However, we found completely different patterns in R&D productivity levels when we broke down collaborative structures in the light of the type of focal organisations (see *Figure 7.1* and *7.2* in section 7.1). For example, the productivity levels in terms of SCI p

apers, patent applications and patents-granted produced by R&D collaborations led by fi rms with NFP partners are significantly higher than those for non-collaboration R&D pr ojects run by firms. In addition, R&D collaboration projects between focal universities a nd FP partners had a significantly higher productivity level with regard to technology lic ensing compared with non-collaboration R&D projects run by universities. Moreover, w e have also obtained similar findings through the binary logistic regression analyses (i.e. univariate analysis), which indicate how much each form of collaborative structure of R&D projects has more or less impact on the production of each type of R&D performance as compared with non-collaboration R&D projects (see *Table 7.6, 7.7.* and *7.8*). In addition, we have carried out multivariate analysis in order to examine whether the findings from the univariate analysis in section 7.2.1. concerning the effects of different collaborative structures on R&D performance are robust. Through this analysis, we have confirmed that R&D collaboration projects led by focal firms with NFP organisations (Focal firms + NFP) are more likely to produce SCI papers and patents-granted in comparison with a reference group consisting of non-collaboration R&D projects run by firms, with a confidence of 95%. We have also confirmed that R&D collaboration projects led by focal universities with not-for-profit organisations (Focal universities + NFP) tend to generate 76% and 64% less R&D performance in terms of patent applications and patents-granted, respectively, than R&D projects led by universities without any partner at a significance level of 0.05 (see *section 7.2.2*). However, other findings from the univariate analysis in *section 7.2.1* are not robust enough at a significance level of 0.05 (see *Table 7.15*). Hence, readers should treat these findings with due caution.

Table 7.15 The non-significant results from mulivariate analysis, compared with the findings from univariate analysis

Dependent Variable	Predictor	B	Wald χ^2	Sig.	Odds Ratio EXP(B)	95% C. I. for EXP(B)	
						Low	High
Patent applications	Focal firms + NFP	0.47	2.61	0.11	1.60	0.91	2.84
Technology licensing	Focal universities + FP	1.06	1.11	0.29	2.88	0.40	20.50
Patent-applications	Focal PRIs + FP	1.67	1.61	0.21	5.29	0.40	69.32
	Focal PRIs + NFP	0.69	0.57	0.45	2.00	0.33	12.03

* The reference predictor group is the R&D performance generated by R&D projects run by firms, universities, or PRIs without any partner, respectively.

In addition, we have discussed the institutional implications for various aspects of R&D performance. According to the results, for-profit-firms under this institutional pressure tend to improve their technological capabilities by learning from their collaborating partners in order to develop their own particular technologies or products. This may lead to concentrating more on the production of SCI papers, patent applications and patents-granted, rather than emphasising immediate commercialisation aspects like technology licensing. In contrast, not-for-profit organisations (hospitals, PRIs, and universities) affected by institutional pressure that enforce or encourage the establishment of collaboration are likely to obtain benefits from understanding different perspectives to technologies including the demands of end-users. Hence, this may bring about more opportunities for not-for-profit organisations to generate IPR or commercialisation possibilities through the process of inter-organisational collaborations, rather than focusing more specifically on scientific knowledge creation (see *section 7.3*).

These findings are supported by the results from multivariate analysis in section 7.2.2, because we have confirmed that institutional pressure to establish R&D collaboration, in the form of either encouragement or enforcement, is more likely to generate SCI papers in R&D projects led by firms, while institutional pressure is less likely to create technology licensing in R&D projects run by firms, compared with R&D projects run by firms without such institutional pressure. Moreover, we have also confirmed that the institutional pressure has a positive impact on the probability of producing patent applications in R&D projects led by universities in comparison with R&D projects led by universities free from such institutional pressure (see *Tables 7.9 and 7.10*).

Finally, additional benefits and unrevealed outcomes from the establishment of inter-organisational R&D collaboration in the digital healthcare sector were collected through face-to-face interviews (see *Table 7.14*). According to the results, the benefits and unrevealed outcomes from establishing collaboration tend to reflect the distinctive features of each focal organisation type and the environment surrounding them. For instance, focal firms, universities, and PRIs particularly appreciated the benefits from collaborating with their hospital partners thanks to employing medical knowledge and data, whereas focal hospitals gain help to implement their research ideas or concepts derived from clinical practice. In addition, focal firms tend to regard the application of technologies developed from R&D collaboration into their own products or services as

an unrevealed outcome, although focal universities are likely to see achieving the development of human resources as a key outcome. In addition, the establishment of better infrastructure in the Korean digital healthcare sector tends to be regarded as an unrevealed outcome by focal PRIs, while focal hospitals are likely to consider the development of technical standards as one of their unrevealed outcomes. Thus, these findings may perhaps contribute a better understanding of how different collaborative structures have an effect on various aspects of R&D performance.

The following chapter will summarise and synthesise the empirical findings based on empirical chapters in this thesis. It will discuss the main conceptual, methodological, and empirical contributions made through addressing the research questions in this thesis. It will conclude by discussing policy implications, limitations of this research, and the options for future research.

Chapter 8. Discussion and Conclusion

This chapter will synthesise the main findings of this thesis in section 8.1 and draw out the conceptual, methodological, and empirical contributions to knowledge regarding the characteristics of inter-organisational collaborations and their implications for R&D performance – in terms of SCI papers, patent applications, patents-granted, and technology licensing – in the Korean digital healthcare sector in section 8.2. Additionally, the policy implications and limitations of this thesis and options for future studies will be discussed in section 8.3, and this chapter will be ending with a brief summary of contributions of this thesis.

8.1. Research Questions and Main Findings

This research aims to understand the characteristics of collaborative structures and their implications for the performance of public R&D projects in the Korean digital healthcare sector. The role of collaboration is becoming progressively more important to achieve innovation in an environment that is continually experiencing rapid technological change as well as changing modes of knowledge production (Alexiev, et al., 2016; Elango, et al., 2012). The digital healthcare sector seems to experience such an environment, and this sector is also confronted by demographic changes, particularly with an ageing population in many parts of the world, not least Korea. In addition, the demographic changes have an impact on the increasing healthcare expenditures, and the undermining the expectation of universal health coverage (Hayes, et al., 2016; UN, 2013), whereas personalised-medicine/precision medicine has been spreading as a result of the rapid development of healthcare-related technologies such as biomedical science, ICT, and clinical science (Frizzo-Barker, et al., 2016). This is bringing about a paradigm shift in the healthcare sector from being cure and healthcare provider-centred to shedding more light on care/prevention and a patient-centred approach where knowledge reconfiguration and integration through collaborations with various external partners are more essential (Anderson, et al., 2005; Gérvas, et al., 2008; Traver, et al., 2010).

However, little attention has been paid to understanding the characteristics of collaboration and its effect on performance in the digital healthcare sector. Thus, understanding the characteristics of collaboration for developing research capabilities through public R&D projects should yield important insights and policy implications for this sector, because public R&D is likely to play a pivotal role in emerging markets such

as the digital healthcare sector, given that private firms are reluctant to invest in these markets due to the large risks (Bozeman, 2000). Hence, the aims of this research are (1) to identify why organisations that participate in public R&D projects in the Korean digital healthcare sector establish inter-organisational collaborations, (2) to explore why different structures of these inter-organisational collaborations are established, and (3) to explore what effects the development of inter-organisational collaborations has on innovative performance. Accordingly, three research questions to address these issues are:
(i) What are the motives of the focal organisations[76] influencing the establishment of inter-organisational collaboration in public R&D projects of the Korean digital healthcare sector?
(ii) How are different collaborative structures developed in the public R&D projects?
(iii) What effects do these different collaborative structures have on diverse aspects of R&D performance?

In order to address these questions, we have carried out a combination of desk-based research, a survey, and interviews focusing on four different organisational types (i.e. firms, universities, PRIs, and hospitals) in the innovation system of the Korean digital healthcare sector. In order to deal with the questions, data were generally collected based on a total of 207 public R&D collaboration projects in the Korean digital healthcare sector between 2012 and 2015, which account for around £92.5 million of the R&D budget.

More specifically, for dealing with *the first research question*, closed questions involving motives linked to both the institutional properties of the system and the intrinsic properties of individual organisations were asked via a survey in order to understand to what extent each motive linked to three theoretical approaches (i.e. the NIS, TCE, and the RBV perspectives) affects the establishment of inter-organisational collaboration. Through the survey, 57 project topics (44.5%) and 92 R&D projects (44.4%) were covered out of a total of 128 project topics and 207 R&D projects in the digital healthcare sector of Korea for the period from 2012 to 2015. In addition, an open-ended question was tested through interviews for cross-validation of the findings in which respondents are able to introduce their own answers that do not fit within the interviewer's coding schemes (Roulston, 2008b). In course of the interviews, 39 project topics and 64 R&D projects were covered through interviews with 35 principal investigators (28.2%) out of a total of 124 principal

[76] The role of focal organisations, which launch initiatives with the strategic purpose of establishing collaboration, is vital in R&D projects.

investigators, 128 project topics, and 207 R&D projects in the Korean digital healthcare sector for the period from 2012 to 2015. In contrast to intrinsic properties of individual organisations, respondents in research organisations are likely to have bounded information in terms of the institutional properties of the innovation system, or they might not even perceive them because these institutional properties tend to be 'taken-for-granted' within the national R&D system, being accepted without question (Lu, 2002). Hence, an additional investigation of the institutional pressures affecting the establishment of collaboration by enforcing or encouraging was carried out through exploring the 'request for proposals' (RFPs) of each R&D project in order to obtain a better understanding of the motives with regard to the institutional properties of the innovation system in establishing collaboration.

In order to address *the second research question*, the survey-based data and interview data in terms of the motives in the establishment of R&D collaboration were classified in terms of focal organisational types (i.e. firms, universities, PRIs, and hospitals). Thus, this classification provides information on how the development of different collaborative structures based on various focal organisational types depends on different motives in establishing the collaboration. Furthermore, the survey-based data were classified by collaborating partner type, and these classified groups were employed to analyse how the motives influence focal organisations to choose a particular type of partners in establishing R&D collaboration. In order to carry out a more in-depth investigation, interview-based data were utilised. These data were collected to gain information on the strategic expectations of focal organisations with regard to their partner organisations in the establishment of different collaborative structures. Thus, this analysis may also contribute to a better understanding of how different focal organisations developed R&D collaborations with particular types of collaborating partners.

The last research question was generally addressed by quantitative analysis in order to understand what effects different collaborative structures categorised by focal organisational type have on various aspects of R&D performance – SCI papers, patent applications, patents-granted, and technology licensing. In addition, we carried out an investigation to ascertain the institutional implications for R&D performance through exploring the 'request for proposals' (RFPs) of each R&D project. Finally, unrevealed aspects of R&D performance that are not captured through the national R&D information

system were explored based on interview data. Hence, this analysis also contributes to arriving at a better understanding of how the establishment of inter-organisational R&D collaboration has an effect on various aspects of R&D performance.

Based on the above, the main findings are presented by responding to each research question in sections 8.1.1, 8.1.2, and 8.1.3.

8.1.1. RQ (i) What are the Motives Influencing the Establishment of Inter-organisational Collaboration?

The most influential motive in the establishment of inter-organisational R&D collaboration in the digital healthcare sector **turns out** to be '*to gain access to complementary resources and capabilities*', a factor involving **the RBV perspective**, and strategic motives involved in this theoretical perspective influence the establishment of collaboration significantly more than motives involved in the other theoretical perspectives based on TCE and the NIS (see *Tables 5.8 and 5.14* in section 5.2.1). This emerges from quantitative analysis and is also cross-validated with qualitative analysis based on interview data (see *section 5.2.2* and *Appendix 5*). In addition, this finding is consistent with the results from Yasuda (2005), Odagiri (2003) and Hagedoorn, et al. (1991), who suggested that strategic motives linked to the RBV perspective outweigh the motives involving TCE perspective in explaining the establishment of collaborations. The reason for this finding may be because focal organisations cannot on their own carry out their diverse research tasks due to either a lack of internal resources or capabilities, or because of the characteristics of their research aims in the digital healthcare sector where interactions and integration between different organisations with diverse specialised capabilities and resources based on bio-medical technology, healthcare services, and ICT are essential.

Moreover, we found that funding agencies or government ministries are more likely to require or encourage the establishment of inter-organisational collaboration if the goal of the R&D programs is to develop particular technologies or products. We also found that universities were less likely to build collaboration than other organisational types if there is no institutional pressure. This may be because scholars in universities, relatively free to pursue academic curiosity, tend to regard activities engaging with external organisations (e.g. firms) as a discretionary form of behaviour (D'este, et al., 2011). Thus, government may need suitable strategies to induce universities to participate in R&D

collaboration. Meanwhile, private firms were more likely to establish collaboration voluntarily without any influence in the form of institutional pressure than other organisational types. This could explain why private firms tend to depend on collaborating partners in order to achieve their research aims, to develop their technological capabilities, and to minimise research expenses, given that more than 91% of private firms taking part in the R&D projects in the digital healthcare sector are SMEs, generally suffering from a shortage of internal resources and capabilities.

8.1.2. RQ (ii) How are Different Collaborative Structures Developed in the Public R&D Projects?

In order to answer the second research question, we investigated the characteristics of strategic motives in establishing collaboration for different collaborative structures categorised by focal organisational type. The reason is that each type of organisation has its own features (Isaksen, et al., 2017; Rainey, 1989), and the role of focal organisations, who launch initiatives with the strategic purpose of establishing collaboration in the R&D projects, is therefore crucial, given that both managerial leadership and technical leadership have a substantial impact on R&D and innovative performance (DiBella, 1995; Pelz, et al., 1966; Shim, et al., 2001). In addition, strategic motives of the focal organisations in the choice of the particular type of collaborating partners were explored. Hence, this investigation could provide evidence on how different motives influence the development of different collaborative structures.

According to the quantitative analysis based on a survey, the results demonstrate that collaborative structures led by focal firms are significantly more affected by motives in terms of '*cost-economising* (e.g. through developing economies of scale, costs sharing/reduction in research, and reducing administrative costs) and *gaining IPRs*' in establishing collaboration than not-for-profit organisations such as universities and PRIs (see *Table 6.6* in section 6.2.1). In addition, we found that strategic motives linked to *a TCE perspective* affect *focal firms* significantly more than not-for-profit organisations like universities and PRIs in developing collaboration. This may be because the not-for-profit organisations face less severe efficiency pressures than private organisations from the perspective of TCE because other incentives such as political or other non-economic forces may induce distinctive strategic decisions from the not-for-profit organisations (Brody, 1996; Coles, et al., 1998).

Moreover, the qualitative analysis based on interviews in order to achieve additional coverage shows that each type of focal organisations (i.e. firms, universities, PRIs, and hospitals) is also extensively affected by distinctive motives, although all types of focal organisations are greatly influenced by the motive 'to access complementary capabilities or resources' (see section 6.2.2). For instance, *focal firms* tend to focus on '*developing existing technologies*', while *focal universities* are likely to be concerned with '*achieving benefits from potential grants*' in establishing R&D collaboration. In addition, the strategic motive '*to pursue certain missions mandated from the government, funding agency, or society*' is like to affect the establishment of R&D collaboration *led by PRIs*, whereas focal hospitals tend to be primarily influenced by the motive '*to gain access to new technologies or markets*', although this is not a distinctive motive only for focal hospitals (see *Table 8.1*).

Table 8.1 Distintive motives in establishing different collaborative structures by focal organisational type

Distinctive motives in establishing R&D collaboration by focal organisational type	Collaborative structures
'To develop existing technologies', 'to gain access to new technologies or markets', and 'to achieve R&D commercialisation'	Led by focal firms
'To obtain help for R&D commercialisation' and 'to achieve benefits from potential grants'	Led by focal universities
'To gain access to new technologies or markets', and 'to pursue certain missions mandated from the government/agency or society'	Led by focal PRIs
'To gain access to new technologies or markets'	Led by focal hospital

Source: author's elaboration based on *Table 6.8* in section 6.2.2

Furthermore, we learned how strategic motives affect focal organisations in choosing their collaborating partner types. According to the statistical analysis based on survey data, focal firms are significantly more concerned with '*minimising research expenses'* in the choice of hospitals as their collaborating partner than focal universities, while the motive '*to shorten lead time*' influences focal hospitals in choosing collaborating partner firms significantly more so than focal universities. In addition, the choice of collaborating partner universities is relevant to diverse strategic motives by focal organisational type. For instance, focal firms are significantly more influenced by the motive '*to have priority over IPR*' and of '*reducing administrative costs*' in establishing R&D collaboration with partner universities than focal universities and PRIs, respectively. However, focal firms are significantly less influenced by the motive '*to achieve benefits from potential grants*' for an

R&D collaboration with partner universities than focal hospitals (see *Table 6.10*).

According to the results from analysing interview data, focal firms are likely to expect '*securing component technologies or specific items*' to develop their own products or services with the expectation of '*a reduction in transaction costs*' by collaborating with partner firms, while not-for-profit focal organisations including universities, PRIs, and hospitals tend to collaborate with partner firms '*to gain help in the implementation of research concepts and their technologies*'. In addition, most focal organisations regardless of their organisational types are likely to expect '*to obtain highly specialised capabilities or technologies*' with regard to their university partners, except for focal hospitals being likely to focus on '*benefits from technical standards and exploratory research capabilities*'. Meanwhile, all types of focal organisations tend to '*look for technological capabilities*' from their PRI partners, while focal firms and hospitals are also likely to expect '*to gain help in dealing with institutional issues*' by choosing PRIs as their collaborating partners. When it comes to hospital partners, all types of focal organisations are likely to employ hospitals in order '*to secure the clinical validation*' of their technologies, products, or services (see *Table 8.2*).

Table 8.2 A summary of focal organisations' main expectations with regard to their partners

Collaborating partners' type	Main expectations with regard to collaborating partners	Focal organisations
Firm	**To secure component technologies or specific items** held by partner firms for developing the focal firm's products or services with the expectation of **a reduction in transaction costs**	Firm
University	In order **to gain highly specialised technology** and to develop technical standards	
PRI	**To obtain benefits from PRIs' research capabilities** and **to overcome institutional barriers** such as approval information on new products	
Hospital	**To employ hospitals as testbeds for the clinical validation** of focal firms' products or services and to obtain clinical insights	
Firm	**To gain help in the implementation of research concepts and developing technologies**; To benefit from technology commercialisations such as licensing-out; In order to understand end-users' demands and to validate their existing technology in the marketplace	University
University	**To benefit from specialised capabilities** such as optical bio-sensors and immunological anonymization, and syntactic analysis technology	
PRI	**To acquire highly specialised capabilities** such as biosensor-related software and the system integration	
Hospital	In order to secure medical data and **to carry out the clinical validation** of developing technologies	
Firm	In order **to implement their research concepts and technologies** and to support SMEs as a public research organisation	PRI

Collaborating partners' type	Main expectations with regard to collaborating partners	Focal organisations
University	**To benefit from the development of specialised technologies**	
PRI	In order **to benefit from partners with component technologies**	
Hospital	**To get help with the clinical validation** for targeted technologies and to obtain clinical insights and knowledge on their research	
Firm	To benefit from complementary capabilities such as existing technologies or platforms of the partner firms in relation to ICT and digital services in order **to implement their ideas derived from clinical practice**	Hospital
University	In order **to get benefits from technical standards** based on medical information and exploratory research capabilities	
PRI	**To gain help with institutional issues** and **technological capabilities**	
Hospital	**To employ partner hospital(s) as additional clinical test-beds**	

Source: author's elaboration based on *Tables 6.12, 6.13, 6.14, and 6.15* in section 6.4.

8.1.3. RQ (iii) What effects do these different collaborative structures have on diverse aspects of R&D performance?

Through addressing this research question, we found very interesting features concerning R&D performance of the R&D collaboration projects compared with that of non-collaboration R&D projects. *The productivity levels of R&D collaboration projects are generally lower than those of non-collaboration R&D projects in all aspects of R&D performance* including SCI papers, patent applications, patents-granted, and technology licensing. However, *we found completely different patterns* in R&D productivity levels *by breaking down collaborative structures* from the perspective of the type of focal organisations as we shall see below.

<u>Collaborative structures led by focal firms and their R&D performance</u>

R&D collaboration projects led by focal firms tend to exhibit higher productivity levels in terms of SCI papers, patent applications and patents-granted than non-collaboration R&D projects carried out by firms, while the former have around three times lower productivity in terms of technology licensing than the latter (see *Figure 7.3* and *Table 7.3*). These findings were also confirmed with our binary logistic regression analyses. According to these analyses, R&D collaboration projects led by focal firms are more likely to produce SCI papers and patent applications than non-collaboration R&D projects run by firms. In addition, focal firms collaborating with NFP partners[77] tend to create more patents-granted than our reference group, non-collaboration R&D projects run by

[77] The NFP (not-for-profit) collaborating partner means there is no for-profit organisation included among the partners, as mentioned earlier in chapter 7.

firms (see *Table 7.6*).

These findings may be explained by the fact that focal firms in R&D collaboration projects may put more emphasis on learning and the development of existing or new technologies than on the immediate commercialisation of their products or services, given that their most influential motive in establishing R&D collaboration is 'to develop existing technologies' followed by 'to gain access to new technologies or markets' through the establishment of inter-organisational collaboration (see *section 6.2.1*). Thus, these motives may contribute to the higher research outputs of R&D collaboration projects in terms of SCI papers, patent applications and patents-granted compared with non-collaboration R&D projects. In contrast, it may take more time and funds to produce research outcomes in the form of technology licensing from R&D collaboration projects led by focal firms than non-collaboration R&D projects run by firms. The reason may be to do with a conflict of interest between focal and partner firms and a lack of willingness among collaborating partners to generate technology licensing for their focal firms in the R&D collaboration projects, as mentioned earlier in section 7.1. Another possible reason is that focal firms in R&D collaboration projects do not have to deal with other collaborating partners for technology licensing because they can learn or internalise what they need by interacting with their collaborating partners. Indeed, interviewee F05 said that the strategic motive to establish collaboration is "to add core algorithm technology to our own technology in order to achieve the commercial use" (see *Appendix 5*). Moreover, the survey study shows that the agreement level of focal firms on the motive 'for learning and internalisation of embedded skills from partners' in the establishment of collaboration is 5.4, which lies in the range between 'slightly agree' and 'agree' (see *Appendix 6*).

Furthermore, the results from multivariate analysis, which has been carried out in order to examine whether the findings from the binary logistic regression analysis (i.e. univariate analysis) are robust, are consistent with these findings. Here, focal firms collaborating with NFP partners are more likely to generate SCI papers and patents-granted than non-collaboration R&D projects led by firms with a 95% confidence level (see *Table 7.9*).

Collaborative structures led by focal universities and their R&D performance

The productivity levels in terms of SCI papers, patent applications, and patents-granted

for R&D collaboration projects led by focal universities are much lower than those for non-collaboration R&D projects run by universities. However, R&D collaboration projects between focal universities and FP organisations[78] generated better productivity in terms of technology licensing than non-R&D collaboration projects (see *Figure 7.4* and *Table 7.3*). Meanwhile, the results of our binary logistic regression analyses showed that R&D collaborations between focal universities and FP partners are more likely to generate patent applications, patents-granted, and technology licensing than non-collaboration R&D projects led by universities at a significance level of 0.05 (see *Table 7.7*). These results may be explained by what we found in section 6.4.2. The main expectations of focal universities with regard to for-profit partners are 'to benefit from technology licensing-out' and 'to understand end-user's demands', this being an essential part of the innovation process because many of the important and novel products and processes in a variety of fields have been developed or modified by user firms or by individual users (von Hippel, 2005). Thus, these motives of focal universities in the establishment of collaboration with FP partners may positively affect the R&D performance in terms of commercial aspects like technology licensing. In this case, readers should treat this finding with caution, because focal universities collaborating with FP partners tend to generate more technology licensing than non-R&D collaboration projects led by universities, but **without meeting a significance level of 0.05** in the multivariate analysis in section 7.2.2 (see *Table 7.15*).

Collaborative structures led by focal PRIs and their R&D performance

The productivity levels in terms of all aspects of R&D performance in R&D collaboration projects led by focal PRIs are higher than in non-collaboration R&D projects run by PRIs (see *Figure 7.5* and *Table 7.3*). This may be due to the fact that many non-collaboration R&D projects run by PRIs aim to create infrastructure for IT systems and databases, and PRIs in non-collaboration R&D projects might not be able to focus on R&D performance as much as focal PRIs in R&D collaborations. Additionally, R&D collaboration projects between focal PRIs and FP partners tend to produce more patent applications than non-collaboration R&D projects run by PRIs at a significance level of 0.05 in our binary logistic regression analyses (see *Table 7.8*). This result can be influenced by the main expectations of focal PRIs with regard to their partner firms as described in section 6.4.3,

[78] The FP organisations mean that at least one for-profit organisation is included among the collaborating partners, as noted previously in chapter 7.

which are ‘to implement the research concepts and technologies they have’ and ‘to support SMEs as a public research organisation’. Through supporting SMEs, focal PRIs may have encouraged SMEs to codify their tacit knowledge and technologies for the purpose of a patent application. In addition, focal PRIs may have developed their own technological concepts and ideas by collaborating with FP partners to reach a suitable technology readiness level for the patent application. This result can be influenced by the main expectation of focal PRIs with regard to their partner firms as described in section 6.4.3, which is ‘to implement the research concepts and technologies they have’, and thus focal PRIs may have developed their own technological concepts and ideas by collaborating with FP partners to reach a suitable technology readiness level for the patent application. In addition, focal PRIs may have encouraged SMEs to codify their tacit knowledge and technologies for the purpose of a patent application through ‘supporting SMEs as a public research organisations’, which is the main expectation of focal PRIs with regard to their partner firms (see *Table 6.14*). Indeed, interviewee P03 responded that “our partner firms expect to seek help in dealing with administrative tasks[79] in relation to the R&D project” through developing R&D collaboration, as noted in *Appendix. 13.1*. Hence, these motives of focal PRIs in developing collaboration with FP partners might well have positively influenced the production of patent applications.

In this case, too, readers should treat this finding with caution, because focal PRIs collaborating with FP partners are more likely to produce patent applications than non-R&D collaboration projects led by PRIs, but **without meeting a significance level of 0.05** in the multivariate analysis in section 7.2.2 (see *Table 7.15*).

Collaborative structures led by focal hospitals and their R&D performance

R&D collaboration projects led by focal hospitals tend to exhibit better productivity in terms of patent applications, patents-granted, and technology licensing than non-collaboration R&D projects run by hospitals, although the opposite pattern is shown in terms of productivity as reflected in SCI papers (see *Figure 7.6* and *Table 7.3*). This result may be influenced by diverse R&D policies and programs initiated by the Korean government such as the establishment of medical clusters by fostering research-oriented

[79] The majority of firms are SMEs in the Korean digital healthcare sector usually suffering from a lack of knowledge management (Durst, et al., 2012), and thus they are likely to depend heavily on other types of organisations in the NIS such as PRIs in dealing with administrative tasks in terms of patenting activities. The reason is that patenting is likely to become a costly process in that a large amount of their time to cope with the legal and bureaucratic issues is required for patenting activities (Jensen, et al., 2002)

hospitals since 2006 (Lee, 2008), which led to a rapid increase in the number of patent applications and of start-up companies linked to research-based hospitals, as described in section 4.2.4.

However, there is a no significant association between collaborative structures categorised by focal hospitals and their R&D performance based on our binary logistic regression analyses (see *Appendix 15*), and the multivariate analyses (see *Appendix 17*). This would seem to suggest that the role of hospitals as a collaborating partner is very important in the achievement of innovation for other types of organisations such as a firm, PRI, and university. Hence, all the other types of focal organisations mentioned that they particularly appreciated the benefits from collaborating with their hospital partners, as described in section 7.4. However, hospitals in South Korea only focused on their role as healthcare-providers up until 2006 before the introduction of the strategy for facilitating a healthcare industry by the Presidential Commission on Healthcare Industry Innovation in 2006, as noted earlier in section 4.2.4. Thus, hospitals might not have had enough time to develop their capabilities in the innovation system in order to lead other collaborating partners toward the achievement of their distinctive research goals.

Institutional implications for R&D performance

Inter-organisational collaboration involving a variety of technologies and bodies of knowledge in diverse areas such as ICT, bio/medical technologies, and healthcare services play a pivotal role in developing particular technologies or products in the digital healthcare sector. Hence, funding agencies or government ministries are more likely to require or encourage (i.e. through institutional pressures) the establishment of inter-organisational collaboration if the goal of the R&D programs is to develop particular technologies or products. As a consequence, for-profit-firms under this institutional pressure tend to improve their technological capabilities by learning from their collaborating partners in order to develop their own particular technologies or products. This may lead to concentrating more on the production of SCI papers and patents-granted, rather than emphasising immediate commercialisation aspects like technology licensing (see *section 7.3*). In contrast, not-for-profit organisations (hospitals, PRIs, and universities) affected by institutional pressures that enforce or encourage the establishment of collaboration are likely to obtain benefits from understanding different perspectives to technologies including the demands of end-users. Hence, this may bring about more

opportunities for not-for-profit organisations to generate IPR or commercialisation possibilities through the process of inter-organisational collaborations, rather than focusing more specifically on scientific knowledge creation (see *section 7.3*).

These findings are supported by the results from the multivariate analysis in section 7.2.2, because we have found that institutional pressure (whether in form of encouragement or enforcement) to establish R&D collaboration is more likely to generate SCI papers in R&D projects led by firms, while institutional pressure is less likely to create technology licensing in R&D projects run by firms, compared with R&D projects run by firms without such institutional pressure. Moreover, we have also confirmed that the institutional pressure has a positive impact on the probability of producing patent applications in R&D projects led by universities in comparison with R&D projects led by universities free from such institutional pressure (see *Tables 7.9 and 7.10*).

8.2. Main Contributions of this Thesis to Knowledge

The main contributions of this study can be divided into three categories, namely, conceptual, methodological, and empirical contributions, as described below.

8.2.1. Conceptual Contributions of this Thesis

This research aims to investigate the strategic motives in the establishment of different inter-organisational collaborative structures categorised by different organisational type and the implications of the collaborative structures for innovative performance in public R&D projects of the Korean digital healthcare sector. Consequently, we expected to arrive at a better understanding of the underlying collaboration mechanisms among diverse types of organisations including both for-profit and not-for-profit organisations. Yet, extant literature on inter-organisational collaboration lacks a shared understanding of the underlying collaboration mechanisms in the not-for-profit sector (Weber, et al., 2017) and from the perspective of not-for-profit organisations (Omar, et al., 2014), although all types of organisations participating in collaboration have their own mission and role to achieve improved innovation. Thus, the development of a conceptual framework that can deal appropriately with inter-organisational collaboration mechanisms among diverse types of organisations such as for-profit (i.e. a firm) and not-for-profit (i.e. a university, PRI, and hospital) organisations is needed to meet the research goals of this thesis.

For the development of the conceptual framework, we assumed that the behaviour of organisations in the real world is largely shaped by external environmental influences, namely, institutions, even though conformity with institutions does not seem to serve organisations' own interests directly (Oliver, 1991) because this is a means to gain legitimacy and to decrease the uncertainty of organisational activities (Berthod, 2018). At the same time, it is also assumed that the behaviour of organisations including establishing collaboration is determined by the organisations' self-interests (e.g. cost-minimising and value-maximising determinants), albeit the influence level of these determinants on the behaviour may vary by organisational type. Here, these assumptions are in line with those who adopt a reductionist approach, assuming that the behaviour of organisations (i.e. collaboration) is determined by their component parts such as the strategic motives of organisations at the organisational level. The formation of those strategic motives behind the behaviour of organisations is, in turn, seen as being determined by various component parts including certain intrinsic properties (e.g. cost-minimising and value-maximising determinants) and institutional properties. In the light of these issues, we decided to employ a novel conceptual framework, combining three different theoretical approaches, the NIS (National Innovation System), TCE (Transaction Cost Economics), and the RBV (Resource-Based View).

More specifically, since the digital revolution based on ICT has accelerated a paradigm shift from an industrial economy to a knowledge-based economy (Godin, 2006; Harris, 2001), intellectual capabilities are becoming more important in the pursuit of novelty and innovation through accelerating scientific and technical advance (Lundvall, 2007; OECD, 1996; Powell, et al., 2004). In particular, novelty and competitive advantages can almost never be achieved by a single organisation operating in isolation, instead requiring interaction with other organisations in the knowledge-based economy (Edquist, 2005; Fagerberg, 2006). In addition, the behaviour of organisations is shaped by institutions because organisations are embedded in an institutional context, which also has an intensive influence on the pace and direction of innovation processes by stimulating or constraining collaboration among diverse organisations in the innovation system (Dachs, et al., 2008; Edquist, 2006).

As a consequence, institutions could affect the motives behind various behaviours including the establishment of collaboration (Edquist, et al., 1999; Golichenko, 2016).

Hence, understanding institutions can perhaps offer a better insight into the characteristics of diverse organisations and the reasons for establishing collaboration as one of various organisational activities. Moreover, this thesis focuses on exploring R&D collaboration mechanisms in an emerging sector where government institutions such as a R&D policy play a pivotal role due to the large risks and inherent uncertainty. Therefore, the NIS perspective emphasising the importance of collaboration among diverse actors[80] as an important learning process in order to achieve novelty and innovation was adopted to form the basis of the conceptual framework of this thesis.

However, the NIS perspective tends to put less emphasis on the intrinsic characteristics of individual organisations involved in establishing collaboration (Acs, et al., 2017; Markard, et al., 2008; Markard, et al., 2009). In addition, the formation of the motives in establishing collaboration, which cannot be covered with a single theoretical perspective (Tsang, 1998), is likely to be influenced by the strategic decision-making process incorporating a variety of internal and external determinants. Thus, the TCE (i.e. cost-economising) and the RBV (i.e. value-maximising) perspectives, with their focus on intrinsic properties in establishing collaboration at the organisational level, need to be combined with the NIS perspective in order to offset the missing dimension of the NIS[81], and thus provide a broader conceptual framework for this thesis. The reason is that the missing dimension in the NIS perspective seems to be suitably complemented by TCE and RBV perspectives, which focus on the most economical governance mode or on the maximisation of value creation through securing strategic resources from the perspective of innovating actors, respectively.

Consequently, this conceptual framework allows us to cope with comprehensive collaboration mechanisms in the innovation system, in particular, the formation of strategic motives affected by a variety of determinants such as cost-minimising, value-maximising, and institutional influences in the establishment of R&D collaboration (Sambasivan, et al., 2013; Todeva, et al., 2005; Tsang, 1998). In addition, this framework allows us to deal with the strategic motives of diverse types of organisations comprising

[80] Dachs, et al. (2008) argued the collaboration behaviour of private firms also seems to be closely embedded in the national innovation system.

[81] In fact, Markard, et al. (2008); Markard, et al. (2009) have explored the associations of the resource-based reasoning at the micro-level of organisational actors with the innovation system approach at the meso-level of system analysis in terms of institutional structures and collaborations in order to address the gap of a micro-level foundation of innovation systems.

both for-profit and not-for-profit organisations (i.e. a firm, university, PRI, and hospital). Thus, a combination of these three theoretical approaches provides us with a holistic picture of underlying collaboration mechanisms in the innovation system through incorporating both the intrinsic properties at the organisational level and the institutional properties of the innovation system, thereby offering a better framework for understanding the motives in establishing inter-organisational collaboration and the implications for innovative performance.

Furthermore, this novel conceptual framework was used to address the strategic motives of diverse types of organisations such as firms, universities, PRIs, and hospitals in establishing collaborations. This framework was tested through the interview analysis in chapter 6 in order to validate it. This is important because aspects of strategic motives in establishing R&D collaborations may vary between those four types of organisations depending on the point of view of different focal organisational types, with each type of organisation having its own attributes depending upon internal and external factors (Isaksen, et al., 2017; Rainey, 1989). According to the results in chapter 6, the main strategic motives of all types of focal organisation were well covered within the conceptual framework in this thesis based on the three theoretical approaches, even though this conclusion emerged from interview data with open-ended questions (i.e. questions without any theoretical restrictions) (see *Table 6.8 and 8.2*). Thus, we can say that this novel conceptual framework can deal appropriately with various determinants affecting the formation of strategic motives in establishing collaborations (i.e. cost-minimising and value-maximising determinants, and institutional influences) among different types of organisations (i.e. firms, universities, PRIs, and hospitals).

8.2.2. Methodological Contributions of this Thesis

The existing literature regarding the effect of diverse collaborative structures on innovative performance presented in section 2.5, suggests that there is a lack of consensus on the benefits from various collaborative structures in terms of improved innovative performance (Tsai, 2009). There may be particular reasons for these inconsistent results. For instance, they could be a result of data limitations and research design, leading to inconsistent results in the impact of collaborative activities on innovative performance. Many extant studies show that they tend to employ *indirect variables* based on survey data (e.g. the Community Innovation Survey) for examining the relationships between different forms of collaboration and their innovation performance (e.g. Amara, et al., 2005;

Amponsah Odei, et al., 2019; Arranz, et al., 2008; Becker, et al., 2004; Belderbos, et al., 2004b; Bjerke, et al., 2015; Caldas, et al., 2019; Fey, et al., 2005; Luo, et al., 2007; Okamuro, 2007; Scannell, et al., 2000). In addition, most research designs for the studies depend largely on *quantitative methods*, which tends to limit or restrict opportunities for the deep explanation of complicated issues (Choy, 2014), where carefully crafted interview questionnaires, *a qualitative method*, may complement their limitations. Therefore, we adopted a *mixed methods* approach for this thesis because, to a large degree, quantitative methods alone do not provide much opportunity to explore issues such as the motives, benefits, and the distinctive features of individual organisations participating in collaborative activities.

More specifically, this thesis collected and employed *direct variables* (i.e. quantitative data) regarding information on the various structures of R&D collaboration projects and their innovative performance in terms of academic papers, patent activities, and technology licensing in order to conduct quantitative analysis. In addition, we have collected and utilised *comprehensive interview data* (i.e. qualitative data) such as the motives in establishing collaboration and the benefits from the development of collaborations from different types of organisations. As a result, these efforts (i.e. using a mixed methods approach and direct variables) could contribute to arriving at a clearer understanding with regard to the relationship between diverse collaborative structures and their innovative performance, including how each collaborative structure and its innovative performance is influenced by the strategic decisions of individual organisations in establishing collaboration.

8.2.3. Empirical Contributions of this Thesis

This thesis provides a detailed explanation of inter-organisational collaboration mechanisms from the strategic motives in establishing collaborations, to the formation of different collaborative structures, and to their implications for innovative performance in the digital healthcare sector of Korean public R&D projects, an emerging and inter-/multi-disciplinary sector. In addition, this thesis tried to understand the inter-organisational collaboration mechanisms from the perspective of a novel conceptual framework based on the national innovation system perspective combined with two other complementary theoretical approaches (i.e. TCE and the RBV perspectives) in establishing collaboration at the organisation level.

(1) The characteristics of diverse aspects of innovative performance relating to different collaborative structures in comparison with the formation of non-collaboration at a single analytical domain were explored in order to understand what effects the different collaborative structures have on the innovative performance.

The productivity levels of *R&D collaboration projects are generally lower than those of non-collaboration R&D projects in all aspects of R&D performance*. However, we found *completely different patterns in R&D productivity levels by breaking down collaborative structures* from the perspective of the type of focal organisations, as mentioned previously in section 8.1.3. Hence, we may begin to understand why the extant literature presented rather inconsistent results in terms of the relationship between collaborations and innovative performance, as described previously in section 2.5. Not surprisingly, this result can be expected because each type of focal organisation has particular aims to achieve through the establishment of R&D collaboration, although they have to bear more costs such as time, money, and drawing upon diverse tangible and intangible resources in order to undertake R&D collaboration than when they carry out R&D projects internally.

(2) Existing literature on inter-organisational collaboration lacks a shared understanding of the underlying collaboration mechanisms in the not-for-profit sector (Weber, et al., 2017) and from a not-for-profit organisations (Omar, et al., 2014), although all types of organisations taking part into collaboration have their own mission and role to achieve improved innovation. Additionally, the active role of other types of organisations in this sector such as a university and public research institute seems to be relatively neglected in the Community Innovation Survey and similar surveys such as the Korean Innovation Survey[82], which were utilised to examine collaboration mechanisms in many empirical studies. However, we shed light on the distinctive characteristics of other organisational types in the not-for-profit sector as well as private firms in collaboration mechanisms in this thesis, which may contribute to a more holistic understanding of the underlying collaboration mechanisms in the innovation system.

We also illuminate the role of hospitals in inter-organisational collaboration as one of the main actors in the national innovation system including firms, universities, and PRIs, because the features of collaboration between hospitals and other organisations remain

[82] Because the design of the surveys is to understand the innovation activities of firms in the private sector.

relatively poorly understood in the digital healthcare sector. Nevertheless, the importance of the hospital as part of 'a hidden research system', the core role of the hospital in health innovation, and the usefulness of the hospital-based research system have been highlighted by some (e.g. Hicks, et al., 1996; Hopkins, 2006; Lander, et al., 2011). Hence, this may also contribute to a better understanding of the collaboration mechanism in the innovation system of the digital healthcare sector.

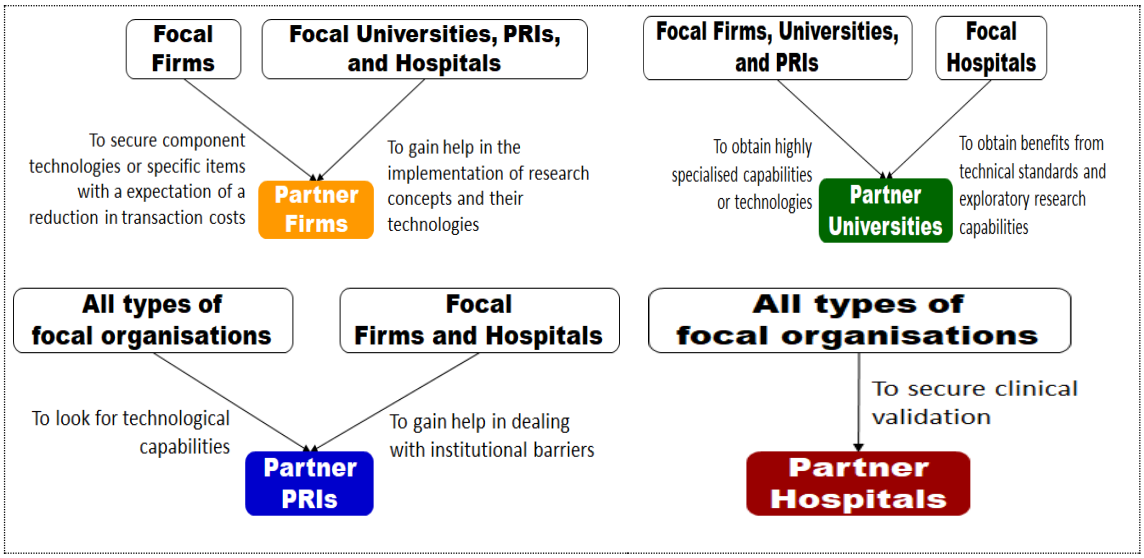
(3) According to the analysis, **the most influential motive** in the establishment of inter-organisational R&D collaboration in the digital healthcare sector **turns out** '*to gain access to complementary resources and capabilities*' **involving *the RBV perspective***. However, it is also clear that *cost-minimising motives* (a TCE perspective) are significantly distinctive motives affecting the development of inter-organisational collaboration between for-profit and not-for-profit organisations, although these strategic motives are generally the least influential in establishing the collaboration in comparison with other strategic motives linked to the RBV and NIS perspectives.

(4) In this regard, each type of focal organisation (i.e. firms, universities, PRIs, and hospitals) is largely influenced by distinctive motives, although the strategic motive 'to access complementary capabilities or resources (an RBV perspective)' has a primary effect on focal organisations in developing collaborative structures. For example, focal firms tend to focus on '*developing existing technologies* (an RBV perspective)', while focal universities are likely to be concerned with '*achieving benefits from potential grants* (a NIS perspective)' in establishing R&D collaborative structures. In addition, the strategic motive '*to pursue certain missions mandated from the government, funding agency, or society* (a NIS perspective)' is likely to affect the establishment of R&D collaboration led by PRIs (see *Table 8.1*).

(5) Additionally, this thesis provides detailed information in terms of how strategic motives affect focal organisations in choosing a particular type of collaborating partners. For instance, *focal firms* are likely to expect '*securing component technologies or specific items* (an RBV perspective)' with the expectation of '*a reduction in transaction costs* (a TCE perspective)' by collaborating with *partner firms*, while *not-for-profit focal organisations* tend to collaborate with them '*to gain help in the implementation of research concepts and their technologies* (an RBV perspective)'. In addition, all types of focal organisations, except for focal hospitals, are likely to expect '*to obtain highly*

specialised capabilities or technologies (an RBV perspective)' by choosing *universities* as their collaborating partners, while *focal hospitals* are likely to highlight '*benefits from technical standards and exploratory research capabilities* (the NIS and RBV perspectives)'. Meanwhile, all types of focal organisations tend to '*look for technological capabilities* (an RBV perspective)' from their *PRI partners*, while *focal firms* and *hospitals* are also likely to expect '*to gain help in dealing with institutional issues* (a NIS perspective)' with regard to their *PRI partners*. When it comes to *hospital partners*, all types of focal organisations are likely to employ hospitals in order '*to secure the clinical validation* (an RBV perspective)' of their technologies, products, or services (see *Figure 8.1*).

Figure 8.1 Main strategic motives of focal organisations in the choice of their collaborating partner types



Source: author's elaboration

(6) Lastly, this thesis also contributes to our understanding of the role of institutional pressure (i.e. the encouragement or enforcement of establishing collaboration) as a means of developing particular technologies or products in an emerging and inter-/multi-disciplinary sector, in the establishment of collaboration and with regard to innovative performance. For the establishment of collaboration, *universities were less likely to engage in collaboration* than other organisational types *if there is no institutional pressure*, whilst *private firms were more likely to establish collaboration voluntarily* without any influence in the form of institutional pressure than other organisational types. Meanwhile, *for-profit focal firms* influenced by institutional pressure tend to improve their technological capabilities by learning from their collaborating partners in order to develop

their own/existing particular technologies or products. Hence, this may lead *to producing SCI papers* and *patents-granted*, rather than emphasising immediate commercialisation aspects like technology licensing. In contrast, *not-for-profit focal organisations* are likely to obtain benefits from understanding different perspectives to technologies including the demands of end-users through establishing collaboration due to institutional pressures. Thus, this is likely to bring about more opportunities *to generate IPR* or *commercialisation* possibilities through the process of inter-organisational collaboration, rather than focusing more specifically on scientific knowledge creation.

8.3. Policy Implications, Limitations, and Future Studies

8.3.1. Policy Implications

This study has certain implications for policy makers involved in science and technology innovation. First, policy-makers should pay more attention to the development of distinctive capabilities of core actors in the national innovation system, in particular, in research areas where the establishment of collaboration is essential to achieve technological innovation such as the digital healthcare sector. The reason is that the most influential motive in establishing R&D collaboration turns out to be 'to gain access to complementary resources and capabilities', and this motive can act as a driver to establish collaboration only if the required complementary resources or capabilities exist in external organisations. However, the role of PRIs in Korea has been becoming less clear since firms began to develop their own research capabilities from the 1990s onwards, although their role in the national innovation system as a supporter of firms was very clear by 1980s. On top of that, the development of research capabilities at universities from the 1990s has also contributed to undermining the distinctive role of PRIs. Moreover, the project-based funding system unintendedly brought about increasing ambiguity in PRI roles because PRIs were more likely to be forced to focus on short-term outputs in order to secure external funding sources that are less relevant to their roles, as discussed earlier in section 4.2.3.

In addition, since 2006 the government has introduced many R&D programs such as translational research and research-oriented hospitals to promote the research capabilities of hospitals, as mentioned previously in section 4.2.4. The emergence of this new actor in the innovation system may well have given rise to increasing ambiguity in the roles of universities, PRIs, and hospitals in the healthcare-related R&D system. Therefore, policy

makers should have smart strategies to develop complementary roles for each type of actors on the basis of their competitive advantages such as possessing research manpower, dealing with large-scale projects and social issues, and holding medical data and clinical capabilities in the innovation system. These strategies are very important for private firms as well, given that the performance of firms tends to be better if they collaborate with partners with dissimilar resources rather than similar ones (Rothaermel, 2001). Therefore, policy makers should keep in mind that the success of the national innovation system relies heavily on benefits from complementary resources or capabilities among actors (Acs, et al., 2017).

However, coordination costs increase in order to manage more complex complementary resources or capabilities in an inter-organisational collaboration in that PIs in the focal organisations need to deal with more extensive coordination (Becker & Murphy, 1992). Thus, policy and institutional supports to secure effective coordination in the inter-organisational collaboration are needed to reduce coordination costs and enhance innovative performance. Effective coordination may be realised by drawing up a detailed contract including clearly allocating tasks, roles, and responsibilities among partners (Carson, et al., 2006; Mayer, et al., 2004), by facilitating communication channels for information-sharing between partners (Argyres, et al., 2007), or by learning about partners' capabilities and resources (Gulati, et al., 2012b), as noted previously in section 2.6.

Indeed, around 57% of PIs responded in interviews that the most important capability that PIs should have in order to cope with inter-organisational R&D collaboration is 'managerial coordination capability', and more than 71% of them said that the benefits from the inter-organisational R&D collaboration can then be satisfied[83]. In contrast, only 56% of PIs who did not believe that the most important PIs' capability is 'managerial coordination capability' are satisfied with the benefits from their inter-organisational R&D collaborations. Hence, the productivity levels in terms of SCI papers, patent applications, patents-granted, and technology licensing for R&D collaboration projects with detailed management of their research teams are respectively 0.7, 1.7, 0.9, and 0.5 higher than the rest of R&D collaboration projects within the interview population for every one billion KRW of research funding (see *Appendix 16*). Therefore, policy

[83] These results are based on interview questions 2.2 and 4.1 (see *Appendix 4.*).

instruments that offer a chance to cultivate the coordination capability of PIs in inter-organisational R&D collaboration are needed for reducing coordination costs. For instance, a standard research contract between a focal organisation and its partners can be suggested by funding agencies in order to provide a detailed contact, which can help address coordination challenges such as the ambiguity of tasks, roles, and responsibilities clear between them (Carson, et al., 2006). In addition, policy measures that encourage communication between collaboration participants for information-sharing would also be helpful to reduce coordination costs or to improve R&D performance in that they can pursue jointly determined research plans and goals.

Second, this research may be helpful for developing tailored-policies and regulations, and thus contribute to the more efficient allocation of public resources because policy makers can understand the demands of each type of actors in R&D collaboration in order to achieve improved innovative performance. For example, focal firms tend to focus on '*developing existing technologies* (an RBV perspective)', while focal universities are likely to be concerned with '*achieving benefits from potential grants* (a NIS perspective)' in establishing R&D collaborative structures. In addition, the strategic motive '*to pursue certain missions mandated from the government, funding agency, or society* (a NIS perspective)' is like to affect the establishment of R&D collaboration led by PRIs. Additionally, *cost-minimising motives* (a TCE perspective) are significantly distinctive motives affecting the development of inter-organisational collaboration between for-profit and not-for-profit organisations, although these strategic motives are generally the least influential in establishing the collaboration.

In a similar vein, policy-makers may be able to employ the findings of this thesis in terms of the R&D performance productivity of different collaborative structures to meet their policy goals of R&D programs more efficiently and effectively. The reason is that the productivity levels based on diverse aspects of R&D performance show distinguishing pictures for different collaborative structures. For instance, focal firms are likely to have a positive effect on productivity in terms of academic papers and patents-based performance via establishing collaboration, whereas the establishment of R&D collaboration tends to negatively affect the productivity level of technology licensing. Meanwhile, not-for-profit focal organisations tend to obtain benefits from producing technology licensing by establishing R&D collaboration, whereas they are less likely to generate academic papers by establishing collaboration. Furthermore, the unrevealed

R&D outcomes, i.e. those which are not captured through the national R&D information system, investigated in this thesis may be greatly helpful for policy-makers to understand what they are missing in introducing, evaluating, or developing R&D-related programs and policies (see *Table 7.14* in section 7.4).

Finally, we found that universities were less likely to engage in collaboration than other organisational types if there is no institutional pressure, although private firms were more likely to establish collaboration voluntarily without any influence in the form of institutional pressure than other organisational types. Thus, government may need to introduce suitable strategies or policies such as financial incentives [84] to induce universities to participate in R&D collaboration and thus provide more options for firms to choose their collaborating partners.

8.3.2. Generalisation and Limitations of this Study

The boundaries of our empirical study may provide some clue as to the extent to which the findings of this thesis can be generalised. We have examined underlying collaboration mechanisms based on a novel conceptual framework (through combining both the institutional properties of the innovation system and the intrinsic properties of individual actors in establishing collaboration) in an emerging and inter-/multi-disciplinary sector (i.e. digital healthcare sector) in a country (i.e. South Korea) suffering from the burden of healthcare expenditure and facing a reduction in universal health coverage due to its ageing population. The digital healthcare sector, an important sector in coping with the challenges of the ageing population, was selected because the collaborative activities involving diverse actors and technological fields play a pivotal role in achieving innovation or novelty in the sector. In addition, as an emerging or embryonic industry this sector tends to depend heavily on government R&D and institutions because private firms are reluctant to enter or invest in this type of sector owing to the high risks and uncertainty. Thus, these empirical boundaries in terms of public R&D projects in an emerging and inter-/multi-disciplinary sector in a nation suffering from an ageing population may restrict the extent to which the empirical findings of this thesis can be applied more generally. Therefore, the distinctive characteristics of the public R&D in the Korean digital healthcare sector should be carefully considered if the insights of this thesis are to

[84] Focal universities tend to be substantially influenced by the motive to 'achieve benefits from potential grants' in establishing R&D collaboration (see *Table 6.5*).

be applied or extended to other sectors or countries, because the role and behaviour of actors in the innovation system may vary by country or sector. This consideration is important in that "generalisation is an act of reasoning that involves drawing broad conclusions from particular instances − that is, making an inference about the unobserved based on the observed" (Polit, et al., 2010, p. 1451). In order words, this consideration should be cautiously treated because extrapolation from sample to population (i.e. the applicability of findings to different settings) can never be fully justified logically (Firestone, 1993).

When it comes to limitations of this thesis, there is a lack of consensus on the definition of the digital healthcare sector, so we employed the Korean national standard classification of science and technology (NSCST) to define the sector, namely technological fields involved in 'health information and health information system technologies'. Hence, it might be difficult to define the extent of the sector in different institutional contexts.

Another limitation results from a restriction regarding data on public R&D collaboration projects, which were only collected during the short period of time between 2012 and 2015[85]. Hence, we could not analyse institutional influences on the establishment of diverse collaborative structures and their implications for R&D performance from a longitudinal perspective in this thesis, although many policies and (de)regulations related to the promotion of the digital healthcare sector in Korea have recently been introduced. In particular, seminal (de)regulations were introduced between 2016 and 2018 such as the use of healthcare data (which can also be stored and managed via cloud storage outside healthcare providers) for commercial purposes as long as the data are suitably de-identified to protect personal information, and a regulatory sandbox for telemedicine, which is still banned in Korea, as noted previously in section 4.1.4. In a similar vein, having a chance to discuss the institutional impact with staff in funding agencies on the establishment of R&D collaboration and its R&D performance would be meaningful for arriving at a more comprehensive understanding of the underlying collaboration mechanisms among diverse types of organisations. Here, we have focused on four different types of organisations, namely, a firm, university, PRI, and hospital, in R&D

[85] The Korean government started to collect detailed information regarding R&D collaboration in 2012. At the same time, we should take into account the fact that there may be a time-lag of 2-3 years with regard to R&D performance (van Beers, et al., 2008), and the data on R&D performance were collected between 2012 and 2017.

collaboration excluding funding agencies, although we have analysed the RFPs from an institutional perspective, these being provided by staff in funding agencies and which reflect relevant policies and regulations.

Furthermore, one additional limitation arises from choosing the digital healthcare sector as an empirical site for investigating the formation of different collaborative structures and the implications for R&D performance. Although one of the motivations for choosing this sector is because this sector could contribute to reducing the considerable burden of healthcare funding, we were not able to include any indication of whether the R&D collaborations succeeded in reducing healthcare costs. There are several reasons for this. In particular, the technologies or services developed in public R&D projects generally take a great deal of time to be adopted in practice before they yield economic benefits as they have to proceed via complicated procedures involving the several stages of clinical trials as well as approval of any new medical devices. In addition, some technologies and services related to telemedicine developed in the public R&D projects are still not available for clinical practice, as noted previously in section 4.1.4.

Moreover, we decided not to include the findings in terms of the motives of collaborating partners in establishing R&D collaboration with regard to a particular type of focal organisations in this thesis. The reason is that the evidence we found seems not to be robust enough due to the fact that we have investigated these expectations of collaborating partners by asking PIs in focal organisations, not by directly asking the main researchers in the collaborating partners. Nevertheless, the exploration of strategic motives from the perspective of collaborating partners with regard to their particular focal organisational type would be potentially helpful because any form of collaboration needs to be motivated by both focal organisations and collaborating partners at the same time (Sytch, et al., 2008). Thus, this thesis would contribute to arriving at a better understanding of inter-organisational collaboration mechanisms if we could carry out further research by directly interviewing the main researchers in the collaborating partners.

Lastly, we have shown that the productivity levels of R&D collaboration projects are generally lower than those of non-collaboration R&D projects in terms of all aspects of R&D performance. Together with this finding, we also identified completely different patterns in the R&D productivity levels when we broke down collaborative structures in the light of the type of focal organisation (see *Table 7.3*). In addition, these findings were

supported with binary logistic regression analysis in *section 7.2.1* (see *Tables 7.6, 7.7, and 7.8*). For instance, R&D collaboration projects between focal firms with NFP organisation(s) tend to create significantly more SCI papers, patent applications, and patents-granted than non-collaboration R&D projects run by firms. Likewise, R&D projects led by focal universities with for-profit partner(s) tend to produce significantly better technology licensing performance than R&D projects led by universities. For R&D projects run by focal PRIs, R&D collaboration projects regardless of their partner type are significantly more likely to generate patent applications than non-collaboration R&D projects.

Moreover, we have partially confirmed these findings through multivariate analysis by adding four control variables - the amount of research funding, the number of partners, the features of funding input by participants, and the attributes of the institutional pressure - together with different types of collaborative structures as independent variables. Here, we have confirmed that R&D collaboration projects led by focal firms with NFP organisation(s) tend to generate more SCI papers and patents-granted in comparison with non-collaboration R&D projects run by firms with a confidence of 95%. However, other findings from the binary logistic regression without other control variables in *section 7.2.1* are not robust enough at a significance level of 0.05 (see *Table 7.15*). Hence, readers should treat these findings with due caution.

8.3.3. Options for Future Research

The above discussion of the limitations of this thesis points to various options for future research. The first comes from the empirical boundaries of this thesis, public R&D projects in an emerging and inter-/multi-disciplinary sector in a particular country, where the digital healthcare tend to be utilised to address challenges associated with an ageing population like most developed countries. However, the role and behaviour of actors in the innovation system may vary by country even within developed countries because they are likely to be affected by different institutional settings such as historical, social, cultural, and political features of each nation (Lundvall, 2007). The role and behaviour of actors may also differ by sector or technology even within the same country, according to the innovation policy of the country. Therefore, further research focusing on other countries and industries would enhance the extent to which empirical insights drawn from this thesis could be applied more generally. Likewise, comparative research between public

and private R&D projects would provide potentially beneficial insights to arrive at a more comprehensive understanding of collaboration mechanisms. The reason is because the objectives of establishing R&D collaboration contingent on the objectives of the R&D projects are likely to be different between public and private R&D projects leading to different characteristics of R&D performance. More specifically, publicly funded R&D tends to be more involved in the public sector performance and potential complementary effects between public and private organisations, whereas privately funded R&D is likely to focus more on economic performance (Maroto, et al., 2016).

Another possible further research results from lacking a longitudinal data analysis in terms of institutional influences on collaboration mechanisms. Thus, such longitudinal analysis would provide considerable insights into institutional influences on collaboration mechanisms if we could carry out such a study from a longitudinal perspective based on long-term data. The reason that longitudinal data analysis is a powerful method to evaluate the impact of institutional change and to analyse the dynamics of the impact of the institutional change over time (French, et al., 2008; Lagarde, 2011). In addition, the dissemination of the institutional change in a real sense takes time to be effective in terms of influencing the behaviour of actors in the innovation system, given that actors in the institutional context have to adapt to the new 'rules of game' or a new institutional setting.

Furthermore, this thesis has placed the main emphasis on investigating the strategic motives of focal organisations based on the NIS, TCE, and the RBV approaches in the establishment of inter-organisational collaboration, how these motives affect the establishment of different collaborative structures, and their implications for innovative performance. Although other factors (e.g. the number of partners, the amount of research funding, matching funding, and so on) less directly related to this study were not taken up to analyse their influence on innovative performance, they may nevertheless affect the establishment of different collaborative structures and subsequently the innovative performance. Hence, it would be beneficial to identify the characteristics of R&D performance from those perspectives together.

In addition, we have failed to show a statistically significance in direct relationship between strategic motives and R&D performance, although we have carried out correlation analysis between the strategic motives in establishing R&D collaboration (as gleaned from a survey study) and R&D performance. Thus, it would be helpful if we

could understand the direct effect of the strategic motives in establishing R&D collaboration on R&D performance with a more sophisticated research design and/or with specific models.

Lastly, it would be greatly beneficial to explore the expectations of collaborating partners with regard to their focal organisations in establishing R&D collaboration to arrive at a better understanding of why different collaborative structures are developed, although we did not include the findings related to this due to a lack of robustness, as explained previously in section 8.2.2. The reasons are that any form of R&D collaborations requires a mutual agreement whereby both the partners and focal organisations have to be motivated at the same time to enter into the R&D collaboration (Sytch, et al., 2008), and extant literature has tended to concentrate on only one party in the collaboration, neglecting the dyadic characteristics of the collaboration (Koschmann, et al., 2012; Schiller, et al., 2013; Weber, et al., 2017). In addition, the motives of organisations (i.e. a focal or partner organisation) for participating in R&D collaboration may differ according to their specific expectations in the R&D collaboration. For example, focal organisations tend to concentrate mainly on gaining benefits from their partners in order to achieve their research goals while partner organisations are likely to provide relatively less important capabilities for focal organisations and to focus more on reaping rewards from their contributions.

8.4. Concluding Remark

We would like to close this thesis with a metaphorical expression derived from a very early version of the research proposal of this thesis for the PhD application, because this expression well demonstrates the purpose and motivation of this thesis.

> This research will be a process of investigating underlying mechanisms of innovation through understanding collaboration activities. By analogy with the concept of the 'central dogma[86]' in molecular biology, the patterns of collaborative networks and the motives in establishing the patterns (i.e. genotype) may determine innovative performance (i.e. phenotype) corresponding with the combination of nucleobases[87] encoding proteins that regulates functions in biological systems, which are also

[86] This is a basic framework for how genetic information flows from a DNA sequence to a protein, a functional molecule.
[87] Nucleobases, the basic building blocks of DNA and RNA, are consist of A (adenine), T (Thymine), G (guanine)/U (uracil) and C (cytosine).

influenced by environmental factors.

This motivation led us to pay particular attention to strategic motives in establishing collaborations among diverse types of organisations in the innovation system, and to the implications of developing different collaborative structures for innovative performance. In the end, we were able to achieve various contributions starting from this early version of the research motivation. For instance, we obtained very interesting findings in terms of the different aspects of innovative performance for different collaborative structures in comparison with non-collaboration activities. We found *completely different patterns in R&D productivity levels by breaking down collaborative structures* from the perspective of the type of focal organisations, whilst the productivity levels of *R&D collaboration projects are generally lower than those of non-collaboration R&D projects in all aspects of R&D performance*. In addition, we confirmed that each type of focal organisations (i.e. firms, universities, PRIs, and hospitals) is largely influenced by distinctive motives, although the strategic motive '*to access complementary capabilities or resources* (an RBV perspective)' has a primary effect on focal organisations in developing collaborative structures. Additionally, this thesis provides detailed information in terms of how particular strategic motives may affect focal organisations in choosing a particular type of collaborating partners. Lastly, this thesis has put forward and tested a novel conceptual framework based on the combination of the NIS, TCE, and RBV perspectives in order to deal with strategic motives in the establishment of different inter-organisational collaborations led by diverse focal organisational types (firms, universities, PRIs, and hospitals), and the implications for innovative performance.

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Appendices

Appendix 1. An Example of the General Information on Public R&D Projects and their Performance

e.g. Information on R&D projects and collaboration

Project ID	Funding Source	Program Name	Project Topic	Year	NSCST[1)]	Focal Organisation	Partner Organisation	Funding
e.g. 12548713	Ministy of S&T	SRC Program	3-D model creation using medical data	2013	ICT(70%)+Health(30%)	Nusco(Firm)	ETRI(PRI); Bestian Hospital	£1.5 M

1) National Standard Classification of Science and Technology

e.g. Information on SCI papers

Project ID	Year of Output	Journal Name	Paper Title	First author
e.g. 12548713	2016	INTERNATIONAL JOURNAL OF CLINICAL PHARMACOLOGY AND THERAPEUTICS	Comparative analysis of the efficacy of low- and moderate-intensity statins in Korea	Kim, HS

e.g. Information on patents

Project ID	Year of Output	Country	Application/Granted	Application/Granted No.	Name of Application	Applicant	Date
e.g. 12548713	2015	UK	Granted	1016632970000	Development of Automated Human Physiological Monitoring System for the Management of chronic diseases	AMP	05/10/2016

e.g. Information on technology licensing agreements

Project ID	Year of Output	Name of Agreement	Acquition Organisation	Licensing Fee
e.g. 12548713	2015	Network basedobesity management systems	Softnet	£50,000

Appendix 2. Participant Information Sheet

PARTICIPANT INFORMATION SHEET

Study title
Characteristics of Collaborative Structures and their Implications for R&D Performance: An empirical study on public R&D projects in the digital healthcare sector of South Korea

Invitation paragraph
You are being invited to take part in a research study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the study?
This research aims to explore why organisations that participate in public R&D projects in the digital healthcare sector of Korea establish different structures of inter-organisational collaboration, and how those different collaborative structures have an impact on R&D performance.

Why have I been invited to participate?
- (For a survey) You have been invited to take part because you have been participating in the public R&D project(s) in the digital healthcare sector between 2012 and 2015 as a principal investigator or core officials. Your data will be used together with the data collected from interviews and from desk-based research for achieving the purpose of this study.
- (For interviews) You have been invited to take part because you have been participating in the public R&D project(s) in the digital healthcare sector between 2012 and 2015 as a principal investigator or core officials. We have recruited or will recruit up to around 40 participants for the interviews. In addition, each of principal investigators or core officials in the whole public R&D projects are invited to take part for the survey.

Do I have to take part?
It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked either to sign a consent form or to permit a record of oral informed consent. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?
- (For a survey) You will be asked around 25 questionnaires using a seven-point Likert-type scale. The survey may take around five to ten minutes.
- (For interviews) Face-to face interviews will be basically conducted, and each interview will last between 45 and 50 minutes and will be audio-recorded. You will be asked questions regarding your motives to establish organisational collaboration and to select your partner(s). Moreover, We will ask about benefits and costs of establishing inter-organisational

collaboration based on your experiences in specific public R&D project(s) that is suggested by the interviewer.

What are the possible benefits and risks of taking part?

We cannot promise that taking part will benefit you directly. By taking part you will help us to understand motives of establishing different patterns of organisational collaboration, and how those different patterns of collaboration have an effect on innovative performance. The results may be used in the future to design improved and better public R&D programs.

We do not plan to cover any sensitive or embarrassing issues. However, if you feel uncomfortable during the interview, the interviewer will pause for a break, after which you can choose to end the interview or carry on.

Will my information in this study be kept confidential?

All information collected about the individual will be kept strictly confidential. You will not be identified or identifiable in any reports or publications. Any data collected about you in the questionnaire will be stored in a form protected by passwords and other relevant security processes through coded or anonymised. Data collected may be shared in an anonymised form to allow reuse by the research team for further studies. These anonymised data will not allow any individuals to be identified or identifiable.

What will happen to the results of the research study?

The results of the study will provide information about the motives of establishing different patterns of organisational collaboration, and how those different patterns of collaboration have an effect on innovative performance. The findings will be used in the interviewer's thesis and may be published in a scientific journal or presented at a conference. However your identity will remain anonymous in all publications and presentations of the findings.

Who is organising and funding the research?

I am conducting this research as a doctoral student at Science Policy Research Unit (SPRU) at University of Sussex and a researcher in Korea Health Industry Development Institute (KHIDI). This PhD research project is funded by the SPRU fieldwork grant at the University of Sussex. Also, this fieldwork is partially funded by the Research and Development Management Association (RADMA).

Who has approved this study?

This research has been approved by the Social Sciences & Arts Cross-Schools Research Ethics Committee (C-REC). The application number is ER/KH282/1.

Contact for Further Information

If you have any questions or concerns relating to this research, please contact:

Research Student	Supervisors	
Han, Kyung-Ju T: +44 (0)7414 831573 E: kh282@sussex.ac.uk kjhan@khidi.or.kr	Ben Martin T: +44 (0)1273 873562 E: B.Martin@sussex.ac.uk	Puay Tang T: +44 (0)1273 877078 E: P.Tang@sussex.ac.uk

In addition, the University of Sussex has insurance in place to cover its legal liabilities in respect of this study.

We wish to thank you for taking the time to read this sheet and considering taking part in the research study

Appendix 3. Questionnaires for a Survey

Questionnaire

This survey is to understand the motives involved in establishing inter-organisational collaboration in public R&D projects and how those motives influence the development of different inter-organisational collaborative structures.

<**Information on R&D project**>: Project topic (A period of research)/The name of focal organisation – The name of collaborating organisation(s)

(**PIs' name**): (**Position at that time**):

How much do you agree or disagree that each motive as below influenced the establishment of inter-organisational collaboration in the R&D project(s)?	Strongly disagree	Disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Agree	Strongly agree
To minimise research costs through developing economies of scale	☐	☐	☐	☐	☐	☐	☐
To minimise research costs through developing economies of scope	☐	☐	☐	☐	☐	☐	☐
To minimise research expenses through costs sharing/reduction in research	☐	☐	☐	☐	☐	☐	☐
For sharing any risks and losses	☐	☐	☐	☐	☐	☐	☐
To shorten lead time	☐	☐	☐	☐	☐	☐	☐
To reduce administrative costs	☐	☐	☐	☐	☐	☐	☐
To gain priority over intellectual property right	☐	☐	☐	☐	☐	☐	☐
To obtain help for R&D commercialisation	☐	☐	☐	☐	☐	☐	☐
To gain access to new technologies or markets	☐	☐	☐	☐	☐	☐	☐
To develop existing technologies or products	☐	☐	☐	☐	☐	☐	☐
For learning and internalisation of embedded skills from partners	☐	☐	☐	☐	☐	☐	☐
To access human resources	☐	☐	☐	☐	☐	☐	☐
To understand demand-side needs	☐	☐	☐	☐	☐	☐	☐
To gain access to complementary resources and capabilities	☐	☐	☐	☐	☐	☐	☐
To gain help from a partner's administrative division	☐	☐	☐	☐	☐	☐	☐
To utilise partner's research facilities	☐	☐	☐	☐	☐	☐	☐
To get benefits from partner's reputation	☐	☐	☐	☐	☐	☐	☐
To get help with overcoming legal or regulatory barriers	☐	☐	☐	☐	☐	☐	☐
To get information on current trends of government policies and regulations	☐	☐	☐	☐	☐	☐	☐
To pursue certain missions mandated from the government/agency or society	☐	☐	☐	☐	☐	☐	☐
Enforced by funding agencies or government	☐	☐	☐	☐	☐	☐	☐
To develop technical standards	☐	☐	☐	☐	☐	☐	☐
To achieve benefits from potential grants	☐	☐	☐	☐	☐	☐	☐

Appendix 4. Outline of Interview Questions

Outline of Interview Questions

These interview questions are consist of five parts as below. You will be asked in terms of general and background information in the first two parts of the questions. After that, the interviewer will ask you regarding your experiences on the public R&D project in the digital healthcare sector shown in the below.
Project Name/No.(Year): provided by the interviewer

1. General Information

1.1. What year have you joined in your institution?
1.2. What was your position in your institution as you led the project? / How about your current position?
1.3. Did your institution have a research organisation? / How many researchers in there?
1.4. Did your institution have a division dedicated to supporting research groups?

2. Background Information

2.1. Have you had any experiences as a principal investigator before taking part this project?
2.1-1. If so, were they private R&D projects or public R&D projects? Or private-public R&D projects?
2.2. How do you see the role of the principal investigator?
2.3. Have you had any experiences of establishing inter-organisational collaboration before this project?
2.3-1. How do you generally identify them as potential collaborators?
2.3-2. Which factors have influenced your partner selection?
2.3-3. If so, What was the main purpose of the collaboration(s)?
2.4. How do you feel about its earlier collaboration? Was it successful or unsuccessful? and Why?
2.5. Do you have rivals in your research area? Who is the main rival?

3. Information on the Project

3.1. What was your aim of joining the project? What did you expect to achieve in this project?
3.2. What were your motives in establishing collaboration with the partners in the project?
3.2-1. What are your views of the costs and benefits from the collaboration in the project?
3.3. What did you consider to be strengths and weaknesses of your own research group in the project?
3.3-1. What did you expect to gain from each partner in the project, respectively?
3.3-2. What did you intend to offer to each partner in the project, respectively?
3.4. Did your institution have an administrative division which is devoted to supporting researchers?
3.5. How did you manage the project team?
3.5-1. Were you deeply involved in managing the team? If not please explain.
3.6. How did you allocate the research budget for your research team?

4. Information on performance of the project

4.1. Do you think the collaboration of the project has been successful or unsuccessful? and Why?
4.2. How did you allocate the outputs and outcomes with other partners?
4.3. What uncodified outcomes did you gain from the collaboration which are not captured by agencies?
4.4. What kind of help have you received from the research supporting division in your institution to produce outputs and outcomes?

5. R&D Policies and Regulations on the digital healthcare sector

5.1. Why did you participate into the public R&D project rather than joining private R&D projects?
5.1-1. What suggestions do you have for the public R&D program to enable it be more effective?
5.1-2. What are strengths and weaknesses of the public R&D programs compared with the private R&D programs?
5.2. What are your views on regulatory changes in the digital healthcare sector of Korea?
5.2-1. What are your views of the drivers or barriers to develop the digital healthcare sector of Korea in the perspective of regulations?
5.2-2. Do you have any comments and suggestions for regulatory improvements in the sector?

Appendix 5. Motives in the Establishment of Collaboration according to Interviewees

ID	Project Topics	Motives
F01	SW convergence smart-tool set development for vocational rehabilitation of the disabled	- "To obtain core capabilities such as clinical data from the national rehabilitation centre" in order to achieve the research aim, and "accessing to specialised knowledge in patenting" to protect their IPR - "One of collaborating partners, a public institute, was required to join the project by a funding agency"
F02	Development of a personalized healthcare system exploiting users' life-log and open government data for proving the business service model on lifecycle care	"Diverse core capabilities are needed in order to launch their product to the market given the feature of the digital healthcare sector, and they used collaborating partners to obtain complementary capabilities such as information security, data mining, and clinical validation"
F03	All-in-one automatic CPR (Cardio-Pulmonary Resuscitation) machine including CPR feedback, AED (Automated External Defibrillator) and a remote monitoring unit.	"Collaboration was decided by considering the diverse research areas of the project. We need information on the approval process of the medical device, on its market, and we need, also, clinical information in practice"
F04	Development of a smart healthcare system and a pilot project for military personnel and global healthcare	"To obtain complementary IT capabilities and clinical data from collaborating partners in order to achieve a research aim"
F04	Development of a smart wellness companion service system through the monitoring emotional and mental health	"To obtain complementary capabilities and resources, for instance contents and algorithm involving mental health, and remote monitoring technology, from collaborating partners in order to achieve the research aim"
F05	Development of a prediction and prevention system of cardiac arrhythmia using ultrasound images and ECGs (Electrocardiograms)	"To add core algorithm technology to our own technology in order to achieve the commercial use"
F06	Development of a service model through development of the bio-signal measurement and analysing program	"To acquire complementary capabilities and resources in order to deal with new technology (i.e. the development of medical devices based on bio-signals) given that SMEs like us cannot cover every technology needed for developing the product"
F07	Three major infectious diseases (AIDS, Tuberculosis, Malaria) and maternal and child healthcare solutions based on smart-pads for developing countries	"In order to attain the research aim, we need to obtain clinical data (from a hospital) and to access the business network in developing countries" through the digital hospital export agency.
F08	Global healthcare information framework development	"We cannot cover all needed technological areas in the research topic, and securing the technological capabilities through collaboration is an effective way"
F09	Compact AED development managed with independent power from solar energy for the outdoor use	"As a SME, we cannot cover all the process of product development from technological development to commercialisation. In particular, the development of energy storing, remote controlling, and transferring technology was needed" from external sources.
F10	Advancement and clinical demonstration of the follow-up care services according to tumour types	"Need to gain medical capabilities for the clinical validation of the existing service platform through collaboration" (with hospitals)

ID	Project Topics	Motives
F11	Development of ovarian cancer screening technology by home-based urine testing	"Collaborating with hospitals are essential (in order to secure complementary resources) given that only hospitals have sample data we need such as a sample for ovarian cancer"
F12	Development of a medical multi-purpose network-based monitoring platform and of the signal processing and diagnosis library	"Considering the reputation of the collaborating partner", (which has capabilities in the clinical field)
F13	Development of a sustainable and practical age-friendly wellness system utilizing emotional mechanisms and smart media	"To access specialised human capabilities in diverse technological areas due to a lack of internal resources"
U01	Development of a community system integrated platform and test-beds for self-growing u-smart space	"To obtain complementary capabilities from private firms regarding the commercialisation of our existing technology"
U02	Development of a customized cyber-doctor suited to monitoring bio-signals to provide precision health management	"To obtain complementary capabilities and resources that we do not have"
U03	Advancement of next generation clinical-informatics by constructing a multicentre-integrated CDW (Clinical Data Warehouse)	"In order to establish a clinical data supply-chain, we needed to collaborate with hospitals as many as possible. Additionally, other complementary capabilities such as building CDW and developing clinical data anonymization algorithm"
U03	Development and application of an open-innovative clinical data visualization and analysis platform based on OHDSI (Observational Health Data Sciences and Informatics)	"In order to establish an evidence-based supply-chain in the clinical sector, we needed to collaborate with hospitals as many as possible. In addition, we collaborated with a university to access a core talent"
U04	Development and demonstration of the patient-centred medication literacy and its adherence program	"To gain complementary capabilities and resources that we do not have such as clinical data and capabilities"
U05	Development of an individualized drug use process with knowledge base for appropriate medication therapy	"In order to apply the service platform developed this project about appropriate medication therapy to clinical practice"
U06	Development of generic technologies for medical text mining	"Paying attention to clinical applications through exploiting diverse existing capabilities and resources in different organisations is important in the medical information-related sector, rather than focusing on the development of high-end technology. … Hence, we collaborated with different organisations to obtain their complementary capabilities or resources to achieve the research aim."
P01	Planning a strategy and building a certification framework of national health information	"Considering collaborating partners' capabilities and resources (based on our capabilities and resources) in order to achieve the research aim"
P02	Ontology-based traditional Korean medicine knowledge framework development	"We cannot internally hold every capability and resource for attaining the research goal, and complementary capabilities and resources are essential such as clinical data collection and IT system development"

ID	Project Topics	Motives
P04	The development of skin adhesive patches for monitoring and predicting mental disorders	"To acquire complementary capabilities from hospitals and private firms that we cannot cover such as clinical and commercialisation capabilities"
H01	Standardization of human genome sequencing reports in the electronic medical record system	"Need to acquire complementary capabilities regarding data standard technology that cannot be dealt with us"
H02	Development of a rehabilitation platform for LMS (learning management system)-based cochlear implant patients	"In order for the demonstration of the service model drawn from clinical practices, we needed to gain complementary capabilities and resources concerning the development of mobile service applications"
H03	Development of medical devices for arrhythmia diagnosis and therapy	"To gain complementary capabilities that we do not have or have insufficient capabilities such as hardware development and sensing technology"
H04	Development of open-source based personal health record management for a series of operations for a cleft palate	"To obtain complementary capabilities such as the development of the mobile service platform in order for the demonstration of the service model for patients having a cleft palate"
H05	Standardization and development of a health information exchange platform based on mobile PHR (Personal Health Record)	"To acquire about capabilities based on IT security, platform development and standard technology of healthcare information"
H06	Development of a patients-centred medical content service	"To obtain complementary capabilities that we cannot be covered with our own capabilities"
H07	Development of multi-platform based health management and a service model for chronic disease patients	"To obtain complementary capabilities that we cannot be covered with our own capabilities such as lifelog data and the development of the SW and the platform"
H08	AAL (Active and Assisted Living) applied health care services based on smart development for housing residents	"To obtain complementary capabilities that we cannot cover with in the hospital such as life-log data and the instalment of diverse sensors in the living space"
P03	CBR (Case-based Reasoning) agent-based u-Wellness mentor support system for customized consulting services	"In order to contribute to the refinement of the healthcare service model owned by a SME"(, as conducting the role of a PRI)
P05	A development and feasibility study on after-care service based on IoT for seriously illness patients	"In order to create a new market, an after-care service, through collaborating medical and information technology"(, as a PRI)
P06	Development of a u-Health monitoring system for diagnosing respiratory infections	"This project was designed by a funding agency in order to promote collaboration between different PRIs"
U07	Development of an ear attachment device for monitoring eating and sleeping habits	"This project was designed for promoting Industry-University collaboration by a funding agency. Hence, the collaborating partner (a firm) in this project asked me to collaborate together for winning this research grant"

* Although ID codes are used to anonymise personal information, the ID codes show the organisational types to which interviewees belong. The first letter of ID codes means the first letter of four different organisational types, a firm, university, PRI, and hospital.
** Interviewee U08 did not respond to this interview question.

Source: author's elaboration

Appendix 6. Descriptive Characteristics of Motives in the Establishment of Different Collaborative Structures by Focal Organisational Type

Descriptive characteristics of motives by focal organisational types

Theoretical approaches	Motives	Firm	Hospital	PRI	Univ.	Total
TCE	(V01) To economise research and administrative expenses through developing economies of scale	5.50	4.70	3.54	4.79	4.74
	(V02) To minimise research costs through developing economies of scope	5.55	5.60	4.85	4.86	5.23
	(V03) To minimise research expenses through costs sharing/reduction in research	4.25	3.20	2.69	2.64	3.32
	(V04) For sharing any risks and losses	4.40	4.30	3.38	3.14	3.84
	(V05) To shorten lead time	4.70	5.90	3.92	4.07	4.58
	(V06) To reduce administrative costs	3.40	3.10	1.77	2.36	2.72
	Average	4.63	4.47	3.36	3.64	4.07
RBV	(V07) To gain priority over intellectual property right	4.20	3.20	2.23	2.07	3.05
	(V08) To obtain help for R&D commercialisation	5.80	5.60	5.15	5.43	5.53
	(V09) To gain access to new technologies or markets	5.85	6.30	5.92	5.07	5.75
	(V10) To develop existing technologies or products	6.05	5.90	5.23	5.21	5.63
	(V11) For learning and internalisation of embedded skills from partners	5.35	5.20	4.77	4.57	5.00
	(V12) To access human resources	5.05	5.00	5.15	4.71	4.98
	(V13) To understand demand-side needs	4.85	5.20	5.38	5.14	5.11
	(V14) To gain access to complementary resources and capabilities	5.70	6.20	5.85	5.64	5.81
	(V15) To gain help from a partner's administrative division	3.65	3.70	2.85	3.50	3.44
	(V16) To utilise partner's research facilities	4.75	4.20	4.08	3.86	4.28
	(V17) To get benefits from partner's reputation	4.20	4.90	3.77	3.21	3.98
	Average	5.04	5.04	4.58	4.40	4.78
NIS	(V18) To get help with overcoming legal or regulatory barriers	3.85	4.20	3.85	3.29	3.77
	(V19) To get information on current trends of government policies and regulations	4.00	3.70	4.00	2.93	3.68
	(V20) To pursue certain missions mandated from the government/agency or society	4.35	4.90	5.69	4.00	4.67
	(V21) Enforced by funding agencies or government	3.20	4.00	3.62	3.36	3.47
	(V22) To develop technical standards	4.60	5.40	4.62	5.29	4.91
	(V23) To achieve benefits from potential grants	4.35	5.40	4.54	5.29	4.81
	Average	4.06	4.60	4.38	4.02	4.17

* There are 20, 10, 13, and 14 R&D projects led by firms, hospitals, PRIs, and universities, respectively, in the survey.

Source: author's elaboration

Appendix 7. Statistical Analysis on Agreement Levels of Motives in Establishing Different Collaborative Structures by Organisational Funding Feature

The result of the Mann-Whitney U test on agreement levels of motives by organisational funding feature

Organisational funding features	Motives	N	Mean Rank	Agreement levels
For-profit		20	35.33	5.50
Not-for-profit	V01	37	25.58	4.32
Total	(TCE)	57		
For-profit		20	30.93	5.55
Not-for-profit	V02	37	27.96	5.05
Total	(TCE)	57		
For-profit		20	36.88	4.25
Not-for-profit	V03	37	24.74	2.81
Total	(TCE)	57		
For-profit		20	33.95	4.40
Not-for-profit	V04	37	26.32	3.54
Total	(TCE)	57		
For-profit		20	29.80	4.70
Not-for-profit	V05	37	28.57	4.51
Total	(TCE)	57		
For-profit		20	35.93	3.40
Not-for-profit	V06	37	25.26	2.35
Total	(TCE)	57		
For-profit		20	39.25	4.20
Not-for-profit	V07	37	23.46	2.43
Total	(RBV)	57		
For-profit		20	29.95	5.80
Not-for-profit	V08	37	28.49	5.38
Total	(RBV)	57		
For-profit		20	29.80	5.85
Not-for-profit	V09	37	28.57	5.70
Total	(RBV)	57		
For-profit		20	34.53	6.05
Not-for-profit	V10	37	26.01	5.41
Total	(RBV)	57		
For-profit		20	31.45	5.35
Not-for-profit	V11	37	27.68	4.81
Total	(RBV)	57		
For-profit		20	28.53	5.05
Not-for-profit	V12	37	29.26	4.95
Total	(RBV)	57		

Motives	N	Mean Rank	Average values of motives
	20	25.55	4.85
V13	37	30.86	5.24
(RBV)	57		
	20	25.60	5.70
V14	37	30.84	5.86
(RBV)	57		
	20	31.23	3.65
V15	37	27.80	3.32
(RBV)	57		
	20	33.28	4.75
V16	37	26.69	4.03
(RBV)	57		
	20	30.35	4.20
V17	37	28.27	3.86
(RBV)	57		
	20	29.70	3.85
V18	37	28.62	3.73
(NIS)	57		
	20	31.75	4.00
V19	37	27.51	3.51
(NIS)	57		
	20	25.08	4.35
V20	37	31.12	4.84
(NIS)	57		
	20	26.75	3.20
V21	37	30.22	3.62
(NIS)	57		
	20	23.98	4.60
V22	37	31.72	5.08
(NIS)	57		
	20	24.33	4.35
V23	37	31.53	5.05
(NIS)	57		

Source: author's elaboration

Mean differences of motives by organisational funding feature

	v01	v02	v03	v04	v05	v06	v07	v08	v09	v10	v11
Mann-Whitney U	243.50	331.50	212.50	271.00	354.00	231.50	165.00	351.000	354.00	259.50	321.00
Wilcoxon W	946.50	1034.50	915.50	974.00	1057.00	934.50	868.00	1054.00	1057.00	962.50	1024.00
Z	-2.166	-0.668	-2.697	-1.715	-0.273	-2.375	-3.505	-0.332	-0.285	-1.950	-0.846
Asymp. Sig. (2-tailed)	0.030	0.504	0.007	0.086	0.785	0.018	0.000	0.740	0.776	0.051	0.397

v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23
360.50	301.00	302.00	325.50	284.50	343.00	356.00	315.00	291.50	325.00	269.50	276.50
570.50	511.00	512.00	1028.50	987.50	1046.00	1059.00	1018.00	501.50	535.00	479.50	486.50
-0.164	-1.187	-1.199	-0.759	-1.455	-0.461	-0.238	-0.939	-1.336	-0.767	-1.737	-1.605
0.870	0.235	0.230	0.448	0.146	0.645	0.812	0.348	0.182	0.443	0.082	0.108

a. Grouping Variable: Organisational features

Source: author's elaboration

Appendix 8. The Results of Assumption Tests on Theoretical Approaches in the Establishment of Different Collaborative Structures by Focal Organisational Funding Feature

Descriptive statistics of theoretical approaches by focal organisational funding feature

Theoretical approaches	Organisational features	N	Mean	Std. Deviation	Std. Error Mean
NIS	For-profit	20	4.0585	1.04376	.23339
	Not-for-profit	37	4.3062	1.20425	.19798
RBV	For-profit	20	5.0415	.79450	.17766
	Not-for-profit	37	4.6362	.95097	.15634
TCE	For-profit	20	4.6335	.91448	.20448
	Not-for-profit	37	3.7662	1.12900	.18561

Source: author's elaboration

The normality test of theoretical approaches based on focal organisational funding features

Theoretical approaches	Organisational features	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
NIS	For-profit	.153	20	.200*	.925	20	.122
	Not-for-profit	.089	37	.200*	.964	37	.262
RBV	For-profit	.157	20	.200*	.955	20	.454
	Not-for-profit	.089	37	.200*	.960	37	.202
TCE	For-profit	.092	20	.200*	.977	20	.889
	Not-for-profit	.109	37	.200*	.977	37	.616

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Source: author's elaboration

Appendix 9. The Statistical results of Mean Differences of Theoretical Approaches in the Establishment of Different Collaborative Structures by Focal Firms' Size

The normality test of theoretical perspectives by size of firms

Theoretical perspectives	Firm sizes	Means	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
			Statistic	df	Sig.	Statistic	df	Sig.
NIS	Small-sized	4.42	.283	11	.014	.713	11	.001
	Medium & large-sized	3.61	.197	9	.200*	.913	9	.337
RBV	Small-sized	5.07	.226	11	.120	.902	11	.196
	Medium & large-sized	5.01	.128	9	.200*	.957	9	.763
TCE	Small-sized	4.77	.132	11	.200*	.977	11	.945
	Medium & large-sized	4.46	.105	9	.200*	.991	9	.997

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Source: author's elaboration

The statistical result of the Mann-Whitney U test for the NIS-related motives

Test statistics[a]	NIS
Mann-Whitney U	22.500
Wilcoxon W	67.500
Z	-2.057
Asymp. Sig. (2-tailed)	.040
Exact Sig. [2*(1-tailed Sig.)]	.038[b]

a. Grouping Variable: Firm sizes
b. Not corrected for ties.

Source: author's elaboration

The statistical result of independent-samples t-test on the RBV and TCE approaches

Theoretical approaches		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
RBV	Equal variances assumed	.121	.732	.151	18	.882	.05525	.36666	-.71506	.82557
	Equal variances not assumed			.155	17.978	.879	.05525	.35742	-.69572	.80623
TCE	Equal variances assumed	.003	.955	.749	18	.464	.31141	.41586	-.56228	1.18511
	Equal variances not assumed			.755	17.656	.460	.31141	.41269	-.55683	1.17966

Source: author's elaboration

Appendix 10. Mean Differences of Motives in the Establishment of Different Collaborative Structures based on Focal Organisational Type

Mean differences of motives based on focal organisational type

Variables	Motives	Firm	Hosp'l	PRI	Univ.	Sig.
V01	To economise research and administrative expenses through developing economies of scale	5.50	4.56	3.54	4.79	0.039
V03	To minimise research expenses through costs sharing/reduction in research	4.25	2.89	2.69	2.64	0.037
V05	To shorten lead time	4.70	5.78	3.92	4.07	0.042
V06	To reduce administrative costs	3.40	2.89	1.77	2.36	0.015
V07	To gain priority over intellectual property right	4.20	3.11	2.23	2.07	0.002
V20	To pursue certain missions mandated from the government/agency or society	4.35	4.78	5.69	4.00	0.035

* 1: Strongly disagree; 2: Disagree; 3: Slightly disagree; 4: Neither agree nor disagree; 5: Slightly agree; 6: Agree; 7: Strongly agree

** The null hypotheses are the distributions of each motive are the same across categories of focal organisational types

Source: author's elaboration

Appendix 11. The Results of Assumption Tests on Theoretical Approaches in the Establishment of Different Collaborative Structures by Focal Organisational Type

The normality tests on theoretical approaches by focal organisational type

Theoretical approaches	Focal organisational types	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
NIS	Firm	.154	20	.200*	.925	20	.124
	Hospital	.144	10	.200*	.956	10	.744
	PRI	.154	13	.200*	.922	13	.265
	University	.133	14	.200*	.944	14	.473
RBV	Firm	.155	20	.200*	.956	20	.464
	Hospital	.162	10	.200*	.937	10	.519
	PRI	.184	13	.200*	.947	13	.557
	University	.093	14	.200*	.983	14	.990
TCE	Firm	.092	20	.200*	.977	20	.891
	Hospital	.190	10	.200*	.940	10	.557
	PRI	.163	13	.200*	.965	13	.823
	University	.140	14	.200*	.965	14	.803

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Source: author's elaboration

The Levene's test on theoretical approaches by focal organsiational type

Theoretical approaches	Levene Statistic	df1	df2	Sig.
NIS	1.768	3	53	.164
RBV	.491	3	53	.690
TCE	.399	3	53	.754

Source: author's elaboration

Appendix 12. The Result of an ANOVA test on Theoretical Approaches in the Establishment of Different Collaborative Structures by Focal Organisational Type

A one-way ANOVA test on theoretical approaches by focal organisational type

Theoretical approaches		Sum of Squares	df	Mean Square	F	Sig.
NIS	Between Groups	2.858	3	.953	.712	.549
	Within Groups	70.873	53	1.337		
	Total	73.731	56			
RBV	Between Groups	4.530	3	1.510	1.899	.141
	Within Groups	42.148	53	.795		
	Total	46.678	56			
TCE	Between Groups	17.047	3	5.682	5.520	**.002**
	Within Groups	54.561	53	1.029		
	Total	71.608	56			

Source: author's elaboration

The post-hoc tests on theoretical approaches by focal organisational type

Dependent Variable	(I) Focal organisational types	(J) Focal organisational types	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
TCE	Firm	Hospital	.16667	.39296	1.000	-.9104	1.2437
		PRI	**1.27436***	.36147	**.005**	.2836	2.2651
		University	**.99048***	.35356	**.043**	.0214	1.9596
	Hospital	Firm	-.16667	.39296	1.000	-1.2437	.9104
		PRI	1.10769	.42677	.073	-.0621	2.2774
		University	.82381	.42009	.331	-.3276	1.9752
	PRI	Firm	-1.27436*	.36147	.005	-2.2651	-.2836
		Hospital	-1.10769	.42677	.073	-2.2774	.0621
		University	-.28388	.39080	1.000	-1.3550	.7873
	University	Firm	-.99048*	.35356	.043	-1.9596	-.0214
		Hospital	-.82381	.42009	.331	-1.9752	.3276
		PRI	.28388	.39080	1.000	-.7873	1.3550

* The mean difference is significant at the 0.05 level.

** The Bonferroni test can control the overall type-one error (i.e. false positive) and tend to be conservative and powerful (Frane, 2015).

Source: author's elaboration

Appendix 13. Partners' Expectations with regard to their Focal Organisations based on Qualitative Analysis

In this appendix, our focus shifts to exploring *partner* organisations' expectations with regard to their *focal* organisations in the development of R&D collaboration in the digital healthcare sector. Any form of R&D collaborations requires a mutual agreement whereby both the partners and focal organisations have to be motivated at the same time to enter into the R&D collaboration (Sytch, et al., 2008). In addition, the motives of organisations for participating in R&D collaboration may be different by their specific expectations in the R&D collaboration (i.e. a focal or partner organisation). The reason is that focal organisations tend to concentrate on gaining benefits from their partners in order to achieve their research goals with great dedication while partner organisations are likely to provide relatively less important capabilities for focal organisations and to focus more on reaping returns on their contributions. Thus, we should also take into account in terms of our attention to the expectations of partner organisations with regard to their focal organisations in each R&D collaboration.

Through this exploration, we can perhaps arrive at a better understanding of why a specific type of partner organisations might agree to develop R&D collaboration with a particular type of focal organisation. Data for this exploration are based on interviews with 35 principal investigators (PIs) engaged with 39 R&D collaboration projects, asking a question about what benefit each partner organisation expected to gain from the development of R&D collaboration with a given focal organisation. There are 21 R&D projects out of a total of 39 R&D projects which involved a partner firm while partner universities engaged in 18 R&D projects. In addition, eight and 22 out of the 39 R&D projects involved partner PRIs and hospitals, respectively.

This appendix includes four sections which indicate the expectations of the four different types of partner organisations with regard to particular types of focal organisations in different R&D collaborative structures.

Appendix 13.1. Partner Firms' Expectations with regard to their Focal Organisations

First, we will explore the expectations of partner firms with regard to their focal organisations in this section, initially exploring the expectations of *partner firms* associated with *focal firms*. As described in section 6.4.1, focal firms are likely to expect to secure component technologies or specific items from their partner firms for

developing the focal firms' products or services. However, partner firms tend to primarily expect to become a potential supplier, to gain access to a new market, and to benefit from the technological capabilities of focal firms through R&D collaboration with focal firms. For example, interviewee F03 (CTO) and F06 (CTO/Executive director) responded that their partner firms took part in an R&D collaboration with them in order "to become a potential supplier by providing batteries and bio-sensors", respectively. Interviewee F04 (Founder/CEO) noted that "partner firms intended to become potential suppliers and to gain access to a new market" through collaborating with a focal firm. In addition, interviewee F02 (Founder/CEO) said "our partner firms expected to establish a joint business model with us, to develop their own existing business model, and to become potential suppliers" through the establishment of R&D collaboration. Meanwhile, interviewee F08 (CTO) mentioned that "partner firms wanted to obtain technological knowledge from us (regarding health information systems) and to expand into a new market" (i.e. a particular healthcare sector).

Here, we will shift our attention to the expectations of *partner firms* in the development of R&D collaboration with *focal universities*. According to the interview data, partner firms are likely to expect to obtain research funding, to get help with the development of their existing technologies, and to carry out technology commercialisation through the establishment of an R&D collaboration with their focal universities. In contrast, focal firms tend to expect to acquire highly specialised technology and to develop technical standards from partner universities as noted in section 6.4.1. For instance, interviewees U01 (Full professor), U02 (Full professor), U03 (Full professor, MD), and U07 (Assistant professor) said that their partner firms' expectations from them were primarily "to gain research funding." However, interviewee U01 also noted that "our partner firms expected to develop their existing technology and to acquire technology for commercialisation" by collaboration with focal universities. Similarly, interviewee U02 answered "our partner firms wanted to benefit from the advancement of their existing technology for commercialisation" through R&D collaboration with a focal university. In addition, interviewee U07 noted that their partner firm expected "to gain help with administrative tasks" involving the R&D project by developing collaboration with them.

When it comes to the expectations of *partner firms* with regard to *focal PRIs*, they may hope to expect to obtain research funding by establishing R&D collaboration with focal

PRIs although focal firms are likely to expect to obtain benefits from PRIs' research capabilities and to overcome institutional barriers through collaborating with partner PRIs as illustrated in section 6.4.1. Interviewees P02 (Principal researcher) and P03 (Principal researcher) responded that their partner firms seemed to expect "to gain research funding" by establishing R&D collaboration with them. Nevertheless, interviewee P03 also answered that "our partner firms expect to seek help in dealing with administrative tasks in relation to the R&D project" and "to advance their existing technology or service" through developing R&D collaboration with our firm, respectively.

Next, we will focus on the expectations of *partner firms* with regard to *focal hospitals* in R&D collaborations. From the interview data, it would seem that partner firms expect to gain research funding, to carry out technology commercialisation, and to access a new market through R&D collaboration with focal hospitals, whereas focal firms tend to expect to employ partner hospitals as testbeds for the clinical validation, as described in section 6.4.1. Four interviewees H02 (Full professor/Director, MD), H03 (Full professor, MD), H07 (Full professor, MD), and H08 (Full professor, MD) generally responded that their partner firms expected "to get research funding" by collaborating with them. Moreover, interviewees H03, H06 (Full professor/Vice Dean, MD), H07, and H08 also said that their partner firms had an interest in the commercialisation of developed services and technologies in their R&D collaborations with them. Meanwhile, interviewees H04 (Full professor, MD) and H07 also mentioned that "our partner firms expected to enter a new market" (the digital healthcare service sector) by R&D collaboration with focal hospitals.

Table A-1 below give a summary of the expectations of partner with regard to each focal organisational type.

Table A-1. Summary of partner firms' main expectations with regard to their focal organisations

Partner firms' main expectations	Focal organisational type
In order to become a potential supplier, to gain access to a new market, and to benefit from the technological capabilities of focal firms	Firm
To gain research funding, to get help with the development of their existing technologies, and to carry out technology commercialisation	University
In order to obtain research funding	PRI
To gain research funding, to carry out technology commercialisation, and to access a new market	Hospital

Source: author's elaboration

Appendix 13.2. Partner Universities' Expectations with regard to their Focal Organisations

Here, using interview data we will analyse the expectations of partner universities in R&D collaboration in the digital healthcare sector with regard to their focal organisations broken down by type. An analysis of the expectations of *partner universities* with regard to *focal firms* will be conducted first. According to the analysis, partner universities are likely to expect to carry out licensing-out activities for potential royalties of their technologies, to promote their human resources, and to secure research funding through R&D collaboration with focal firms. For example, interviewees F04 (Founder/CEO) and F06 (CTO/Executive director) said "our partner universities wanted "to transfer their existing technologies" to our firms while interviewees F02 (Founder/CEO) and F05 (CTO) observed that "our partner universities expected to gain potential royalties" by licensing-outs of their technologies on the basis of R&D collaboration with focal firms. In addition, interviewee F06 said that their partner university intended "to establish the industry-university cooperation model in which PhD researchers can jointly participate in the R&D project" with researchers in focal firms. Interviewee F13 (CTO, Full professor) also mentioned that the partner university in an R&D project expected "to develop its human resources" through engaging in research with a private focal firm. Lastly, interviewees F03 (CTO) and F13 (CTO, Full professor) responded that their partner universities expected "to gain research funding" through the establishment of R&D collaboration with them.

Moving to the expectations of *partner universities* from their *focal universities* in R&D collaborations, partner universities tend to expect to gain research funding and to advance their existing technologies for commercialisation, while focal universities mainly expect to get help from the specialised capabilities of partner universities, as noted in section 6.4.2. For instance, interviewees U02 (Full professor, MD), U03 (Full professor, MD), and U06 (Full professor, MD) mentioned that their partner universities expected "to gain research funding" from the establishment of R&D collaboration with them. In addition, interviewee U02 also responded that "one of our partner universities expected to develop their existing technology for commercialisation and they are now running a spin-off company from the university." Interviewee U06 also said that one of their partner universities wanted "to advance existing technology for commercialisation to be utilised in clinical practice" through R&D collaboration with their focal university.

In the light of the expectations of *partner universities* with regard to *focal PRIs* in R&D

collaboration, partner universities are likely to have an interest in obtaining research funding by taking part in R&D collaboration with focal PRIs even though focal universities tend to acquire highly specialised capabilities from collaborating with their partner PRIs as noted in section 6.4.2. In this regard, interviewees P01 (Principal researcher/Team head), P04 (Principal researcher/Assistant vice president), and P06 (Principal researcher/Director) responded that their partner universities primarily expected "to obtain research funding" by collaborating with focal PRIs. On the other hand, interviewee P01 also mentioned that their university partners expected "to get involved in the establishment of policies, regulations, and technical standards" related to their research while interviewee P04 said "our partner universities tended to participate in the R&D collaboration with us due to their own interests in the research topic."

Lastly, we will consider the expectations of *partner universities* with regard to *focal hospitals* in R&D collaboration. According to interviewees, partner universities are likely to expect to get research funding and to produce research outputs through R&D collaboration with focal hospitals, while focal universities are likely to expect to secure medical data and to carry the clinical validation of developing technologies from partner hospitals, as noted in section 6.4.2. For example, interviewees H01 (Research assistant professor), H05 (Principal researcher), and H08 (Full professor, MD) all said that their university partners seemed to expect "to gain some research funding" by developing R&D collaboration with focal hospitals. Moreover, their partner universities expected "to get benefits from the production of research outputs" such as papers through R&D collaboration with them.

Table A-2 below give a summary of the expectations of partner universities with regard to each focal organisational type.

Table A-2 Summary of partner universities' main expectations with regard to their focal organisations

Partner universities' main expectations	Focal organisational type
To carry out licensing-outs for potential royalties based on partner universities' technologies, to promote their human resources, and to secure research funding	Firm
In order to gain research funding and to develop their existing technologies for commercialisation	University
To get research funding	PRI
To get research funding and in order to generate research outputs	Hospital

Source: author's elaboration

Appendix 13.3. Partner PRIs' Expectations with regard to their Focal Organisations

This appendix explores the expectations of partner PRIs with regard to their focal organisations in R&D collaborations. We will first look at *partner PRIs*' expectations with regard to *focal firms* in an R&D collaboration. According to interviewees, partner PRIs expect to gain research funding and to carry out their mandated role in the innovation system. In contrast, focal PRIs are likely to expect to implement their research concepts and technologies, to support SMEs as a public research organisation, and to benefit from technology commercialisation by R&D collaboration with partner firms as noted in section 6.4.3. For instance, interviewees F04 (Founder/CEO) and F09 (CTO) answered that their partner PRIs expected "to gain research funding" through R&D collaboration with them. In addition, interviewees F01 (Founder/CEO) and F09 (CTO) said the expectation of a partner PRI was "to perform its mandated role" in the innovation system as a public organisation by supporting the development of the focal firm's technological capabilities.

When it comes to the expectations of *partner PRIs* with regard to *focal universities* in the R&D collaboration, there was only one R&D project led by a university which involved two partner PRIs. Interestingly, the relevant interviewee U02 (Full professor, MD) mentioned that their partner PRIs expected "to understand clinical demand aspects" through R&D collaboration with them. However, this can be explained by the fact that the focal research team (including interviewee U02) belongs to the medical school at the focal university.

Next, we move on to the expectations of *partner PRIs* with regard to *focal PRIs* in an R&D collaboration. Interviewee P06 (Principal researcher/Director) responded that "our partner PRIs intended to acquire research funding and to develop their existing technological capabilities through the establishment of R&D collaboration with us".

Lastly, the analysis of the expectations of *partner PRIs* with regard to *focal hospitals* in an R&D collaboration will be carried out. According to this analysis, partner PRIs are likely to expect to gain research funding by developing R&D collaboration with their focal hospitals, while focal PRIs tend to establish R&D collaboration with partner hospitals in order to benefit from clinical validation and clinical insights and knowledge, as described in section 6.4.3. Interviewees H03 (Full professor, MD) and H07 (Full professor, MD) responded that their partner PRIs wanted "to gain research funding"

through R&D collaboration with them. In addition, interviewee H03 stated that the partner PRI in the R&D project took part in the research project in order "to deal with its mandated role as a public organisation" through supporting a focal hospital to facilitate technology commercialisation. Nevertheless, interviewee H07 also said that "our partner PRI expected to advance their existing digital healthcare service platform through R&D collaboration with us".

Table A-3 below give a summary of the expectations of partner PRIs from each focal organisational type.

Table A-3 Summary of partner PRIs' main expectations with regard to their focal organisations

Partner PRIs' main expectations	Focal organisational type
To gain research funding, to carry out its mandated role in the innovation system as a public organisation	Firm
To understand the clinical demand aspects	University
To acquire research funding and to develop their existing technological capabilities	PRI
To gain research funding	Hospital

Source: author's elaboration

Appendix 13.4. Partner Hospitals' Expectations with regard to their Focal Organisations

In this appendix, we will focus on the expectations of partner hospitals with regard to their focal organisations in R&D collaborations. First of all, we will focus on *partner hospitals*' expectations in terms of their *focal firms* in an R&D collaboration, and the analysis will once more be based on interview data. As we saw earlier in section 6.4.4, the expectations of focal hospitals with regard to their partner firms in an R&D collaboration is to benefit from complementary capabilities such as existing technologies or platforms of partner firms in relation to ICT and digital services. In contrast, partner hospitals are likely to participate in R&D projects with focal firms because of their own specific interests in the research topics. In addition, they generally expect to gain research funding and to produce research outputs such as papers, and to obtain technology licensing agreements for potential royalties through establishing R&D collaboration with focal firms.

For instance, interviewee F06 (CTO/Executive director) noted that the partner hospital "has an interest in our research topic", the development of the healthcare service model based on bio-signals, because "they have experienced in doing research in this area."

Likewise, interviewee F10 (Founder/CEO) mentioned that the partner hospital "has a strong interest in the research topic", the development of follow-up care services for cancer patients, and "they expected to apply the advanced care services for cancer patients to their hospital." Interviewee F12 (Team head) also responded that "our partner hospital took part in the R&D project due to their own interest in the research topic." Moreover, interviewee F03 (CTO) said that their hospital partner expected "to procure research funding and to produce some research outputs such as papers" through the development of the R&D collaboration with their firm. Interviewee F11 (Executive director) likewise said that "our partner hospitals intended to benefit from research funding and potential royalties by collaborating with us." Similarly, interviewee F12 responded that their hospital partner expected "to get research funding" while interviewees F02 (Founder and CEO) and F07 (Founder and CEO, MD) mentioned that the partner hospital(s) expected "to get potential royalties through licensing-out" their technologies on the basis of the R&D collaboration with focal firms.

We will move on to the expectations of *partner hospitals* in R&D collaboration with *focal universities*. According our analysis of the interview data, partner hospitals are likely to benefit from research funding and the application of developed technology to clinical practice in their hospitals, while focal hospitals generally expect to gain benefits from technical standards and the exploratory research capabilities of their partner universities, as described in section 6.4.4. For example, interviewees U03 (Full professor, MD), U04 (Full professor/Dean), and U06 (Full professor, MD) all said that their hospital partners expected "to gain research funding" through developing R&D collaboration with them, although interviewee F06 also mentioned that the hospital partner wanted "to apply developed technology (from the R&D project) to clinical practice" in their hospital. In addition, interviewee U05 (Full professor) responded that the hospital partner expected "to apply the individualized drug use process developed from the R&D project to their clinical practice" as well.

Next, an analysis of the expectations of *partner hospitals* with regard to *focal PRIs* in the establishment of R&D collaboration will be carried out. Partner hospitals tend to expect to acquire research funding through R&D collaboration with focal PRIs, and are likely to develop R&D collaboration with focal PRIs due to their own interests in particular research topics, while focal hospitals primarily expect to gain help with institutional

issues and technological capabilities from their partner PRIs. For instance, interviewees P01 (Principal researcher/Team head), P02 (Principal researcher) and P03 (Principal researcher) responded that their partner hospitals expected "to benefit from research funding" by developing R&D collaboration with them. Meanwhile, interviewees P02 and P03 also mentioned that the partner hospitals "have their own interests in the research topics" of the R&D projects and they wanted to conduct the R&D projects together.

When it comes to the expectations of *partner hospitals* in terms of *focal hospitals* in an R&D collaboration, partner hospitals generally expect to acquire research funding and to produce research papers, while focal hospitals mainly expect to employ partner hospitals as additional clinical test-beds through the development of the R&D collaboration. For example, interviewees H03 (Full professor, MD), H07 (Full professor, MD), and H08 (Full professor, MD) said their partner hospitals expected "to get research funding" through R&D collaboration with them while interviewees H03 and H08 also mentioned that the partner hospitals expected "to generate research papers" by working together with their focal hospitals.

Table A-4 below give a summary of the main expectations of partner hospitals with regard to each focal organisational type.

Table A-4 Summary of partner hospitals' expectations with regard to their focal organisations

Partner hospitals' main expectations	Focal organisational type
Due to their own interests in particular research topics, to gain research funding, in order to generate research outputs such as papers, and to obtain technology licensing agreements for potential royalties	Firm
To benefit from research funding and to apply developed technology to clinical practice	University
To gain research funding and to deal with partner hospitals' own interests in research topics	PRI
To acquire research funding and in order to produce research papers	Hospital

Source: author's elaboration

Appendix 14. Normality tests for the R&D performance per one billion KRW by diverse collaborative structures categorised by focal organisational type and partners' funding feature

i) Normality tests for R&D performance, SCI papers, patent applications, patents-granted, and technology licensing and collaborative structures led by focal firms

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Collaborative_Structures	Statistic	df	Sig.	Statistic	df	Sig.
SCI	Firms+FP	.511	37	.000	.349	37	.000
	Firms+NFP	.507	57	.000	.369	57	.000
	Firms+None	.532	84	.000	.086	84	.000
Application	Firms+FP	.299	37	.000	.600	37	.000
	Firms+NFP	.248	57	.000	.707	57	.000
	Firms+None	.452	84	.000	.503	84	.000
Granted	Firms+FP	.423	37	.000	.578	37	.000
	Firms+NFP	.344	57	.000	.681	57	.000
	Firms+None	.463	84	.000	.336	84	.000
Licensing	Firms+FP	.403	37	.000	.428	37	.000
	Firms+NFP	.452	57	.000	.545	57	.000
	Firms+None	.332	84	.000	.591	84	.000

a. Lilliefors Significance Correction

ii) Normality tests for R&D performance, SCI papers, patent applications, patents-granted, and technology licensing and collaborative structures led by focal universities

Tests of Normality[b]

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Univ_structures	Statistic	df	Sig.	Statistic	df	Sig.
SCI	Univ+FP	.393	28	.000	.427	28	.000
	Univ+NFP	.371	31	.000	.579	31	.000
	Univ+None	.358	257	.000	.519	257	.000
Applications	Univ+FP	.273	28	.000	.772	28	.000
	Univ+NFP	.537	31	.000	.275	31	.000
	Univ+None	.405	257	.000	.394	257	.000
Granted	Univ+FP	.354	28	.000	.396	28	.000
	Univ+NFP	.502	31	.000	.278	31	.000
	Univ+None	.444	257	.000	.358	257	.000
Licensing	Univ+FP	.504	28	.000	.438	28	.000
	Univ+None	.533	257	.000	.100	257	.000

a. Lilliefors Significance Correction

b. Licensing is constant when Univ_structures = Univ+NFP. It has been omitted.

iii) Normality tests for R&D performance, SCI papers, patent applications, patents-granted, and technology licensing and collaborative structures led by focal PRIs

Tests of Normality[b]

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	PRIs_structures	Statistic	df	Sig.	Statistic	df	Sig.
SCI	PRIs+FP	.332	5	.074	.740	5	.024
	PRIs+NFP	.459	19	.000	.343	19	.000
	PRIs+None	.536	16	.000	.273	16	.000
Applications	PRIs+FP	.316	5	.116	.898	5	.396
	PRIs+NFP	.307	19	.000	.684	19	.000
	PRIs+None	.501	16	.000	.377	16	.000
Granted	PRIs+FP	.473	5	.001	.552	5	.000
	PRIs+NFP	.292	19	.000	.627	19	.000
	PRIs+None	.518	16	.000	.401	16	.000
Licensing	PRIs+FP	.473	5	.001	.552	5	.000
	PRIs+NFP	.523	19	.000	.374	19	.000

a. Lilliefors Significance Correction

b. Licensing is constant when PRIs_structures = PRIs+None. It has been omitted.

iv) Normality tests for R&D performance, SCI papers, patent applications, patents-granted, and technology licensing and collaborative structures led by focal hospitals

Tests of Normality[b]

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Hospitals_structures	Statistic	df	Sig.	Statistic	df	Sig.
SCI	Hospitals+FP	.421	21	.000	.489	21	.000
	Hospitals+NFP	.459	9	.000	.564	9	.000
	Hospitals+None	.404	44	.000	.248	44	.000
Applications	Hospitals+FP	.338	21	.000	.488	21	.000
	Hospitals+NFP	.519	9	.000	.390	9	.000
	Hospitals+None	.428	44	.000	.317	44	.000
Granted	Hospitals+FP	.420	21	.000	.618	21	.000
	Hospitals+NFP	.519	9	.000	.390	9	.000
	Hospitals+None	.485	44	.000	.196	44	.000
Licensing	Hospitals+FP	.528	21	.000	.352	21	.000
	Hospitals+None	.538	44	.000	.218	44	.000

a. Lilliefors Significance Correction

b. Licensing is constant when Hospitals_structures = Hospitals+NFP. It has been omitted.

Appendix 15. A Summary of Chi-squared Tests between Collaborative Structures and R&D Performance

▶ Between collaborative structures categorised by focal firms and their R&D performance

Type of performance: SCI papers

Focal firms_Structures * SCI Crosstabulation

			SCI		
			0	1	Total
Focal firms_Structures	Firms+FP	Count	33	4	37
		% within Focal firms_Structures	89.2%	10.8%	100.0%
	Firms+NFP	Count	50	7	57
		% within Focal firms_Structures	87.7%	12.3%	100.0%
	Firms+None	Count	83	1	84
		% within Focal firms_Structures	98.8%	1.2%	100.0%
Total		Count	166	12	178
		% within Focal firms_Structures	93.3%	6.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.873[a]	2	.020
Likelihood Ratio	9.237	2	.010
Linear-by-Linear Association	5.542	1	.019
N of Valid Cases	178		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.49.

Type of performance: Patent applications

Focal firms_Structures * Patent applications Crosstabulation

			Patent applications		
			No	Yes	Total
Focal firms_Structures	Firms+FP	Count	21	16	37
		% within Focal firms_Structures	56.8%	43.2%	100.0%
	Firms+NFP	Count	26	31	57
		% within Focal firms_Structures	45.6%	54.4%	100.0%
	Firms+None	Count	66	18	84
		% within Focal firms_Structures	78.6%	21.4%	100.0%
Total		Count	113	65	178
		% within Focal firms_Structures	63.5%	36.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.822[a]	2	.000
Likelihood Ratio	17.171	2	.000
Linear-by-Linear Association	9.082	1	.003
N of Valid Cases	178		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 13.51.

Type of performance: Patents-granted

Focal firms_Structures * Patents granted Crosstabulation

			Patents granted		
			No	Yes	Total
Focal firms_Structures	Firms+FP	Count	27	10	37
		% within Focal firms_Structures	73.0%	27.0%	100.0%
	Firms+NFP	Count	35	22	57
		% within Focal firms_Structures	61.4%	38.6%	100.0%
	Firms+None	Count	71	13	84
		% within Focal firms_Structures	84.5%	15.5%	100.0%
Total		Count	133	45	178
		% within Focal firms_Structures	74.7%	25.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.685[a]	2	.008
Likelihood Ratio	9.686	2	.008
Linear-by-Linear Association	3.824	1	.051
N of Valid Cases	178		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.35.

Type of performance: Technology licensing

Focal firms_Structures * Technology licensing Crosstabulation

			Technology licensing		
			No	Yes	Total
Focal firms_Structures	Firms+FP	Count	28	9	37
		% within Focal firms_Structures	75.7%	24.3%	100.0%
	Firms+NFP	Count	44	13	57
		% within Focal firms_Structures	77.2%	22.8%	100.0%
	Firms+None	Count	53	31	84
		% within Focal firms_Structures	63.1%	36.9%	100.0%
Total		Count	125	53	178
		% within Focal firms_Structures	70.2%	29.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.891[a]	2	.143
Likelihood Ratio	3.902	2	.142
Linear-by-Linear Association	2.807	1	.094
N of Valid Cases	178		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 11.02.

▶ Between collaborative structures categorised by focal universities and their R&D performance

Type of performance: SCI papers

Focal universities_Sturctures * SCI papers Crosstabulation

			SCI papers		
			No	Yes	Total
Focal universities_Sturctures	Universities+FP	Count	21	7	28
		% within Focal universities_Sturctures	75.0%	25.0%	100.0%
	Universities+NFP	Count	21	10	31
		% within Focal universities_Sturctures	67.7%	32.3%	100.0%
	Universities+None	Count	175	82	257
		% within Focal universities_Sturctures	68.1%	31.9%	100.0%
Total		Count	217	99	316
		% within Focal universities_Sturctures	68.7%	31.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.574[a]	2	.751
Likelihood Ratio	.596	2	.742
Linear-by-Linear Association	.413	1	.521
N of Valid Cases	316		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.77.

Type of performance	Results of Chi-squared tests
Patent applications	**Focal universities_Sturctures * Patent applications Crosstabulation**

			Patent applications		
			No	Yes	Total
Focal universities_Sturctures	Universities+FP	Count	14	14	28
		% within Focal universities_Sturctures	50.0%	50.0%	100.0%
	Universities+NFP	Count	29	2	31
		% within Focal universities_Sturctures	93.5%	6.5%	100.0%
	Universities+None	Count	198	59	257
		% within Focal universities_Sturctures	77.0%	23.0%	100.0%
Total		Count	241	75	316
		% within Focal universities_Sturctures	76.3%	23.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.873[a]	2	.000
Likelihood Ratio	15.764	2	.000
Linear-by-Linear Association	4.045	1	.044
N of Valid Cases	316		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.65.

Patents-granted	**Focal universities_Sturctures * Patents granted Crosstabulation**

			Patents granted		
			No	Yes	Total
Focal universities_Sturctures	Universities+FP	Count	18	10	28
		% within Focal universities_Sturctures	64.3%	35.7%	100.0%
	Universities+NFP	Count	28	3	31
		% within Focal universities_Sturctures	90.3%	9.7%	100.0%
	Universities+None	Count	211	46	257
		% within Focal universities_Sturctures	82.1%	17.9%	100.0%
Total		Count	257	59	316
		% within Focal universities_Sturctures	81.3%	18.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.108[a]	2	.029
Likelihood Ratio	6.538	2	.038
Linear-by-Linear Association	2.517	1	.113
N of Valid Cases	316		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.23.

Technology licensing	**Focal universities_Sturctures * Technology licensing Crosstabulation**

			Technology licensing		
			No	Yes	Total
Focal universities_Sturctures	Universities+FP	Count	24	4	28
		% within Focal universities_Sturctures	85.7%	14.3%	100.0%
	Universities+NFP	Count	31	0	31
		% within Focal universities_Sturctures	100.0%	0.0%	100.0%
	Universities+None	Count	253	4	257
		% within Focal universities_Sturctures	98.4%	1.6%	100.0%
Total		Count	308	8	316
		% within Focal universities_Sturctures	97.5%	2.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.473[a]	2	.000
Likelihood Ratio	10.410	2	.005
Linear-by-Linear Association	11.405	1	.001
N of Valid Cases	316		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .71.

▶ Between collaborative structures categorised by focal PRIs and their R&D performance

Type of performance	Results of Chi-squared tests
SCI papers	**Focal PRIs_Structures * SCI papers Crosstabulation**

			SCI papers		
			No	Yes	Total
Focal PRIs_Structures	PRIs+FP	Count	3	2	5
		% within Focal PRIs_Structures	60.0%	40.0%	100.0%
	PRIs+NFP	Count	16	3	19
		% within Focal PRIs_Structures	84.2%	15.8%	100.0%
	PRIs+None	Count	15	1	16
		% within Focal PRIs_Structures	93.8%	6.3%	100.0%
Total		Count	34	6	40
		% within Focal PRIs_Structures	85.0%	15.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.421[a]	2	.181
Likelihood Ratio	3.031	2	.220
Linear-by-Linear Association	2.988	1	.084
N of Valid Cases	40		

a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is .75.

Patent applications	**Focal PRIs_Structures * Patent applications Crosstabulation**

			Patent applications		
			No	Yes	Total
Focal PRIs_Structures	PRIs+FP	Count	1	4	5
		% within Focal PRIs_Structures	20.0%	80.0%	100.0%
	PRIs+NFP	Count	11	8	19
		% within Focal PRIs_Structures	57.9%	42.1%	100.0%
	PRIs+None	Count	14	2	16
		% within Focal PRIs_Structures	87.5%	12.5%	100.0%
Total		Count	26	14	40
		% within Focal PRIs_Structures	65.0%	35.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.433[a]	2	.015
Likelihood Ratio	8.871	2	.012
Linear-by-Linear Association	8.160	1	.004
N of Valid Cases	40		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.75.

Patents-granted	**Focal PRIs_Structures * Patents granted Crosstabulation**

			Patents granted		
			No	Yes	Total
Focal PRIs_Structures	PRIs+FP	Count	4	1	5
		% within Focal PRIs_Structures	80.0%	20.0%	100.0%
	PRIs+NFP	Count	11	8	19
		% within Focal PRIs_Structures	57.9%	42.1%	100.0%
	PRIs+None	Count	14	2	16
		% within Focal PRIs_Structures	87.5%	12.5%	100.0%
Total		Count	29	11	40
		% within Focal PRIs_Structures	72.5%	27.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.980[a]	2	.137
Likelihood Ratio	4.129	2	.127
Linear-by-Linear Association	1.116	1	.291
N of Valid Cases	40		

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is 1.38.

Type of performance	Results of Chi-squared tests
Technology licensing	**Focal PRIs_Structures * Technology licensing Crosstabulation**

			Technology licensing		
			No	Yes	Total
Focal PRIs_Structures	PRIs+FP	Count	4	1	5
		% within Focal PRIs_Structures	80.0%	20.0%	100.0%
	PRIs+NFP	Count	17	2	19
		% within Focal PRIs_Structures	89.5%	10.5%	100.0%
	PRIs+None	Count	16	0	16
		% within Focal PRIs_Structures	100.0%	0.0%	100.0%
Total		Count	37	3	40
		% within Focal PRIs_Structures	92.5%	7.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.674[a]	2	.263
Likelihood Ratio	3.520	2	.172
Linear-by-Linear Association	2.604	1	.107
N of Valid Cases	40		

a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is .38.

▶ Between collaborative structures categorised by focal hospitals and their R&D performance

Type of performance	Results of Chi-squared tests
SCI papers	**Focal hospitals_Structures * SCI papers Crosstabulation**

			SCI papers		
			No	Yes	Total
Focal hospitals_Structures	Hosptials+FP	Count	16	5	21
		% within Focal hospitals_Structures	76.2%	23.8%	100.0%
	Hospitals+NFP	Count	7	2	9
		% within Focal hospitals_Structures	77.8%	22.2%	100.0%
	Hospitals+None	Count	35	9	44
		% within Focal hospitals_Structures	79.5%	20.5%	100.0%
Total		Count	58	16	74
		% within Focal hospitals_Structures	78.4%	21.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.097[a]	2	.953
Likelihood Ratio	.096	2	.953
Linear-by-Linear Association	.095	1	.758
N of Valid Cases	74		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.95.

Patent applications	**Focal hospitals_Structures * Patent applications Crosstabulation**

			Patent applications		
			No	Yes	Total
Focal hospitals_Structures	Hosptials+FP	Count	14	7	21
		% within Focal hospitals_Structures	66.7%	33.3%	100.0%
	Hospitals+NFP	Count	8	1	9
		% within Focal hospitals_Structures	88.9%	11.1%	100.0%
	Hospitals+None	Count	35	9	44
		% within Focal hospitals_Structures	79.5%	20.5%	100.0%
Total		Count	57	17	74
		% within Focal hospitals_Structures	77.0%	23.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.147[a]	2	.342
Likelihood Ratio	2.168	2	.338
Linear-by-Linear Association	1.039	1	.308
N of Valid Cases	74		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.07.

Patents-granted	**Focal hospitals_Structures * Patents granted Crosstabulation**

			Patents granted		
			No	Yes	Total
Focal hospitals_Structures	Hosptials+FP	Count	15	6	21
		% within Focal hospitals_Structures	71.4%	28.6%	100.0%
	Hospitals+NFP	Count	8	1	9
		% within Focal hospitals_Structures	88.9%	11.1%	100.0%
	Hospitals+None	Count	40	4	44
		% within Focal hospitals_Structures	90.9%	9.1%	100.0%
Total		Count	63	11	74
		% within Focal hospitals_Structures	85.1%	14.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.377[a]	2	.112
Likelihood Ratio	3.999	2	.135
Linear-by-Linear Association	3.957	1	.047
N of Valid Cases	74		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.34.

Technology licensing	**Focal hospitals_Structures * Technology licensing Crosstabulation**

			Technology licensing		
			No	Yes	Total
Focal hospitals_Structures	Hosptials+FP	Count	19	2	21
		% within Focal hospitals_Structures	90.5%	9.5%	100.0%
	Hospitals+NFP	Count	9	0	9
		% within Focal hospitals_Structures	100.0%	0.0%	100.0%
	Hospitals+None	Count	42	2	44
		% within Focal hospitals_Structures	95.5%	4.5%	100.0%
Total		Count	70	4	74
		% within Focal hospitals_Structures	94.6%	5.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.275[a]	2	.529
Likelihood Ratio	1.641	2	.440
Linear-by-Linear Association	.515	1	.473
N of Valid Cases	74		

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is .49.

Appendix 16. The Features of R&D Performance Depending on the Management Style of Research Team in Inter-Organisational R&D Collaboration

Management style	No. of R&D projects	Funding in million KRW	SCI papers	Patent applications	Patents-granted	Technology licensing
Involving deep and detailed management	32	28,836	1.11	2.70	1.28	0.73
Others	28	22,591	0.40	0.97	0.35	0.22
Differences			0.71	1.73	0.93	0.51

*The R&D performance, SCI papers, patent applications, patents-granted, and technology licensing, shows the number of the production for one billion Korean won, respectively.

Appendix 17. Multivariate Analysis in terms of the relationships between the characteristics of R&D projects and their R&D performance

In order to estimate the relationships between the characteristics of public R&D projects such as the number of partners, the amount of government funding, the features of the funding input, the attributes of the institutional pressure, and different types of collaborative structures and R&D performance such as SCI papers, patent applications, patents-granted, and technology licensing, the probit link function in the generalized linear model was conducted as follows.

- Dependent variables, SCI papers, patent applications, patents-granted, and technology licensing performance, are binary data, and '1' indicates that a R&D project generated R&D performance, '0' is given if not.
  - SCI: SCI papers performance
  - Applications: patent applications performance
  - Granted: patents-granted performance
  - Licensing: technology licensing performance
- Independent variables
  - Partners: the number of partners in R&D collaboration projects
  - Funding: the amount of research funding in Korean million won
  - Matching: this variable is binary, and '1' indicates that any partner(s) invest research funding matching with government funding, while '0' is given if not.
  - RFP: this variable is also binary, and '1' indicates that an RFP includes any types of institutional pressure such as encouragement or enforcement to establish R&D collaboration, while '0' is given if not.
  - Structures: this variable is categorical, and '0' indicates that R&D projects of each type of focal organisations, a firm, university, PRI, and hospital, do not collaborate with any partner, '1' is given if each type of focal organisations collaborate with partner(s) including a for-profit organisation, and R&D collaboration projects are coded as '2' in cases where R&D collaboration projects are not coded as '1'

<R&D projects led by firms>

- Dependent variables

SCI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	166	93.3	93.3	93.3
	Production	12	6.7	6.7	100.0
	Total	178	100.0	100.0	

Application

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	113	63.5	63.5	63.5
	Production	65	36.5	36.5	100.0
	Total	178	100.0	100.0	

Granted

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	133	74.7	74.7	74.7
	Production	45	25.3	25.3	100.0
	Total	178	100.0	100.0	

Licensing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	125	70.2	70.2	70.2
	Production	53	29.8	29.8	100.0
	Total	178	100.0	100.0	

- Independent variables

Categorical Variable Information

Factor	Structures	Firm+NFP	57	32.0%
		Firm+FP	37	20.8%
		Firm+None	84	47.2%
		Total	178	100.0%
	RFP	Pressure	85	47.8%
		Free	93	52.2%
		Total	178	100.0%
	Matching	Inputs	176	98.9%
		No input	2	1.1%
		Total	178	100.0%

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Covariate	Funding	178	30.00	4111.00	537.8989	588.99087
	Partners	178	.00	15.00	1.1573	1.88001

[SCI papers]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
38.524	6	.000

Dependent Variable: SCI

Model: (Intercept), Structures, RFP, Matching, Funding, Patners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	Upper
(Intercept)	-9.073	17665.4054	-34632.631	34614.486	.000	1	1.000	.000	.000	[a]
[Structures=2.00]	1.622	.6891	.271	2.972	5.538	1	.019	5.062	1.311	19.539
[Structures=1.00]	.670	.8406	-.977	2.318	.636	1	.425	1.955	.376	10.151
[Structures=.00]	0[b]	.	.	.	.	.	.	1	.	.
[RFP=1.00]	2.339	1.0763	.230	4.449	4.724	1	.030	10.374	1.258	85.529
[RFP=.00]	0[b]	.	.	.	.	.	.	1	.	.
[Matching=1.00]	3.880	17665.4054	-34619.678	34627.438	.000	1	1.000	48.425	.000	[a]
[Matching=.00]	0[b]	.	.	.	.	.	.	1	.	.
Funding	.002	.0005	.001	.003	12.778	1	.000	1.002	1.001	1.003
Partners	-.355	.1532	-.655	-.055	5.370	1	.020	.701	.519	.947
(Scale)	1[c]									

Dependent Variable: SCI

Model: (Intercept), Structures, RFP, Matching, Funding, Partners

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.

[Patent applications]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
47.265	6	.000

Dependent Variable: Application

Model: (Intercept), Structures, RFP, Matching, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	Upper
(Intercept)	-6.685	19475.9228	-38178.792	38165.422	.000	1	1.000	.001	.000	[a]
[Structures=2.00]	.472	.2916	-.100	1.043	2.614	1	.106	1.602	.905	2.838
[Structures=1.00]	-.501	.4859	-1.453	.452	1.062	1	.303	.606	.234	1.571
[Structures=.00]	0[b]	.	.	.	.	.	.	1	.	.
[RFP=1.00]	-.101	.2443	-.579	.378	.169	1	.681	.904	.560	1.460
[RFP=.00]	0[b]	.	.	.	.	.	.	1	.	.
[Matching=1.00]	5.532	19475.9228	-38166.575	38177.639	.000	1	1.000	252.655	.000	[a]
[Matching=.00]	0[b]	.	.	.	.	.	.	1	.	.
Funding	.001	.0003	.001	.002	13.111	1	.000	1.001	1.001	1.002
Partners	.149	.1335	-.113	.410	1.244	1	.265	1.161	.893	1.508
(Scale)	1[c]									

Dependent Variable: Application

Model: (Intercept), Structures, RFP, Matching, Funding, Partners

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.

[Patents-granted]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
28.586	6	.000

Dependent Variable: Granted

Model: (Intercept), Structures, RFP, Matching, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-7.059	19237.4980	-37711.862	37697.744	.000	1	1.000	.001	.000	[a]
[Structures=2.00]	.654	.2722	.120	1.188	5.772	1	.016	1.923	1.128	3.279
[Structures=1.00]	.041	.4255	-.793	.875	.009	1	.923	1.042	.453	2.399
[Structures=.00]	0[b]	.	.	.	.	.	.	1	.	.
[RFP=1.00]	.450	.2453	-.030	.931	3.370	1	.066	1.569	.970	2.537
[RFP=.00]	0[b]	.	.	.	.	.	.	1	.	.
[Matching=1.00]	5.596	19237.4980	-37699.207	37710.399	.000	1	1.000	269.308	.000	[a]
[Matching=.00]	0[b]	.	.	.	.	.	.	1	.	.
Funding	.001	.0003	.000	.001	11.155	1	.001	1.001	1.000	1.001
Partners	-.153	.0968	-.343	.037	2.506	1	.113	.858	.710	1.037
(Scale)	1[c]									

Dependent Variable: Granted

Model: (Intercept), Structures, RFP, Matching, Funding, Partners

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.

[Technology licensing]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
23.536	6	.001

Dependent Variable: Licensing

Model: (Intercept), Structures, RFP, Matching, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-6.349	18836.5416	-36925.292	36912.594	.000	1	1.000	.002	.000	[a]
[Structures=2.00]	-.213	.2867	-.775	.349	.551	1	.458	.808	.461	1.418
[Structures=1.00]	.210	.4384	-.649	1.069	.229	1	.632	1.234	.522	2.913
[Structures=.00]	0[b]	.	.	.	.	.	.	1	.	.
[RFP=1.00]	-.715	.2489	-1.203	-.228	8.262	1	.004	.489	.300	.796
[RFP=.00]	0[b]	.	.	.	.	.	.	1	.	.
[Matching=1.00]	6.401	18836.5416	-36912.542	36925.344	.000	1	1.000	602.507	.000	[a]
[Matching=.00]	0[b]	.	.	.	.	.	.	1	.	.
Funding	-.001	.0003	-.001	-8.150E-5	5.084	1	.024	.999	.999	1.000
Partners	.050	.1249	-.195	.295	.158	1	.691	1.051	.823	1.342
(Scale)	1[c]									

Dependent Variable: Licensing

Model: (Intercept), Structures, RFP, Matching, Funding, Partners

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.

<R&D projects led by universities>

- Dependent variables

SCI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	217	68.7	68.7	68.7
	Production	99	31.3	31.3	100.0
	Total	316	100.0	100.0	

Application

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	241	76.3	76.3	76.3
	Production	75	23.7	23.7	100.0
	Total	316	100.0	100.0	

Granted

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	257	81.3	81.3	81.3
	Production	59	18.7	18.7	100.0
	Total	316	100.0	100.0	

Licensing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	308	97.5	97.5	97.5
	Production	8	2.5	2.5	100.0
	Total	316	100.0	100.0	

- Independent variables

Categorical Variable Information

Factor	Structures	University+NFP	31	9.8%
		University+FP	28	8.9%
		University+None	257	81.3%
		Total	316	100.0%
	Matching	Inputs	60	19.0%
		No input	256	81.0%
		Total	316	100.0%
	RFP	Pressure	93	29.4%
		Free	223	70.6%
		Total	316	100.0%

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Covariate	Funding	316	5	3060	183.65	413.412
	Partners	316	0	9	.44	1.247

[SCI papers]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
23.649	6	.001

Dependent Variable: SCI

Model: (Intercept), Structures, Matching, RFP, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-.543	.0938	-.727	-.359	33.466	1	.000	.581	.483	.698
[Structures=2]	-.285	.3617	-.994	.424	.622	1	.430	.752	.370	1.528
[Structures=1]	-1.097	.6018	-2.277	.082	3.324	1	.068	.334	.103	1.086
[Structures=0]	0[a]	.	.	.	.	.	.	1	.	.
[Matching=1]	-.551	.2389	-1.020	-.083	5.325	1	.021	.576	.361	.920
[Matching=0]	0[a]	.	.	.	.	.	.	1	.	.
[RFP=1]	.187	.2110	-.227	.601	.786	1	.375	1.206	.797	1.823
[RFP=0]	0[a]	.	.	.	.	.	.	1	.	.
Funding	.001	.0003	.000	.001	10.894	1	.001	1.001	1.000	1.001
Partners	.080	.1415	-.197	.358	.321	1	.571	1.083	.821	1.430
(Scale)	1[b]									

Dependent Variable: SCI

Model: (Intercept), Structures, Matching, RFP, Funding, Partners

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

[Patent applications]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
60.932	6	.000

Dependent Variable: Application

Model: (Intercept), Structures, Matching, RFP, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-1.097	.1110	-1.314	-.879	97.612	1	.000	.334	.269	.415
[Structures=2]	-1.421	.4945	-2.390	-.452	8.257	1	.004	.241	.092	.637
[Structures=1]	-.578	.4863	-1.531	.375	1.413	1	.234	.561	.216	1.455
[Structures=0]	0[a]	.	.	.	.	.	.	1	.	.
[Matching=1]	.360	.2347	-.100	.820	2.352	1	.125	1.433	.905	2.270
[Matching=0]	0[a]	.	.	.	.	.	.	1	.	.
[RFP=1]	.793	.2220	.358	1.228	12.763	1	.000	2.210	1.430	3.414
[RFP=0]	0[a]	.	.	.	.	.	.	1	.	.
Funding	.001	.0004	.000	.002	6.614	1	.010	1.001	1.000	1.002
Partners	.014	.1586	-.297	.325	.008	1	.929	1.014	.743	1.384
(Scale)	1[b]									

Dependent Variable: Application

Model: (Intercept), Structures, Matching, RFP, Funding, Partners

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

[Patents-granted]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
42.326	6	.000

Dependent Variable: Granted

Model: (Intercept), Structures, Matching, RFP, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-1.181	.1134	-1.403	-.959	108.467	1	.000	.307	.246	.383
[Structures=2]	-1.017	.4688	-1.936	-.099	4.711	1	.030	.362	.144	.906
[Structures=1]	-.960	.5374	-2.013	.094	3.188	1	.074	.383	.134	1.098
[Structures=0]	0[a]	.	.	.	.	.	.	1	.	.
[Matching=1]	.257	.2360	-.205	.720	1.187	1	.276	1.293	.814	2.054
[Matching=0]	0[a]	.	.	.	.	.	.	1	.	.
[RFP=1]	.422	.2271	-.023	.867	3.455	1	.063	1.525	.977	2.380
[RFP=0]	0[a]	.	.	.	.	.	.	1	.	.
Funding	.001	.0003	.000	.002	8.877	1	.003	1.001	1.000	1.002
Partners	.145	.1548	-.158	.449	.880	1	.348	1.156	.854	1.566
(Scale)	1[b]									

Dependent Variable: Granted

Model: (Intercept), Structures, Matching, RFP, Funding, Partners

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

[Technology licensing]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
30.596	6	.000

Dependent Variable: Licensing

Model: (Intercept), Structures, Matching, RFP, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-2.682	.3554	-3.378	-1.985	56.932	1	.000	.068	.034	.137
[Structures=2]	-4.553	4274.7201	-8382.850	8373.745	.000	1	.999	.011	.000	.
[Structures=1]	1.056	1.0022	-.908	3.020	1.111	1	.292	2.876	.403	20.500
[Structures=0]	0[b]	.	.	.	.	.	.	1	.	.
[Matching=1]	1.203	.4903	.242	2.164	6.021	1	.014	3.330	1.274	8.706
[Matching=0]	0[b]	.	.	.	.	.	.	1	.	.
[RFP=1]	-1.157	.7736	-2.673	.359	2.236	1	.135	.315	.069	1.433
[RFP=0]	0[b]	.	.	.	.	.	.	1	.	.
Funding	.001	.0004	.000	.002	5.546	1	.019	1.001	1.000	1.002
Partners	-.144	.1850	-.506	.219	.605	1	.437	.866	.603	1.244
(Scale)	1[c]									

Dependent Variable: Licensing

Model: (Intercept), Structures, Matching, RFP, Funding, Partners

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.

<R&D projects led by PRIs>

- Dependent variables

SCI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	34	85.0	85.0	85.0
	Production	6	15.0	15.0	100.0
	Total	40	100.0	100.0	

Applications

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	26	65.0	65.0	65.0
	Production	14	35.0	35.0	100.0
	Total	40	100.0	100.0	

Granted

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	29	72.5	72.5	72.5
	Production	11	27.5	27.5	100.0
	Total	40	100.0	100.0	

Licensing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	37	92.5	92.5	92.5
	Production	3	7.5	7.5	100.0
	Total	40	100.0	100.0	

- Independent variables

Categorical Variable Information

Factor	Matching	Inputs	16	40.0%
		No input	24	60.0%
		Total	40	100.0%
	RFP	Pressure	20	50.0%
		Free	20	50.0%
		Total	40	100.0%
	Structures	PRI+NFP	19	47.5%
		PRI+FP	5	12.5%
		PRI+None	16	40.0%
		Total	40	100.0%

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Covariate	Funding	40	21	4000	967.47	1214.970
	Partners	40	0	11	1.48	2.088

[SCI papers]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
8.580	6	.199

Dependent Variable: SCI

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-1.653	.5897	-2.809	-.497	7.860	1	.005	.191	.060	.608
[Matching=1]	5.884	9569.3602	-18749.717	18761.485	.000	1	1.000	359.218	.000	.
[Matching=0]	0[b]	.	.	.	.	.	.	1	.	.
[RFP=1]	-.574	.7936	-2.129	.982	.522	1	.470	.564	.119	2.669
[RFP=0]	0[b]	.	.	.	.	.	.	1	.	.
[Structures=2]	-4.602	9569.3603	-18760.204	18750.999	.000	1	1.000	.010	.000	.
[Structures=1]	-3.523	9569.3603	-18759.124	18752.079	.000	1	1.000	.030	.000	.
[Structures=0]	0[b]	.	.	.	.	.	.	1	.	.
Funding	.000	.0002	.000	.001	.521	1	.471	1.000	1.000	1.001
Partners	-.125	.3539	-.819	.568	.125	1	.723	.882	.441	1.765
(Scale)	1[c]									

Dependent Variable: SCI

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.

[Patent applications]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
9.803	6	.133

Dependent Variable: Applications

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-1.244	.4548	-2.135	-.352	7.479	1	.006	.288	.118	.703
[Matching=1]	.537	.6428	-.723	1.797	.698	1	.403	1.711	.485	6.031
[Matching=0]	0[a]	.	.	.	.	.	.	1	.	.
[RFP=1]	.221	.5968	-.948	1.391	.138	1	.711	1.248	.387	4.019
[RFP=0]	0[a]	.	.	.	.	.	.	1	.	.
[Structures=2]	.285	.9428	-1.563	2.133	.092	1	.762	1.330	.210	8.441
[Structures=1]	1.130	1.3197	-1.457	3.717	.733	1	.392	3.096	.233	41.126
[Structures=0]	0[a]	.	.	.	.	.	.	1	.	.
Funding	6.828E-5	.0002	.000	.000	.114	1	.736	1.000	1.000	1.000
Partners	.088	.1581	-.221	.398	.313	1	.576	1.092	.801	1.489
(Scale)	1[b]									

Dependent Variable: Applications

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

[Patents-granted]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
6.310	6	.389

Dependent Variable: Granted

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-1.129	.4509	-2.013	-.245	6.271	1	.012	.323	.134	.782
[Matching=1]	.466	.7045	-.915	1.847	.438	1	.508	1.594	.401	6.341
[Matching=0]	0[a]	.	.	.	.	.	.	1	.	.
[RFP=1]	-.295	.6332	-1.536	.946	.217	1	.641	.744	.215	2.575
[RFP=0]	0[a]	.	.	.	.	.	.	1	.	.
[Structures=2]	1.196	.9786	-.722	3.114	1.493	1	.222	3.306	.486	22.506
[Structures=1]	.606	1.3999	-2.137	3.350	.188	1	.665	1.834	.118	28.506
[Structures=0]	0[a]	.	.	.	.	.	.	1	.	.
Funding	2.438E-5	.0002	.000	.000	.014	1	.904	1.000	1.000	1.000
Partners	-.192	.2184	-.620	.236	.775	1	.379	.825	.538	1.266
(Scale)	1[b]									

Dependent Variable: Granted

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

[Technology licensing]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
6.588	6	.361

Dependent Variable: Licensing

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-6.502	6881.5482	-13494.089	13481.084	.000	1	.999	.002	.000	[a]
[Matching=1]	5.675	9111.9854	-17853.488	17864.839	.000	1	1.000	291.610	.000	[a]
[Matching=0]	0[b]	.	.	.	.	.	.	1	.	.
[RFP=1]	-.115	.9091	-1.897	1.667	.016	1	.900	.892	.150	5.296
[RFP=0]	0[b]	.	.	.	.	.	.	1	.	.
[Structures=2]	.535	11418.5805	-22379.472	22380.541	.000	1	1.000	1.707	.000	[a]
[Structures=1]	.824	11418.5806	-22379.182	22380.831	.000	1	1.000	2.280	.000	[a]
[Structures=0]	0[b]	.	.	.	.	.	.	1	.	.
Funding	-3.070E-5	.0006	-.001	.001	.003	1	.956	1.000	.999	1.001
Partners	-.306	.4879	-1.262	.650	.393	1	.531	.736	.283	1.916
(Scale)	1[c]									

Dependent Variable: Licensing

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.

<R&D projects led by hospitals>

- Dependent variables

SCI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	58	78.4	78.4	78.4
	Production	16	21.6	21.6	100.0
	Total	74	100.0	100.0	

Applications

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	57	77.0	77.0	77.0
	Production	17	23.0	23.0	100.0
	Total	74	100.0	100.0	

Granted

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	63	85.1	85.1	85.1
	Production	11	14.9	14.9	100.0
	Total	74	100.0	100.0	

Licensing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	70	94.6	94.6	94.6
	Production	4	5.4	5.4	100.0
	Total	74	100.0	100.0	

- Independent variables

Categorical Variable Information

Factor	Matching	Inputs	29	39.2%
		No Input	45	60.8%
		Total	74	100.0%
	RFP	Pressure	46	62.2%
		Free	28	37.8%
		Total	74	100.0%
	Structures	Hospital+NFP	9	12.2%
		Hospital+FP	21	28.4%
		Hospital+None	44	59.5%
		Total	74	100.0%

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Covariate	Funding	74	30	4016	340.65	621.474
	Partners	74	0	8	1.09	1.994

[SCI papers]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
4.216	6	.647

Dependent Variable: SCI

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-.665	.2751	-1.204	-.126	5.844	1	.016	.514	.300	.882
[Matching=1]	-.101	.5087	-1.098	.896	.039	1	.843	.904	.334	2.450
[Matching=0]	0[a]	.	.	.	.	.	.	1	.	.
[RFP=1]	-.442	.3954	-1.217	.333	1.251	1	.263	.643	.296	1.395
[RFP=0]	0[a]	.	.	.	.	.	.	1	.	.
[Structures=2]	.111	.6256	-1.115	1.338	.032	1	.859	1.118	.328	3.810
[Structures=1]	-.525	.6897	-1.877	.827	.580	1	.447	.592	.153	2.286
[Structures=0]	0[a]	.	.	.	.	.	.	1	.	.
Funding	.000	.0003	-.001	.001	.197	1	.657	1.000	.999	1.001
Partners	.217	.1359	-.050	.483	2.545	1	.111	1.242	.952	1.621
(Scale)	1[b]									

Dependent Variable: SCI

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

[Patent applications]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
20.672	6	.002

Dependent Variable: Applications

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-.816	.2893	-1.383	-.249	7.948	1	.005	.442	.251	.780
[Matching=1]	.768	.6051	-.418	1.954	1.612	1	.204	2.156	.659	7.059
[Matching=0]	0[a]	.	.	.	.	.	.	1	.	.
[RFP=1]	-.690	.4236	-1.520	.140	2.654	1	.103	.502	.219	1.150
[RFP=0]	0[a]	.	.	.	.	.	.	1	.	.
[Structures=2]	-.894	.7854	-2.433	.646	1.295	1	.255	.409	.088	1.907
[Structures=1]	-1.406	.8426	-3.057	.246	2.784	1	.095	.245	.047	1.278
[Structures=0]	0[a]	.	.	.	.	.	.	1	.	.
Funding	.000	.0004	.000	.001	1.164	1	.281	1.000	1.000	1.001
Partners	.387	.1708	.052	.722	5.135	1	.023	1.472	1.054	2.058
(Scale)	1[b]									

Dependent Variable: Applications

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

[Patents-granted]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
17.332	6	.008

Dependent Variable: Granted

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-1.527	.3778	-2.268	-.786	16.334	1	.000	.217	.104	.455
[Matching=1]	1.120	.6733	-.199	2.440	2.768	1	.096	3.065	.819	11.470
[Matching=0]	0[a]	.	.	.	.	.	.	1	.	.
[RFP=1]	-.401	.5125	-1.405	.604	.611	1	.434	.670	.245	1.829
[RFP=0]	0[a]	.	.	.	.	.	.	1	.	.
[Structures=2]	-.627	.8147	-2.223	.970	.592	1	.442	.534	.108	2.638
[Structures=1]	-1.054	.8741	-2.768	.659	1.455	1	.228	.348	.063	1.932
[Structures=0]	0[a]	.	.	.	.	.	.	1	.	.
Funding	.000	.0003	.000	.001	.202	1	.653	1.000	1.000	1.001
Partners	.321	.1522	.023	.619	4.445	1	.035	1.378	1.023	1.857
(Scale)	1[b]									

Dependent Variable: Granted

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

[Technology licensing]

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
11.266	6	.080

Dependent Variable: Licensing

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Compares the fitted model against the intercept-only model.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-6.486	4009.9416	-7865.827	7852.855	.000	1	.999	.002	.000	[a]
[Matching=1]	5.846	4009.9416	-7853.495	7865.187	.000	1	.999	345.906	.000	[a]
[Matching=0]	0[b]	.	.	.	.	.	.	1	.	.
[RFP=1]	-.071	.8485	-1.734	1.592	.007	1	.933	.931	.177	4.913
[RFP=0]	0[b]	.	.	.	.	.	.	1	.	.
[Structures=2]	-5.885	8508.4237	-16682.089	16670.319	.000	1	.999	.003	.000	[a]
[Structures=1]	-.959	1.0807	-3.077	1.159	.787	1	.375	.383	.046	3.188
[Structures=0]	0[b]	.	.	.	.	.	.	1	.	.
Funding	9.808E-5	.0004	-.001	.001	.075	1	.784	1.000	.999	1.001
Partners	.102	.1840	-.259	.462	.305	1	.581	1.107	.772	1.588
(Scale)	1[c]									

Dependent Variable: Licensing

Model: (Intercept), Matching, RFP, Structures, Funding, Partners

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.