UNIVERSITIES' ACADEMIC RESEARCH AND KNOWLEDGE-TRANSFER ACTIVITIES IN A CATCH-UP COUNTRY:

THE CASE OF KOREA

Universities' Academic Research and Knowledge-transfer Activities in a Catch-up Country: the Case of Korea

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SUMMARY

The main research topic of this study is universities' academic research and knowledge-transfer activities in a catch-up country, particularly the relationship between the two activities, which has been rarely examined in previous research. In order to understand this issue against existing literature, a critical review of previous studies has been attempted, considering the idiosyncratic characteristics of the Korean national innovation system. As a result, at the three analysis levels (i.e. national, organisational and individual levels), we propose three conceptual elements respectively: a tentative historical path of universities in catch-up countries; critical factors influencing knowledge-transfer activities of universities in catch-up countries; and academics operating in synergy mode. Thereafter, based on the methodology integrating not only the three analysis levels but also qualitative and quantitative approaches, we analyse the data collected from the interviews with Korean academics, survey responses from Korean academics and government White Papers on the activities of Korean universities.

The results show a close and positive relationship between Korean universities' academic research and knowledge-transfer activities across the three levels. Firstly, during the last several decades, the Korean government has strongly encouraged the development of teaching, academic research and knowledge-transfer activities of Korean universities in harmony with the different developmental stages of Korean industry. This has resulted in selective patterns of the universities' three activities (e.g. concentration of scientific activities in certain fields). Secondly, organisational factors such as scientific capacity and industry funding are important for universities' knowledge-transfer activities in a catch-up country, which corroborates the positive relationship between the two activities. Finally, in terms of the factors influencing the synergy mode (i.e. a positive relationship between academic research and knowledge-transfer activities), academics' career stage and disciplines are important. This is related to the rapid expansion of the Korean academic system and the selectivity found in its activities. Based on these findings, it is tempting to conclude that universities in East Asian catch-up countries have developed their own academic system different from those in developed countries, which can be characterised as having strong government control and a high level of interaction with other actors in the national innovation system. Therefore, the application of the controversy over the direct economic contribution of universities in western countries to the context of catch-up countries is quite limited.

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Chapter 1 Introduction

1.1 The motivation of the research

Awareness of the importance of academic knowledge for technological innovation is increasing both for policy practitioners and academics. Various policy measures for strengthening university-industry linkages have therefore been implemented not only in developed countries but also in developing countries. However, particularly in developing countries, science policy practitioners are less well-informed as to how best to implement programmes, and how to create legal regulations in order to commercially exploit their academic potential, considering the characteristics of the national innovation system (i.e. universities in those countries have insufficient research resources, and their links to industry are relatively weak).

Within the academic community, the contribution of academic research to industrial innovation has been highlighted within the last few decades. For example, university research is positively related to the R&D intensity of companies (Nelson, 1986), and to firms' invention of new processes and products (Mansfield, 1991, 1998). However, despite some recent attention to the relationship between public science and industrial innovation in developing countries (Nelson, 2004; Mazzoleni, 2003; Albuquerque, 2001; Pavitt, 2001, 1998), the topic is still relatively unexplored. Furthermore, similar issues, including weak university-industry linkages in developing countries, have been investigated only very recently (e.g. Sutz, 2000; Intarakumnerd et al., 2002). Additionally, the relationship between universities' academic research and entrepreneurial activities in developing countries is far less well-explored than the relationship between public science and industrial innovation.

South Korea (hereafter, referred to as Korea) is known as a successful country in terms of its rapid economic catch-up. Several studies have been carried out to explain the process of innovation of Korean firms set against the overall Korean system of innovation (Kim, 1997; Shin, 1996; Amsden, 1989). In contrast, the role of Korean universities in the catch-up process has not been adequately explained, other than receiving some negative comments in the midst of a brief description of the overall

Korean innovation system (Kim, 2000; Pack, 2000). Therefore, academics interested in the Korean national innovation system have arrived at the point where they need to focus more closely on subsystems such as universities and publicly funded research institutes.

1.2 Research Objectives

In the previous section, the motivation and problem domain of this thesis was introduced. Thus, in order to clarify the objective of this study, the aforementioned issues will be more intensively examined both in theoretical and empirical terms.

First of all, in terms of empirical evidence, the evolution of universities in developing countries has not been sufficiently investigated (Chapman and Austin, 2002). In particular, the evolution of the three main missions (teaching, research and service to society) of universities has rarely been explored in the context of the characteristics of the national innovation system (Hershberg et al, 2007). This study therefore aims to understand the three missions of Korean universities by focusing on the relationship between the second and the third missions, considering the idiosyncratic properties of the Korean national innovation system. As a result, the empirical evidence found in this study can contribute to comparative studies between Korean universities and those of other developing countries, as well as developed countries. Moreover, the revealed conditions for ensuring efficient relationships can be a lesson for universities in developing countries as well as those in developed countries.

In theoretical terms, we can introduce two contrasting views on the relationship between academic research and direct contributions to the economy. According to the ‘triple helix’ and ‘national innovation system’ approach (Etzkowitz, 2008; Freeman and Soete, 1997), strengthening the linkages between university and industry is one of the essential conditions for technological innovation of the national system. In contrast, some scholars in ‘the new economics of science’ warn that industry’s direct involvement in academic research activity can hamper the efficient operation of scientific community, which results in negative effects not only for academia but also for industry eventually (Nelson, 2004; David, 2000). However, in developing countries, the role and condition of universities’ activities have been different from those in developed countries. For example, elite teaching has been a main mission for universities in developing countries, while their research activity has generally not been strongly established due to inadequate research resources (World Bank, 2000; Altbach, 1991). If we consider this different situation of developing countries, the controversy about the relationship between academic research and industry involvement needs to be reassessed and adjusted. Thus, based on the empirical findings suggested, this study aims to evaluate the theoretical frameworks introduced above. As a result, this study will contribute to our understanding of the relationship between the research and economic contributions of universities, particularly in catch-up countries as well as in developing countries.

If we consider the research objectives suggested above, the central research question guiding this research can be summarised as follows: **what are the relationships between academic research and knowledge-transfer activities in Korean universities?** By answering this question, we can meet the objectives of this research. That is to say, in empirical terms, we can observe the research and knowledge-transfer activities of Korean universities using quantitative and qualitative methods, and can investigate the relationship between the two activities, considering the idiosyncratic properties of the Korean higher education system and the Korean innovation system. In terms of theoretical perspectives, based on empirical evidence of the relationship between academic research and knowledge-transfer activities of Korean universities, we can discuss the application of the debate between the two groups of scholars (e.g. triple helix and the new economics of science). In particular, in the context of developing countries, an adjusted or alternative conceptual framework explaining the relationship between academic research and knowledge-transfer activities can be created.

In order to grasp the overall picture related to the research objective, the main research question is addressed at multiple levels (i.e. the levels of the national higher education system, individual organisations and academics) by the provision of appropriate empirical evidence as well as conceptual discussion. This is discussed in Section 1.3 in more detail. Consequently, three further questions at different levels are addressed in our study.

- Firstly, how are research and knowledge-transfer activities related to each other in the Korean academic system?

- Secondly, is the research capacity of universities critical for entrepreneurial activities at an organisational level?
- Thirdly, what are the determinants of the positive or negative relationship between research and entrepreneurial activities of individual academics?

1.3. Scope and approach of the study

In order to address the main and subsequent questions suggested in the previous section, the scope of the study can be described in cross-sectional and longitudinal terms. First of all, in order to investigate the multi-level research questions, the research is implemented at three levels in cross-sectional terms. For example, in order to address the third question above, data collection and analysis are carried out at the level of individual academics. In longitudinal terms, the scope of this study is based on the current research and entrepreneurial activities of Korean universities and academics in science and engineering after two academic 'revolutions' have taken place. Additionally, the historical background and the evolution of the Korean higher education system in the last few decades are examined in the first empirical chapter.

Furthermore, the mixed approach adopted here, which integrates quantitative and qualitative approaches, enables us to generate robust findings (Creswell, 2002). As a quantitative approach, data were collected through the distribution of a survey questionnaire to individual academics, and from the annual survey of Korean universities. As a qualitative approach, interviews with Korean academics, and document analysis were both conducted. Thus, the analysis was implemented in a complementary way. In other words, the interpretation of the quantitative findings is based not only on statistical results but also on the observations of individual academics during the interviews.

1.4 The Structure of the Thesis

This thesis consists of four major parts. The first part provides a conceptual framework for investigating the research questions (Chapter 2). This framework is mainly based on existing studies in developed countries, but with some conceptual adjustment carried out allowing for the characteristics of the innovation systems of developing countries.

The second part provides the methodology of this study (Chapter 3). As introduced in Section 1.3, the research method was based on the integration of three different levels and on the mixed qualitative and quantitative approach.

The third part of the thesis is the empirical core of the study (Chapters 4, 5, 6 and 7). Each chapter addresses research questions at different levels. In Chapters 4 and 5, the analysis is carried out at the system level. Chapter 6 focuses on the organisational level, while Chapter 7 focuses on the individual level. Finally, based on the empirical findings presented in the previous chapters, Chapter 8 provides the conclusion of this study. In this conclusion, after a summary of each level of findings in the empirical chapters, and drawing on the conceptual framework suggested in Chapter 2, we focus on the main research question by integrating these findings and by considering the interactions between different actors at these three levels.

Chapter 2 Literature Review and Conceptual Framework

2.1 Introduction

In this chapter, theoretical issues regarding the relationship between research and the entrepreneurial activities of universities are addressed at three different levels: the national higher education system, the organisation (i.e. individual universities) and individual academics. In addition, certain issues regarding the context of developing countries are discussed at each level.

In Section 2.2, a review of existing literature on research and entrepreneurial activities of universities is introduced. Firstly, the characteristics of the first and second academic revolutions in industrialised countries are briefly summarised. Secondly, the two contrasting views on the close interaction between the universities' academic research (the 2nd mission) and direct contributions to the economy (the 3rd mission) in industrialised countries are discussed in the next subsection. Finally, the application of the two issues presented in the two previous subsections is discussed in the context of developing countries.

The relationship between universities' research and knowledge-transfer activities at the organisational level is the main focus of Section 2.3. First of all, based on several selected studies, a new categorisation of factors influencing the knowledge-transfer activities of universities is developed. Next, based on the four new categories, we review literature addressing the influence of scientific capacity, financial structure, and institutional and environmental factors (i.e. size, legal status and various characteristics of geographical location and industry partners) on knowledge-transfer activities. In particular, the importance of scientific capacity and sources of funding in the knowledge-transfer activities of universities and, again, the application of those issues in the context of developing countries are discussed.

Section 2.4 starts with the debate on the negative and positive relationships between academic research and the knowledge-transfer activities. Next, a conceptual framework centring on the distinction between 'a synergy mode' and 'a separation mode' (representing positive and negative relationships between the research and entrepreneurial activities of individual academics) is developed. Finally, in Section 2.5, after presenting a summary of the review presented in the previous three sections, we suggest an integration of different levels of conceptual frameworks. In particular, its application to our case (i.e. Korean universities) is discussed.

2.2 Science, Technology and Universities

This section examines three main issues: firstly, the institutionalisation of scientific research and the emergence of universities' direct contribution to economy in western countries; secondly, the debate on the effect of industry's engagement with academia; and thirdly, research and entrepreneurial activities of universities in developing countries.

2.2.1 The emergence of the second and the third missions of universities

The university, as an autonomous community of students and teachers providing education in specific disciplines, is generally regarded as an invention of western society (Charle & Verger, 1989). For a long time, teaching has usually been seen as the main mission of universities since the mediaeval age. Even though scientific research as a profession had been institutionalised outside of universities, it began to be widely formalized as another mission of the universities in the 19^{th} century (Ben-David, 1984). Later, research skills were transferred to students through seminars and training in laboratories rather than through private groups (Charle & Verger, 1989). This change started in Germany with the so-called 'Humboldtian University'. The Humboldtian model can be characterised in terms of the strong autonomy of universities and academics in spite of their dependency on state funding (Martin, 2003; Geuna, 1999).

During the 1980s, many western countries were exposed to a change that influenced the relationship between university and society. Martin (2003) suggests that there were three driving forces for this change: growing competition in global market, tight constraints for government research funding, and the growing importance of science and technology. Therefore, under these conditions, the 'third mission' of universities, that of making a direct socio-economic contribution to society, emerged to become more prominent (Martin & Etzkowitz, 2001). Against this background, in terms of the relationship between universities and society, the Humboldtian social contract has been 'revised'. Guston and Keniston (1994) maintain that under the new social contract, the scientific community is accountable in providing society with a rationale of not only their 'usefulness' but also the 'relevance' of their scientific research for public interests such as national security and the local economy. In this vein, the academic knowledge from university research started to be recognised as an important source for economic growth by public policy makers as well as academics. In order to exploit this academic potential, many industrialised countries have witnessed a policy re-orientation to strengthen the interaction between academic research and its industrial application (Mowery & Sampat, 2005).

However, the above description on the emergence of the two missions can be criticised for being oversimplified. With regard to the historical development of higher education in industrialised countries, the third mission is not totally new; moreover, different types of universities have coexisted within one country. For example, in the late 19th century, we can find a type of university which dedicated themselves to the third mission, such as technical universities and *Fachhochschulen* in Germany which coexisted with Humboldtian universities (Martin, 2003). Furthermore, the above description could be criticised for overlooking the fact that the two missions of universities vary according to the idiosyncrasies of the role and structure of each national system. At the end of the 18th century, France created the Ecole Polytechnique and similar institutions to provide national military technology. In spite of these counter-examples, the simplified explanations of the sequential emergence of the second and third missions of universities provide us with a starting point for understanding the influence of the introduced mission (direct socio-economic contributions to society) on the pre-existing two missions (teaching and research), as we shall discuss in the next subsection.

2.2.2 Relationship between the second and the third missions of universities

We can introduce two groups of contrasting theoretical views on the relationship between the second and third missions of universities and between university and industry at the macro level. The first group of theoretical frameworks such as 'triple helix', the 'mode 2' and the 'national innovation system' view the relationship positively.

Firstly, the ‘triple helix’ framework, developed by Etzkowitz and Leydesdorff (1997), stresses that in a knowledge-based economy, the role of the university has emerged as an important partner to the other two major actors (i.e. industry and government). These authors even maintain that the three actors increasingly ‘take the role of the other’ (Etzkowitz 2003), so the boundary between the university, industry and government is becoming blurred. In this vein, Etzkowitz (2008) regarded the universities actively capitalising academic knowledge in the ‘triple helix’ as ‘entrepreneurial universities’. Moreover, the emergence of the integration of research and economic development (i.e. the transition of the research university into the entrepreneurial university) is referred to as the ‘second academic revolution’ (Webster & Etzkowitz, 1991; Etzkowitz, 1989). According to the spirit of the ‘triple helix’, ‘entrepreneurial universities’ and ‘the second academic revolution’, the close interaction between the second mission and the third mission of universities will possibly generate productive output to society as well as to universities themselves. However, these concepts can be criticised for the weak conceptual contribution of the model (Shinn, 2000) and evidence of some historical counter examples (e.g. the land-grant universities in the US) in terms of the novelty of the university model (Martin & Etzkowitz, 2001).

Secondly, the ‘mode 2’ approach put forwarded by Gibbons et al. (1994) provides an explanation for the recent change of knowledge-production processes. According to these authors, in mode 2, the producer of knowledge exists not only in the academic sphere but also in the networks between universities, research institutes, governments and industry. Therefore, knowledge tends to be produced ‘in the context of application’. In this vein, in terms of problem-solving, the knowledge has a ‘trans-disciplinary’ nature. However, this idea can be criticised in that the mode 2 concept is not entirely new (Martin, 2003). Historically, the German and the US universities in the 19th century actively participated in application-oriented research. Furthermore, regarding the trans-disciplinary property, historical observations (e.g. the evolution of biology and the transition from chemistry into biochemistry) imply that multi- and inter- disciplinary research often later transferred into one ‘discipline’ (Martin & Etzkowitz, 2000). In spite of some of weaknesses mentioned above, this perspective provides a possible justification for the assertion that a university can actively generate knowledge through interaction with other actors such as industry and government.

Finally, as an approach to explain the international differences in economic performance (particularly, the Japanese case), the 'national innovation system' was introduced by Freeman (1987), and was later developed more theoretically by other scholars such as Lundvall (1992) and Nelson (1993). While much previous science policy research concentrates on individual actors (e.g. research institutes and universities), this approach focuses on the analysis of institutional settings such as the relationship between the actors in the national system. However, the NIS approach focuses more on the role of firms and regards universities and government merely as supporting structures, while the triple helix approach places more emphasis on the leading role of universities (Etzkowitz, 2003; Etzkowitz & Leydesdorff, 2000). In spite of this difference, strong university-industry linkages are regarded as one of the important conditions for generating innovation in the national system. Therefore, from this perspective, the relationship between the second and the third missions is not only positive but also essential.

However, some concerns that the identity of academia might be undermined, due to the direct exposure to industrial influences, have been raised by a group of scholars engaged in developing the 'new economics of science' as well as by certain other researchers.

Firstly, in spite of criticism that such ideal types lack supporting empirical evidence, Merton (1973) suggests that the operation of the scientific community is governed by four fundamental norms (CUDOS): communalism, universalism, disinterestedness and organised scepticism. In particular, regarding communalism, David (2003) maintains that scientific activity is based on 'a social process' rather than 'an individual program'. Therefore, in terms of the operation of the 'open science' community, privatisation of the results of scientific research hampers the free access of community members to 'the academic commons'. Moreover, allocation of scientific resources on the basis of usefulness rather than by scientific importance tends to distort the academic reward system, which is mainly based on priority of discovery and, accordingly, tends to result in inefficiency with regard to scientific progress. This could negatively affect both academia and industry in the long run and is referred to as the 'tragedy of the academic commons' (Nelson, 2004). According to this view, the academic research and direct economic contribution to society of universities can be regarded as being in conflict with one another.

Next, Slaughter and Rhoades (1996) assert that the governments in industrialised countries have recently focused on the exploitation of academic research by university-industry linkages as a source of technological innovation. Responding to this environmental change, many universities are actively involved in the commercialisation of their intellectual assets by responding to financial cuts from government in their activities. In a similar vein, defining ‘the commercialisation of higher education’ as ‘the efforts of universities to make profit by teaching, research and other activities on campus’, Bok (2003) warns that fundamental academic values are under threat. However, he disagrees somewhat with Slaughter and Rhoades (1996), by asserting that the decrease in public funding is not the ‘catalyst’ for the commercialisation, and that present commercialisation represents the final stage in the universities’ evolution. According to these views, academic activities can be influenced by their interaction with industry, and, in order to protect academic identity from external manipulation, the scientific community need to keep an appropriate distance from industry as well as government.

However, the national-level empirical evidence in the US does not strongly support the claim that the academic research activity of universities has been negatively influenced by their close interaction with industry (Mowery et al., 2004) According to the US National Science Board, despite the two-fold increase in the number of university-industry research centres in the 1980s, the proportion of US universities’ basic research remained relatively constant (Van Looy et al., 2006). Other researchers also found similar evidence. Between 1981 and 1995, in spite of the abrupt increase of academic patenting by US universities, basic research did not decrease (Hicks and Hamilton, 1999). Based on the analysis of 18-years of panel data on US universities, Owen-Smith (2003) suggests that a new hierarchical structure for universities called the ‘hybrid regime’ has emerged after implementation of the Bayh-Dole Act. In other words, under the influence of the commercial orientation of US science system, the success of the universities in the academic arena has become pratly dependent on that in the commercial arena and vice versa.

2.2.3 Emergence of the second and the third missions of universities and their relationship in developing countries

In the previous subsection, regarding the relationship between the second and the third missions of universities, we discussed two contrasting views on the university-industry linkage. These two views, as well as the controversy between them, are based on the development of academia in industrialised countries. However, in the context of developing countries, the historical and institutional background is very different from that in developed countries, so the application of these reviews above needs to be discussed from another perspective. Therefore, in this subsection, after a review of the literature on science and universities in developing and catch-up countries, we discuss the relationship between the second and third missions taking account of the context of these countries.

Emergence of academic research and entrepreneurial activities of universities in developing countries and catch-up countries

Nowadays, it is usual to find various institutional forms of higher education outside of western countries where universities are created. However, the role of higher education in developing countries is quite different from that in industrialised countries. Furthermore, if we consider the universities' public function and close entanglement in the national system, universities in developing countries are likely to show their own characteristics with regard to carrying out their three missions. In order to explore these idiosyncrasies, we need to consider some conceptual modifications to take account of the context in developing countries. Accordingly, the existing literature on teaching, research and economic contribution of universities in developing countries, and particularly the relationship between the second and the third missions, is discussed in what follows.

First of all, **teaching** has usually been the main mission for universities in developing countries as in industrialised countries. However, the accessibility of higher education is quite different in the two groups of countries. According to Trow's definition, most developing countries still remain in the stage of 'elite education' (less than 15% of students of university age enrolled) rather than achieving 'mass education' (up to 50%

enrolment rate), while industrialised countries have reached at 'universal education' stage (with an enrolment rate) (World Bank, 2000). In OECD countries, more than 55% of students who enrolled in upper secondary education in 2005 entered tertiary education (OECD, 2007). Regarding the generally low level of accessibility to higher education in developing countries, Chapman and Austin (2002) suggest a higher return of investment in primary and secondary education than higher education in those countries as a possible factor.

However, more recently some developing countries have been facing an increasing need for higher education. This is because they are now producing more potential entrants for tertiary education due to a long period of investment in secondary and primary education, and because they are becoming aware that high-quality labour is an important factor for their economic development (World Bank, 2000). In the case of catch-up countries such as Korea and Taiwan, they have produced a considerable number of graduates (particularly, in the field of science and engineering) based on a rapidly increasing enrolment rate in higher education from the early catch-up stage (Mazzoleni and Nelson, 2007; Mazzoleni, 2003; Hobday, 1993). In this process, the overseas trained and highly qualified scientists and their return home has been important for upgrading the technological capabilities for the absorption of international technical knowledge (Albuquerque, 2001). In contrast, from the early period of economic development, universities in Latin America focused on the education of a small number of 'professional elite' (particularly, outside the field directly applicable to industry and agriculture) (Bernasconi, 2008; Ribeiro, 1969). The key difference between the Korean and Latin American cases is the scale of provision of domestically trained engineers during the industrialisation.

Secondly, various existing studies in the literature addressing academic **research** in developing countries suggest three characteristics: backwardness of scientific resources, dependence on overseas academia, and isolation of the academic system from the local communities. Regarding the backwardness of scientific resources for research, the academics in the centre lead the main stream of science based on well-equipped laboratories and attracting the brightest students from all over the world, and they operate prestigious international journals in their mother tongue (Altbach, 1991). In contrast, those in the periphery (at the opposite end) tend to copy existing knowledge and have difficulty in producing creative knowledge due to their unprivileged condition (Hershberg et al., 2007). For example, India has the third biggest university system in the world, but most of the universities are suffering from inadequate financial support, obsolete laboratories and small libraries. Although the situation has begun changing recently, it was very hard to find a university with a 'critical mass' in terms of facilities and researchers a few decades ago (Altbach, 1991). Some universities in less developed countries, especially in the Middle East, are expected to meet the needs of society in regard to agricultural research, commerce, health and so on (Akrwi, 1969). Unfortunately, it is still not unusual to find inadequate research capacity and facilities to solve the practical problems of the local area.

In terms of dependency, Shils (1972) maintains that the academics in major universities in the industrialised world are regarded as being located in centre, while those in developing countries are on the periphery. Based on this idea, Shrum and Shenhav (1995) assert that some researchers in less developed countries have strong connections to the 'scientific core' in developed countries, so they can be recognised as competent scholars by addressing research topics evaluated as important in the core. Therefore, academic research in developing countries tends to be mainly focused on the interests of the academics' own global community rather than local needs.

Isolation from other local actors is another characteristic of academia in developing countries. In other words, the relationship between academia and industry in developing countries does not show strong linkages, and this has largely been the case until today (Crane, 1977; Waissbluth et al., 1988; Sutz, 2000; Intarakumnerd et al., 2002). Therefore, some scholars (e.g. Goontatilake, 1984; Shrum & Shenhav, 1995) maintain that the academic activities in less developed countries tend to be isolated from local needs. For example, Bryant (1969) maintains that in developing countries there is some mismatch between the biomedical technology and the diseases of their countries. Moreover, Latin American universities have focused on basic research that is not directly applicable to industrial innovation (Velho, 2004; Thomas, 1999).

However, some studies refuting the 'linear centre-periphery' relationship in global knowledge production have emerged. In her case study of the research collaboration between Iceland and Canada, Thorsteinsdóttir (1998) maintains that scientists in a 'scientific periphery' or in 'small science system' can carry out their own research in certain disciplines based on exploiting their local advantages. This study shows the possibility that academic research closely related to local demand and industrial development in periphery can be carried out. Furthermore, concerning the development of science and universities in catch-up countries such as Korea, Taiwan, Singapore and Malaysia, Altbach (1998) stresses the importance of infrastructure (e.g. laboratories and libraries) and the sharing of scientific findings (e.g. through domestic journals and scientific societies) in order to create a domestic scientific system.

Thirdly, in terms of the third mission of universities, **the contribution to the local economy** through academic research is difficult due to the inadequate research capacity as shown above. In the case of East Asian catch-up countries, it is very difficult to find evidence that university research itself directly contributed to their economic catch-up (Altbach, 1989). Mazzoleni and Nelson (2007) also maintain that the important contribution to catch-up has been the result of the application of knowledge or skills of technical labour in the field of engineering and applied research rather than directly from basic academic research. In a similar vein, Mazzoleni (2003) maintains that in the process of catch-up, the education system is important, because education enables countries to absorb external knowledge and to diffuse knowledge through the national system. He also adds that, in the case of Korea and Taiwan, the exploitation of human resources trained overseas is positively related to the national absorptive capacity.

Recently, developing countries as well as developed countries have witnessed a policy orientation towards strengthening the interaction between academic research and industrial application (Etzkowitz et al, 2000; Sutz, 2000; Dagnino and Velho, 1998). As the economy becomes more knowledge-based, universities' economic contribution to society through the transfer of academic knowledge through formal and informal channels (i.e. human resource training and contracted research) has begun to be emphasised in developing countries as well as in catch-up countries (Altbach, 2004). For example, some public Brazilian universities are increasingly their production of patents (Etzkowitz at al., 2005); furthermore, 1,500 companies have been spun-off from Brazilian universities in the last two decades (Anprotec, 2007). Catch-up countries in Asia such as Singapore and Korea have recently started to commercialise academic research (Hershberg et al., 2007). As a distinctive example, the Singaporean case shows recent efforts to create a strong interaction between the universities' activities and local economic development. In order to support 'strategic' sectors such as biotechnology, medical and financial services, the Singaporean government expanded university enrolment in these disciplines and permitted the establishment of private universities for the first time (Tan, 2004). Furthermore, in the late 1990s, the National University of Singapore (NUS) launched a series of initiatives, including reorganisation of its technology transfer offices to be more 'inventor oriented', creation of a Venture Support unit and provision of seed funding, which encouraged NUS researchers to begin spin-off activities (Wong et al, 2007).

Relationship between the second and third mission of universities in developing countries and catch-up countries

As far as we can tell, it is very hard to find existing literature directly investigating the relationship between the academic research and economic contributions of universities in developing countries. However, some studies on the relationship between science and technology in rapid catch-up countries such as Korea and Taiwan can provide us with relevant material to approach the relationship we are interested in. Regarding the relationship between technical development and scientific progress, Kim (1997) asserts that after the low-level technological capacity of catch-up countries is achieved (i.e. the 'imitation' period), there is a period of high-level R&D capacity based on science (i.e. the 'innovation' period). This can be termed as an 'inverted linear model', because it is in contrast to the view that scientific knowledge benefits technological development in the long run (i.e. the linear model of innovation). Moreover, Okimoto and Saxonhouse (1987) explain technology development in Japan (as a successful catch-up country in the early 20th century) in terms of 'backward integration' in their case study. They argue that the recent achievements of Japanese basic research (ranked 4th in the world in terms of SCI publications from 1981 to 1994) are influenced by developments in industrial technology. This can be called the 'influence of national technology on the science base'.

In contrast, in terms of the 'influence of the science base on technology', Albuquerque (2001) argues that a certain level of scientific capacity is a 'precondition' for technological progress and industrial development, while the main role of science in developing countries, he argues, is different from that in advanced countries. According to this scholar, science in catch-up countries could enable the national innovation system to connect with 'the international scientific and technological flows'. He adds that investment in the scientific infrastructure should begin during the initial stage of catch-up. In this vein, the 'inverted linear model' underestimates the role of universities in educating domestic engineers and scientists and in transferring tacit technological knowledge embodied in graduates to industry at the early catch-up phase. In this process, if we interpret 'the science' as a broader term including academic research as well as training of scientists, the inverted model is not contradictory to this model.

As a synthesis of the two contrasting models, we can suggest another view (referred to as an 'interaction' model) on the relationship between science and technology in catch-up countries. Pavitt (1998, 2001) suggested that there are close links between national science, national technology and the national economy. Lattimore and Ravesz (1996) investigated the relationship between national patterns of scientific publications and major societal requirements such as medical, agricultural and industrial needs. They categorise Korea, Taiwan, Singapore and India as 'industry-based countries' in terms of patterns of comparative advantage in scientific publications. Empirically, catch-up countries such as Korea and Taiwan show a simultaneous increase in both publishing and patenting, whereas Brazil only shows an increase in publishing (Bernardes and Albuquerque, 2003). In the same vein, analysing the publishing and patenting activities of 241 scientific institutions in more than 20 countries, Van Looy et al. (2006) show that national technological performance is positively related to scientific capabilities.

Two Scenarios: Emergence of the missions in East Asian and Latin American catch-up countries and their relationship

Based on the literature and its discussion above, we can summarise the emergence of academic research and the economic contribution of universities in developing countries and the relationship between the two missions. From this summary, we can put forward several propositions to help us understand universities and their role in catch-up countries.

Firstly, teaching is one of the main missions of universities in both developing and developed countries. In the initial stage, the investment in primary and secondary education provides developing economies with industrial labourers who are literate and have modest skills. However, during the process of the catch-up, the enrolment rates of catch-up countries in higher education (particularly, in science and engineering disciplines) are distinctively higher than those in developing countries. This may be partly due to the catch-up industry's increasing need for technical labour and to the increased income level of household enough to pay the university fees.

Secondly, research as well as the economic contribution of universities in developing countries tends to be limited due to the 'vicious circle' existing in the national innovation system. With regard to supply-side factors, a scarcity of highly qualified researchers and adequate equipment means that universities do not attract industry's attention as collaborators. In terms of demand-side factors, mismatched demand from industry and weak linkages between university, industry and government tend to fail to stimulate the production of application-oriented research to meet local requirements.

However, East Asian catch-up countries such as Korea and Taiwan, as well as other developing countries, are more likely to be dependent upon public institutes in the early stage of economic development. As both the global and local economy becomes knowledge-based, scientific knowledge produced by the universities becomes more important than before. Responding to this, governments have been trying to strengthen and harmonise the relationship between university and industry through various policy measures such as laws and public R&D expenditure. For example, in the opto-electronics sector, Taiwanese universities provide expertise in chemicals and materials to private sector (Mathews & Hu, 2007).

Thirdly, the active role of governments is one of the most influential factors in explaining the relationship between university and industry and between academic research and the economic contribution of universities in catch-up countries (particularly in Asia) (Cummings, 1997). In the initial stage of catch-up, the government often has a strong emphasis on economic development, seeing industry and universities as means to achieve their policy goal (Song, 2002). The government may have chosen several industrial sectors to be supported strategically, and may have encouraged the immediate provision of human resources (particularly in the strategically chosen field of science and engineering) by academia. As academic research capacity increases, public R&D funds are invested in the 'strategic' research areas. For example, in case of Singapore, the government identified several areas such as biotechnology, electrical engineering, computer science and financial management to be supported for its survival, and invested heavily on research in these areas as well as on the training of human resources (Altbach, 1989). Therefore, we may tentatively propose a coevolving growth of science and technology (i.e. a positive relationship) and consequently, a close structural similarity between certain sectors of industry and the associated disciplines with regard to the teaching and research activities of universities.

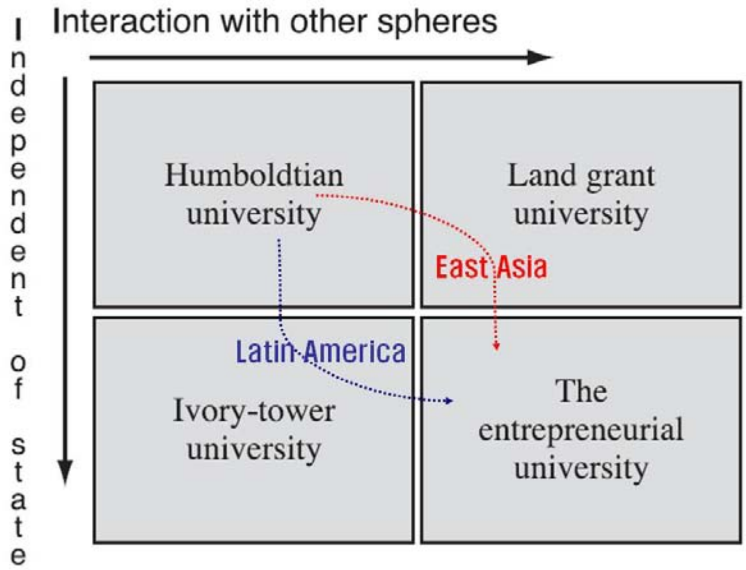
If we consider the three points made above, the controversy between opponents of the 'triple helix' and the 'open science' approach adopted by scholars of the 'new economics of science' cannot be directly applicable to academia in catch-up countries. In addition to different institutional settings of those two groups of countries, this is because the reward system of scientific communities in catch-up countries is more dependent on governments' R&D objectives than the recognition of their peers in the scientific community. Furthermore, because the criteria for the resource allocation of scientific research are directly influenced by the government (sometimes, based on informal networks between government officers and scientists), the scientific community's opportunity to set up their own merit system has been delayed (Song, 2003). According to Bak (2006), in the Korean scientific community the traditional norms developed in industrialised countries (i.e. communalism and disinterestedness) have not yet been deeply established, while the nationalist view of science (e.g. scientists as patriots) contributes to strengthening the government-guided commercialisation of academic research.

In order to suggest a tentative evolutionary model of the universities in catch-up countries in contrast to those in developing countries, we start from a framework developed by Etzkowitz (2003) explaining the emergence of entrepreneurial universities. In spite of the lack of agreed complete model of entrepreneurial universities[1], this scholar maintains that the entrepreneurial university has two characteristics 'high

[1] For example, Clark (2004) understands the 'entrepreneurial activity' as commercialisation of academics' idea.

interaction with other spheres' (as contrasted with the Humboldtian university) and 'high independency of state' (as contrasted with the 'Ivory-tower' university) as shown in Figure 2.1.

Figure 2.1 Two different scenarios: paths of universities in East Asian and Latin American catch-up countries



Source: Revised from Etzkowitz (2003), p.318.

Based on the two criteria of this framework, two tentative scenarios on the historical paths of universities in the two regions can be suggested. From the beginning, both the universities in East Asian and Latin American catch-up countries have been under the strong control of their respective governments, and accordingly they have a very weak level autonomy (the second quadrant in Figure 2.1). In their early period of economic development, the former were encouraged to interact with other spheres such as industry by strong initiatives by government (the first quadrant in Figure 2.1), whereas the latter interact relatively weakly with industry due to several of the reasons mentioned above, and they tend to remain in their own territory (the third quadrant in Figure 2.1). According to Bernasconi (2007), the Latin American universities in the 1960s and early 1970s can be characterised in terms of 'autonomy from state intervention'. In a similar vein, De Campos (2006) maintains that the 'attitude' of the universities in Latin America is closer to a classical university in terms of their strong involvement in basic research, while those in East Asia are more like a technical university in terms of their training of a vast number of technical human resources.[2] Cummings (1997) also maintains that recently emerging East Asian universities in Korea, Taiwan, Thailand, Malaysia, Singapore and Indonesia have three common characteristics influenced by the Japanese higher education model (referred to as the 'J-model'): strong coordination of the relationship between industry and academia, higher priority for the field of engineering and science in tertiary education, and the important role of private education.

Recently, in both regions, the two types of university are now trying to approach entrepreneurial universities in the sense of Etzkowitz (2003)'s definition. In other words, both interaction with other spheres and independency from the state are emphasised (the fourth quadrant in Figure 2.1). In East Asia, encouragement of the universities' interaction with industry has been continuously accelerated in order to produce industry-relevant knowledge. In this process, based on the accumulated scientific infrastructure, the interaction channels between university and industry have expanded from provision of R&D labour to direct interaction with industry such as contracted research (De Campos, 2009). Furthermore, institutional autonomy through devolution has been improved partly due to increased political democratisation. In Latin America, the importance of university-industry linkages has recently been widely accepted, although this was not legitimated two decades ago (Arocena and Sutz, 2001). However, due to inadequacies in the universities' research infrastructure, the provision of qualified human resources relevant for industry is still rather limited. Moreover, universities in this region are currently facing challenges to produce synergy between science and technology.

With regard to the emergence of the two missions of universities in catch-up countries and the relationship, the two missions are harmonised by strong government intervention. However, an investigation of the factors and process of harmonised interaction between the two missions in national innovation systems has not been sufficiently conducted thus far. Accordingly, in this research, based on the proposed model tentatively suggested above, the Korean case is investigated.

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[2] Based on the typology of Martin (2003: 14), De Campos (2006) suggests that the university model that has prospered in Korea is closer to the 'technical university', which mainly trains human resources and provides useful knowledge for society rather than, the 'classical university', which is highly autonomous and involved in research largely for its own sake.

2.3 Determinants of Knowledge-Transfer Activities of Universities: a selective survey of the literature

This section provides a review of the existing literature on factors that influence the entrepreneurial performance of universities at an organisational level. After discussing the different categorisations of the determinants of university activities, we propose a new set of categories that relate to scientific capacities and funding sources. Next, various views of the existing literature in each category are examined. Finally, in each category, the application of the reviewed studies in the context of developing countries is discussed.

2.3.1 Various categorisations of organisational factors influencing the knowledge-transfer activities of universities

In general, the various categorisations of the influencing factors related to the particular variable that we are interested in are dependent on the theoretical lens or core research questions adopted in the individual research. Here, by reviewing several studies which identify the organisational factors that influence knowledge-transfer activities, we can identify some common factors as well as how they might be categorised for the purpose of comparison. Then, after considering the characteristics of universities in developing countries, we discuss appropriate factors and categories explaining the knowledge-transfer activities of universities at the organisational level.

Focusing on the resource-dependency of organisations, Powers (2003) divides the explanatory variables for universities' knowledge-transfer into four categories: financial resources (e.g. federal funding and industrial funding), physical resources (e.g. presence of a medical school or an engineering school), human capital resources (e.g. quality of science and engineering faculty) and organisational resources (e.g. an institution's private or public status). Other factors influencing the knowledge-transfer activities such as entrepreneurial climate, level of venture capital availability, annual state support, size and age of TTOs (Technology Transfer Offices) are employed as control variables.

In an alternative approach, in order to identify the organisational factors that explain the firm-creation activities of universities, Di Gregorio and Shane (2003) suggest four sets of independent variables. The categories are: venture capital availability (e.g. the number of local companies receiving funding from venture capitalists), commercially oriented research measured by industrial funding, intellectual eminence measured by official academic rating scores, and university policies (e.g. inventor share of royalties). In this research, the number of inventions, TTO size and level of sponsored research funding are included in the regression model as control variables.

In another study, Owen-Smith and Powell (2001) compare two universities' technology-transfer activities with regard to three aspects: institutional characteristics (e.g. private and public status), research capacity (e.g. number of researchers and papers published) and technology transfer capacity (e.g. size of TTO). Similar to this categorisation, Sapsalis et al. (2006) developed four 'constructs' for investigating organisational propensity for academic patenting: the institutional characteristics of the university, the entrepreneurial orientation of the university, the research orientation of the university and the industrial environment of the university.

Reviewing the studies on university-to-industry knowledge transfer, Agrawal (2001) evaluates literature according to four categories: firm characteristics, university characteristics, geography in terms of localised spillovers, and channels of knowledge transfer. In particular, according to this review, the 'university characteristics' category focuses on the issues related to licensing strategies, the incentives for professors to patent and policies such as taking an equity stake. In another extensive review of university-industry links (De Campos, 2006), the activities of universities (e.g. teaching and research), the 'attitudes' of universities (e.g. those embraced in the classical university and the technical university) and policies towards universities (e.g. governmental policy promoting the commercialisation of academic knowledge) are considered as supply-side (i.e. university) factors.

Based on the various studies introduced above, each categorisation scheme in the existing studies is compared in Table 2.1. According to the result of this comparison, in spite of minor discrepancies between the categories, some common categories were found – in particular, funding structure, entrepreneurial orientation, scientific capacity, institutional characteristics and external factors.

Table 2.1 Different categorisations of the factors influencing the knowledge-transfer activities of universities

Categories Authors	Funding structure/ External factors	Entrepreneurial Orientation	Scientific Capacity	Institutional characteristics
Powers (2003)	Financial resources	*Physical resources*	Human capital resources	Organisational resources
Di Gregorio & Shane (2003)	Venture capital Availability			Intellectual eminence
Owen-Smith & Powell (2001)		Technology transfer capacity	Research capacity	Institutional characteristics
Sapsalis et al. (2006)	*Industrial environments*	Entrepreneurial orientation	Research orientation	Institutional characteristics
Agrawal (2001)	*Geography, Firm characteristics*	*Channel of transfer*		University characteristics
De Campos (2006)	*Policies toward universities*	Attitude of universities	Activities of universities	

*The categories expressed in italics partially overlap with others in the same column.

Source: the author

In the previous section, some general characteristics of the research and entrepreneurial activities of universities in developing countries and catch-up countries are suggested: backwardness of scientific resources, dependence on overseas academia, and a domestic academic system isolated from local communities (in the case of developing countries), and strong interaction between science and technology under the control of the government (in the case of catch-up countries). Among those characteristics, considering both the recent development of universities' scientific capacities and the government's financial encouragement of university research, two categories – funding structure and scientific capacities – need to be investigated intensively. In particular, the influence of the scientific capacities on the entrepreneurial activity of universities is the same issue addressing the relationship between the missions of universities discussed in the previous section, while the unit of analysis shifts from the nation to the organisation.

Accordingly, in the following two sections, we review the literature particularly in the two main categories related to the scientific capacities (subsection 2.3.2) and sources of R&D expenditure (subsection 2.3.3) of universities. Moreover, two additional categories - institutional characteristics and environmental conditions (subsection 2.3.4) - are suggested, based on the common categories indentified in Table 2.1.

2.3.2 Scientific capacity and the entrepreneurial activities of universities

In this subsection, we focus on the effect of academic research on the industrial collaboration of universities at the organisational level. Even though the direction of the causality needs to be carefully considered, this is rephrased as an issue addressing the relationship between academic research (i.e. the second mission) and industrial collaboration (i.e. the third mission) activities of universities at the organisational level. Regarding this issue, existing literature can be divided into two rather contradictory camps.

Some studies suggest a negative relationship between the second and third mission. For example, the empirical results from a survey carried out by Rahm and Morgan show that the applied orientation of academic research is positively related to the intensity of collaboration with companies (cited in Florida and Cohen, 1999). Moreover, the quality of the universities' academic output has a negative effect on the propensity of their academics to interact with the private sector (Ponomariov, 2008). However, this proposition can not be applied to all kinds of universities. Brooks and Randazzese (1999) mention that academics in relatively few prestigious institutions are unlikely to be vulnerable to industrial short-term needs. In a similar vein, Geuna (1997) shows that a large portion of UK universities are involved in short-term and less basic research contracts from the industry, while a few prestigious universities enjoy long-term and more basic research contracts.

In contrast, studies refuting this negative relationship between academic research (or scientific excellence) and various entrepreneurial activities (e.g. patenting and incubating activities) have also emerged. Based on 18 years of panel data from 89 U.S. universities, Owen-Smith (2003) maintains that a newly emerged 'hybrid regime' encourages the universities with a better scientific reputation (as measured by publication impact) to patent more and vice versa. In a similar vein, analysing the outputs and characteristics of UK universities and affiliated academics, Ambos et al. (2007) hold that the conflict between academic and commercial orientation can be harmonised through the establishment of a dual structure at the university or department level. Sapsalis et al. (2006) hold the view that the scientific capacities are essential for industrial collaboration. In the case of 87 European universities, they show that publication activity at the organisational level has a statistically significant and positive relationship to patenting activities. Moreover, investigating the spin-off rate of 101 U.S. universities, Di Gregorio and Shane (2003) maintain that universities with higher intellectual eminence can more easily create start-ups. Similarly, universities with highly rated departments in science and engineering are also strongly involved in spin-off activity (O'Shea et al., 2005).

However, as far as we can tell, literature directly investigating this issue (particularly at the organisational level) in the context of developing countries is rare. Furthermore, the debate between the two contrasting views cannot be directly applicable to universities in developing countries. This is because the scientific capacity of the higher education system in those countries is generally not strong enough to be fully exploited for economic contributions as discussed in Section 2.2. Accordingly, other factors (such as sources of funding and institutional characteristics) may be more important than scientific capacity. Furthermore, the contribution of scientific capacity of developing countries' universities could be channelled through a different route. As De Campos (2009) mentions, the channels of economic contribution of universities in developing region (e.g. teaching and informal consultancy) may be different from those in industrialised regions (e.g. formal long-term research contracts).

2.3.3 Funding structure and entrepreneurial activities of universities

Griliches and his colleagues have applied econometric models of the relationship between academic patenting and R&D expenditure using a patent production function (Adams & Griliches, 1996; Griliches, 1990). In terms of applying of this model, the following studies are in a similar vein to these scholars. Mansfield (1998) suggests that the size of US universities' R&D expenditure has a positive relationship to the contribution to industry. This is supported by the empirical finding that annual university-wide R&D expenditure has a significant, positive relationship to spin-off activity (Carlsson & Fridh, 2003; Powers & McDougall, 2005). Furthermore, in the case of US universities, Coupé (2003) finds not only a significant, positive effect of academic R&D expenditure but also decreasing returns on patenting activities at the university level. In particular, this subsection reviews existing literature on the influence of structural characteristics (particularly, funding sources) of academic R&D expenditure on a university's entrepreneurial activities. Furthermore, some methodological problems of existing studies and their implications in the context of developing countries are discussed.

Intuitively, funding from industry is more likely to encourage universities to produce commercially-oriented knowledge for industry and transfer it than funding from other sources such as governments. Regarding this, Di Gregorio and Shane (2003) suggest three possible explanations for why industry funding is positively related to universities' entrepreneurial activities. Firstly, industry is more likely to invest in potentially commercial research than government. Secondly, industry is more likely to fund low-risk research than government. Thirdly, government-funded research is more likely to face information asymmetry problems than industry-funded research, so the former is less likely to be financed by entrepreneurs than the latter.

Empirically, Powers (2003) supports the above proposition based on the finding that the size of industrial funding has a significant, positive relationship to patent production within universities. Di Gregorio and Shane (2003) find that a university with a higher amount of industry funding creates a significantly higher number of spin-offs. Conversely, universities with a strong attitude towards research focusing on commercial research for industry are more likely to attract funding from industry than other universities (Rosenberg & Nelson, 1994).

However, certain other empirical studies provide rather different evidence that is inconsistent with the empirical findings supporting a positive relationship between the size of industrial funding and the entrepreneurial activities of universities. Foltz et al. (2000) show that industrial and internal funding have no significant effect on universities' patenting activities, while federal and state funding have a significant, positive effect on them. Payne and Siow (2003) also find that federal funding is significantly and positively related to the patent production of universities. However, in contrast to their results from previous a study in 2000, Foltz et al. (2001) find that internal funding and state funding are positively and significantly related to patenting activities in the field of agricultural biotechnology, while industry and federal funding are not. In a similar vein, Powers (2004) also confirms that the industry R&D support is not significantly related to university technology transfer.

Furthermore, considering not only the absolute amount but also the proportion of certain sources of funding relative to the total funding, the empirical findings from existing studies appear to be more complicated. Henderson et al. (1998) suggest that the proportion of industry funding is related to application-oriented academic research. O'Shea et al. (2005) find that the proportion of industry funding has a significant, positive impact on the establishment of university spin-off firms. However, Di Gregorio and Shane (2003) find that the proportion of industry funding is not significantly related to the universities' creation of spin-offs, while absolute size of industry funding is significantly related to the creation of such spin-offs.

According to the review given above, the empirical results of the influence of industrial funding in terms of both absolute amount and proportion on academic patenting at the university level are inconsistent. Accordingly, we may conclude that the evidence on the relationship between sources of funding and entrepreneurial activities is inconclusive (De Campos, 2006). This may be due to several methodological reasons, as we now discuss.

Firstly, the inconsistent statistical findings introduced above could be the result of different sampling. The characteristics of the university samples selected, as well as the population adopted in the existing literature, vary from study to study. For example, both Foltz et al. (2001) and Foltz et al. (2000) are interested in agricultural biotechnology patents; however, the former's research is based on cross-sectional data of 142 U.S. universities from the US patent office database, while the latter's research is based on eight years of panel data for 127 US universities from the AUTM survey. Both Powers (2004) and Powers (2003) are based on annual licensing surveys of the AUTM (Association of University Technology Managers). However, the universities in the older study are 108 US Research I and II institutions based on the Carnegie (1994) classification, while those in Powers (2004) are 104 U.S. doctoral-intensive and extensive institutions categorised as the two new top-tiers of the Carnegie Classification. Furthermore, the study of Payne and Siow (2003) includes 223 U.S. higher institutions categorised as research or doctoral universities based on the Carnegie (1994) classification, while Di Gregorio and Shane (2003) selected the 116 U.S. universities with two or more years of TTO data available from AUTM.

Secondly, as noted in the first point, most of the research we are interested in here has been carried out mainly on US universities rather than European and Japanese universities, except for a few recent studies such as Ljunngberg et al. (2007) on a Swedish university case and Ambos et al. (2007) on UK universities. Moreover, it is currently very hard to find studies that consider the developing countries' context, with the exception of some recent studies about strengthening the university-industry linkages in developing countries as introduced in subsection 2.2.3. Therefore, in order to extend the application of existing findings to other countries (or other regions), research on the relationship between the industry funding and entrepreneurial outputs of developing countries may contribute to filling both an empirical and theoretical gap with respect to existing studies.

Finally, with regard to a possible reason for the inconsistent statistical results given above, Carayol (2007) asserts that the university level is not appropriate for investigating the relationship between industry funding and the entrepreneurial activities of a university; moreover, he suggests a change of the analysis unit from the university to the laboratory level. However, this is not the only solution. In other words, through a suitable classification of universities, we can obtain a more homogeneous subgroup for our sample. Moreover, this classification can be included in statistical models as one of the control variables, so we can manage the heterogeneity of the various types of universities selected in the sample.

2.3.4 Other organisational factors influencing knowledge-transfer activities of universities

This subsection mainly reviews the other variables such as institutional and environmental factors influencing the entrepreneurial activities of universities at the organisational level. Based on the variable categories introduced in subsection 2.3.1, various factors identified in the existing literature are discussed in this subsection. The variables identified here are used as control variables in the econometric model as well as important factors in the case study adopted in the following empirical chapters.

Institutional factors affecting knowledge-transfer activities of universities

Many attempts have been made to investigate the **institutional factors** affecting knowledge-transfer activities, such as organisational properties and entrepreneurial orientation of universities.

Firstly, institutional properties such as size and legal status (or ownership of institution) are identified as being related to the patenting activities of universities at organisational level. The size of universities, as measured by the number of academics affiliated, is positively and significantly related to knowledge-transfer activities (Sapsalis et al., 2006; Powers, 2004). Furthermore, diminishing returns to the size of universities on patent production is also observed (Coupé, 2003). Investigating the determinants of patent production in an econometric model, Lach and Schankerman (2003) adopt the number of academics as a significant control variable in the model.

Next, the legal status of institutions can also be regarded as an important factor for the activities. Mowery and Sampat (2001) maintain that in the early 20th century, public universities (i.e. land grant universities) in the US provided useful academic knowledge generated by applied research within local society, while private universities focused on basic research and humanities. However, in spite of their institutional history, several empirical studies indicate that public universities have shown worse performance in terms of both quantity and quality of invention (Hegde, 2005; Sine et al., 2003; Siegel et al., 2003; Thursby and Kemp, 2002; Adams and Griliches, 1998). Various explanations for this unexpected empirical result are provided. First of all, Thursby and Kemp (2002) explain this empirical result by public universities' adoption of diverse objectives which are far from the private sector. Next, Siegel et al. (2003) attribute this result to the inflexible technology-transfer policy of public universities. Finally, Sine et al. (2003) maintain that private universities' prestige attracts local firms willing to get in touch with qualified scientists in a specific area, as well as having the accumulated know-how in applying patents.

However, the explanations of the empirical studies presented above are provided considering the specific current and historical status of US universities. Moreover, universities' institutional characteristics (as measured by not only legal status but also the existence of a medical department and the types of university such as Land-Grant University and Carnegie Research I University) are generally closely entangled with that of certain higher education systems and a certain national innovation system. Therefore, in investigating the effect of institutional properties on (a certain type of or a certain countries') universities' knowledge-transfer activity, we need to consider the historical and systemic characteristics of the universities chosen as well as their individual properties. In this vein, the study of Feldman and Desrochers (2003) on Johns Hopkins University provides a persuasive explanation for the influence of historical context on the university's weak commercial activity.

Secondly, much research on the effect of universities' entrepreneurial orientation on their knowledge-transfer activities – focusing on intellectual property (IP) policy and university TTOs' characteristics – has been carried out. First of all, the contents of the IP policy of university (e.g. the incentive system for the knowledge-transfer activities of the academics affiliated) are likely to be influenced by the individual university's orientation. In this vein, on the one hand, a case study on a particular university is often adopted as shown in Debackere and Veugelers (2005)'s research on identifying factors influencing effective IP management of the university in the case of K. U. Leuven. Moreover, based on interviews with 98 US academics, Renault (2006) maintains that institutional policy can affect the entrepreneurial behaviour of its academics. On the other hand, econometric analyses on this issue also show that rewards for academics involved in technology transfer have a significant impact on their entrepreneurial activity (Friedman and Silberman, 2003; Lach and Schankerman, 2003).

Next, in terms of quantitative TTOs' characteristics, generally a TTO's size as measured by the number of staff is included as a significant predictor in quantitative studies investigating factors related to universities' technology transfer activities (Thursby and Kemp, 2002; Rogers et al., 2000; Foltz et al. 2000; Siegel et al., 2003; Thursby et al., 2001; Carlsson and Fridh, 2002). Furthermore, Chapple et al. (2005) show the diminishing returns of scale with respect to the size of TTOs in the entrepreneurial activity of UK universities. In addition to the size of TTOs, the salary level of TTO personnel (Markman et al., 2004) and the TTO's years of experience (Friedman and Silberman, 2003) have been adopted as predictors. In terms of qualitative TTOs' characteristics, TTO's organisational structure (e.g. financial autonomy from the university) can be regarded as a factor affecting academic entrepreneurial productivity (Bercovitz et al., 2001; Feldman et al., 2002).

However, the universities' entrepreneurial orientation reviewed above is closely related to the idiosyncratic properties of a certain higher education system, so we need to be careful in applying the findings from existing studies (Collins and Wakoh, 2000). For example, in catch-up countries with strong governmental leadership for commercial exploitation of academic potential, TTOs' years of experience and organisational structure are often relatively uniform due to the government's policy intervention.

Environmental factors affecting knowledge-transfer activities of universities

Various **environmental** (or external) **factors** of universities at the organisational level**,** such as geographical proximity to industry and the characteristics of industrial partners (e.g. size, sector and R&D intensity of firms), are related to universities' knowledge-transfer activities.

Several studies on the geographical location of universities let us understand that the geographical proximity of university to industry is a significant factor for the universities' entrepreneurial activities. An empirical study by Friedman and Silberman (2003) show that in the U.S., universities located in a region with a concentration of high-tech industry are more likely to be involved in knowledge-transfer activity. Mansfield and Lee (1996) show that the companies closer to universities are more likely to provide R&D funding to the universities in the U.S. Based on a significant positive correlation between the R&D expenditure of the US universities and patenting activity of local firms at state level, Jaffe (1989) focuses on the localised knowledge-spillover activities of universities. In a German case, Audretsch et al. (2004) confirm that geographical proximity is an important factor for human resource flow between university and industry.

Next, a great deal of research has been done on the relationship between the characteristics of industry partners such as size, sector, R&D intensity of firms and the knowledge-transfer activity of universities. With respect to the size of firms, Arundel et al. (1995) report that public research is more important for large firms. Moreover, Charles and Conway (2001) show that more than 75% of UK universities' industrial income came from research contracts with large firms. Furthermore, many other studies show that a firm's size is positively and significantly related to the probability of firm's research contract with universities (Hughes et al., 2006; Veuelers and Cassiman, 2005). In terms of specific traditional sectors such as chemical and electrical energy, historical evidence shows that the university-industry linkage is very close (Freeman and Soete, 1997; Von Tunzelmann, 1995; Rosenberg and Nelson, 1994). Recent empirical studies show that certain industrial sectors are more related to universities' knowledge-transfer activities. These include: utilities and aerospace (Arundel and Geuna, 2004); TV/radio, communication, drugs and oil (Cohen et al., 2003); pharmaceutical, aerospace and food (Arundel et al., 1995). In particular, according to Arundel and Geuna (2004), the sectors of firms evaluating public research as important sources of knowledge vary from region to region (i.e. Europe, other Europe, North America and Japan). This means that we need to consider the industrial structure of a certain country where the university and industry are located. Finally, according to several studies (Chapple et al., 2005; Sine et al., 2003; Varga, 1998), the R&D intensity of local industry needs to be considered as a demand-side factor encouraging the transfer of academic knowledge to firms.

As shown by the review above, various institutional and environmental factors of universities are related to their knowledge-transfer activities, but very few studies have been conducted in developing countries. Moreover, the institutional and environmental factors influencing the knowledge-transfer activities of universities are very closely related to the specific historical context and policy environment of the university, as well as to the particular country. Therefore, we need a careful interpretation taking account of the idiosyncratic feature of the particular national innovation system when these variables are included in a statistical model. In particular, in developing countries we need to include the specific conditions of the universities that are related to the conditions of knowledge-transfer activities at the organisational level. This is the main topic of the following subsection.

2.3.5 Determinants of knowledge-transfer activities of universities in developing countries and rapid catch-up countries

In Section 2.3, we reviewed the existing literature on the factors influencing the knowledge-transfer activities of universities at the organisational level. Applying the identified relationship between the two variables (i.e. characteristics of universities at the organisational level and their knowledge-transfer activities) to the context of the universities in developing countries, we need to consider the relationship between the universities and industry and between academic research and knowledge-transfer activities of universities in developing countries as introduced in Section 2.2. Therefore, we may suggest that in developing countries the combination of dependent and independent variables may be very different from that in developed countries.

First of all, in terms of dependent variables, Section 2.2 stresses that the universities' knowledge-transfer activities themselves in **developing countries** are different from those in developed countries in terms of form and intensity, given the primary focus of universities in the former on teaching as well as their lack of adequate research capacities. Furthermore, the interaction channels between universities and industry in developing countries tends to be limited to human resource training and informal consultancy, whereas those in developed countries include long formal research contracts as well as informal channels. This means that we need to carefully choose suitable variables for measuring the universities' knowledge-transfer activities considering the context of the country we are investigating. Next, in terms of independent variables, scientific capacity in developing countries' universities is generally not as distinctive and not as directly connected to economic contribution as discussed in Section 2.2. Therefore, universities' scientific capacity at the organisational level is possibly less important than the variables in other categories (see subsection 2.3.1), such as the characteristics of funding and the institutional properties, discussed above. In particular, relatively poor scientific resource conditions as measured by the amount of funding and number of academics need to be investigated further as factors influencing the knowledge-transfer activities of universities.

The characteristics of universities' activities in **rapid catch-up countries** are different not only from those in developed but also from developing countries as shown in

Section 2.2. These characteristics need to be considered when we investigate the factors influencing the knowledge-transfer activities of the universities in catch-up countries. The most distinctive characteristic is the simultaneous and harmonised rapid growth in industry and academia, and in the academic research activities and the knowledge-transfer activities of universities (in specific areas and disciplines). This may imply that sectoral differences in the contribution of the scientific capacity of universities to knowledge-transfer activities are important. Furthermore, the research funding has been mainly provided by central government, so the characteristics of funding could influence the knowledge-transfer activities of the universities. Finally, the institutional and environmental factors are also very different from those in developing countries and catch-up countries, so these factors are necessary to be included in the econometric model to be established.

2.4 Synergy and Separation mode: the relationship between academic research and knowledge-transfer activities of academics

2.4.1 The relationship between academic research and industrial influence

Recently, the study of the relationship between the academic research and the knowledge-transfer activities of academics has not only been revitalised but has also created a debate between two contrasting views. Some scholars maintain that the knowledge transfer of academics is an activity beneficial to the economy, and it constitutes a new way of knowledge production (Etzkowitz & Leydesdorff, 1997; Gibbons et al., 1994). In contrast, others are concerned about the negative effect on the academic community from their involvement in commercial activities (Nelson, 2004a; Geuna, 2001 & 1999; Dasgupta & David, 1994). The two groups' empirical data also contradict each other, as discussed later on. In this review, we focus on the relationship at the individual level rather than at the systemic and organisational level. Then, the limitations of the existing studies are discussed.

On the one hand, scholars in the 'new economics of science' are concerned about the commercial 'contamination' of academic research. David (1998) maintains that academics frequently interacting with industrial partners are likely to change their research orientation towards short-term commercial research and to decrease the quality of the university research. The unintended consequences of the commercial orientation of individual academics can be summarised as a ‘secrecy problem’ and a ‘skewing problem’ (Van Looy et al., 2004). In terms of the secrecy problem, Blumenthal et al. (1996) carried out a survey and found that 47% of firms asked scientists not to disclose the results obtained from the contract research. According to another survey by Rham (1994), 53% of the academics replied that they had been requested to delay the publication of the research output by the cooperating companies. The skewing problem is observed in the study by Gulbrandsen and Smeby (2005). They found that academics funded by industry do less basic research than those without industry funding. Furthermore, Godin and Gingras (2000) showed that the university researchers cooperating with industry are more involved in applied research than those not engaged in such collaboration.

On the other hand, a different group of the empirical studies that have been carried out do not support a negative relationship between academic research and commercial influence. Agrawal and Henderson (2002) found that the number of patents produced by academics is positively related to the number of papers they published. Ranga et al. (2003) could not find any evidence supporting a trade-off relationship between applied research and basic research. Markiewicz and Di Minin (2004) found that there was not a substitution but a complementary relationship between the number of papers and the number of patents applied for after publication. Moreover, in terms of the quality of the research, the papers co-authored by scientists in academia and industry recorded higher citation counts than those authored by academics only (Hicks and Hamilton, 1999).

In order to explain the positive and reinforcing effects from the relationship between publishing and patenting activities, there have been several theoretical analyses. Owen-Smith (2003) maintains that a ‘hybrid regime’ emerged in the US university system after the 1980s. He states that success in the commercial sphere interacts with that in the academic sphere. In this vein, Van Looy et al. (2004) develop the concept of a ‘compounded Matthew effect’ at the individual level. They assert that the interaction between the production of papers and patents creates a ‘cumulative advantage’ altogether, so academics successful in the scientific area are also able to demonstrate excellence in the area of knowledge-transfer activities. Regarding ‘a resource effect’, Calderini et al. (2007) and Breschi et al. (2004) maintain that university patenting can attract more financial and cognitive resources for academic research from industry. Azoulay et al. (2006) argue that academics involved both in publishing and patenting activity can benefit from ‘within-scientist economies of scope’. Stephan et al. (2007) suggest ‘duality’ of the research output as a reason for the apparent complementarity between patenting and publishing. The results from ‘dual’ research may be not only publishable but also patentable.

Based on the review on the aforementioned literature, the limitations of previous studies would appear to be as follows. On the one hand, the majority of empirical studies are based on the behaviour of academics in research-oriented universities such as MIT (Agrawal and Henderson, 2002) and the Catholic University of Leuven (Ranga et al, 2003; Van Looy et al., 2004) rather than in local teaching-oriented universities. Because of the resource effect, the research outputs produced by academics in this type of universities tend to support a positive relationship between publishing and patenting. Furthermore, most of the empirical studies address these issues by focusing on academics in the disciplines of ‘use-inspired’ science such as mechanical and electrical engineering (Agrawal & Henderson, 2002), life sciences (Blumental et al., 1996; Louis et al., 1989; Owen-Smith & Powell, 2003) and nano-science (Meyer, 2006). Academics in these disciplines are likely to produce commercial outputs as well as contributing to scientific progress. Accordingly, the research focussing on areas of applied research such as life sciences and nano-science is likely to support a positive empirical relationship between academic research and entrepreneurial activities. Considering the limitation of the type of institutions and the disciplines involved, a research framework covering a wider set of characteristics of academics can probably produce richer information on the relationship between academic and entrepreneurial activities at the individual level.

On the other hand, the studies reviewed above have identified the existence of both negative and positive relationships between research and knowledge-transfer activities. However, these two apparently ‘contradictory’ findings are arguably addressing different aspects of the relationship. In other words, the empirical studies on the negative relationship focus on normative concerns (e.g. secrecy and skewing problems) with the behaviour of individual academics suggested by Merton (1973) and Nelson (2004), while the other studies denying a negative relationship mainly investigate just the individual production of papers and patents which is one of the various channels of university-industry linkage (other include the exchange of researchers, conferences, informal contact within networks, recruitment of graduates, etc.). Furthermore, the secrecy and skewing problems do not necessarily mean that the academics involved in industrial collaboration decrease the quantity and the quality of their academic research. Conversely, even though a positive relationship between patents and papers production is found, the concerns about the 'contamination' of open science due to secrecy and the skewing problem may still be valid.

Therefore, in order to find empirical evidence addressing the effects of industrial influences on academics' research activities, we need to develop alternative concepts and variables to measure the effects instead of just counting the number of papers and patents. For example, we can design a questionnaire to ask academics whether the collaboration with industry generates actual benefit to their academic research in terms of facilities and ideas. Furthermore, instead of focusing on the question 'What is the relationship?', we need to consider 'What are the determinants of the relationship?', a question that may provide richer information to enable us to understand the influence of industrial orientation on academic research.

Furthermore, during the last few decades, the determinants of the productivity of science have been one of the main topics in the fields of the institutional sociology of science and the economics of science (Hess, 1997; Stephan, 1996), whereas that of academic patenting has been investigated only more recently. Stephan et al. (2007) maintain that the relation of individual characteristics to academic patenting has been far less investigated than the relation to the publishing of scientific papers. In terms of both institutional characteristics (e.g. organisational culture, the effectiveness of TTO and the field of specialisation) and individual characteristics (e.g. age, citizenship and gender), Stephan et al. (2007) addressed the effects of these characteristics on the academic patenting. However, strictly speaking, the factors influencing the relationship between the two activities (i.e. academic research and knowledge transfer) and the determinants of the productivity of each activity are totally different. In other words, as far as we can tell, there has been little research directly addressing the influence of individual and contextual factors on the relationship between research and knowledge transfer activities.

2.4.2 Conceptual framework: synergy and separation modes

In this section, based on the review and the criticism of previous studies on the relationship between academic research and knowledge transfer activities presented in section 2.4.1, a conceptual framework based on '**synergy**' and '**separation**' modes is suggested. After addressing the relationship between the typologies of research and the interaction with industrial influences, the new conceptual framework is introduced in order to incorporate the previously suggested empirical observations and to explain the relationship between academic research and industrial collaboration activities more plausibly than previous theoretical rationalisations.

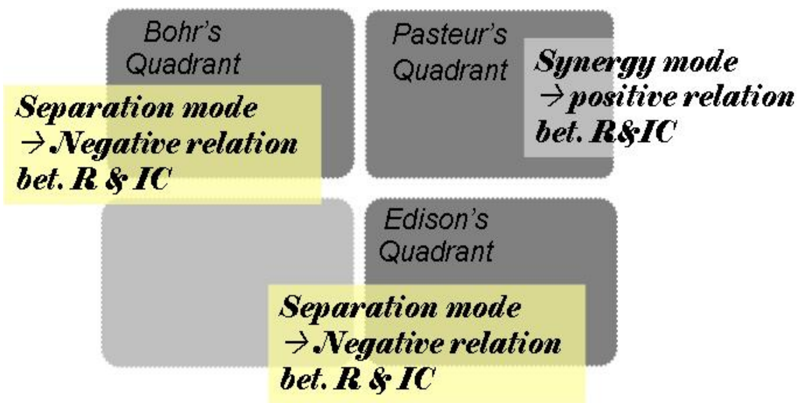
Intuitively, it is not difficult to envisage that industrial involvement and orientation may negatively influence academic research. However, recent empirical studies suggest that industrial involvement not only has no appreciable effect on academic research, but that the two sets of activities are also complementary to each other. Why do we have such a discrepancy between common sense and the empirical evidence? Possibly, there is a hidden process underlying the confusing empirical data. Therefore, this section tries to provide a reasonable conceptual framework in order to bridge the theory and the empirical findings.

Based on the generally accepted categorization of the different types of R&D activity (e.g. basic, applied, and development), the relationship between the different types of activities and output of the activity can be suggested to be as follows. Basic research is likely to produce academic outputs such as papers, while applied research and development are likely to produce not only artefacts but also by-products such as patents. Because of limited resources (e.g. time, the amount of funding and the number of researchers in the laboratory), a trade-off relationship between the production of patents and papers might be expected to be observed. Therefore, a reinforcing relationship between patenting activity and publishing activity is quite a strange empirical finding to be reported in many previous studies. This may be due to the traditional typology of research failing to provide a satisfactory explanation for why many academics produce research output that is both patentable and publishable.

In this regard, an alternative approach put forward by Stokes (1997) provides us with a better starting point for understanding the relationship between the different types of research and how their outputs interact with industry. He suggested a third type of research termed 'Pasteur's quadrant' involving both 'considerations of use' and 'quest for fundamental understanding'. Earlier than the Stokes' typology, Blume (1990) had already introduced a similar notion of a 'transfer science', which is beneficial both in terms of academic norms and industrial exploitation. Academics involved in this type of research are able to show a synergy effect between academic excellence in terms of high quality research and industrial contribution in terms of commercial exploitation.

A dichotomy between the 'synergy mode' and the 'separation mode' is suggested as a key concept in the theoretical framework of this study. As shown in the figure below, the synergy mode and the separation mode can be explained in relation to the various Stokes' quadrants. If the type of research is in the area of Pasteur's quadrant, the research outputs are likely to be both publishable and patentable, so the academics engaged in this type of research can be seen to be operating in the 'synergy mode' of academic research and industrial collaboration. In contrast, academics in the area of Bohr's quadrant are unlikely to produce commercially exploitable results, while those in Edison's quadrant are unlikely to produce results with a large scientific impact. Therefore, the academics in Bohr's quadrant and in Edison's quadrant can be said to be operating in the 'separation mode' of academic research and industrial collaboration. In this way, the positive empirical relationship between patenting and publishing can be explained.

Figure 2.2 Synergy and separation mode considering type of research only



Source: Elaborated by the author, based on the typology of the research suggested by Stokes (1997).

However, in this conceptual framework, only the type of research is considered as an influencing factor for the determination of the two modes. In other words, we can imagine many other factors influencing the choice of the two modes. For example, even though some academics are in Pasteur's quadrant, they may be reluctant to apply for a patent, because the incentive system is not appropriate. Some academics can choose informal channel of industrial collaboration such as the exchange of students or sharing of research facilities instead of a formal channel such as patenting, because academic patenting may be discouraged by limited research resources such as research students and facilities. Therefore, if we include other factors such as career, gender, the characteristics of affiliated institutions and the national academic system, we can investigate the determinants of the two modes in richer detail.

2.5 Conclusion

In the previous three sections, we reviewed literature addressing the relationship between universities' academic research and entrepreneurial activities at a system, organisation and individual levels. Thus, in this section, after a brief summary of the review at these three levels, an integration of the separate conceptual framework based on the interaction between actors at the three levels is attempted. Finally, the need for empirical evidence for this integrated framework is suggested. A summary of the literature review is as follows.

Firstly, at the system level, in terms of the emergence of academic research and knowledge-transfer activities and their relationship, developing countries are contrasted to developed countries. Recently, these two activities are regarded to be important but not fully operated in universities in developing countries, while the three missions of universities in developed countries have been institutionalised in sequence. In particular, universities in catch-up countries have developed these two missions more actively and coherently than those in developing countries. Furthermore, we suggest the possibility of a sectoral similarity between universities' academic research and knowledge-transfer activity in catch-up countries. Considering the characteristics of these activities in developing countries reviewed above, we suggested a tentative model of two contrasting historical paths in developing countries based on two criteria: interaction with other spheres and independence from the state. The development of universities in catch-up countries (particularly in East Asia) can be characterised in terms of strong stat control and active interaction with other spheres in the society.

Secondly, at the organisational level, the influencing factors on knowledge-transfer activities are introduced through the existing literature. Most of the literature on the explanatory predictors for universities' knowledge-transfer activity is confined to universities in developed countries, and to certain type of universities (e.g. prestigious research-oriented universities). In the context of a catch-up country, these factors can be newly categorised into: scientific capacity, funding structure, and other organisational factors. Considering the tentative historical model suggested at the system level, we examined the influences of various factors at the organisational level. In this vein, scientific capacity of universities is important both for developing and developed countries, not only because it can be alternatively interpreted as their academic research activity, but also because scientific capacity measured by the number of qualified papers is likely to be unimportant in developing countries. Furthermore, in the context of catch-up countries, government support is critical, so the funding structure of the university needs to be considered as an essential factor. Additionally, due to the idiosyncratic features of a specific higher education system and national system, other organisational factors (i.e. institutional and environmental factors) also need to be considered in the empirical analysis.

Thirdly, at the individual level, two contradictory views on the relationship between universities' academic research and knowledge-transfer activities are introduced. However, these two views have their own weaknesses such as sample bias in terms of universities and research areas, and measuring problems due to limited indicators (e.g. numbers of patents and papers). Furthermore, studies directly addressing the influencing factors have rarely been conducted. Against this background, we propose a conceptual framework that is focused on individual academics who operate in synergy mode and separation mode between academic research and knowledge-transfer activity as well as influencing factors such as academics' area of research and how it relates to these two modes. Even though the context of developing countries is not explicitly discussed in the review at the individual level, we can apply this framework to universities in developing countries as well as developed countries. In particular, the positive relationship between the academic research and knowledge-transfer activities and influencing factors such as the area of research (e.g. engineering and natural science) is a critical issue of this study.

The three levels are related to each other. The system level characteristics constrain the behaviour of lower level actors (i.e. the individual university and academics), and vice versa. Among the various interactions between actors at different levels, the relationship between academic research and knowledge-transfer activity is the core cross-cutting variable enabling the integration of each framework at the three levels. By investigating the influencing factors on the relationship and the relationship itself (i.e. whether it is positive or not) at the three levels, we can understand more intensively and extensively the universities' academic research and knowledge-transfer activities as a whole. Furthermore, along the relationship variable across the three levels, the interaction between the different levels can be investigated. For example, the disciplinary bias of the national science performance can be based on the proportion of the number of academics and their activities in the certain range of research areas.

In terms of the application of the suggested framework based on the literature review, our case focuses on Korean universities. After applying this conceptual framework, at the three different levels, to the Korean case in the following empirical parts (Chapters 4, 5, 6 and 7), the implications of the evidence are discussed in Chapter 8. Before this work, in the next chapter, certain methodological issues are discussed more intensively.

Chapter 3 Methodology

3.1 Introduction

This chapter sets out the research design and overall research strategy (Section 3.2) for the thesis. Furthermore, the details of the data sources, the methods for collecting data and the ways of analysing the data in this research (Section 3.3) are presented.

To begin with, Section 3.2 presents the overall strategy and research design. Firstly, the overall methodological framework guiding this research is introduced. In this framework, based on the three axes of country, time and analysis level, the boundaries of this research are discussed. Secondly, in terms of the research strategy, the two approaches of interviews (i.e. qualitative) and a survey (i.e. quantitative) are introduced, and their integration strategy within the overall research design is discussed. Thirdly, after several case designs employed in this research are introduced, the linkages between the designs, as well as different analysis levels, are discussed.

Next, Section 3.3 focuses on the data sources, collection methods, and the analysis of the data. With regard to the three levels of system, organisation and individual, details of the data sources and their collection methods during the fieldwork are presented. Furthermore, the strategy by which the data have been analysed is discussed. Additionally, some issues related to the analysis of the data, concerning the different levels and the integration of the different approaches are discussed.

Finally, in Section 3.4, following the summary of this chapter, further issues related to this research methodology are provided. In particular, the strengths and weaknesses of the integrative approach of this research design are discussed.

3.2 Overall Strategy and Research Design

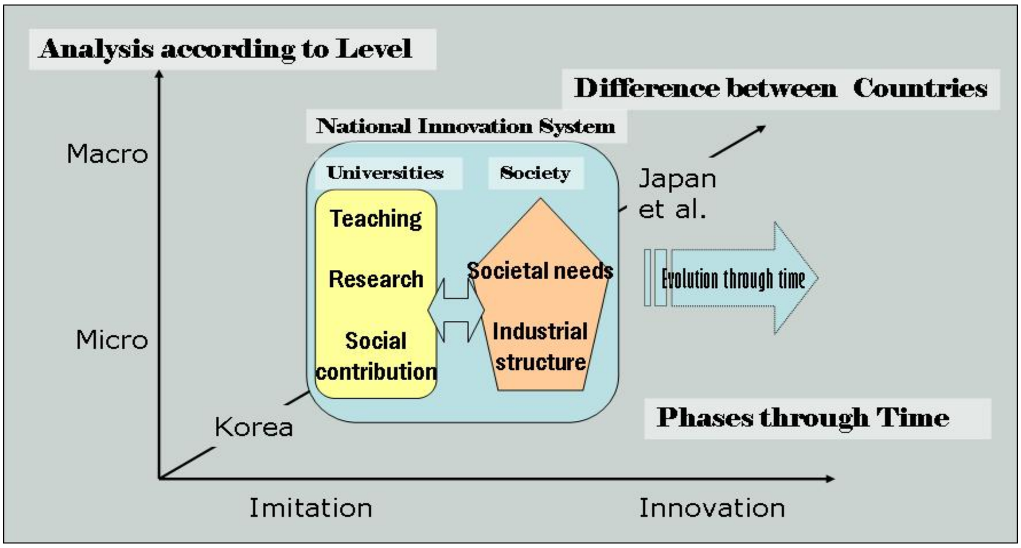
This section presents the overall strategy and research design of the study. In order to do this, and based on the main research question guiding this research, certain strategies for formulating the research framework to answer this question are presented. The first subsection introduces the overall methodological framework, consisting of three different perspectives. In the second section, two distinctive methodological characteristics of this research are suggested: the integration of qualitative and quantitative analysis, and linking the three levels of analysis.

3.2.1 Overall methodological framework based on three axes

As presented in Figure 3.1, the overall framework of this research can be explained in terms of three axes: the context of the national system; the time line; and the analysis level. Firstly, in terms of the **country axis**, each country has its own characteristics of its national system. In particular, the university-society relationship in catch-up countries may be different from those in developed countries. Thus, the specific characteristics of the Korean academic system, as well as those of the national innovation system, need to be considered in this research. On the other hand, common characteristics of university-industry linkage between developed countries and developing countries can also be identified in the existing literature.

In this vein, the conceptual framework developed in Chapter 2, which considers the context of catch-up countries' universities, is applied in four empirical chapters (i.e. Chapters 4, 5, 6 and 7). In order to suggest a framework for catch-up countries, in contrast to other developing countries as well as to developed countries, a brief comparison is carried out based on existing literature. In a similar vein, in the concluding chapter, some specific properties of the Korean university system, compared to those systems of developed countries, are discussed with regard to the application of the conceptual framework to the interpretation of the empirical findings.

Figure 3.1 Overall methodological framework of this research



Source: author

Along the **time axis**, the historical development of the Korean university system can be investigated. As different governmental higher education and industrial policies have been formulated and implemented according to different stages, university-society relations have evolved during the different time periods. Regarding these evolutionary changes, we can explain them in terms of a multi-stage model, as applied in Chapter 4.

Finally, in terms of the **analysis level axis**, the analysis is carried out not only at the national level, but also at organisational and individual levels. At the national level, the characteristics of the Korean higher education system are investigated against the historical background of Korean universities. In Chapter 4, according to different stages, we focus on the interaction between Korean universities and government policies. In addition, academic research and knowledge-transfer activities as measured by the number of papers and patents of the Korean academic system are investigated in terms of their relation to the evolution of Korean industry. In Chapter 5, Korean universities are categorised into several types, and their activities (i.e. teaching, research and knowledge transfer) are analysed according to their type. In these two chapters, we carry out an investigation of the relationship between academic research and the economic contribution of Korean universities at the national level.

Next, against the characteristics of the Korean university system addressed at the national level, Chapter 6 employs an analysis of Korean universities as individual organisations. In other words, the findings in the analysis at the national level are considered as a part of the information to analyse data at the organisational level. In order to address our research question at the organisational level, this chapter focuses on the relationship between the organisational characteristics of Korean universities and their outputs (e.g. scientific publications, patents and income from licensing of their intellectual properties). Thus, Chapter 6 focuses on the same issue (i.e. our main research question) that is addressed in Chapters 4 and 5. Finally, Chapter 7 sets out an analysis of individual Korean academics, considering both the national and organisational characteristics of Korean universities. Again, this chapter explores individual academics' research and industrial collaboration activities as well as the relationship between the two activities (i.e. the main research theme of this thesis at the level of individual academics).

3.2.2 Qualitative and quantitative research designs: a mixed research method

This section consists of two major parts. The first part discusses the two types of research method (i.e. case study and survey) adopted in this study. The second part focuses on the integration of these two methods and the rationale for their adoption. In particular, the means of integrating the methods suitable for this study (particularly the research question) is discussed.

Two research designs: case study and survey

This study aims to explain not only the quantitative relationship between the two activities, but also the qualitative process of the interaction involving other factors related to the activities. As presented in Chapter 1, the main research question guiding this research is: what are the relationships between the academic research and industrial collaboration activities of Korean universities? This question requires not only an examination of the quantitative statistical relationship between the two variables (i.e. research and industrial collaboration), but also a qualitative explanation of this relationship. Furthermore, one of the three subsequent questions is: how are the activities of academic research and knowledge transfer related to each other in the Korean academic system? In order to investigate this question, we need to focus on the qualitative process of the interaction between the two main activities of universities, and between the activities and other factors involved in the process.

Next, what specific research methods have been adopted for our research questions? Firstly, among quantitative research methods, this study employs survey questionnaires. The reason for using a survey is mainly due to the type of the research question (i.e. a 'what' question). In particular, the question mainly investigates the quantitative relationship between the two variables of academic research and industrial collaboration. Consequently, by this method, we can collect quantitative data, which provides us with useful information for our investigation. For example, some statistical figures on research and industrial collaboration activities and other related figures can be used to investigate the relationship between the two activities and other factors through the use of statistical tests (e.g. regression models). In addition to the formal annual census of Korean universities, the data required were collected from the survey questionnaires created by the author, and can be quantified by the use of multiple choice responses.

As a qualitative method of the research design, case studies were designed to address the research questions. The two reasons for adopting the case-study approach can be summarised as follows. Firstly, the case of Korean universities in this study needs to be analysed in terms of the Korean context, in which the country has focused on economic growth during the last half-century. Considering the public function of universities within a society, university activities are usually closely entangled with the society surrounding the organisation. Therefore, the importance of context and its characteristics provides a good reason for a case study to be a reasonable research approach. Secondly, the research questions of the thesis can be addressed appropriately by case studies. The research questions mainly deal with 'how' questions and are focused on contemporary events as described in the above section. Experiments, historical analysis, and case studies have been identified as appropriate for addressing 'why' and 'how' questions. However, historical analysis is a research strategy for dealing with past events rather than contemporary events (Yin 2003). Furthermore, even though some control in case studies can be implemented at the analysis stage (Bechhofer and Paterson, 2000), 'ex-ante' control of behavioural events is not appropriate for this kind of social research. As a result, after excluding historical analysis and experiments, the case study approach would seem to be a reasonable research design for this type of research.

In conclusion, in order to answer our research questions both quantitatively and qualitatively, the research design of this study employs not only surveys but case studies. In this way, we can provide more persuasive and robust evidence to address the research question by the use of 'triangulation', which involves using a variety of types of evidence such as interviews, documents, surveys, etc. Next, both types of design complement the other's methodological weaknesses. In other words, a quantitative study such as a survey can help careful sampling in the case study; moreover, this method generally provides an analysis based on established procedures and statistical generalisation. Moreover, a persuasive explanation for the statistical results of the survey can be generated by the case study, while the method usually suggests insightful qualitative details of the case at hand. In particular, as the data employed in the statistical tests are cross-sectional (see Section 3.3), the weakness of statistical inference based on cross-sectional data can be lessened by the introduction of qualitative evidence from interviews.

Integration of the two research designs and its rationale

The research design of this study adopts two types of research designs simultaneously. Moreover, these two designs are closely integrated in the overall research design. This subsection discusses the appropriateness of this integration, after the introduction of existing studies based on the mixed research method of qualitative and quantitative approaches.

Yin (2003) discusses the issues of convergence and non-convergence of evidence from multiple sources as well as from multiple research methods. He maintains that convergence of evidence by 'triangulation' is essential to provide persuasive conclusions. In term of convergence of multiple (e.g. qualitative and quantitative) methods, Creswell (2002: 210) suggests two approaches based on mixed research methods: a concurrent procedure and a sequential procedure. The concurrent procedure is one in which the two different methods are implemented simultaneously throughout the research process, while in the sequential procedure the two methods alternate with each other during the research. In a similar vein, according to Miles and Huberman (1994: 41), four types of research design linking qualitative and quantitative methods can be categorised as shown in Table 3.1.

Table 3.1 Illustrative designs of linking qualitative and quantitative data

Type	Process of collection and analysis of data
Design 1	QUAL • QUANT ---→ (continuous, integrated collection of both kinds of data)
Design 2	QUANT wave 1 ↘ ↗ wave 2 ↘ ↗ wave 3 QUAL ------------ continuous fieldwork ---
Design 3	QUAL -------------------→ QUANT ---------------------→ QUAL (exploration) (questionnaire) (deepen, test findings)
Design 4	QUANT -----------------→ QUAL -----------------------→ QUANT (survey) (fieldwork) (experiment)

Source: Miles and Huberman (1994), p.41.

In Design 1, both quantitative and qualitative data are collected continuously during the fieldwork. In Design 2, multiple surveys can be done while the fieldwork is implemented. In Design 3, pilot fieldwork can be implemented before a survey questionnaire is created, allowing the results of the questionnaire to be tested in the subsequent qualitative work. In Design 4, fieldwork is implemented based on an initial quantitative analysis; a quantitative experiment testing the hypotheses that emerged in the fieldwork is subsequently carried out.

In the research design of this thesis, following Creswell (2002)'s terminology, both the 'sequential procedure' and 'concurrent procedure' are adopted together. Based on Miles and Huberman (1994)'s discussion, the means of integration of the qualitative and quantitative methods is similar to the process introduced in Design 4 in Table 3.1. The specific research procedure is as follows.

First of all, the interview design was based on existing statistical data collected from the KRF survey (2007) on the activities of Korean universities. Then, based on the analysis of the characteristics and the typology of Korean universities as presented in Chapter 5, the universities to be visited were chosen. Finally, in Chapter 6, the emerging pattern from interviews of the organisational relationship between academic research and industrial collaboration was more intensively investigated by statistical tests of the hypothesis formulated on the basis of the interview findings. In addition, at the individual level, the hypothesis based on the findings from interviews with academics is tested by an econometric model in Chapter 7. Therefore, even though data collection was implemented concurrently, the approach to the analysis is sequential: (i) quantitative analysis based on statistical data; (ii) qualitative analysis of interviews; and (iii) deeper quantitative analysis based on the survey results.

As briefly mentioned in the previous subsection, discussions and interpretations based on quantitative and qualitative analyses are also implemented in a complementary way. That is to say, qualitative data based on the interviews are used not only to draw hypotheses to be tested by quantitative data, but also to complement the weakness of quantitative explanations for the process of interaction between academic research and industrial collaboration, as well as the linkage between the two activities, and factors related to the two activities.

3.2.3 Different case designs and linking levels of analysis

Several case designs are employed together in this study and the reasons for choosing them are presented in this subsection. Thereafter, we discuss a method of linking the different levels of analysis in the case study design adopted.

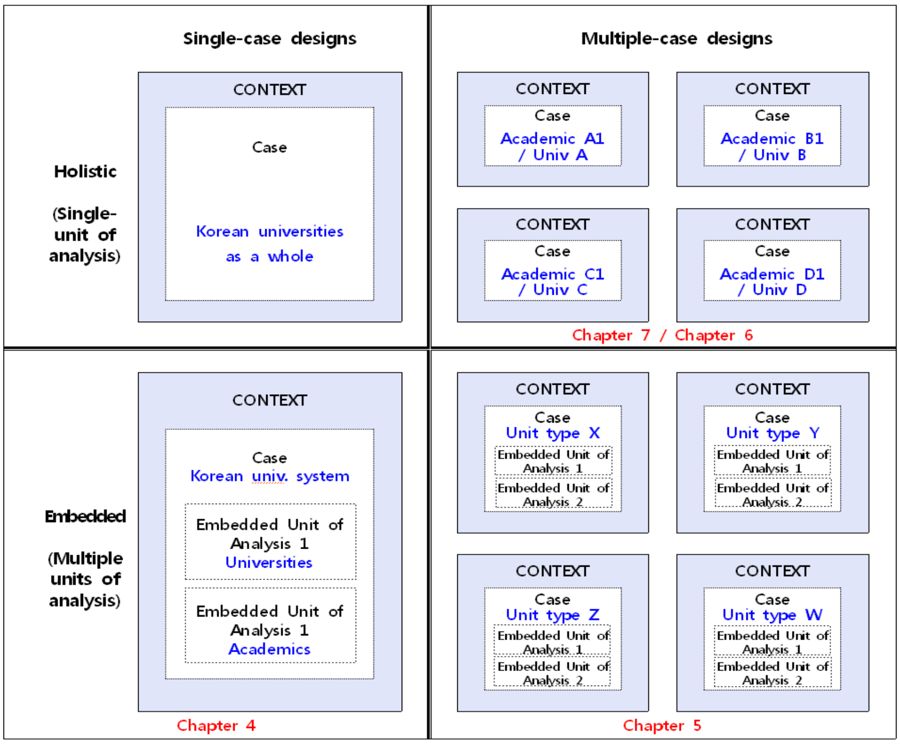
Different case designs

The number of 'cases', the unit of analysis, and the levels of analysis of our research can be deed as follows. The 'case' in this research can be regarded as all Korean universities as a whole, or individual universities, or individual academics, while the unit of analysis can be seen as Korean universities as a whole, or universities as an organisation, or individual academic staff, or all three. Moreover, in order to attain a richer picture and to address interactions between different levels of the research objective, this research deals with Korean universities in science and engineering at three levels: the national university system as a whole; universities as organisations; and individual researchers.

Based on two criteria (the number of cases and the unit of analysis), Yin (2003) provides a typology for different case-study designs. As shown in the figure below, four types of case design can be identified according to this typology. For example, if a case study has multiple cases and a single unit of analysis, we can categorise it as holistic multiple case design. Thus, according to three levels of analysis, the several different case designs that are employed in our research can be presented as follows.

Firstly, at the national level, a university sector can be regarded as a single unit and a single case of analysis; therefore, this design is termed a **holistic single-case design**. In Chapter 4, the Korean case is analysed in terms of universities in rapidly and successfully industrialised countries, which have evolved into one of the competent actors in the national innovation system. In contrast, Chapter 5 is mainly based on an **embedded single-case** design. This means that lower level units such as organisations and individuals belonging to the Korean academic system are regarded as sources providing information about the system.

Figure 3.2 Different types of designs for case studies in this research



Source: based on Yin (2003), Figure 2.4, p.40, but supplemented by the author.

Secondly, the analysis at the organisational level is based on an **embedded multiple-case design**. This design is based on embedded units such as individual universities and academics. That is to say, academics who belong to a certain (type of) university provide evidence regarding the organisational behaviour of the university by commenting on the internal conditions with regard to academic research and industrial collaboration. Furthermore, the design consists of multiple cases. This is because the analysis in Chapter 5 is based on ten types of universities.

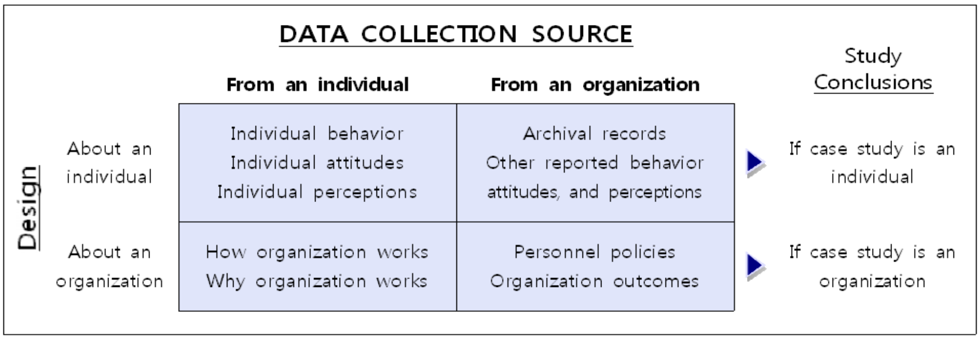
Finally, a **holistic multiple-case design** is introduced at the levels of individual academics and universities respectively. In this design, individual academics are regarded as units of analysis and the number of cases is about 2,000, so Chapter 7 explores several personal (e.g. career and discipline) and contextual (e.g. organisational) characteristics that are related to the individual activities of academic research and industrial collaboration. Next, individual universities are also regarded as units of analysis, and here the number of cases is 169. As a matter of fact, these designs (particularly that in Chapter 6) are closer to statistical quantitative design than to case studies in a strict sense. In other words, the 'case' in this design is different from the 'case' in case studies. However, in terms of integration of qualitative evidence (e.g. interviews, documents) into this design, it is not wrong to call this design a holistic multiple-case design.

Linking the three levels of analysis

The research design of this study also aims to link or integrate three levels of analysis: the system, the organisation and the individual. The conditions identified in the upper-level analysis can work as constraints for lower-level actors. For example, the government's orientation of higher education policy towards Korean universities has strongly influenced the research and industrial collaboration activities of universities (i.e. organisations) as well as academics (i.e. individuals). In this way, the findings from the upper-level analysis can provide a basis for explanation of the behaviour of lower-level actors.

When we collect information from different levels of actors, according to Yin (2003), it is a fallacy to collect data about individual's behaviour and attitudes in a case study which focuses on organisations or upper-level entities. In other words, individuals' comments about their own behaviour and attitude cannot be automatically used to investigate an organisation's operation. Therefore, in order to prevent this fallacy, data collection from the embedded units (i.e. lower-level entities) needs to be focused on the individuals' comments on the working of the organisation and the country they belong to, as shown in the figure below (see the second row).

Figure 3.3 Design versus data collection: different units of analysis



Source: Yin (2003), Figure 3.5, p.76

Accordingly, in the research design of this thesis, during the interviews, both the individuals' comments on the conditions of organisations, and individual properties related to academic research and industrial collaboration were questioned. In order to avoid the pitfall suggested above, these two types of data were allocated separately to the different designs. In other words, the interview data on individual orientation and attitudes were analysed in a holistic multiple-case design in Chapter 7, while the interview data comprising individuals' comments on organisations were analysed in the embedded single-case design in Chapters 4, 5 and 6.

3.3 Data sources, collection method and analysis

This section provides details of data sources and data collection methods at the three levels. Furthermore, these three levels of data are linked to the analysis of each chapter respectively (e.g. most of the data at the system level is dealt with in Chapter 4).

3.3.1 Data and analysis at the system level

In Chapter 4, the data is mostly based on secondary sources such as existing studies and White Papers on the Korean academic system, while sometimes the contents of the interviews that were carried out during the fieldwork are cited to corroborate the arguments of the chapter. In contrast, some parts of Chapter 4 (particularly Section 4.4) depend more on quantitative data than the other parts. For example, the last 20 years of data on Korean academic patents were collected from the KIPRIS (Korea Intellectual Property Rights Information Service) website (http://www.kipris.or.kr). These data enable us to analyse the relationship between academic research and knowledge-transfer activities of Korean universities.

Furthermore, in the first half of Section 5.2, in order to analyse systemic change and to generate a typology of the 169 Korean universities in science and engineering, we examine their organisational properties such as the founding year, legal status, location and the number of academic staff and departments. Furthermore, the data about universities' activities, such as the number of students, papers and patents, is used to investigate the specific characteristics of different types of the universities. These data are shared with the organisational analysis carried out in Chapter 6, so more specific details of the variables are described in the following section.

3.3.2 Data and analysis at the organisation level

The investigation at the organisational level is the main task in Chapter 6. Furthermore, both the quantitative and the qualitative data are integrated at this level of analysis as follows.

Quantitative data at the organisational level

A data-set was compiled from the 2007 annual survey of KRF (the Korea Research Foundation). The scope of the survey covers all Korean universities that have at least a four-year undergraduate programme[3], so this can be regarded as a census on four-year Korean universities. This survey mainly aims to generate statistical information about activities (i.e. teaching, research and knowledge transfer), research expenditure and university laboratories of Korean universities and Korean academics under the supervision of the Ministry of Education, Science and Technology. In particular, at the organisational level, it contains input and output variables of the universities as organisations, such as the number of academic staff, the amount of research funds from different sources, the number of internal research institutes and their budgets, and the

[3] The university here is defined as 'an institution granting a bachelor's degree to graduates which is listed in the law of higher education'.

number of papers, books, patents, technology-transfer and research projects. In addition, based on the data from the Korea National Centre for Education Statistics & Information (http://cesi.kedi.re.kr), information on the number of undergraduate and postgraduate students has been added to this data-set.

The variables according to each of the main categories are listed as follows:

- **Properties** of the 145 universities in science and engineering[4]: legal status, location, number of academic staff, number of departments, founding year, existence of a natural science department, and category (based on the different types of universities developed in Chapter 5)
- **Input** variables: number of academic staff and postgraduate students, amount of research funds from different sources, number of research institutes and their budgets, size (budget and personnel) of TTOs (Technology Transfer Offices)
- Activity (or **output**) variables: research (number of papers), industrial collaboration (patent, technology transfer), teaching (number of undergraduate students)

Qualitative data at the organisational level

The interviews consisted of two parts: one to do with the organisational level, and the other to do with the individual level. Here, we focus on the organisational information from the interviews. In order to explore the characteristics involved in organisational processes, 13 professors in charge of the office of research or industrial collaboration were interviewed. Each interview took at least one hour. The 13 universities were also chosen as representatives of the ten different types of Korean universities in science and engineering. These interviews focus on the individual university's conditions as well as on organisational strategies for research and industrial collaboration. Consequently, these interviews contribute to the explanation of the different and common organisational characteristics of different types of universities in terms of the relationship between academic research and knowledge transfer. Furthermore, the comments of individual academics (who were not directors) on the organisational process related to teaching, research and industrial collaboration were considered as offering important information.

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[4]We choose two different definitions of universities in science and engineering. For more details, see subsections 5.2.1 and 6.2.1.

3.3.3 Data and analysis at the individual level

In Chapter 7, as with system-level analysis (in Chapters 4 and 5) and organisation-level analysis (in Chapter 6), the individual-level analysis also integrates qualitative and quantitative data.

Quantitative data at the individual level

The web-based survey questionnaires given at the end of this thesis were distributed to 18,523 professors in science and engineering at 56 Korean universities, which is supported by an two research projects funded by KRF and IDRC respectively. The process of the survey took two weeks (from 28 May to 11 June 2007) to complete; moreover, in order to increase the response rate, e-mails encouraging replies were sent to the professors who had not replied to the survey after one week. Overall, 2,395 professors participated in this survey, a response rate of about 13%. In order to check the response bias, an independent two sample T-test was implemented according to the various characteristics of the academics such as age, gender, career, location, etc. (See Appended document for the results of the response analysis.)

The 56 universities consisted of two groups: 52 universities involved in the governmental programme, and four universities not involved. The selected professors in this survey were affiliated to the 52 Korean universities chosen by the government as institutions to be supported by the 'Connect Korea' programme, which is targeted to stimulate an institution's scientific knowledge to be exploited industrially. In addition, four additional universities representing the different types of universities were included, because the four universities were not included in the 52 universities that participated in the programme. The professors in these 56 universities totalled 19,671 in 2005, representing 66% of the total 29,285 Korean professors in science and engineering in the same year.[5]

According to three categories, the specific variables generated from the data collected in

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[5]This means that 34% of academics in science and engineering belong to the other 112 small universities in science and engineering, which is a relatively small percentage. For more details about size of Korean universities in science and engineering, see subsection 5.2.1.

the survey are as follows:

- **Individual** variables: age, gender, discipline, year of employment and country of training;
- **Contextual** variables: laboratory size (the number of postgraduate and post-doctoral students), legal status, location, size, number of departments, founding year (or categories representing the different types of universities) and the business R&D expenditures of the 16 regions;
- **Output** variables: synergy and separation mode, research activities (number of papers published in SCI journals in the last three years) and knowledge-transfer activities (domestic and foreign patents applied for in the last three years).

Qualitative data at the individual level

As shown in Appendix Table 7.2, 65 Korean university professors were interviewed between 7 May and 27 June 2007, and they can be categorised into two groups: the first group consists of 13 professors who were in charge of the office of research affairs or the office of university-industry collaboration, while the second group contained 52 professors in different science and engineering disciplines as well as in different types of universities. Interviews with the second group formed the main sources of qualitative analysis at the individual level, while those in the first group were more concerned with the organisational level as discussed above.

According to preliminary analysis of characteristics of the Korean university system and its historical background, some distinctive characteristics were found at the system level. Firstly, Korean universities have developed very rapidly and recently. Secondly, certain disciplines of academia have been important than others. Thirdly, an imbalanced growth of universities is noticeable. In summary, the career, discipline and institution with which one is affiliated can be regarded as important factors for Korean academics. Therefore, the 52 interviewees chosen, who were on a tenure track or already tenured in different science and engineering disciplines, belong to the ten different types of universities. These interviews lasted at least one hour. In terms of the process of choosing academics to interview, firstly, universities were chosen to represent specific type of universities. Next, the disciplines were classified into three categories: (i) natural sciences, such as mathematics and physics; (ii) traditional engineering fields, such as mechanical and electronic engineering; and (iii) recently developed engineering fields, such as bio-technology and nano-technology. Thereafter, according to the period of recruitment, senior and junior professors were categorised in each department representing the disciplines.

3.4 Conclusion

This chapter provides the overall research design of this study consisting of three perspectives: the country context, the time period, and the level of analysis. Then, based on this overall framework and the objectives of the study, the research strategy based on quantitative (i.e. survey) and qualitative (i.e. interview) methods is outlined. Furthermore, considering the research questions set out in Chapter 1, the details of the data sources, the methods of collecting data, and the ways of analysing this data in the research are presented.

In particular, our research methodology adopts an integrative approach combining quantitative and qualitative approaches and linking three analysis levels. As a result of this, some methodological issues related to this approach are introduced and discussed. Firstly, the method of integration of quantitative and qualitative research design can provide richer information as well as more persuasive interpretation. However, because of the nature of the two different types of data and the difficulties of replication, if we fail to maintain consideration of this in the collection and analysis of the data, the robustness of this integration can be weakened (Jick, 1979). Secondly, issues to do with the integration of different levels of analysis are introduced. This integration enables us to understand similar phenomena (in this case, the relationship between academic research and industrial collaboration) at the different levels more ‘systematically’. In spite of this strength, based on the interaction between our research question and its conceptual framework, selection of data of a manageable size is essential, because of the huge amount of data generated by the multi-level and dual (i.e. quantitative and qualitative) data collection.

Based on the methodology of this chapter, we present the analysis of the data collected in the following empirical chapters (Chapter 4, 5, 6 and 7), considering the research questions at each level (Chapter 1) and the existing literature (Chapter 2).

Chapter 4 Korean Universities and Korean National Innovation System

4.1 Introduction

In general, the university is regarded as an institution that is highly entrenched within the society, and consequently the boundary between them is not distinct. Therefore, before analysing the characteristics of universities in a given national innovation system, it is necessary to look into some idiosyncratic properties of institutions and their environments. In this vein, this chapter aims to analyse the characteristics of the Korean university system. A description of the historical development of Korean higher education institutions should help us to understand some specific characteristics of the current Korean university system. Against this background, the emergence of the second and third missions of the Korean universities is delineated.

Firstly, in terms of longitudinal perspective, section 4.2 provides a brief history of Korean universities from the fourth century to the mid 20th century. Based on this historical background, some specific characteristics of the Korean academic system are considered in the following sections.

Secondly, in section 4.3, we focus on the development of the policy environment of the Korean higher education system. In particular, according to the different stages of higher education policy, the interaction between the responses of universities and institutional settings is also examined. Furthermore, the emergence of the research and entrepreneurial activities of the Korean universities is investigated.

Thirdly, based on the characteristics of the Korean academic system as well as the Korean innovation system, section 4.4 focuses on the co-evolutionary pattern between academic research and entrepreneurial activities of Korean universities. This investigation of the activities looks at two areas: research activities as measured by scientific publications, and entrepreneurial activities as measured by patent applications.

Finally, as a conclusion, Section 4.5 summarises the findings from the previous sections. Based on these findings at the three levels (system, organisation and individual), several stylised facts characterising the two Korean academic revolutions compared to those of developed and developing countries are suggested.

4.2 Brief History of Korean universities

This section briefly introduces the historical development of Korean higher education system broken down into a number of periods from the 4th century to the 1950s.

The traditional higher education period

Generally, the origin of the formal public Korean education institutions can be traced back to the 'Tae-hak' established by a King of the Goguryeo dynasty (BC 37- AD 668) in 372 based on the oldest existing literature on Korean history written by Busik Kim (Kim, 2004: 49). According to this work (Kim, 1145), entrance to the 'Tae-hak' was only open to children of aristocratic bureaucrats and the main aims of this institution were to provide literacy in Chinese and to be well versed in Confucianism.

Afterwards, throughout the Unified Silla (668 – 918), Goryeo (918 - 1392), and Choson dynasties (1392 - 1910), the Korean education system became more systemised and opened up to a wider class of people (Byeun, 2007). For example, the Choson dynasty established a three-stage (primary, secondary and post-secondary) education system integrated with an entrance exam to become a high-rank bureaucrat based on academic performance. Furthermore, even common people were allowed to become a student at the highest level education institution named as 'Sung-kyun-kwan' incorporating 'Tae-hak' (Shin, 2000). However, the merit-based system in hiring bureaucrats had become corrupted by the ruling class by the end of the 19th century. In spite of some reformation efforts to the educational system, the dynasty and its education system collapsed in the face of Japanese imperialism in 1910 (Byeon, 2007).

Western missionaries (1885 - 1910)

After the opening of Kangwhado Island near Incheon to Japan in 1876, the existence of Korea began to be widely recognised by the western world (Byeon, 2007). Responding to this new era, the Choson dynasty created a modern public school named

'Youkyungkongwon' in 1886 providing a western curriculum in English, but this school closed in 1894 because of the corruption of bureaucrats and the political intervention of Russia and China (Umakoshi, 1997).

In contrast, in the private sector, western missionaries contributed significantly to the establishment of the modern institutions of education of Korea after the opening up the country (Lee, 2006). In 1910, 2,250 private schools were recognised by the Ministry of Education, and thirty seven percent (823) of these schools were established by religious organisations and missionaries. Seventy one percent (574) of these religious schools were created by US missionaries (Sohn, 1987).

Moreover, American missionaries began to establish 'seed' institutions of higher education such as House of Universal Grace in 1885, Underwood School in 1885, Pai Chai College in 1886, Ewha School in 1887 and Pyeng Yang Academy in 1897, which has developed into Severence Medical School [Yonsei University], Yonhee College [Yonsei University], Pai Chai High School [Pai Chai University], Ewha Womans College [Ewha Womans University] and Soongsil University respectively around the 1910s (Yoo, 2000). Umakoshi (1997) maintains that it was the US 'colleges of liberal art' in the late 19th century rather than the land-grant universities and research-oriented universities that most influenced the Korean higher education system as a model.

The Colonization period (1910-1945)

After the occupation by the Japanese imperialists in 1910, the Korean people could not develop the educational system in their own way. Under the control of the colonial authority, the Japanese made use of education policy as a major means to control the Korean people. Lee (2004: 149) maintains that the education policy in this period can be characterised as one of 'denationalisation', 'vocationalisation', 'deliberalisation' and 'discrimination'. In the same vein, Lee et al. (1997: 347) concluded that 'practicality' and 'simplicity' are the key words to understand the education system under the Japanese rule.

'Vocationalisation' and 'practicality' mean that education was allowed mainly for the training of lower-level skills and it focused on primary schools (Kim, 1997).

Furthermore, until 1924, the establishment of higher education institutions by Korean people was hindered and none of the tertiary schools was recognised as a university by the colonial authority (Kim, 2000). These two characteristics are also related with regard to the supply of 'simplicity' for minimal education opportunity and 'discrimination' between Japanese and Koreans. For example, the number of private schools (1,973) in 1910 decreased to 604 in 1919 (Umakoshi, 1997). Furthermore, in 1939, only 1.3 Korean students out of every 1,000 Koreans were enrolled at secondary schools, whereas 32.7 Japanese students out of every 1,000 Japanese were enrolled at secondary schools (Kim, 1973). The Kyungsung [Seoul] Imperial College of Japan was established as a university in 1924; however, the majority (more than 60 percent) of the students were Japanese and the quality of faculties was far lower than that of universities in Japan (Kim, 2005). The competition for admission to Kyungsung Imperial College and its operation style has influenced the Korean higher education system in terms of the preference for a state-run and centralised university system (Lee, 2004).

The US military government period (1945-1948)

After the liberation in 1945, in spite of strong aspirations for education, the illiteracy rate was 78% and only two percent of Koreans over 14-years old finished their secondary education, partly due to the previous Japanese education policy (Kim, 1997). However, from 1945 to 1948, the number of institutions, students and faculties increased abruptly as shown in the table below. Some of them were newly created, and some of them were accredited by the civil government after 1948. Lee (2004) interprets this sudden increase as an 'eruption of education fever', education having been suppressed during the colonization period.

Table 4.1 Increase in the number of higher education institutions under the US military government

	1945 (Just after the liberation)	1948 (Establishment of the gov't)
No. of HE institutions*	21 (1 university**)	42 (4 universities)
Students in HE institutions	7110	24000
Faculties in HE institutions	753	1256

*Higher education institutions just after the liberation consisted of tertiary schools after 6-years primary ('botong') and 5-years secondary ('godeung-botong') schools, and the US military government recognised these institutions as consisting of four types of HE institutions: universities consisting of several colleges, colleges granting a bachelor's degree, junior colleges and miscellaneous schools.
**Only Kyungsung university (Kyungsung imperial college) was recognised by the US military government in 1945.
Source: The Monthly Report of Ministry of Education (1948) cited in UNN (2005), *The 50 Years History of Korean Universities,* UNN (University News Network).

In addition to this quantitative growth, the Korean educational system as well as the university system has been exposed to substantial US influence after escaping from the Japanese model during this period. Emulating the US higher education system, the authority reformed the Korean education system in terms of the period of study, the semester system, the categorisation of universities and the status of faculty. The Japanese duplicative system for the period of study based on discrimination (6-5 for Japanese and 4-4 for Korean) and a three-term system beginning in April was replaced by the unified 6-3-3-4 system and the US two-semester system beginning in September respectively (Lee et al., 1998). Categorising higher education institutions (see the note in table 4.1) and providing qualifications for faculty, the authority introduced a four-year undergraduate system granting a bachelor's degree, while in the previous period, the tertiary schools under Japanese rule had provided a three-year course and had not conferred degrees (Lee et al., 1998). Moreover, the Korean Association of Colleges and Universities, which was under the supervision of the military authority, established a system of quality control based on the US model for institutions of higher education (Lee, 2004).

US educational aid (1952-1967)

Lee (2004) maintains that in terms of the higher education system, the US influence on Korean system after the Korean War (1950-1953) is more significant than in the period between 1945 and 1948 during the reconstruction of the country. The US spent more than 19 million dollars from 1953 to 1967, with a great number of aid programmes for the reconstruction of Korea (Dodge, 1971: 199-201).

The biggest programme in terms of the level of expenditure was the 'Minnesota project' between 1954 and 1958. Based on this project, three hundreds academic faculty members (particularly, in the fields of agriculture, engineering and medical science) in Seoul National University were invited to be trained as PhD students in Minnesota University in the US (Dodge, 1971: 199-210), and the facilities and equipment of Seoul National University were enhanced to an international level (McGinn et al., 1980: 91).

Based on another programme, some prestigious private universities in Seoul such as Yonsei University and Korea University entered a contract with Washington University in order to support their faculty training, curriculum development, library enhancement and research programmes (Lee, 2004). Between 1954 and 1967, these kinds of aid programmes enabled 2,883 Koreans to receive advanced training in the US and other western countries (Dodge, 1971: 199-201).

Against the background mentioned above, the US-trained scholars at Korean universities played a leading role in the development of the Korean higher education system (Lee, 2004). However, these programmes created inequality issues in the Korean university system between the public and the private and between the different regions, and a strong preference was established for overseas training, particularly in US institutions (Umakoshi, 1997).

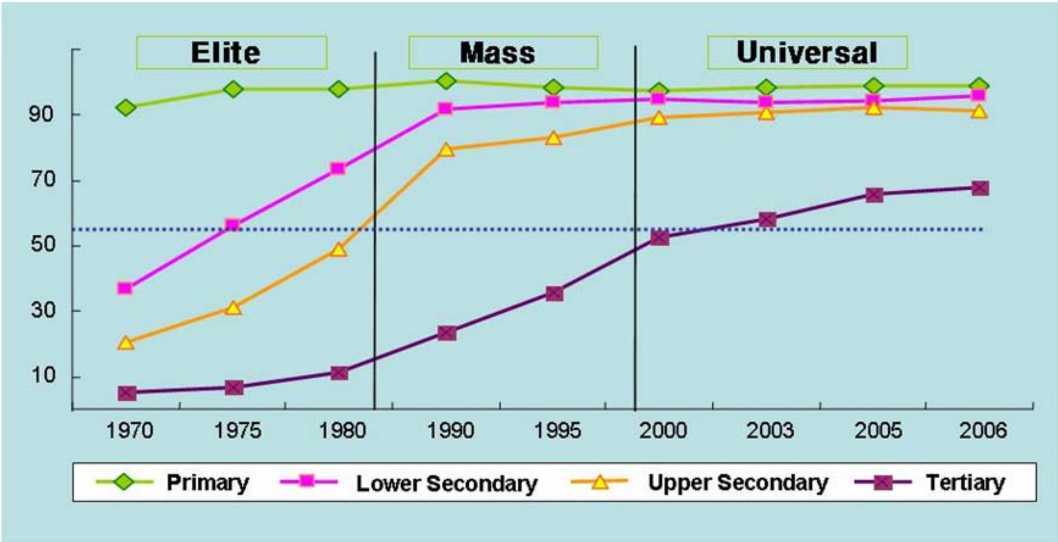
4.3 Explosion of Research and Entrepreneurial Activities: the first and second Korean academic revolutions?

This section focuses more on the Korean university sector in the last half century, while the previous section described the early history of Korean higher education. The main aim of this section is to investigate the interactions between the government's university policies and the activities of universities. In order to do this, this section consists of two major subsections. Section 3.1 addresses government policy and the institutional settings influencing universities' activities, broken down into different periods. On the basis of these conditions, various quantitative and qualitative changes in the activities of Korean universities are presented in Section 3.2.

4.3.1 University policies and institutional changes: characteristics of different periods

During the last half century, Korean universities have experienced tremendous changes, both quantitatively and qualitatively. The number of universities, academic faculties, and students increased at a rapid rate compared to other developing countries as well as developed countries. For example, according to the rate of enrolments of each stage, Trow (1974) suggested three stages of development of higher education: elite (less than 15%), mass (between 15% and 50%) and universal (more than 55%) the higher education. Based on his definition, Korean higher education has moved from the 'elite phase' to the 'universal phase' within only three decades, as shown in Figure 4.1. This rapid development is also confirmed by Appendix Figure 4.1 comparing the situation in different countries.

Figure 4.1 Trajectory of educational expansion



Source: Based on MOE (2005), *Brief Statistics On Korean Education*, MOE.

From the early stage of catch-up, the Korean government has been a dominant actor influencing the growth of the university system as well as industry. Particularly through the provision of technically skilled labour as well as qualified scientists and engineers, Korean universities have been continually encouraged to play a role as a human resource supplier for economic growth up to now. In the 1990s, the government adopted a series of policies for strengthening universities' research activities, and recently Korean universities began to be recognized as one of the direct contributors to local economic development.

In this vein, this section follows the same categorisation of periods introduced in subsection 4.4.1, because this categorisation mostly centres on the development of Korean firms as encouraged by the government's industrial policy. The various responses of universities according to their different policy environments as well as the evolving stages of the Korean national innovation system are discussed in this section as summarised in Table 4.2.

Table 4.2 Characteristics of Korean universities in three main periods

	Strong Regulation (1960 - mid-1970s)	**Massive Expansion** (late 1970s - 1980s)	**Academic revolutions** (1990s - present)
Major policy orientation	- Strong regulation over numbers - Medium-skilled labour - Focus on vocational education	- Policy to meet the needs of the masses - Establishment of research infrastructure	- Deregulation and diversity are strengthened - Encouragement of research and its economic usefulness
Responses	- Limited access to universities - Focus on teaching - Research as an individual activity	- Expansion of higher education system - Open universities and junior colleges	- On-line universities, Credit bank system etc. - Invigoration of research and cooperation with industry

Source: based on the material compiled by the author and described in this chapter

Strong regulation over education system for economic take-up (1960s – mid 1970s)

In the aftermath of Park Chung-Hee's military coup in 1961, strong regulation over the national system as well as the education sector characterises the 1960s and 1970s (Lee et al., 1998). In this period, acting as a supplier of technical labour was regarded as a main role of the secondary and tertiary education system, especially through vocational education and training, while access to universities was limited (Kim and Lee, 2006; Lee et al., 1998). In particular, in addition to encouraging an increase in the supply of human resources in the field of science and engineering to industry, overall governmental control over public universities as well as private universities was based on strong policy measures such as fixed numbers of students.

On the other hand, in this period, the government chose public institutes such as KIST (Korea Institute of Science and Technology) created in 1966 as the main national R&D supporter for industry instead of existing universities. Based on the successful operation of KIST, a series of public institutes were established in order to support 'six national strategic industries' (i.e. iron, chemical, non-metal, machinery, shipbuilding and electronics) (Kim, 2006). For example, KORDI (Korea Ocean Research and Development Institute) was created in 1973 in order to support the shipbuilding industry and KIMM (Korea Institute of Machinery and Materials) in 1976 for the machinery sector. Moreover, the quality of the working condition (e.g. three times higher salary than for professors) of these public institutes attracted a large number of highly qualified scientists and engineers trained in industrialized countries throughout the '70s, the '80s and the '90s, in a process known as the 'reverse brain drain' or 'brain gain'

(Moon, 2004).

After the liberation in 1945 and the Korean War between 1950 and 1953, the reestablishment of the Korean higher education system continued until the ’60s as described in section 4.2. A 5-year economic development plan drafted by the government in 1962 was implemented through various policy measures. At the same time, the government recognised certain problems arising from the ’50s ‘laissez-faire’ education policy, in particular: the heavy concentration of students in the Seoul area, 4-year universities, private universities and the disciplines such as humanities and social sciences (Umakoshi, 1997). To address these problems, the 5-year Education Reconstruction Plan and the Act of Advancement of Industrial Education were drawn up in 1962 and in 1963 respectively. In 1966, the 5-year Plan for the Advancement of Science and Technology was drafted. Based on this plan, the Office of Science Education was established in the Ministry of Education.

The implementation of these plans and laws launched an era of strong government control of the education system. Particularly, according to the Presidential Order no. 2332 in 1965, the fixed number of the students enrolling in tertiary education institutions was to be determined by the Minister of Education. Based on this order, the government could control the number of graduates not only in a given university but also in specific disciplines of the university; therefore, the university system could be easily mobilised to provide increasing human resources in science and engineering, with decreasing numbers of students in humanities and social science.

For example, in 1963 the majority of students enrolled in tertiary education were those in humanities and social science (50.8% in humanities and social science, 39.6% in science and engineering and 9.6% in teacher training), whereas in 1973, the largest number were those in science and engineering (42.0% in science and engineering, compared with 35.1% in humanities and social science and 22.9% in teacher training). Considering the number students in 4-year universities only, the proportion of the students in science and engineering amounted to 59.7%, whereas those in humanities and social science was 38.7% and those in teacher training was 1.6% in 1972 (MOE, 1963; KNCESI). Furthermore, the specific disciplines of these students mostly coincided with the main strategic industries chosen both at the national and regional levels in the 5-year Economic Plan (Cho et al., 2002). Umakoshi (1997) characterises this change as ‘an abrupt transition from a humanities-centred country to a science and engineering-centred one in ten years’.

Along with the increase in the number of students in science and engineering, the government established new forms of institutions such as a ‘5-year higher specialised industrial school’ in 1963 in order to ‘support the efficient provision of field specialists in the industry workforce’ (the Promotion of Industrial Education Act in 1963). This institution can be seen as an integrated form of 3-year upper secondary schools with 2-year tertiary schools. In 1969, the number of these schools amounted to 23, while the number of the enrolled students increased to 20,741. In the 1970s, following a recommendation of the International Development Association, the last two-year course of this school was separated and established as an independent ‘specialised industrial school’. This school developed into various 2-year junior colleges in the 1980s to meet the explosive demand for higher education (Cho et al., 2002).

Based on the fixed number policy, large national universities in the regions were strongly supported. As mentioned above, the government regarded the imbalanced development between the capital area and other regions as a serious problem stemming from the ’50s policies with regard to the economy and education. Therefore, by increasing the quota for enrolled students at regional universities, the government aimed both to reduce the concentration of students in the capital area and to attract them to regional universities. For example, between 1968 and 1978, while the quota of the capital area increased 1.4 times, that of the other regions increased 2.8 times. Moreover, this increase was concentrated in the fields of science and engineering in order to meet the needs of regional industry. This concentration coincided with support for strategic local industry in the third 5-year Economic Plan (1972-1976) (Umakoshi, 1997).

In terms of highly qualified scientists and engineers, the strong dependence on overseas institutions started during this period. In 1950s, the government began to encourage overseas training supported by foreign scholarships and initiated an official supporting programme for students to study abroad in 1954. These initiatives were possible due to U.S aid just after the Korean War (see section 4.2). In the 1960s and 1970s, the training of highly qualified scientists and engineers was motivated by both the government initiatives and by individual demand for higher education at overseas institutions (Kim, 1997). Half of these students were in the field of science and engineering, and most of students went to the institutions in the US, as shown in Table 4.3.

Table 4.3 Number of students going abroad by discipline and country

Periods	1953 – 1960 (%)	1961- 1973 (%)
Humanities/Social Science	2,183 (44.7)	3,588 (47.9)
Natural Science/Engineering	1,614 (33.0)	3,177 (42.4)
Medical/Pharmaceutical Science	651 (13.3)	247 (3.3)
Agricultural/ Maritime	124 (2.6)	127 (1.7)
Education, Etc.	312 (6.4)	347 (4.7)
The United States	4,391 (89.9)	6,398 (85.5)
Germany	160 (3.3)	246 (3.3)
The others	333 (6.8)	842 (11.2)
Total	4,884 (100.0)	7,486 (100.0)

Source: MOE (1974), Report on students studying abroad, Ministry of Education

Massive expansion of higher education system (late 1970s - 1980s)

In the aftermath of the coup in 1980, General Chun Doo-Hwan succeeded Park Chung-Hee. In the light of the vulnerable political legitimacy of the government, a series of distinctive reformations of the education system as well as in the other areas were implemented (Lee et al., 1998). The most significant characteristics of this period are the massive expansion and the relaxation of previous strong regulation of the university system in order to meet the explosive demand for higher education (Kim and Lee, 2006). However, the expansion occurred mainly in terms of the number of students in non-technological disciplines such as humanities and social science, whereas in the previous period, vocational training in the fields of science and engineering was stressed (Cho et al., 2002).

At the same time, the public institutes were mobilised for several national R&D projects organised by government ministries in the early ’80s, whereas they had enjoyed a measure of institutional and financial autonomy for supporting domestic industry directly in the previous period (Kim, 2006; Moon, 2006). Moreover, there were efforts to establish not only several organisations but also broader institutions in order to stimulate high quality knowledge creation activities, which later functioned as a positive condition for the 1990s’ vitalisation of university research. In 1977, KOSEF (the Korea Science and Engineering Foundation) was established to support basic research activities. In 1979, the Act for the Advancement of Academic Research was passed. Based on this law, in 1981 the KRF (Korea Research Foundation) was created in order to support mainly university research.

Around the end of 1970s, the strong regulation policy based on fixed numbers of students faced a few challenges due to the explosion in demand for higher education. For a long time, personal education had been considered as a significant factor for the success of members of Korean society, something that can be traced back to Confucianism (Lee, 2006). Furthermore, as the national economy grew, households accumulated enough wealth to pay for tuition fees, and industry came to need more qualified human resources. More directly, the sudden increase of potential entrants (i.e. graduates from secondary education) in the previous period also contributed to the explosive demand for tertiary education. Therefore, the demand for higher education increased throughout the society (Lee et al., 1998). Responding to these increasing demands, the quota or fixed number of students in higher education institutions was increased from 78,615 in 1978 to 185,065 in 1979, a 250% increase (Kim and Lee, 2002). Considering the much smaller increase from 45,000 in 1969 to 66,000 in 1977, this was a remarkable increase. During the 1980s, the number of students enrolled in higher education institutions increased from 0.57 million to 1.49 million, and 10 new universities were established. Moreover, the form of control policy focused on fixed numbers shifted from the number of entrants to the number of graduates in 1981, allowing the number of freshmen for each university to increase.

With the increase in the number of students and institutions, structural changes in the university system became possible. In the 1980s and 1990s, new forms of higher education institutions were created, whereas in the 1970s, the need for higher education was met mainly through increasing the size of existing institutions. For example, the 2-year air and correspondence colleges and 2-year teacher-training colleges were upgraded to 4-year national universities. The specialised higher schools aiming to provide qualified industrial labour, which had been established around 1970, were upgraded to formal short-term higher education institutions in order to meet the demand from both citizens and industry (Umakoshi, 1997). New forms of institutions such as open universities were introduced in 1982 and various bachelor degrees were launched for students opting for a self-study route.

In particular, various science education institutions for the gifted young and linking secondary to tertiary education were set up by the government in the early 1980s: for example, Science High Schools, KIT (the Korea Institute of Technology) and KAIST (the Korea Advanced Institute of Science and Technology). On the other hand, industry also began to be aware of the importance of highly innovative knowledge. In this vein, POSCO (Pohang Steel Company) established a research-intensive university POSTECH (Pohang Institute of Science and Technology) in 1986. The establishment of these organisations stimulated existing prestigious universities to strengthen their research activities and to upgrade graduate education (Cho et al., 2002). For example, Seoul National University initiated several programmes in order to strengthen graduate education especially in the field of science and technology, such as upgrading the research facilities in the university laboratories, an initiative that was partly supported by the government through a World Bank loan (Woo, 2002).

Around the late 1970s, certain conspicuous changes started to emerge with regard to graduate education (Woo, 2002). The number of graduate students was abruptly expanded, as shown in Table 4.4. In 1970, the number of students enrolled in graduate schools was only 6,640, which amounted to 3.7% of all students in higher education institutions. However, in the 1980s, the increase of postgraduate students in domestic institutions was faster than that of undergraduate students, whereas in the 1970s, most doctoral degrees had been earned abroad except for medical doctors (Umakoshi, 1997). Furthermore, certain changes in military service speeded up these trends. For example, shorter military service as an officer for graduates of masters programme was introduced in 1981, and highly qualified scientists and engineers were exempted from the military service in the same year. As a result, the proportion of postgraduate students in higher education institutions increased to 6.6% in 1993. This formed part of the background of the 1990s' invigoration of academic research in Korean universities.

Table 4.4 Increase of number of postgraduate students

Year	Master program	Doctoral program	Total
1970	6,112	518	6,640
1975	12,351	1,519	13,870
1980	29,901	4,038	33,939
1985	57,698	10,480	68,178
1990	72,417	14,494	86,911
1995	93,993	18,735	112,728
2000	197,436	32,001	229,437
2005	238,753	43,472	282,225

Source: MOE (2005), Annual Report on Educational Statistics, MOE.

Invigoration of research and direct contribution to economy (the 1990s – present)

In 1988, the direct vote system for the Presidential election resumed following popular pressure, and in 1993 a leader of the democratic movement, Kim Young-Sam, was elected as President. Following this, a series of educational reforms as well as political ones were implemented. The '90s democratization speeded up the deregulation of education policy, so it was easier than before to establish higher education institutions. In other words, the previous 'permission' policy was replaced by minimal 'condition' policy for the establishment of new higher education institutions.

For example, one of the most distinctive educational reforms was the abolition of the quota system for higher education institutions (except for those in the capital area) in 1995 (Kim and Lee, 2006). This led to numerous higher education institutions being created, not only typical small- and medium-sized private universities in local areas but also new forms of institution such as graduate schools without undergraduate students and on-line universities. On the other hand, this reform encouraged large private universities in Seoul to create a dozen of local autonomous campuses. This increase can be regarded as the second explosion in the number of universities as well as in the numbers of students enrolled (see the second peak in Figure 4.2). Between 1990 and 1993, twenty new 4-year universities were created.

In terms of higher education policy, the government took note of the 1980s' oversupply, following the massive increase in university graduates. Therefore, the focus of the fixed number policy switched back from the number of graduates to the numbers of entrants to universities in 1987, and the increase in university graduates was focused on science and technology instead of in humanities and social science (Cho et al., 2002), as shown in Table 4.5.

Table 4.5 Number of university graduates overall and in science and engineering

	Graduates – Overall (A)	Graduates - Science & Engineering (B)	B/A
1976	34,725	10,266	29.6
1981	55,846	18,527	33.2
1986	137,846	48,099	34.9
1991	175,586	61,781	35.2
1996	184,212	75,150	40.8
2001	239,702	98,150	40.9
2005	268,833	105,860	39.4

Source: Korean National Center for Education Statistics and Information (http://cesi.kedi.re.kr)

Several new research-oriented universities were also created: for example, GIST (Gwangju Institute of Science and Technology) in 1993, KIAS (the Korea Institute for Advanced Study) in 1996 and ICU (Information and Communications University) in 1998. In order to provide highly qualified scientists and engineers, overseas postdoctoral programmes were implemented for domestically trained PhDs in the field of science and engineering in 1996. On the other hand, new universities more specialised in university-industry cooperation have been created by the government. In 1992, KUT (Korea University of Technology and Education), which aimed to 'educate human resource development facilitators and vocational training instructors' was established by the Ministry of Labour. Moreover, in 1998, KPU (Korea Polytechnic University) was founded by the government in several major industrial parks 'to produce outstanding industrial engineers and improve the nation's competitive edge in industrial technology' through strong university-industry linkages.

Research invigoration: 'the first Korean academic revolution' in the 1990s

Research had begun to be stressed as one of the main missions of universities since the early 1990s by the science and technology policy community, which consists of public officials, scientists and academics related to the field. Accordingly, the government began to establish policy measures encouraging universities to provide innovative knowledge in order to raise the technological capacity of Korean industry. Simultaneously, the main role of public research institutes was re-oriented to 'future-oriented large complex advanced technology development' (Yim and Kim, 2006). Furthermore, national R&D programmes were diversified and expanded by individual ministries without strong coordination among the ministries (Song, 2002). This section summarises various policy measures to support research activities in universities, including various laws, R&D programmes, and other institutional changes.

Firstly, in order to establish an infrastructure for basic research, the government enacted 'the Basic Science Advancement Law' in 1989. According to this law, 'the master plan for advancement of basic research' was drafted. On the other hand, in its final report to the President, PACST (the Presidential Advisory Council on Science and Technology) maintained that national science policy goals needed to be re-oriented to invigorate basic research capabilities (1990, PACST). This led to the creation of 'the Implementation Plan for Innovation in Science and Technology' in 1991, which suggested various policy measures, such as fostering excellent research groups and establishing university laboratories.

Secondly, in addition to the establishment of the infrastructure mentioned above, the research activity of academics was strongly supported through various programmes implemented by KOSEF (the Korea Science and Engineering Foundation). Some of the most successful programmes to support academic research were: SRCs (Science Research Centers) / ERCs (Engineering Research Centers) and RRCs (Regional Research Centers) created in universities by KOSEF and MOST (the Ministry of Science and Technology). On the other hand, the creation of university laboratories was encouraged by MOE (the Ministry of Education) through financial support, and MOIC (the Ministry of Industry and Commerce) established TICs (the Technology Innovation Centers).

Furthermore, as briefly mentioned in the previous section (see Table 4.4), the massive increase in postgraduate students is another characteristic of this period. The 'Brain Korea 21' programme (hereafter referred to as BK 21) was launched based on 'performance contracts' in order to support university researchers, particularly postgraduate students. A sum of 1.2 billion dollars was invested over seven years (1999-2005) in this programme. Moreover, the major outputs were an increase in the number of SCI (Science Citation Index) papers from 4,414 (in 1999) to 7,477 (in 2003), and an increase in patents from 103 (in 1999) to 261 (in 2003) (KRF, 2008). However, some commentators worry that the funding principle of 'selection and concentration' may have aggravated the poor research conditions of non-selected graduate schools (e.g. Lee, 2000).

Thirdly, in order to support various R&D programmes, huge amounts of funding have been invested in the university system through national R&D programmes operated by the ministries. Furthermore, the way of allocating the funding of these programmes has changed since 1990. University researchers have to compete not only with their colleagues in academia but also with researchers in governmental institutes to obtain the funds and to carry out the research proposed by government, whereas in the previous period research funds were allocated based on the number of academics in each university (Cho et al., 2002).

Stress on direct contributions to the economy: the 'second Korean academic revolution' in the 2000s

There have been a large number of policy measures supporting cooperation between universities and industry including various government programmes and laws since the 1960s. However, the policy measures before 2000 were mainly focused on the training of industry-oriented human resources and were based on government-initiated R&D programmes (Park et al., 2007). Around 2000, as the research capacity of universities increased, various governmental and university efforts particularly focused on the exploitation of academic research potential have been implemented. Against this background, this subsection examines the efforts of both government and university authorities to invigorate university-industry linkages. These efforts can be categorised into several areas: enactment of laws, national R&D programmes, national plans, and the other institutional changes including those to the university system.

First of all, the government created new laws and amended existing laws in order to encourage the exploitation of academic potential. The specific laws invigorating university-industry cooperation are as follows: the Promotion of Industrial Education and the University-Industry Cooperation act (1963), the Promotion of Technology Transfer Act (2000) and the Promotion of Invention Act (1994). Including these, eight ministries have enacted or partially amended a total of eleven laws since 2000.

Based on the amendment of the ‘Promotion of Industrial Education and University-Industry Cooperation Act (1963)’ in 2003, legally autonomous organisations such as university-industry cooperation foundations have been established on university campuses since 2003; as a result, Korean universities have been permitted to create for-profit companies based on academics’ inventions. Moreover, a Korean version of the US Bayh-Dole Act, the ‘Promotion of Technology Transfer Act’ was enacted in 2000. This Act enforces public research institutes to create technology licensing offices; moreover, in 2001, the range of this enforcement was extended to forty-six public universities. The ‘Promotion of Invention Act’ was enacted in 1994, and subsequently revised to set out the jurisdiction of intellectual property rights (IPR) of academics in public universities in 2001; as a consequence, the agencies affiliated to universities can manage their IPR and the transfer of university inventions.

Secondly, the government implemented a series of R&D programmes to stimulate the commercial exploitation of academic research as well as to strengthen university-industry linkages. According to Sohn et al. (2006), the level of funding for university-industry cooperation programmes consists of 25% (1.8124 trillion won) of all national R&D projects (7.2283 trillion won) in 2006. Moreover, most of them have been started since 2000, and from around 2004 they have been implemented actively (Park et al., 2007). In terms of size and importance, there are four major programmes of particular importance: the second phase BK21 project, the NURI (New University for Regional Innovation) project, the CK (Connect Korea) project and the HUNIC (Hub University for Industrial Collaboration) project. In addition to these, eleven ministries were operating 50 similar projects in 2006 (KRF, 2006).

The BK21 project in its second phase (2006 - 2012) is focused on university-industry collaborative research, while the first phase (1999 - 2005) was concerned with the overall research capability and the training of students at universities (KRF, 2006). In order to contribute to balanced regional growth across the country, the NURI project (2006 - 2010) encourages universities located outside the Seoul metropolitan area to achieve three goals: enhancing the disciplinary specialisation of regional universities, providing regional human resources, and ‘establishing’ the regional innovation system.

In order to 'connect' the demand side (industry) and supply side (university), the CK project (2006 - 2010) has focused on invigorating technology transfer to industry by strengthening the TLO (Technology Licensing Office) capacity. The HUNIC project (2004 – 2009) is aiming to strengthen the R&D activities of existing industrial clusters by encouraging regional universities to cooperate with industries nearby through various channels, such as cooperative research, training human resources and sharing research infrastructure.

Table 4.6 Four major national R&D projects focusing on university-industry cooperation

Ministries	Supporting Agency	Projects	Year starting	Budget 2006 (Bil. Won)
Ministry of Education	KRF (Korea Research Foundation)	The second Phase Brain Korea 21	2006	290
		New University for Regional Innovation (NURI)	2004	260
		Connect Korea project (University TLO supporting project)	2006	5.8
Ministry of Industry and Commerce	KOTEF (Korea Industrial Technology foundation)	Hub University for Industrial Collaboration (HUNIC) Project	2005	20

Source: revised from KRF (2006), pp. 399-436.

Thirdly, the government has drafted several national plans embracing the university-industry cooperation strategy, such as the 'Plan for University-Industry Cooperation to Establish the National Innovation System (Feb., 2002)', the 'Vision and Strategy for New University-Industry Cooperation (Sep., 2003)' and the 'Plan for the Expansion of University-Industry Cooperation under the MOE, MOIC and MOL (May, 2005)'. In 2002, the 'Plan for University-Industry-Government Cooperation to Establish the National Innovation System' has been jointly drafted by 15 ministries including MOE in order to coordinate ministries' university-industry-government cooperation projects. According to this plan, an associated body for coordinating each ministry's projects has been created, and the incentive system for participants such as professors and researchers in the projects has been strengthened. To upgrade this plan, the 'Vision and Strategy for New University-Industry Cooperation' was announced in 2003. This plan identifies key implementation tasks such as supporting hub universities for university-industry cooperation, enhancing the evaluation system for universities involved in university-industry cooperation, and encouraging universities to create companies. Following these plans, the 'Plan for Expansion of University-Industry Cooperation under the MOE, MOIC and MOL' was published in 2005, and the three ministries have launched the 'Expansion of University-Industry Cooperation Programme' including the HUNIC project.

On the other hand, in response to the government's strong emphasis on invigorating university-industry cooperation, university authorities have not only established an incentive system benefiting the professors involved in entrepreneurial activities by modifying performance evaluation indicators, but they have also implemented various programmes such as the operation of incubation centres, commissioned training for industrial labour, internships in companies and consultancy for regional industry. According to a survey of 26 Korean universities on changes in the performance indicators for university-industry cooperation (Park et al., 2007), all of them reported that patent performance has been considered, and 16 universities (62%) had adopted this indicator by 2000. Moreover, 35% of universities were using the number of technology-transfer agreements as a performance indicator, and recently the proportion has grown rapidly. Another similar survey (KRF, 2007) reported that 100 out of 129 universities were reflecting industrial collaboration activities in their performance evaluation, and 99 universities weighted an international patent as 16% of a SCI paper.

Table 4.7 Inclusion of an industrial collaboration indicator in the performance evaluation of academics

	Patent performance	Equal weighting of patent and int'l paper	Technology Transfer
First year	1974	1982	1998
Last year	2006	2007	2007
Before 2000	16	9	1
After 2000	10	10	15
No of univ.	26 (100%)	19 (73%)	16 (62%)

Source: revised from Cho et al. (2007), p.27.

In terms of the government's efforts with regard to university-industry linkages, most of the laws were created and revised after 2000, and the R&D and supporting programmes started between 2002 and 2004, while the major plans were published after 2002. Furthermore, the universities strongly adopted government policy after 2000. Therefore, we may conclude that the 2000s is a period of invigoration of university-industry cooperation in the Korean academic system.

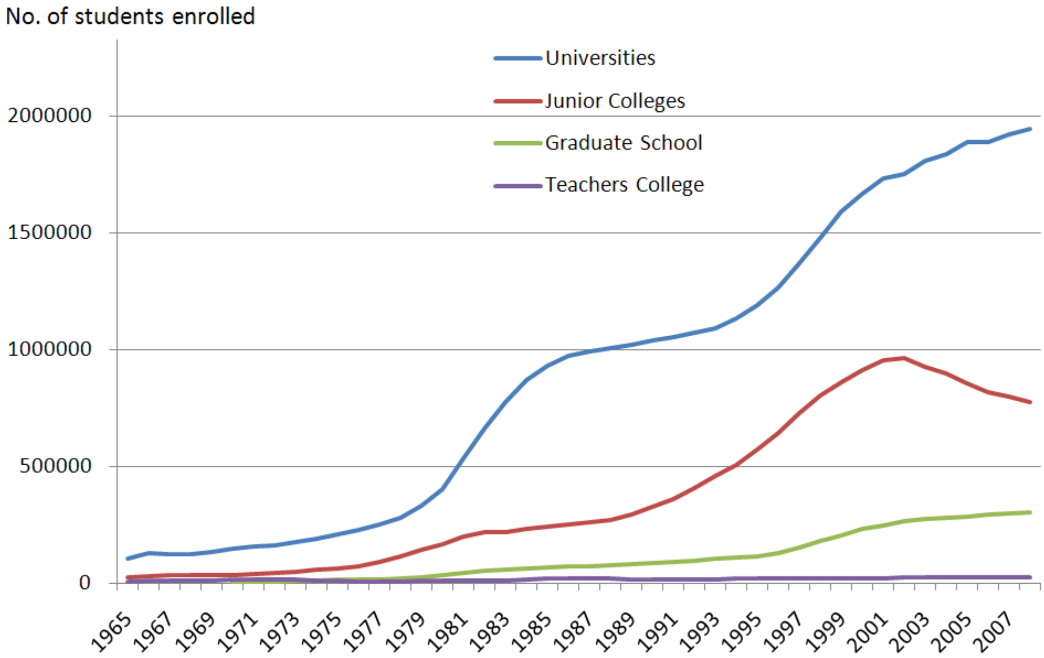
4.3.2 Change to Korean university activities during the last half century

Against the background of the governmental policies and institutional changes described in subsection 4.3.1, Korean universities have experienced considerable developments in terms of their activities during the last five decades. This section focuses on the quantitative and qualitative changes of Korean universities in terms of the three main activities: teaching, research and entrepreneurial activities.

Teaching activities: enrolment of students

The growth of enrolment of students in higher education has been enormous as shown in Figure 4.2. In terms of the enrolment of 4-year colleges, there have been two explosions during the last four decades: the first one was in the early 1980s while the second was in the late 1990s. These two peaks are closely related to the different higher education policies of each period as outlined in subsection 4.3.1. The late 1990s' increase in the enrolment of graduate school was also influenced by both higher education policy and science and technology policy aiming to produce more highly qualified human resources.

Figure 4.2 Expansion of the Korean higher education system over the last four decades



Source: Constructed by the author, based on the data from the website of the Korean National Center for Education Statistics and Information.

On the other hand, in terms of the overall enrolment 'rate', only 0.05% of the total population was enrolled in higher education institutions in 1945. In the aftermath of the Korean War, the percentage increased steadily: from 0.40% in 1955, to 0.49% in 1965 and 0.69% in 1975 (Lee, 2006: 145). As shown in Table 4.8, an explosive increase in enrolment to higher education institutions has been observed during the last three decades. Since 1980, the enrolment has increased enormously: from 11.4% in 1980, to 36% in 1995, 52.5% in 2000 and 65.6% in 2005.

The rapid growth of enrolment in Korea had already surpassed even that of Japan by the mid-1990s, as shown in Table 4.8. Compared to OECD and other countries, the speed of catch-up was remarkable. As shown in Appendix Figure 1, the percentage of the Korean population in the 25-to-35-year-old group attaining at least tertiary education ranked Korea in fourth position in 2005. Furthermore, the percentage gap between the two age groups is the largest of the countries investigated, which means that the fastest change in the world has been achieved by Korea.

Table 4.8 Comparison of the Enrolment Rates* to the HEIs in Korea and Japan**

	1970	1975	1980	1985	1990	1995	2000	2005
Korea	5.4	6.7	11.4	22.9	23.6	36.0	52.5	65.6
Japan	23.6	38.4	37.4	37.6	36.3	32.2	49.1	51.5

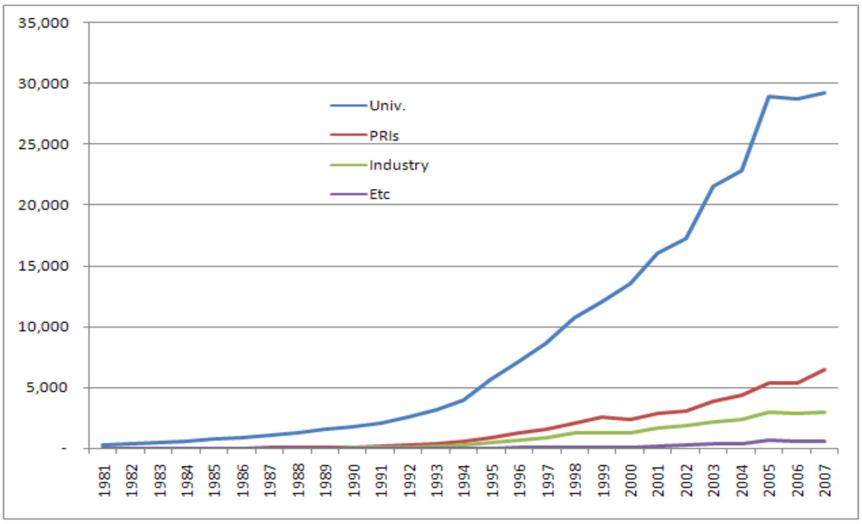
*The enrolment rate here is defined as the ratio of the number of enrolled students graduating in the previous year to the population of 18-years-old (the number of students who completed lower secondary schools and the lower division of secondary schools three years ago).
**For comparison, the HEIs (Higher Education Institutions) include 4-years universities and 2-years vocational junior colleges, while the specialised training colleges in Japan which have no counterpart in Korea are excluded.
Sources: MOE & HRD (Ministry of Education & Human Resources Development) and KEDI (Korean Educational Development Institute) (2005), Analysis on Educational Statistical Data, KEDI; MEXT (2006), Japan's Education at a Glance 2006, MEXT (http://www.mext.go.jp/english/statist/07070310.htm).

Due to the faster increase of enrolments compared to that for the recruitment of professors, the student-professor ratio increased from 22.6 in 1966 to 35.8 in 1985, according to data obtained from the website of the Korean National Center for Education Statistics and Information. Therefore, this situation adversely affected the quality of teaching and research (Kim, 1997). Until the end of the 1980s, most Korean universities remained "primarily undergraduate teaching-oriented rather than graduate research oriented" institutions (Kim and Dahlman, 1992: 446). However, more recent programmes such as NURI (New University for Regional Innovation) and BK (Brain Korea) 21 have been initiated by the government in order to boost the quality of teaching facilities and to encourage recruitment of new academic staff. Although these programmes are still in progress, some evidence of qualitative changes in teaching were detected during the interviews with Korean academics, which are investigated more specifically in the following empirical chapters.

Research activities

In terms of the number of publications in SCI (Science Citation Index) journals, a sharp increase can be observed after the early 1990s, as shown in Figure 4.3. This change is likely to be closely related to the policy measures regarding Korean universities as one of the main actors providing knowledge in the national innovation system as presented in Section 3.1. Furthermore, the contributions of industry as well as public research institutes to this have also increased since the 1990s.

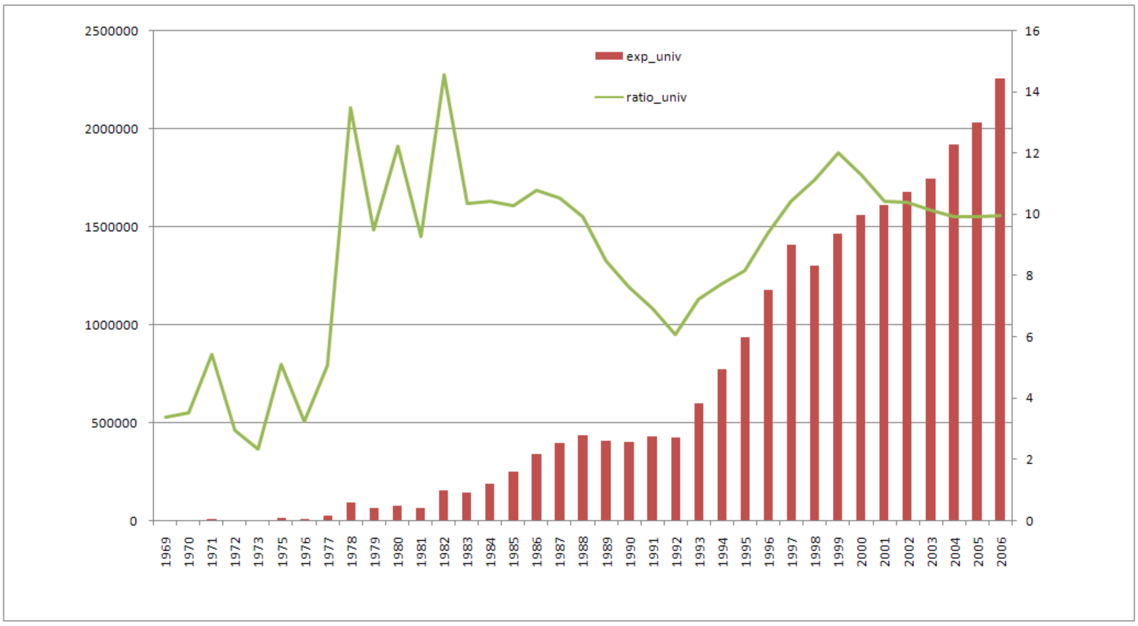
Figure 4.3 The number of publications on SCI (Science Citation Index) journals by sectors



Source: Data based on KRF (2008), *Analysis on the Citation Database for the Korean Researches in 2007*, KRF survey and analysis 2009-001, and Park (2001), *A study on Citation Index of Korean researchers: NCR Korea 1981-2000*, Ministry of Education.

While the policy changes in the 1990s for universities can be regarded as one of the main indirect conditions, a more direct driver is the massive increase of resources in terms of research personnel as well as funding. Figure 4.4 shows that university research expenditure substantially increased in terms of both absolute level and as a share of total domestic R&D expenditure in the 1990s. Moreover, the number of university researchers has nearly doubled every five years after the 1970s, as shown in Table 4.12 in Section 4.4.

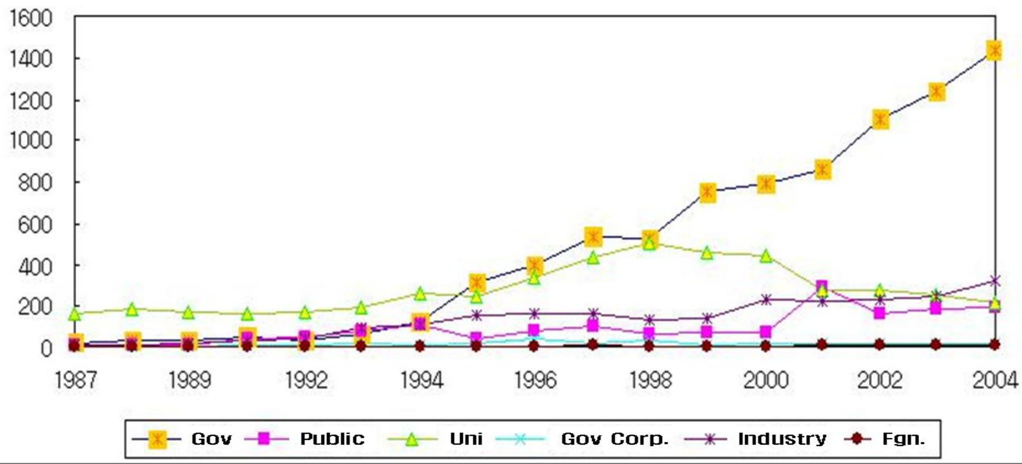
Figure 4.4 R&D expenditure of Korean universities and its ratio to total domestic R&D expenditure (unit: mil won)



Sources: Created by the author, data from MOST (2007), Report on the Survey of Research and Development in Science and Technology, MOST, MOST (1999), Report on the Survey of Research and Development in Science and Technology, MOST.
*In terms of the ratio (the line in the above figure), the sudden increase in 1978 is due to the establishment of KOSEF in 1977 and the decrease after 1980s is due to the increase of industrial R&D expenditure. Moreover, the decrease after 1999 of the ratio is related to the rapid increase of industrial R&D expenditure.

In particular, the increase in expenditure was driven mainly by government funding after the early 1990s, as shown in Figure 4.5. Furthermore, the funding by universities themselves decreased after the late 1990s, while funding from industry increased after the 2000s.

Figure 4.5 Sources of Korean universities R&D expenditure (unit: billion won)



Sources: Bak (2006b), MOST (2005), Report on the Survey of Research and Development in Science and Technology, MOST, MOST (1999), Report on the Survey of Research and Development in Science and Technology, MOST.

In the early catch-up stage, Korean universities were widely regarded as teaching institutions for providing qualified human resources, while research and development were mainly allocated to publicly funded research institutes (Kim, 1999: 7). The government chose the public institutes as an applied research institution providing technological assistance for industry. On the other hand, universities in the period of the early catch-up could not attract external research resources (see Figure 4.4), not only because the government was mainly dependent on publicly funded institute in term of research activities, but also because the needs of the industry sector were not developed enough to encourage research in the universities.

Furthermore, research used to be regarded as a private activity for Korean academic staff until the 1960s (Bak, 2006b: 68). In 1963, the Ministry of Education started to support Korean academics through ‘the Academics Research Support Programme’, which was the only programme for funding the research activities of academics until the late ’70s. However, the amount of funding was mostly too small to support ‘research’, so this support was often regarded as little more than another type of salary for academics (Kim et al., 2000).

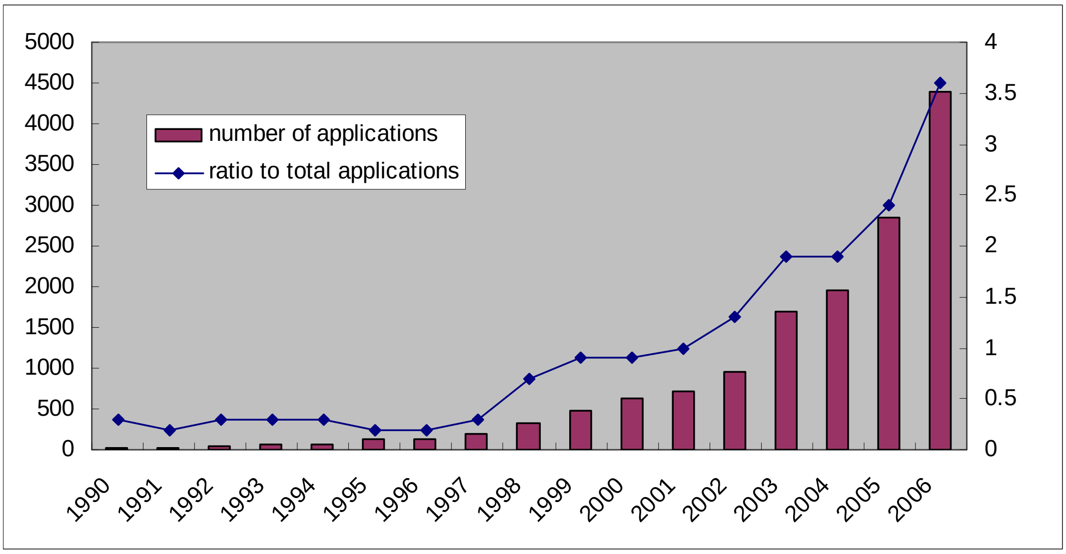
In contrast, since the early 1990s, research has begun to be recognised as an essential part of academics’ every-day life. According to several interviews with Korean academics, an academic with no research activities (particularly, if in the field of science and engineering or among the younger generation) is likely to be regarded as somewhat incompetent by the Korean academic community. This is investigated more specifically in later empirical chapters (particularly in Chapter 7).

Direct contribution to the economy

Since 2000, providing direct economic contributions has begun to be strongly recognized as one of the main missions of universities in particular. This subsection describes the invigoration of the third mission of Korean universities in three terms: patent applications, technology transfer and company spin-offs.

Firstly, as shown in Figure 4.6, the number of domestic patent applications and its ratio to total applications have increased very considerably since the early 2000s. The timing of the abrupt increase coincided with the government policy change to strengthen universities' linkages to industry, as explained in subsection 4.3.1.

Figure 4.6 Increase in number of domestic patents applications and the ratio to the total applications by universities



Source: data based on Appendix table 5.1 in KIPO (2007), The Patent Trends in Korea 2007, KIPO.

Secondly, in terms of the technology transfer activities of universities, the performance after 2003 is distinctive compared to that in previous period. As shown in Table 4.9, about two-thirds of royalties have been created after 2003, and four-fifths of the numbers of technology transfer agreements have been implemented after 2003.

Table 4.9 Royalties from technology transfer by universities (unit: million won)

	~ 2002	2003	2004	2005	2006
royalties - no. of trans. - no. of univ.*	11,191 (410) (34)	2,250 (210) (47)	3,177 (243) (45)	6,878 (587) (50)	9,033 (563) (66)

*Number of universities reporting that they transferred technology to industry
Sources: MOCIE (2006), *A Survey on the Technology Transfers of Public Research Organization* MOCIE; KRF (2007), *White Paper on University-Industry Cooperation* KRF.

Thirdly, in the 2000s, a large number of spin-off companies were established by academics and researchers in public research institutes. A survey on venture creation by researchers and academics was conducted by SMBA (the Small and Medium Business Administration) for 219 universities and 51 public research institutes in 2007. According to this survey, about 70% of academics who created companies have done so after 2001. Moreover, the survival rate of the companies created by professors and researchers (72.7%) is higher than that of other small or medium-sized companies within five years (55%) (Kim, 2005).

Table 4.10 Number of the professors and researchers creating spin-off companies

	'97~ '00	2001	2002	2003	2004	2005	2006	2007	total
Created	348	118	113	77	70	105	90	82	1003
- profs.	263	99	99	72	64	90	82	74	843
- reschrs.	85	19	14	5	6	15	8	8	160
Closed*	43	33	48	31	36	33	33	17	274
Going-on	305	390	455	501	535	607	664	729	729
Survived		85	65	46	34	72	57	65	**72.7%

* Number of sold companies is included.
**Survival rate is calculated the ratio of the going-on (729) to the created (1003).
Source: press release on the website of SMBA (Small and Medium Business Administration), http://www.smba.go.kr/ accessed on 11th May, 2008.

The qualitative change in the third mission of Korean universities can now be considered. First of all, the third mission like the other two missions of Korean universities, has been under direct and indirect control over the last few decades, because the Korean government exploited the universities as a means for pursuing its industrial and science and technology policies. Therefore, some may maintain that the third mission of Korean universities was not totally new when it emerged in the 2000s. However, the mode of implementation of the third mission has certainly changed. In other words, the channels of contribution to the economy have been extended from human resource provision to direct practical research and even to some profit-making activities.

4.4 Coevolving KNIS and Activities of Korean Universities: Coupling Effect?

4.4.1 Evolution of the national innovation system and policies broken down by periods

The brief history of the Korean national innovation system can be represented in several ways. Some authors like Crow and Nath (1992) and Webb (2007) describe the development of the Korean national innovation system in terms of the different decades (e.g. the 1960s, the 1970s and the 1980s). Others (Kim, 1997a; Kim and Yi, 1997; Yim and Kim, 2005; Kim, 1997b; Song, 2002) adopt a multiple-stage model (e.g. initial stage, intermediate stage and knowledge-intensive stage), although their criteria for such a categorisation are different. For example, Song (2002) suggests a categorisation of the stages according to three critical historical moments relating to the development of Korean capitalism: the initiation by the government of the 5-year economic development plan in 1962, the movement to solve the crisis of capital accumulation in 1982, and the IMF (International Monetary Fund) crisis in 1997. However, this study adopts Linsu Kim's categorisation of the various stages, as this approach is not only widely accepted by scholars of the Korean innovation system, but also helps us to understand the systemic changes by characterising each stage in terms of innovation. In his book (1997), Kim characterises the evolution of the Korean national innovation system as a three-stage model: duplicative imitation, then creative imitation and finally innovation.

According to Kim's arguments, as 'a learning facilitator', the Korean government strongly intervened in the dynamic learning process of Korean firms by introducing various policy measures such as enhancement of human resources, the creation of demand for technological learning and financial incentives. Moreover, the Korean innovation system is characterised by close links between economic, industrial and science and technology policies (Crow and Nath, 1992). This has been made possible by the strong initiatives of government's intervention, and university policies are no exception. Focusing on the links between industrial policy, science and technology policy and university policy, we will therefore examine the evolution of the Korean national innovation system according to the three stages as summarised in Table 4.11.

Firstly, the period between the 1960s and the mid-1970s can be characterised as a duplicative imitation stage (Kim, 1997). In the 1960s, the endowments as well as economic performance across the national innovation system were no better than those of other poor countries (Kim and Dahlman, 1992). For example, the gross national product (GNP) per capita of Korea was just $79 in 1960, which was less than that of Sudan and less than one third that of Mexico. In order to boost the economy from this unprivileged condition, the government implemented an export-oriented policy supporting strategically chosen light industries. In the 1970s, the government focused more on heavy and chemical industries. In order to support these industries that lacked in-house R&D capabilities, governmental research institutes were encouraged to support firms with low level R&D activities such as the reverse engineering of overseas technologies (Kim, 2006).

In this period, industries successfully imitated mature technology already proven in the international markets through adopting imitative strategies such as reverse engineering. Such strategies were successful partly due to the well trained human resources available (Kim and Yi, 1997). In this regard, university policy focused on the provision of standardised labour through general education and vocational training rather than high quality researchers. Furthermore, in order to support the industries chosen strategically, the government established a range of infrastructure such as governmental research institutes and the Daedeok Science Town, as well as institutional frameworks such as the Science and Technology Promotion Act in 1967 and the Ministry of Science and Technology in the same year.

Secondly, the period between the late 1970s and the 1980s is characterised as a creative imitation stage based on advanced reverse engineering. This means that Korean industry started to face the need to add something to the product rather than simply imitating as it began to lose its comparative advantage in labour-intensive products (Kim & Dahlman, 1992). Furthermore, industrial policy in this period focused on the technology intensification of strategic industries (Cho et al., 2002). Against this background, Hyun Suk Kim (1997) stresses that the early 1980s were a critical period, not only because the R&D expenditure of business overwhelmingly exceeded that of the government (growing from 48% in 1980 to 80% in 1985), but also because substantial R&D efforts were implemented in industry through various measures such as in-house R&D laboratories rather than re-engineering as shown in Table 4.12. In a similar vein, Song (2002) maintains that this period can be characterised as ‘a start of the industry-led national innovation system’.

Furthermore, government industrial policy focused on indirect measures such as tax incentives and financial aid for in-house industrial R&D effort rather than on direct technical support through the government institutes, as in the previous period (Kim, 1997b; Moon, 2006). In this regard, the government also initiated the first national R&D programme in 1982; moreover, the government research institutes that were given responsibility for these national R&D programmes were restructured and strengthened in order to develop high-risk technology aiming to create large benefits, whereas domestic universities remained as a provider of technicians and engineers rather than high-quality research. On the other hand, the government expanded the university system to cope with a massively increased demand for higher education as the economic conditions improved.

Finally, the innovation stage of the Korean innovation system started in the 1990s. As competition in the international market (particularly, in high-tech markets) accelerated, Korean industry faced a situation where it had to strengthen its technical capacity in order to introduce innovative products to the market. For example, in 1990, no less than 81% of national R&D expenditure was used for the industrial sector. Furthermore, several major Korean companies such as Samsung, Hyundai and LG emerged as top-level companies on the basis of innovative products supported by in-house R&D laboratories as well as global R&D centres (Kim and Yi, 1997).

The government encouraged Korean industries to become more competitive in the world market by various policy measures to fortify the national technological knowledge base. At the national level, ten strategic technologies were chosen to be promoted; accordingly, a large amount of public R&D resources were focused on those technologies. Moreover, several industrial clusters were also chosen to be supported across the country in order to 'establish' regional innovation systems. In this vein, dozens of regional universities were chosen to be an innovative knowledge base for local industries. For example, the name of the main programme supporting regional universities is NURI (New University for Regional Innovation). Universities were also mobilised to support national initiatives by the establishment of national research centres on campus in the 1990s and of technology transfer offices in the 2000s. On the other hand, the aims of governmental research institutes were reoriented to the development of more basic and strategic technologies, and they were exposed to more 'market-like' environments through a re-adjusted system of financial resources allocation.

Table 4.11 Industries, science & technology and universities policies by periods

Periods Policies	**Imitation** (1960s – mid-1970s)	**Creative imitation** (late 1970s-1980s)	**Innovation** (1990s-present)
Industrial policy	- Fostering of export-oriented light industries - Promotion of heavy and chemical industries	- Re-adjustment of industrial structure - Expanding the exportation of technology intensive products	- Promotion of innovative industrial technologies - Increase of efficiency of (human) resource exploitation
S&T policy	- Building up technological infrastructure - Formulating and implementing overall S&T policies and law (MOST)	- Structural adjustment of governmental institutes - Developing national strategic technology area (NRDP initiated in 1982)	- Reform of GRIs structure and R&D (funding) system (Research Council System) - Enhancement of creative innovation capabilities
Higher Education policy	- General education orientation and technically skilled labour - Strong control over universities	- Highly qualified engineers - Liberalization and expansion to meet higher education need of the society	- Emerging role of research and economic contribution - Establishment of research centres and technology transfer units in academe

Source: originally based on Yim and Kim (2005), but revised and supplemented by the author

Table 4.12 Some R&D indicators of Korean innovation system (1965 – 2005)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005
R&D Exp.*	2.1	10.5	42.7	211.7	1,155.2	3,210.5	9,440.6	13,848.5	24,155.4
- Public	1.9	9.2	28.5	109.2	231.3	510.5	1,780.9	3,816.9	5,877.2
- Private	0.2	1.3	14.2	102.5	923.9	2,700.0	7,659.7	10,023.4	18,106.8
Pub. vs. Pri.	90:10	88:12	67:33	52:48	20:80	16:84	19:81	28:72	24:76
R&D / GNP	0.26	0.83	0.42	0.57	1.58	1.95	2.51	2.40	2.98
Researchers	2,135	5,628	10,275	18,434	41,473	70,503	128,315	159,973	234,702
- Govt.	1,671	2,458	3,086	4,598	7,542	10,434	15,007	13,913	15,501
- Univ.	352	2,011	4,534	8,695	14,935	21,332	44,683	51,727	64,895
- Industry	112	1,159	2,655	5,141	18,996	38,737	68,625	94,333	154,306
R&D Exp**	967	1,874	4,152	11,486	27,853	47,514	73,574	86,568	102,920
Researcher***	0.07	0.17	0.29	0.48	1.01	1.64	2.85	3.38	4.86
Industry Lab	0	1****	12	54	183	966	2,152	4,194	7,368

*Unit: billion won, **R&D Expenditure Per Researcher (Unit: thousand won), ***Number of Researchers per 100,000 population, **** Data in 1971. Sources: MOST (1998 - 2006), Report on the Survey of Research and Development in Science and Technology, MOST (Ministry of Science and Technology).

4.4.2 Co-evolving research and entrepreneurial activities: a coupling effect?

This section briefly investigates the relationship between the research and entrepreneurial activities of Korean universities and the changing industrial structure of Korean firms. The first half focuses on the scientific publications, and the second half focuses on the patenting activities.

Scientific activities and industrial development

In the previous sections, the abrupt increase of scientific output during the 1990s, showing a invigoration of the research activities of Korean universities, is discussed. Furthermore, we have already discussed the relationship between the first mission of universities and industrial structure. In terms of the 'teaching' mission, the disciplines (e.g. material science and mechanical engineering) of graduates were related to the main 'national champions' of industries as shown in those sections. In terms of the 'research' mission, this subsection investigates the relationship between the characteristics of scientific output and industrial development.

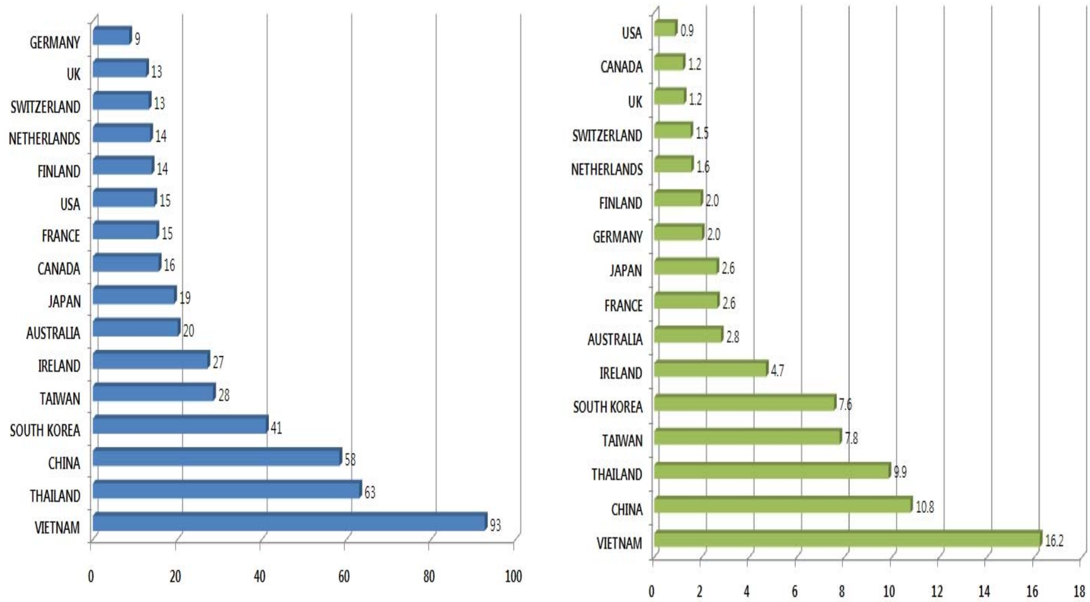
Korea has experienced a rapid shift in the structure of industry as well as an expansion of its size. Appendix Table 4.2 below shows the structural change of Korean industry between 1980 and 1994. In the table, the 'labour-intensive' group (e.g. garments, footwear and toys) decreased in terms of the overall proportion, whereas the 'differentiated' group (e.g. advanced machinery, TVs, power equipment) and the 'science-based' group (electronics, biotechnology and pharmaceuticals) increased. Thus, the structure of industry shifted to more technology-intensive industries.

Therefore, the changes to the Korean industrial structure might affect the activities and missions of Korean universities. It implies that the scientific output of the Korean academic community has some relationship with societal needs such as industrial development. Thus, this section investigates the relationship between the scientific activities and the industrial development in Korea.

In terms of research mission, we can draw some stylised facts from a bibliometric investigation (i.e. based on scientific publications) using the ISI data base. Some previous studies analyse the characteristics of scientific outputs generated by Korea. Lattimore and Ravesz (1996) investigated the relationship between national patterns of scientific publications and major societal requirements such as medical, agricultural and industrial needs. They categorise Korea, Taiwan, Singapore and India as 'industry-based countries' with respect to their 'relative research strengths'. In other words, these countries show comparative advantages in terms of their scientific publications in engineering, computing, chemistry and materials.

Furthermore, Yun and Ahn (2002) define 'the degree of specialisation of the country' as a variance between shares of each field divided by the total share of the country. Following this definition, we measure the degree of specialisation and quality variance across the scientific disciplines of 16 selected countries. According to the results, the countries such as Taiwan, Korea, China, Thailand and Vietnam show higher degree of specialisation and quality variance in scientific disciplines than other countries, as shown in Figure 4.7. This implies that the scientific publications of catch-up countries are highly concentrated in a group of certain fields.

Figure 4.7 Specialisation and quality variance of 16 countries' SCI publications ('01-'05)

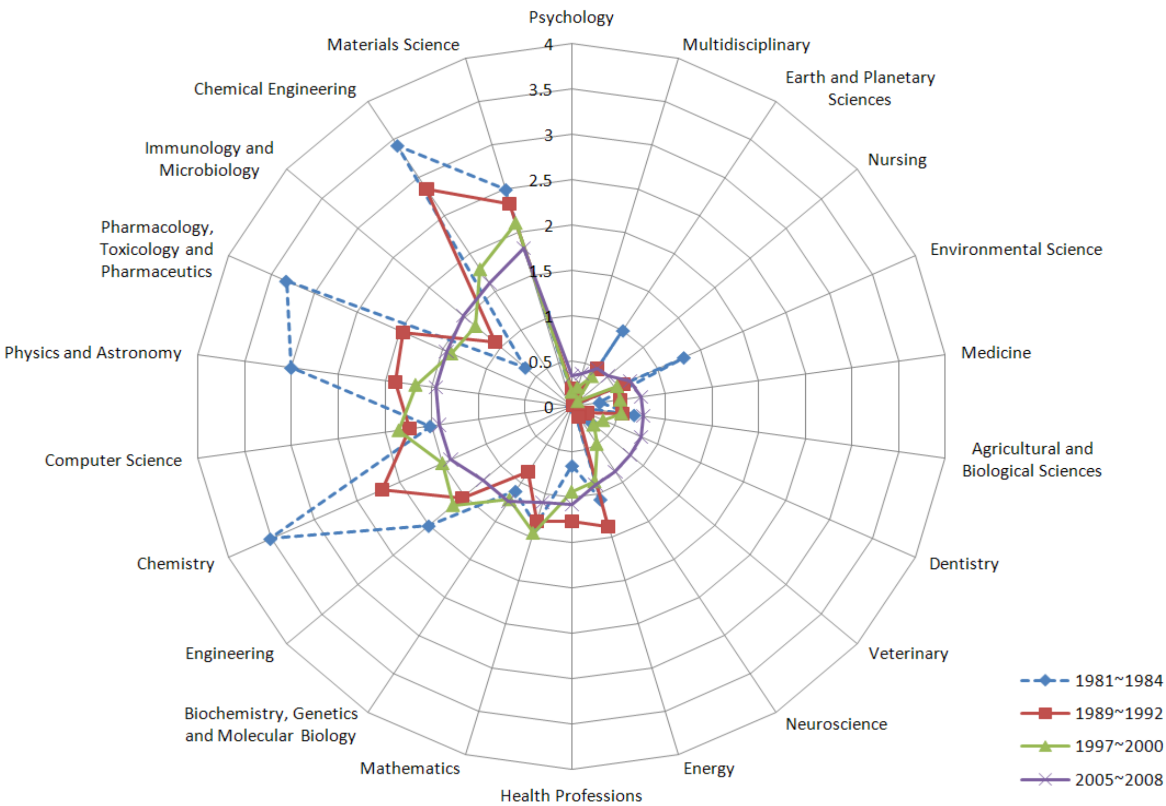


Source: created by the author, based on the SCI database.

In the similar vein, Braun et al. (1995a), noting the high concentration of R&D resources on certain scientific disciplines, also reported that Korea produced 0.97% of world publication total in Material Science while its share in world publication was only 0.29% over the period 1989-1993. In particular, according to Appendix Figure 4.3, in terms of the share of SCI publications produced by Korea, papers in the fields of material science, computer science, engineering, physics, pharmacology, microbiology, chemistry and biology show higher figures than the average (i.e. 2.20%). Therefore, Korean academic research is closely related to the Korean industrial structure. Moreover, in terms of citations, these specialised fields show not less than 1.5%. Overall, except in material science, the world share of citation is significantly smaller than that of number of publications, which may mean that the quality of research needs to be improved compared to the quantity. The other countries such as Taiwan, Singapore and India also show higher shares of and citations than the others in the same disciplines (Yun and Ahn, 2002).

Furthermore, as shown in the figure below, we can find a change in the relative world share of Korean universities' publications in science and engineering between the four periods: 1981-1984, 1989-1992, 1997-2000 and 2005-2008. We observe the increase of the share in the fields of immunology, biochemistry, neuroscience, veterinary, and dentistry. However, the share in the fields of material science, chemical engineering, pharmacology, physics, chemistry, and mathematics has been decreased. Furthermore, the concentration of publication on a small number of fields and the difference of relative world share between different fields has been reduced during the decade noticeably. This may suggest that the structure of Korean science is getting closer to that of developed countries as shown in Figure 4.7.

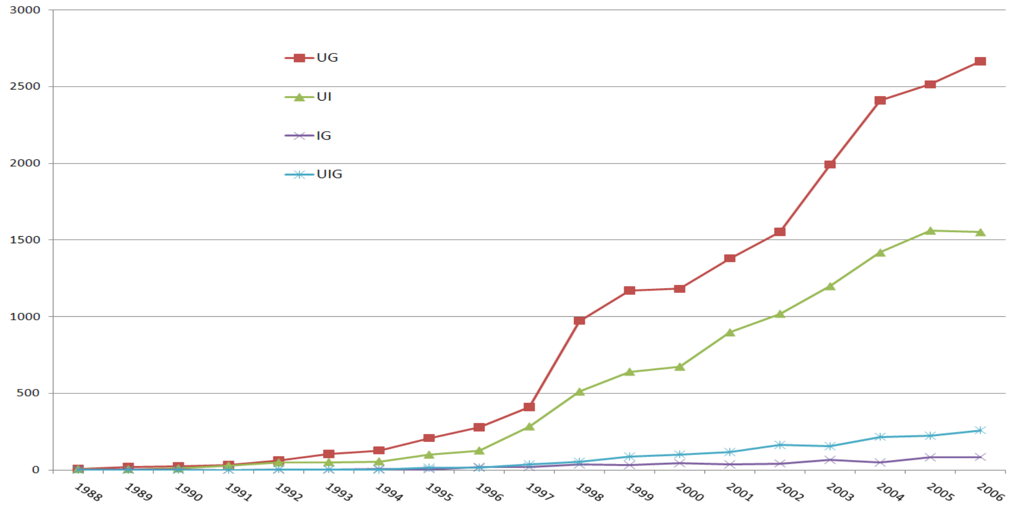
Figure 4.8 Change of relative world share* of Korean universities' publications by periods



* Relative world share is defined as shares of each field divided by the total share of the country.
Source: created by the author, data based on the SCOPUS data.

A large increase of the co-operative research between universities, public institutes and industries has been observed during the last decade. In particular, the increase of university-industry collaboration is faster than that of university-PRIs, and universities may be a more important partner to industries than PRIs as shown in the table below.

Figure 4.9 Number of co-authored SCI publications between universities, institutes and industries



Source: created by the author, based on the SCI database.

Entrepreneurial activities and industrial development

In terms of quantitative growth, as shown in table below, the growth of patenting activity (compared with publishing activities) of East Asian catch-up countries such as Korea and Taiwan is remarkable (particularly at the early catch-up stage). In this regard, Pavitt (1998) assert that the strong capacity of national science is not a 'necessary condition' for the growth of strong technological performance. Furthermore, the shares of world publication of Korea and Singapore increased steadily during the later catch-up period.

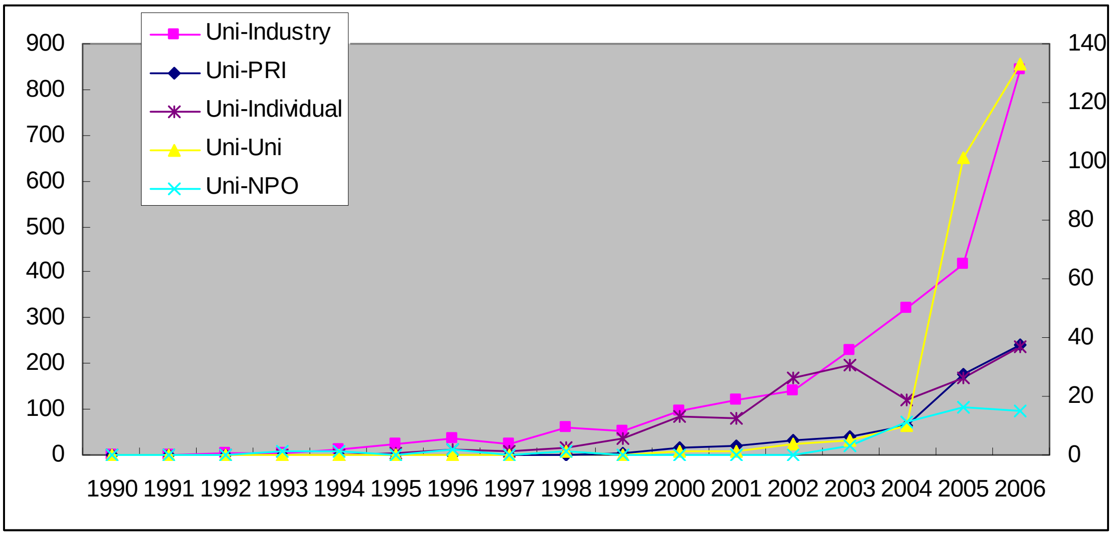
Table 4.13 Trends in scientific and technological performance in selected Asian countries

Country	Change in share of world publications		Change in share of US patents		Publications per million population	
	1993/1982	2006/1995	1993/1983	2006/1995	1980–1984	2002-2006
Taiwan	5.97	1.79	12.81	2.43	23.3	2745
South Korea	5.45	3.46	29.79	2.96	8.0	1786
Singapore	3.53	2.32	3.20	13.5	71.6	5089
Hong Kong	2.37	-	2.42	-	45.9	-
India	0.83	1.14	2.45	7.0	18.1	90

Source: Data based on KIPO (2007) and Pavitt (1998), table 4.

In terms of the qualitative change, Appendix Figure 4.4 and Appendix Table 4.1 indicate that the Korean industrial structure has changed rapidly in just a few decades. The Appendix Figure 4.3 shows the technological advantage of Korea as measured by the world share of patents broken down by disciplines. This means that the disciplines of patents produced by Korea were highly concentrated in a certain fields during the catch-up and were changed in a short period. Moreover, the figure below shows the increasingly close relationship in patenting activities between the main actors of the Korean national innovation system.

Figure 4.10 Increase in the number of co-assigned domestic patents applied for in Korea



*Y-axis to the left side given the number of university-industry co-assigned patent applications.
Source: data based on Appendix table 5.10 in KIPO (2007), The Patent Trends in Korea 2007, KIPO.

Therefore, against the background of the above evidence, we can examine the relationship between the disciplines of university patenting and the Korean industrial structure. In order to do this, information about patents applied for by Korean universities between 1990 and 2008 has been collected. Based on this data, the disciplines of the patents according to different periods (1990-1994, 1995-1999, 2000-2004 and 2005-2008) have been analysed, as shown in the following table.

Table 4.14 Number of domestic patents applied for by Korean universities by IPC and periods

Period	1990-1994		1995-1999		2000-2004		2005-2008	
	IPC	No. (%)	IPC	No. (%)	IPC	No. (%)	IPC	No. (%)
IPC	**H01**	**26 (31.7)**	**H01**	**59 (11.3)**	A61	445 (10.3)	**H04**	**1105 (14.5)**
	C07	6 (7.3)	G01	50 (9.5)	**H01**	**429 (10.0)**	A61	826 (10.9)
	C08	6 (7.3)	C12	48 (9.1)	C12	396 (9.2)	G06	737 (9.7)
	C12	6 (7.3)	C07	45 (8.6)	**H04**	**359 (8.3)**	**H01**	**696 (9.2)**
	G01	6 (7.3)	G06	38 (7.3)	G01	300 (7.0)	C12	586 (7.7)
	C01	4 (4.9)	A61	31 (5.9)	G06	296 (6.9)	G01	462 (6.0)
	A61	3 (3.7)	B01	27 (5.2)	C07	267 (6.2)	C07	303 (4.0)
	H02	3 (3.7)	C23	19 (3.6)	A23	132 (3.1)	A23	239 (3.1)
	H05	3 (3.7)	**H04**	**15 (2.9)**	C08	118 (2.7)	C08	169 (2.2)
	A23	2 (2.4)	H03	14 (2.7)	G02	105 (2.4)	A01	143 (1.9)
Total	25**	82 (100)	59	524 (100)	96	4305 (100)	106	7600 (100)

*The highest ten IPC categories in each period are presented here. **number of IPC classes
Source: the author, using data collected from the KIPRIS (Korean Intellectual Property Rights Information Service) website (http://www.kipris.or.kr/)

As shown in the table above, not only has the number of patents applied for by Korean universities increased rapidly in the last two decades (as discussed in the previous section), but the number of disciplines of patents has also increased. Over the four periods, analysed disciplines such as H01 (basic electric elements), G01 (measuring and testing) and C07 (organic chemistry) have gone down in the rankings, and C12 (biochemistry, beer, spirits, wine, vinegar, microbiology, enzymology and mutation or genetic engineering) has gone down slightly. In contrast, H04 (electric communication technique), A61 (medical or veterinary science and hygiene) and G06 (computing, calculating and counting) are going up in the rankings. This suggests that the disciplines of academic patenting have changed alongside structural changes in Korean industry.

4.5 Conclusion

This chapter started with a brief history of the Korean universities from the 4th century to the 1960s. According to this historical description, it is noticeable that since their opening, institutional forms as well as the culture of the Korean higher education system have been heavily influenced by Japan and the US. For example, in terms of the Japanese legacy, the higher education system started its modern era under strong state control, which was inherited by military government in the 1960s. In addition, in terms of US influences, the 6-3-3-4 education system and the strong preference for the overseas training in the US has been created after the liberation and during the reconstruction after the war.

Since its economic catch-up, the Korean higher education system has developed with a close interaction between government and industry in three different stages. Firstly, at the ‘strong regulation’ stage, the government encouraged the universities to focus on vocational training in science and engineering in order to provide standardised labour to industry. Meanwhile the R&D mission to support infant industry by adapting internationally-proven technology was given to public research institutes. Secondly, the ‘massive expansion’ stage is characterised by an eruption of the need for higher education. This is related not only to the overall enhancement of the economy but also to the intensive investment in primary and secondary education in the previous period. In order to meet this demand, the government increased the number of student places and allowed the creation of new (particularly private) universities. Finally, at the ‘academic revolution’ stage, the government invigorated university research and stressed its direct contribution to the economy. Accordingly, in order to encourage the second and third missions of the universities, the government exerted various efforts such as the creation of laws, the establishment of supporting organisations, and an increase in R&D investment.

During the last half century, Korean universities have experienced a remarkable growth in their three main activities. In terms of teaching, the enrolments rate for higher education increased from 5.4% in 1970 to 65.6% in 2005. Research activity and the amount of funding have dramatically increased since the 1990s, while the source of R&D expenditure is primarily the government. Most recently, the mechanism of industrial collaboration was adopted by the universities for making a direct contribution to the economy, with the result that patenting, technology licensing and spin-off activities have all been intensified since the beginning of the millennium.

In particular, among the three activities of the universities, we focus more on the relationship between academic research and industrial collaboration activities, and the relationship between the development of a national innovation system and that of the higher education system. Interpreting the result of this analysis, we observed a sectoral similarity between publishing and patenting activities. Both activities have co-evolved with the structural changes to industry over different periods. The disciplines of scientific publications have shifted from being close to traditional industry to being close to high-tech industry. The changes in IPC categories of the academic patents broken down by period show a similar pattern in terms of the change in disciplines of scientific publications. Furthermore, the recent increasing trend in co-publishing and co-patenting between university, industry and public research institutes implies that the interactions between these three spheres are growing. This is explained by the government's various efforts to develop both academia and industry in a harmonised way, according to their different developmental stages.

In this regard, during the emergence of academic research and its direct contribution to the society as well as the co-evolution of industry and academia, the government's role can be regarded as one of the most critical factors. Furthermore, the strong governmental involvement in the exploitation of academic potential has influenced the relationship between the second and third mission. Considering the existing literature and the tentative evolutionary model of the universities in catch-up countries introduced in Chapter 2, we need to discuss the applicability of the model to the Korean case as well as its implications.

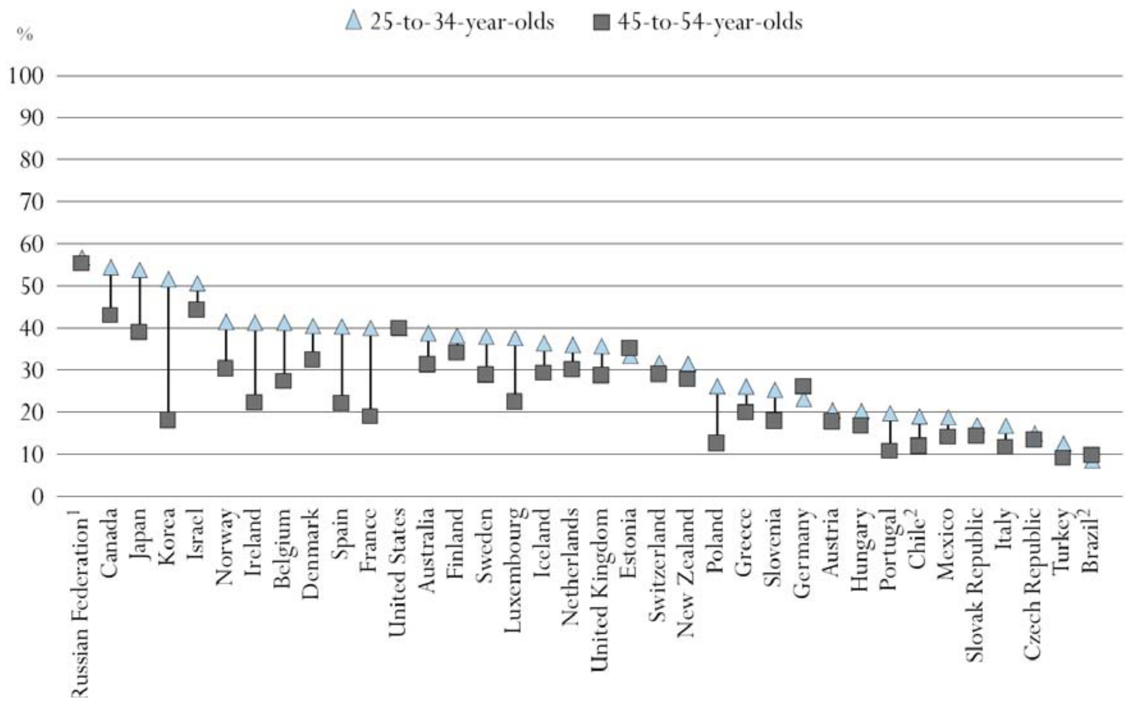
Firstly, the emergence of academic research and its direct contribution of the Korean universities can be compared to that of developed countries. The research and third-stream activities of Korean universities were mostly invigorated by financial and institutional support from the government in the 1990s, while the universities in developed countries began to participate in entrepreneurial activities in the 1980s after the establishment of the fully-fledged scientific community in the late 19th century. In other words, the 'two Korean academic revolutions' occurred nearly at the same time. However, the revolutions are not so 'revolutionary' in the sense that the 'two Korean academic revolutions' were strongly controlled in a 'top-down reformation' by the government rather than a 'bottom-up revolution' by academia. Furthermore, academic norms such as communalism and disinterestedness could not be strongly internalised in the scientific community due to strong government control, which will be discussed more extensively in Chapter 7.

Secondly, as mentioned above, one of the most influential factors in the relationship between the universities' second and third missions in catch-up countries is the existence of strong government control over academia as well as industry. Accordingly, academia in Korea has developed as a subsystem serving economic goals set by the government, rather than independent communities operating under their own norms as found in western countries. In this regard, the ‘triple helix’ approach provides a better perspective to understand the relationship between the two missions than the ‘open science’ approach. Due to the government’s efforts to harmonise the two missions, as well as the two actors (i.e. university and industry), Korean science has developed under a strong interaction between science and technology. Accordingly, we can observe sectoral similarities between academic research, third-stream activities and industrial change.

Finally, in Chapter 2, two contrasting historical paths for universities in developing and East Asian catch-up countries have been tentatively suggested. Considering this conceptual framework, this chapter provides us with extensive evidence to support the proposed model. Historically, the state has been regarded as a central resource provider as well as the most influential stakeholder, so higher education institutions have been supported mainly by the government over a long period of time. In this regard, at the initial stage, Korean universities are also somewhat similar to the Humboldtian model as shown in Figure 2.1. As the economic catch-up started, in terms of their immediate response to the practical needs of the society, they were perhaps closer to the technical university, i.e. to *Fachhochschulen* in Germany and to land grant universities in the US. Recently, the government’s higher education policy has tended to encourage Korean universities to become ‘entrepreneurial universities’, while the ‘entrepreneurial’ activities have been more in response to government guidelines than the needs of the market and industry.

In addition, due to the limited national supply and the explosive demand during the last century, private higher education institutions have made up the majority of Korean universities. They are, under strong government control too, although government support has focused more on public universities. This confirms one of the propositions of the ‘J-model’ by Cummings (1997) introduced in Chapter 2.

Appendix Figure 4.1 Population that has attained at least tertiary education (2005)

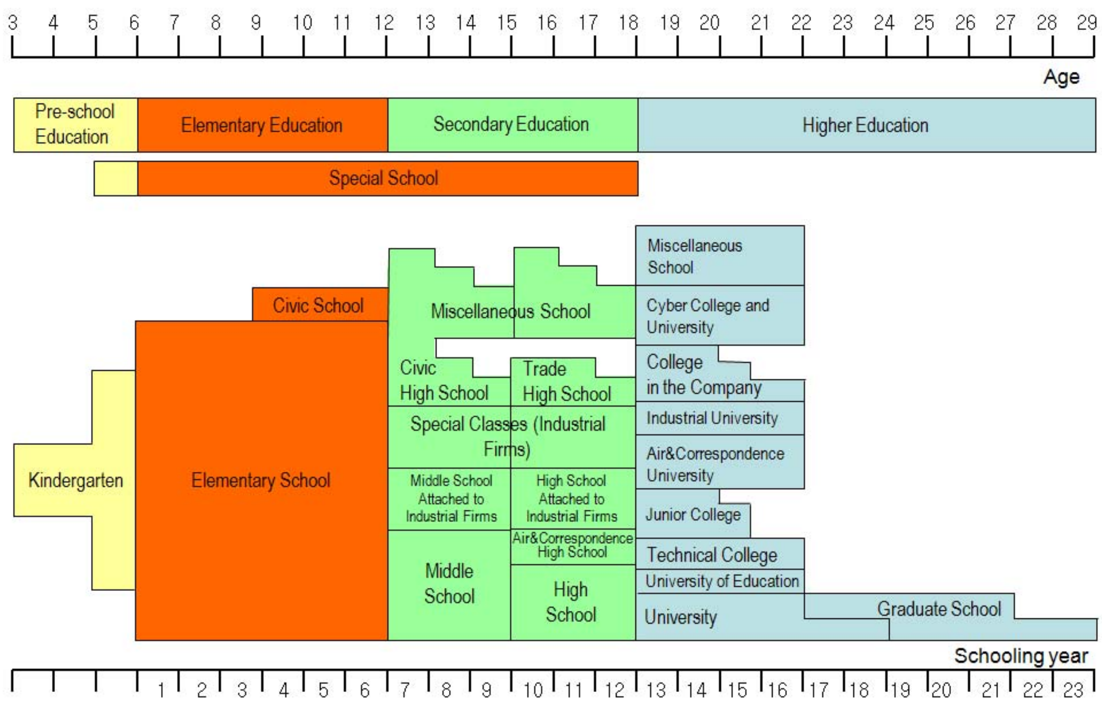


1. Year of reference 2003.
2. Year of reference 2004.

Countries are ranked in descending order of the percentage of 25-to-34-year-olds who have attained tertiary education.

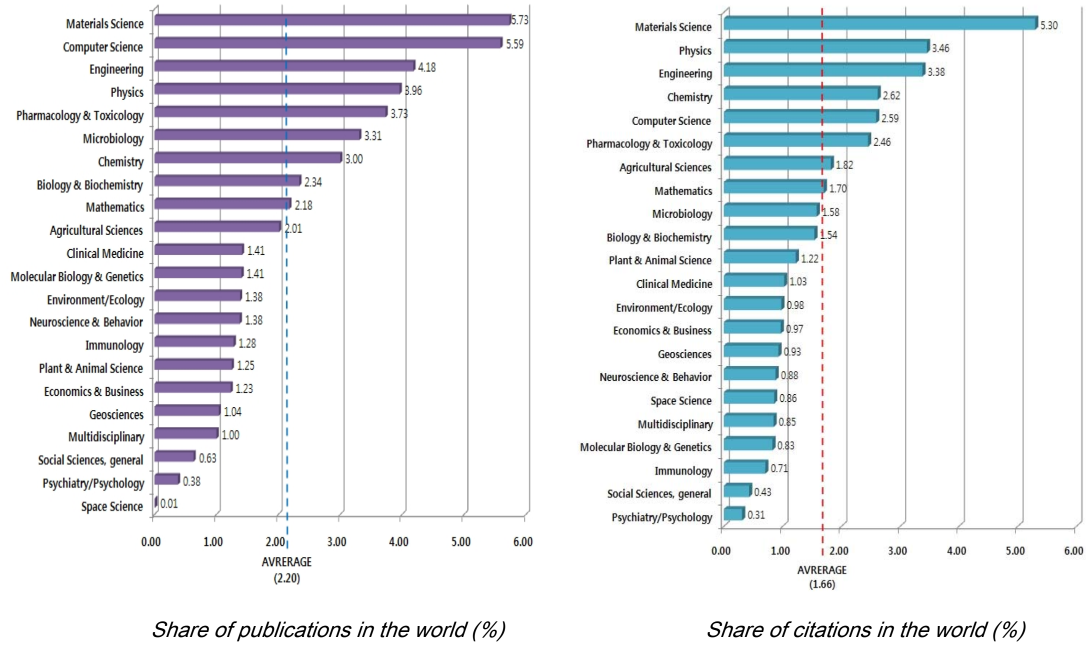
Source: OECD (2007), Education at a Glance 2007, Chart A1.3, p.29, OECD: Paris.

Appendix Figure 4.2 Korean education system broken down by age and schooling year



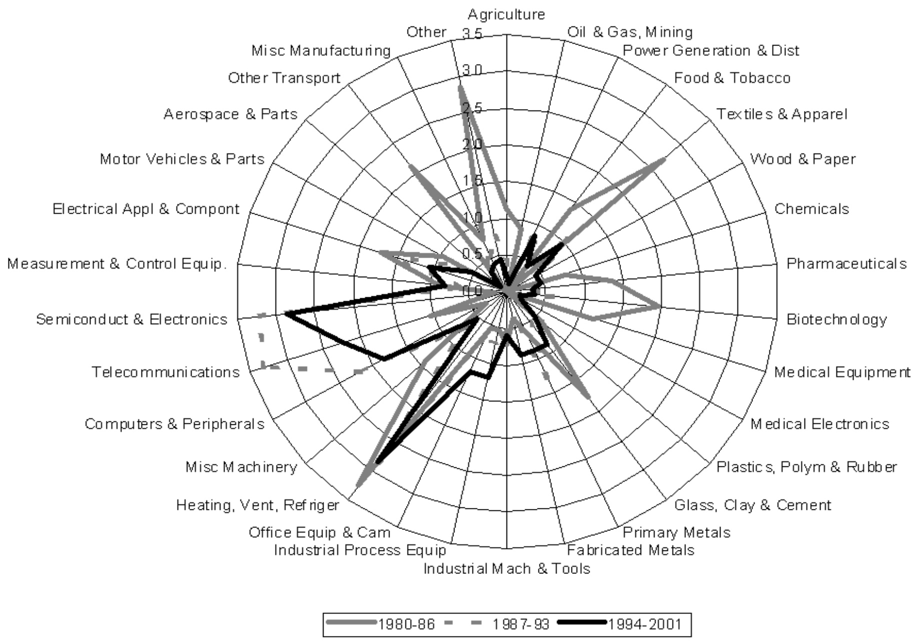
Source: Lee, H.-J. (2009), Higher Education in Korea, a presentation at International Forum for Education,2009 Education 2020 Leadership Institute, East-West Center, Hawaii, USA, 21st Feb. – 7th Mar. 2009.

Appendix Figure 4.3 World share of Korean SCI publications and their citations (’01-‘05)



Source: created by the author, based on the SCI database.

Appendix Figure 4.4 Korea's technological advantage measured by patenting activities



Source: Balaguer, A., et al., (2004). STIC Eurocores Working Paper Series - Technological Specialization in Small and Open Economies, Taipei: STIC-NSC.

Appendix Table 4.1 Distribution of Korean manufactured exports broken down by technological category (%)

Activity Group	Examples	1980	1994
Resource-intensive	Aluminum, food processing, oil refining	7.3	3.8
Labour-intensive	Garments, footwear, toys	49.5	27.8
Scale-intensive	Steel, autos, paper, chemicals	25.8	27.2
Differentiated	Advanced machinery, TVs, power equip.	14.7	35.6
Science-based	Electronics, biotechnology, pharmaceuticals	2.7	5.6

Source: Lall (2000), table 2.2 and 2.3.

Chapter 5 Research and Knowledge-Transfer Activities of Different Types of Korean Universities

5.1 Introduction

The main goal of this chapter is to identify systemic characteristics of both the environments and the research and knowledge-transfer activities of Korean universities in science and engineering.

First of all, the characteristics of Korean universities are presented in Section 5.2. Subsection 5.2.1 focuses on several variables (e.g. founding year, size, legal status, location and generality) of Korean universities. In order to give a cross-sectional view of the Korean academic system, a cluster analysis is implemented to identify different university 'species' and their characteristics in subsection 5.2.2. This cluster analysis is based on the characteristics of the Korean universities in science and engineering described in the previous subsection.

Next, Section 5.3 investigates their three activities (i.e. teaching, research and entrepreneurial activities) and the constraints influencing Korean universities. Subsection 5.3.1 introduces qualitative data based on interviews with directors of the offices of the research and industrial cooperation affairs. In particular, this section discusses the constraints on the research and knowledge-transfer activities according to the types of universities developed in the previous section.

Subsections 5.3.2 and 5.3.3 evaluate the quantitative characteristics of the resources and activities of the universities by type. In order to do this, resource variables such as the amount of funding and the number of postgraduates and activity variables such as teaching, research and industrial collaboration (e.g. number of students, papers and patents) are investigated.

Finally, Section 5.4 summarises the findings regarding the characteristics of the environments of different types of universities and their activities. Furthermore, in the light of the historical background and longitudinal development of Korean universities as investigated in the previous chapter, some general traits and specific characteristics of research and knowledge-transfer activities of the Korean universities are discussed.

5.2 Characteristics and Typology of the Universities Engaged in Science and Engineering

In order to understand the overall organisational properties of Korean universities, subsection 5.2.1 explores the various characteristics (founding year, size, legal status, location and generality) of Korean universities. Based on these characteristics, subsection 5.2.2 attempts to create a typology of Korean universities based on the results of a cluster analysis. This is followed by an investigation on the relationship between the activities and the types of universities in Section 5.3.

5.2.1 Characteristics of Korean universities in science and engineering

In this subsection, after presenting the overall status (or an overview) of current Korean universities, some data on the characteristics of the universities we have chosen (universities engaged in science and engineering) are provided.

Current Status of Korean universities

As shown in Table 5.1, the total number of higher education institutions amounted to 202 in 2006. This includes 158 2-year junior colleges, while the total number of students enrolled in higher education institutions amounted to 3.36 million, which corresponds to 7 percent of the entire Korean population (about 48 million in 2005). The enrolments in these institutions exceeded 62 percent of the age cohort between 18 and 21, while 44 percent of this age group consists of students in 4-year higher education institutions.

Table 5.1 Current status of Korean universities in 2006

Type of Institutions*	**No. of institutions**	**No. of students**	**No. of academics**
Universities	175	1,888,436	51,859
Teacher training	11	25,811	857
Industrial	14	180,435	2,117
Technical	1	130	-
Air & corrs.	1	273,417	134
Total	202	2,368,299	54,967

Sources: KEDI (2007), *The Annual Statistics*, Korea Education Development Institute.
*The types of institutions in this table are based on 'the Act of Higher Education in 1997'[6]. 'Miscellaneous institutions' in the Act of Higher Education in 1997 (Capital Baptist Theological Seminary, Daejeon Theological Seminary & College, Hanmin University, Chugye University for the Arts) have been excluded from the table here. Moreover, universities established by independent law and ordinances (three military academies, the Korea national police university, the Korea Advanced

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6 The Korean Act of Higher Education divided institutions of higher education into seven categories in 1997; universities and colleges, teacher training colleges, industrial universities, technical colleges, vocational colleges, air and correspondence universities, and miscellaneous institutions as follows.
(i) **Universities and colleges** are aimed at "teaching knowledge and research in order to contribute to the wealth of the state as well as the welfare of the humankind…" (The Act of Higher Education in 1997). The act admits that these institutions can establish graduate schools within their organisation. The period for completing courses is 4 years, and 6 years for medical students. These institutions grant a bachelor degree to graduates under the accreditation of the Ministry of Education.
(ii) **Teacher training colleges** have the same legal status and responsibilities as the previous type in terms of the establishment of graduate school and the completion period for degrees. However, the aim of these universities is mainly to produce teachers for primary education. In addition, all teacher training colleges are established by the central government.
(iii) **Industrial universities** are established to serve industry's needs for a skilled work force. Historically, these were created as 2-year vocational colleges mainly for students to become technicians during the industrialisation period. Then, it changed into a 4-year open university with no time-limit for completion for the purpose of meeting the explosive demand for higher education after the industrialisation period. Recently, having being converted again into industrial universities, these are 'de facto' universities with only a few legal constraints prohibiting the establishment of medicine, art and education departments. There is still no limitation for the period of enrolment.
(iv) **Technical colleges** are institutions established within a private company, usually in the field of engineering industry, which also accredit a bachelor's degree. However, they are not easy to establish because of strong legal requirements with regard to facilities and equipments. Therefore, private companies prefer to establish another legal form of institution known as a 'college in company' based on independent law.
(v) **Junior colleges** have 2-year or 3-year courses. These institutions do not grant bachelor's degrees. Instead, they offer another tertiary education degree.
(vi) **The air and correspondence university** was established by the state for distance and life-long education, with both a 2-year degree and 4-year bachelor's degree. The education in these universities usually is provided by broadcasting. Cyber universities mainly based on the web have recently been included in this category by an amendment of the law in 2007.
(vii) **Miscellaneous institutions** are post-secondary institutions for various unique purposes such as the preservation of national heritage. They have to use a different name from 'university'

There is another form of university established by independent laws which pursues a special public purpose such as institutions of military officer training, advancing science, or preserving cultural heritage. Having their own legal base, these institutions are under the control of different governmental agencies instead of the Ministry of Education (MOE). For example, KAIST (the Korea Advanced Institute of Science and Technology) is under the jurisdiction of the Ministry of Science and Technology rather than MOE.

Institute of Science and Technology, the Armed Forces Nursing Academy, the Korean National University Of Arts, and the Korean National University of Cultural Heritage) are all excluded.

Characteristics of Korean universities engaged in science and engineering

Regarding the definition of universities engaged in science and engineering, two methods can be suggested. One is based on the institutional structure, and the other on the activities of the universities. According to the former, 'universities engaged in science and engineering' can be defined as universities with at least one college or department of science and engineering, while the latter focuses on whether a university is actually involved in research activities in the field of science and engineering in spite of the non-existence of such colleges and department.

We are interested in the research and industrial collaboration activities of universities, so in order to investigate only the activities of universities engaged in science and engineering, we will exclude non-related activities such as those of academics in humanities. On the other hand, even though the mission of a certain type of universities is officially dedicated to training ministries or teachers, some academics in such universities do actually participate in research and industrial collaboration. In this regard, 'a university engaged in science and engineering' is defined as 'a university that has at least one academic in science and engineering with research funding from an internal or external body'. According to this definition, 169 out of the 202 universities can be identified as Korean universities engaged in science and engineering.[7] Several of the main characteristics of these universities are presented in Table 5.2.

Table 5.2 Descriptive statistics of 169 Korean universities in science and engineering*

	Mean	Median	SD	Min	Max
Founded year	1958.72	1954.00	28.66	1855	2004
Legal Status (Pub=1/Prv=0)	0.27	-	-	0	1
Size (No of academics)	157.85	95.00	186.72	1	987
Location (distance from the capital)	2.02	2.00	1.44	0	4
Generality (No of colleges)	4.07	4.00	1.54	1	6

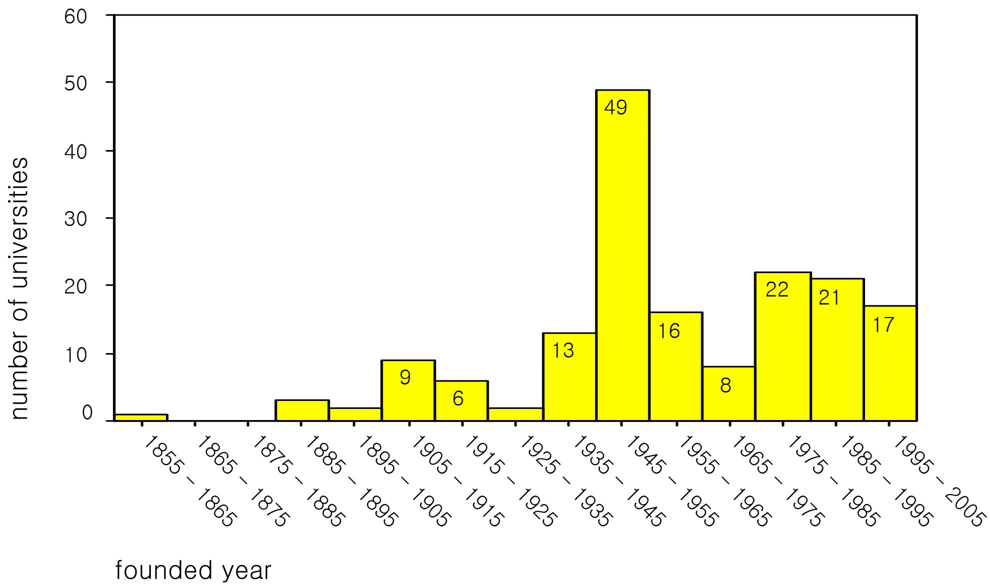
Source: calculated by the author based on data from KRF (2007) and from KCUE (Korean Council for University Education).

7 The majority of the excluded universities in the category (universities engaged in science and engineering) consist of universities on-line and specialised in ministers' and teachers' training.

- *Founded year*

Data on the numbers of universities according to the founding year are shown below. This figure is not so different from the historical picture of the development of Korean higher education system set out in chapter 4, because Korean universities engaged in science and engineering consist of 84% (169 out of 202) of all current Korean universities. For example, we can see two peaks in the figure below: the first sharp one shows the explosion in terms of the number universities after the liberation in 1945, and the other is located in the period of deregulation in the 1980s.

Figure 5.1 Founded year of Korean universities engaged in science and engineering



Source: illustration by the author based on the data from KCUE (Korean Council for University Education)

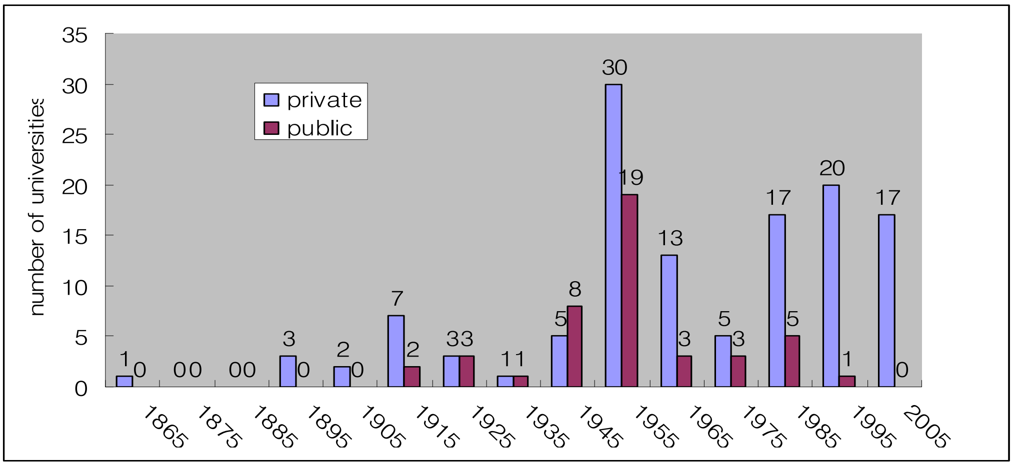
- *Legal status*[8]

In terms of the legal status of current Korean universities engaged in science and engineering, about three quarters of them (124 out of 169) consist of private universities. Furthermore, as shown in the figure below, the growth of the universities has been

[8] The public and private Korean universities are different in terms of three characteristics: ownership, governance system and financial structure. Firstly, public universities are established by central and local governments, and are owned and operated by them. However, the private universities are created by individual or non-governmental bodies. Secondly, central and local government has a strong influence and governmental officers even participate in the management of public universities as directors on the board, while private universities are more autonomous in decision-making than the others. Finally, the financial sources of public universities mainly consist of governmental subsidies, while private universities are largely dependent upon student fees.

mostly dependent on the establishment of private universities during the last half century. In particular, the first peak in the figure consists of both public and private universities across the country, whereas the second peak mostly consists of private universities in the provinces. This implies that the second expansion in the 1980s was dependent on establishment of a large number of private universities outside the capital area, as presented in chapter 4.

Figure 5.2 Public and Private Korean universities engaged in science and engineering by year of foundation



Source: created by the author based on data from KCUE (Korean Council for University Education)

- *Size*[9]

In terms of the size of the universities, the majority of them (76%) are small institutions with less than 200 academics, while only the top 7% of them are large institutions with more than 500 academics. In other words, the size distribution is skewed to the right. In terms of the relationship between the size and legal status of the universities, the private universities dominate the group of small universities, while the public universities tend to dominate the group of large universities, as shown in the table below. The size of the universities is also related to the founding year, reflecting the historical development presented in chapter 4. For example, after the liberation in 1945, a dozen of large public universities were created in addition to several existing large private universities, while after the 1980s, the majority of newly established universities were small universities with less than 200 academics.

[9] We can measure the size of universities by the number of students, the number of academics and the level of budgets. In this analysis, the number of academics is chosen, as these are the main actors carrying out university activities such as teaching, research and industrial collaboration.

Table 5.3 Size of the universities by legal status and founding year

size level	Total	Legal Status		Founding year		
		public	private	1855- 1944	1945-1979	1980-2006
< 100	86	16	70	16	37	33
< 200	43	14	29	10	22	11
< 300	11	3	8	3	5	3
< 400	11	3	8	3	8	-
< 500	5	2	3	-	5	-
< 600	5	2	3	2	3	-
< 700	3	3	-	-	3	-
< 800	3	1	2	1	2	-
< 1000	2	1	1	1	1	-
Total	169	45	124	36	86	47

Source: created by the author and based on data from KRF (2007) and from KCUE (Korean Council for University Education)

- Location (distance from the capital)[10]

In this chapter, in order to measure the geographical characteristics of the universities, the distance from the capital is chosen. This is because the financial and human resources of Korean universities tend to be distributed proportionally to the distance from the capital, as investigated in chapter 4.

As shown in the table below, the distribution of the universities seems to be less imbalanced in terms of distance. However, in the case of the private universities, their locations are relatively concentrated both in the capital (Seoul; 0) and near the capital area (Incheon and Kyunggi; 1). The distance according to founding year is also consistent with the historical development introduced in chapter 4. That is to say, about half of the old universities from before the liberation in 1945 are located in the Capital, while the young universities after 1980s are mostly established outside of the capital, as show in the table below. The distance is not so strongly related to the size here, but the third distance-category, which contains the largest number of universities, has more small universities than the other categories. These universities are located outside of the capital, which explains the higher educations policy during the last half century. In other words, young and small universities have been encouraged to be created far from the capital.

[10] There are several ways of defining the geographical properties of the universities. Firstly, universities can be allocated according to the jurisdiction in which they are located in. Secondly, a certain reference point can be used for measuring the distance between the reference point and the location of universities. Finally, a certain characteristic varying according to location such as BERD (business expenditure for R&D) can be a proxy variable representing the location of universities.

Table 5.4 Distance of the universities from the capital by legal status, founding year and size

Distance*	Total	Legal Status		Founding year			Size		
		Public	private	1855-1944	1945-1979	1980-2006	- 100	-400	- 1000
0	36	6	30	17	14	5	18	13	5
1	26	3	23	5	16	5	13	11	2
2	43	13	30	6	18	19	24	16	3
3	26	6	20	4	13	9	13	10	3
4	38	7	21	4	25	9	18	15	5
Total	169	45	124	36	86	47	86	65	18

Source: created by the author based on data from KRF (2007) and from KCUE (Korean Council for University Education).
*Appendix Figure 5.3 shows the categories on the map of Korea.

- *Generality*

The generality of the universities here is defined as the degree of coverage of all academic disciplines. In order to measure the generality, six categories of disciplines (or colleges) of universities are suggested: humanities, social sciences, natural science, engineering, medical science, and arts & physical training[11]. In terms of this generality, universities with four colleges are most likely to be found among the universities we have chosen, as shown in the table below. However, considering only public universities (and if we exclude specialised institutions devoted to teacher's training with generality '1'), the peak that shows the largest population among the categories shifts to the larger generality '5'. This is because public universities supported by the government are likely to cover a wider range of academic disciplines than private universities.

The young universities established after the 1980s tend to cover a narrower range of disciplines than other universities. Moreover, the smaller universities are likely to have a narrower range of disciplines. Furthermore, the universities near Seoul (Seoul, Incheon and Kyunggi) are likely to have more colleges (i.e. a higher generality) than those of other universities. Based on the four observations above, the small and young private universities established after the 1980s far from Seoul tend to have a few colleges (less than four), while the large old universities near Seoul tend to cover a wider range of disciplines with more than four colleges.

[11] The department of arts and the department of physical training are combined into one administrative unit in most Korean universities.

Table 5.5 Generality of the universities by legal status, founding year, size and location

Generality	Total	Legal Status		Founding year			Size			Location	
		Public	private	- 1944	-1979	-2006	- 100	-400	- 1000	0-1	2-4
1	17	12	5	5	7	5	15	2	-	3	14
2	11	4	7	-	4	7	7	4	-	5	6
3	24	3	21	4	8	12	19	5	-	8	16
4	42	5	37	6	20	16	31	11	-	13	29
5	41	12	29	14	24	3	14	26	1	21	20
6	34	9	25	7	23	4	-	17	17	12	22
Total	169	45	124	36	86	47	86	65	18	62	107

Source: created by the author based on data from KRF (2007) and from KCUE (Korean Council for University Education)

5.2.2. Typology of Korean universities engaged in science and engineering

Three methods for the typology

Based on the characteristics of universities, there are several ways to categorize the type of universities: the historical development, the correlation between the characteristics, a clustering method, the Carnegie classification (Alexander and Zhao, 2005), or a dichotomy using two variables such as ‘prestige vs. reputation’ (RAND Institute, 2006) or ‘public vs. private’, etc. However, traditionally, the Carnegie classification (particularly, the ‘basic classification’) is mainly based on the number of departments (or variety of disciplines) and the level of the degrees granted. However, we have already collected more variables than the last two methods are based on. Therefore, the first three approaches to categorising the Korean universities engaged in science and engineering are adopted here. Furthermore, we can get a more plausible categorisation of universities after comparing and discussing the results obtained by the three methods.

As the first approach to categorise different kinds of universities, we start from the ***historical development*** and current institutional forms of the universities. Based on these two aspects, several distinctive groups of universities and their peculiar characteristics can be identified. Consequently, the several types of the universities are suggested in chronological order, as shown in Figure 5.3.

First of all, **the old large private universities in Seoul** and **the old middle-sized private universities in Seoul** that originated from schools created by Western missionaries before the collapse of the Choson dynasty are identified in Figure 5.3.

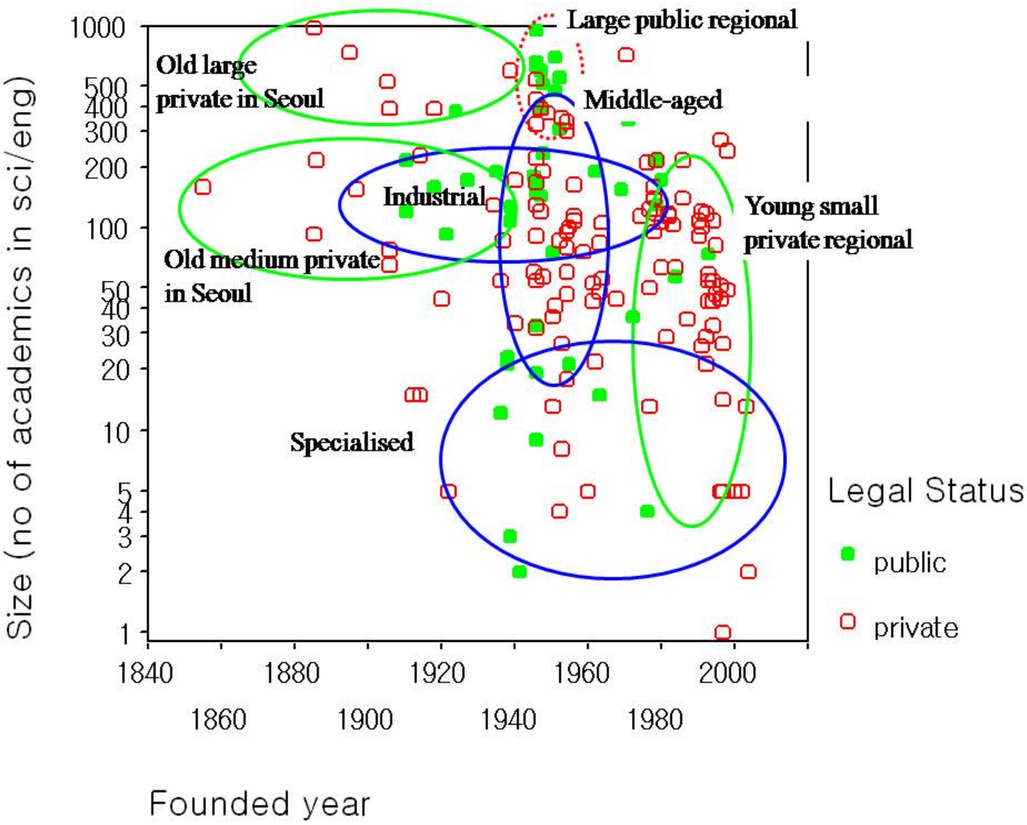
Some of them are large and the others middle-sized. Then, after the colonisation in 1910, no further institutions of higher education were accredited as universities except for Kyungsung [Seoul] Imperial University in 1924. Those institutions established by the colonial authority were mostly vocational institutions known as 'Jeonmoon-Hakkyo' (specialised schools). These schools have mostly developed into *public* **industrial universities**, while the majority (66%) of *private* industrial universities were created after the 1990s. Furthermore, the size of these institutions (the average size of the public universities is 147 academics engaged in science and engineering, and that of the private is 66 such academics) has not intended to increase over time due to their official goal (i.e. they are specialised in the training of industrial technician).

Just after the liberation, there was the first and the highest peak in terms of the number of newly established universities, as shown in the previous section. In addition to the existing institutions established during the colonisation period such as public industrial universities (which were granted the status of universities afterwards by the US military government), new universities were created up to the 1950s. The **middle-aged private** universities as well as the **middle-aged public** universities distributed across the country were the main contributors to the first and strongest explosion of the university creation. In order to reduce the concentration in the capital of the first two types of universities (old large private Seoul and old middle-sized private Seoul), a number of **large public regional** universities were established in each province by the central government. Furthermore, in this period, very small-sized **specialised** public and private universities aimed at teachers and ministries training were also created. However, in Figure 5.3, the universities specialised in science and engineering in general and in a certain field (e.g. ICT, BT, and medical science) are not clearly identified due to their medium size (in other words, they are overlapping with other medium-sized universities), whereas small specialised universities are distinctively clustered in the figure.

Until the '80s, the establishment of new higher education institutions was constrained, as discussed in chapter 4. However, after the 1980s, there was the second explosion of universities, mainly consisting of **young small private regional** universities, as a consequence of the deregulation policy of the central government. They were encouraged to establish their campuses outside the 'near-Seoul' area (i.e. the Seoul, Incheon and Kyunggi areas) in order to reduce the population concentration in the 'near-Seoul' area (e.g. according to Korea National Statistical Office (2005), about half of the Korean population is concentrated in this area).

Based on the discussion above, the types of the universities suggested are: old large private universities in Seoul, old middle-sized private universities in Seoul, industrial universities, large public universities in each region established in the early 1950s, middle-aged private universities from the first expansion, Specialsed universities, and young small private universities. These 'species' can be mapped onto a space with two axes of size and age, as shown in the figure below.

Figure 5.3 Typology of the universities based on their historical development and institutional forms



*The Y-axis is expressed in log scale
Source: created by the author based on data from KRF (2007) and from KCUE (Korean Council for University Education) data

The second method for constructing a typology is based on an investigation of ***the correlations*** between five different property variables. If two variables have a strong relationship, a hidden common factor is assumed to influence both variables strongly. In this way, we can decrease the number of variables. After examination of the table below showing the correlation between the five properties[12], two groups of the variables were identified: one with high correlations between the variables; the others with a low correlation of less than 0.3. That is to say, the variables of age, size and generality are strongly correlated with one another, while the other two variables (i.e. distance and legal status) are not.

Table 5.6 the correlation coefficient between the five properties of universities

			FOUND	LEGAL	SIZE	DISTANCE	GENERAL
Spearman's rho	FOUND	Correlation Coefficient	1.000	-.295**	-.314**	.213**	-.302**
		Sig. (2-tailed)	.	.000	.000	.005	.000
		N	169	169	169	169	169
	LEGAL	Correlation Coefficient	-.295**	1.000	.173*	.223**	-.108
		Sig. (2-tailed)	.000	.	.025	.003	.164
		N	169	169	169	169	169
	SIZE	Correlation Coefficient	-.314**	.173*	1.000	.041	.687**
		Sig. (2-tailed)	.000	.025	.	.600	.000
		N	169	169	169	169	169
	DISTANCE	Correlation Coefficient	.213**	.223**	.041	1.000	-.075
		Sig. (2-tailed)	.005	.003	.600	.	.331
		N	169	169	169	169	169
	GENERAL	Correlation Coefficient	-.302**	-.108	.687**	-.075	1.000
		Sig. (2-tailed)	.000	.164	.000	.331	.
		N	169	169	169	169	169

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Source: created by the author based on data from KRF (2007) and from KCUE (Korean Council for University Education).

Based on this result, by decreasing the number of variables from five to three, a typology framework can be suggested as shown in the table below.

Table 5.7 Typology framework based on the correlation coefficient between the five properties

Properties	Public		Private	
	Seoul	Non-Seoul	Seoul	Non-Seoul
Old, Large and General	Type A	Type B	Type C	Type D
Young, Small and Specialised	Type E	Type F	Type G	Type H

Source: created by the author based on data from KRF (2007) and from KCUE (Korean Council for University Education).

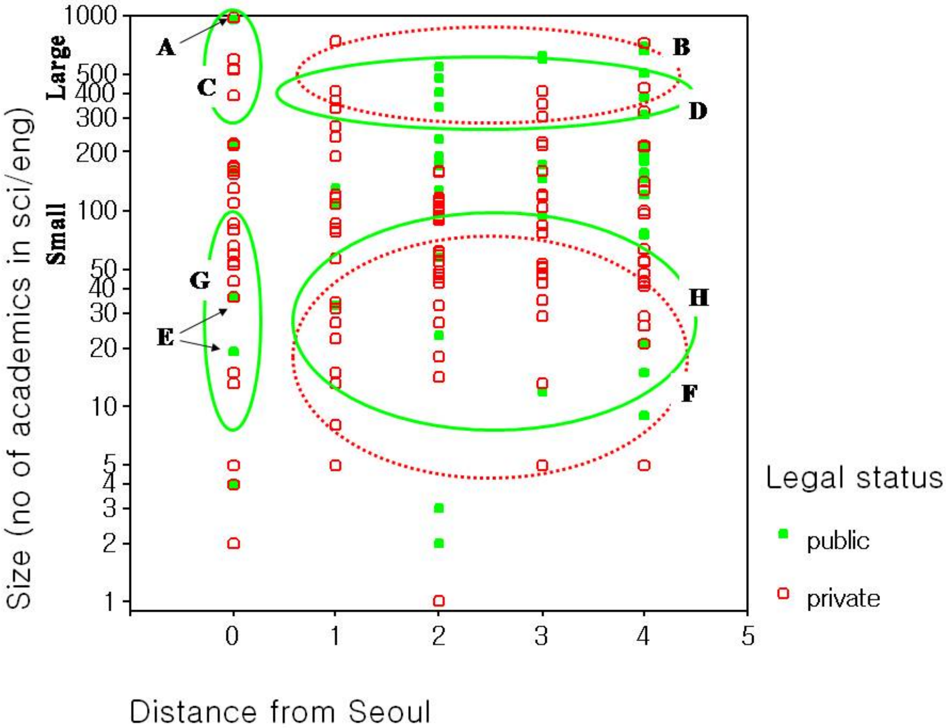
According to the framework, the locations of universities can be mapped onto a space which consists of two axes, such as location and size. In addition, legal status is represented by different markers as shown in the figure below.

As indicated in the figure below, type A and E universities are rare. In other words, in

[12] Here, the Spearman's test is more appropriate than the Pearson's, because the former can be done in the case of ordinal data and the non-requirement of normality.

Seoul, public universities are not easy to observe. The type G is comprised of small private universities in Seoul and large private universities are in the category C, while the H type and the D type represent large and small private universities in the non-Seoul area respectively. The type B universities are regional universities created by the central government just after the liberation, as described in Chapter 4. Type F universities consist of small regional public universities and specialised universities.

Figure 5.4 Typology of universities based on the correlation between the variables



Source: created by the author based on data from KRF (2007) and from KCUE (Korean Council for University Education).

However, in the case of this typology, it is not easy to identify the universities in the middle-sized range. That is to say, those types are difficult to observe: middle-sized private universities in Seoul are located between C and G; middle-sized private universities in the region are located between D and H and public industrial universities; and middle-sized public universities are located between B and F.

The final method for developing the typology introduced here is ***cluster analysis.*** Based on the 'adjusted' K-means technique[13], seven clusters were generated. In order to investigate the characteristics of the seven clusters, the mean, median, standard deviation, minimum and maximum values of the five properties are calculated as shown in the table below.

Table 5.8 Properties of the universities according to the different clusters

CLUSTER		FOUND	LEGAL	SIZE	DISTANCE	GENERAL
1 (N=60)	Mean	1975.5000	.0000	99.2833	2.8667	4.4167
	Median	1979.0000	.0000	83.0000	3.0000	4.0000
	Std. Dev	17.70713	.00000	82.29280	.92913	1.01333
	Minimum	1922.00	.00	5.00	1.00	3.00
	Maximum	1997.00	.00	411.00	4.00	6.00
2 (N=24)	Mean	1982.2917	.0000	55.5833	1.2500	2.4167
	Median	1994.0000	.0000	20.0000	1.0000	2.5000
	Std. Dev	20.25807	.00000	79.24695	.94409	.97431
	Minimum	1950.00	.00	1.00	.00	1.00
	Maximum	2004.00	.00	273.00	3.00	4.00
3 (N=36)	Mean	1931.0833	.0000	184.4167	.4444	4.9444
	Median	1940.0000	.0000	125.0000	.0000	5.0000
	Std. Dev	25.55149	.00000	165.94240	.69465	.79082
	Minimum	1855.00	.00	8.00	.00	3.00
	Maximum	1973.00	.00	596.00	3.00	6.00
4 (N=15)	Mean	1943.3333	1.0000	189.0667	3.2000	4.4667
	Median	1946.0000	1.0000	173.0000	4.0000	5.0000
	Std. Dev	18.41066	.00000	73.73937	.94112	.74322
	Minimum	1910.00	1.00	94.00	2.00	3.00
	Maximum	1979.00	1.00	379.00	4.00	5.00
5 (N=13)	Mean	1940.7692	.6923	644.1538	2.5385	6.0000
	Median	1947.0000	1.0000	624.0000	3.0000	6.0000
	Std. Dev	23.51295	.48038	181.81210	1.50640	.00000
	Minimum	1885.00	.00	401.00	.00	6.00
	Maximum	1970.00	1.00	987.00	4.00	6.00
6 (N=15)	Mean	1955.0667	1.0000	58.9333	2.7333	1.2000
	Median	1946.0000	1.0000	21.0000	3.0000	1.0000
	Std. Dev	18.68715	.00000	90.26348	1.27988	.41404
	Minimum	1936.00	1.00	2.00	.00	1.00
	Maximum	1993.00	1.00	344.00	4.00	2.00
7 (N=6)	Mean	1949.0000	1.0000	108.6667	.3333	4.0000
	Median	1955.5000	1.0000	119.5000	.0000	4.5000
	Std. Dev	30.78961	.00000	77.87083	.51640	1.26491
	Minimum	1910.00	1.00	4.00	.00	2.00
	Maximum	1979.00	1.00	214.00	1.00	5.00

Source: created by the author based on data from KRF (2007) and from KCUE (Korean Council for University Education).

[13] In general, a cluster analysis has two basic approaches: hierarchical and non-hierarchical. The hierarchical method can be divided into 'agglomerative' and 'divisive', while the most popular non-hierarchical method is the K-means technique. Here, the two methods are integrated in order to supplement the weakness of K-means technique in terms of the arbitrary decision on the cluster centre. Specifically, after running K-means to identify appropriate number of clusters, the agglomerative technique is implemented to decide the centres of clusters. Finally, the K-means technique is re-applied in view of the location of cluster centres calculated by the agglomerative technique.

The main features of each cluster can be explained as follows. Firstly, the first cluster consists of 60 private universities, and all the institutions created after the first and second expansion of the universities except one. Furthermore, the mean of the distance (2.89) is larger than the average (2.02) of the population, which means that they are likely to be located in provincial regions. However, the median value of the size (83) is close to the average (95), and the generality value (4.42) is slightly larger than the average (4.07), which means that small, medium, and large universities all coexist in this cluster. Therefore, we can name this cluster as: **Private regional universities**.

24 universities are allocated to the second cluster. All five properties of the universities in this cluster are located at the extreme range rather than the average. The age is very young (60% of them were created in the 1990s), very small (75% of them have less than 55 academics), close to the capital (mean of distance is 1.25) but outside of Seoul (80% of them are located outside of Seoul) and relatively specialised (the mean value of generality is 2.42 which is smaller than the average value 4.07, and 87% of them have less than four departments). Accordingly, the cluster can be characterised as: **Young small specialised private**.

Thirdly, in cluster three, we find 36 universities. The mean and median values of the founding year are 1931 and 1940 respectively, which means they are relatively old. Furthermore, 63% of them are located in Seoul, and a total of 94% of them are located near Seoul. Their generality is also very high (the mean value is 4.94 and median value is 5). However, the distribution of the size variable is relatively even. In other words, we can find all three sizes (small, medium-sized and large) of universities in this cluster. In terms of size as measured by the number of academics, the sizes of universities in the top third are larger than 200 academics, while the sizes of universities of the lowest third are less than 70 academics. Based on these characteristics, we can label these universities as: **Old general private in Seoul**.

Fourthly, the 15 universities in cluster five are relatively old (median value is 1946), public, medium-sized (median value is 173) and generalized (median value is 5). In particular, the number of colleges in these universities is high. The high degree of generality is also a property of public universities as well as universities in Seoul. Therefore these universities are: **Medium general public**.

Fifthly, a group of 13 universities can be regarded as **large public regional** universities. Most of them were created in each province in the first expansion period after the liberation, and the size (as measured by the number of academics in science and engineering) is large (mean and median values are 644 and 624). In particular, all universities have six colleges, which mean that they are highly general.

Sixthly, the 15 universities in cluster six can be characterised as: **Small public regional specialised**. All of these universities were created for special missions given by the central government: for example, the Gyeongin National University for teachers' training, GIST (Gwangju Institute of Science & Technology) and KAIST (Korea Advanced Institute of Science and Technology) for highly qualified scientific research, Kumoh National Institute of Technology for supplying field practitioner for industry, and Mokpo National Maritime University for research and teaching in the maritime area.

The final and smallest cluster may be labelled as small public universities in Seoul. However, considering the characteristics of each university, this cluster consists of two heterogeneous subgroups: the specialised public universities such as Korea National University of Physical Education and Korean National Open University, and the medium general public universities (e.g. Hankyong National University and University of Incheon). The characteristics of these two subgroups are similar to those of previous categories. Therefore, those universities in these subgroups can be moved to cluster 6 and cluster 4 respectively, so this cluster can be excluded later on. The foregoing discussion of the characteristics of universities and the number in each of the final six groups are summarised in the following table.

Table 5.9 Characteristics of the final six clusters and number of the universities in each cluster

Clusters	Characteristics	No of universities
Cluster 1	***Private regional*** *(large, medium and small)*	**60**
Cluster 2	***Young small specialised private***	**24**
Cluster 3	***Old general private in Seoul (****large, medium and small)*	**36**
Cluster 4	***Medium general public***	**19**
Cluster 5	***Large public regional***	**13**
Cluster 6	***Small public regional specialised***	**17**

Source: the author, based on the discussion of the cluster analysis results

The final typology: comparison and integration of the three methods

Comparing the results from the three approaches, we can discuss their similarities and differences. After a detailed discussion, a common final typology can be suggested. Firstly, let us compare the **correlation approach** and the **historical approach**. On the one hand, in terms of the similarities, type B can be interpreted as large public universities in each region. Type C exactly coincides with old large private universities in Seoul. Type D overlaps with large middle-aged universities, and type F can be divided into small public industrial universities and specialised public universities. Type G can be understood as a smaller part of the old medium-sized private universities in Seoul and specialised universities. Finally, type H partly overlaps with young small private regional universities and with specialised universities.

On the other hand, the most distinctive difference between the two approaches is that the correlation approach is very weak in identifying the institutions in the 'medium-sized' range such as the old medium-sized private. Furthermore, the public universities in Seoul (type A and E) can almost be regarded as anomalies, due to the small number of cases. In spite of these weaknesses, the correlation approach identifies the large private regional universities (the type D), whereas the historical approach do not.

Secondly, comparing the result of the **cluster analysis** with that of the **historical approach**, the similarities and the differences are as follows. On the one hand, cluster 1 overlaps with most of the middle-aged private universities, the private industrial universities and the older part of the young small private regional universities; moreover, cluster 2 overlaps with the younger part of the young small private regional universities. Furthermore, cluster 3 covers both old large private universities in Seoul and old medium-sized private universities in Seoul. Cluster 4 consists of public industrial universities and middle-aged public universities. Cluster 5 literally coincides with the 'large public regional' universities. Cluster 6 overlaps with public institutions in specialised universities. Finally, cluster 7 corresponds to both middle-aged public universities and specialised public universities.

On the other hand, there are some differences between the two approaches. The cluster analysis fails to identify industrial universities. Furthermore, cluster 1 is too large to distinguish subgroups such as large, medium and small private regional universities. However, this approach has an advantage in terms of the identification of specialised universities and the legal status of the universities.

Thirdly, comparing the **correlation approach** with the **cluster analysis**, categories B, F and H correspond to clusters 5, 6 and 2 respectively. Category C consists of large institutions in cluster 3. Categories H and D overlap with large and small universities in cluster 1. Moreover, the institutions of type G partly overlap with cluster 3. However, the correlation approach fails to identify medium-sized universities such as cluster 4, and specialised universities are not able to be differentiated. Based on this comparison of the three approaches, the similarities and differences can be summarised as in the following table.

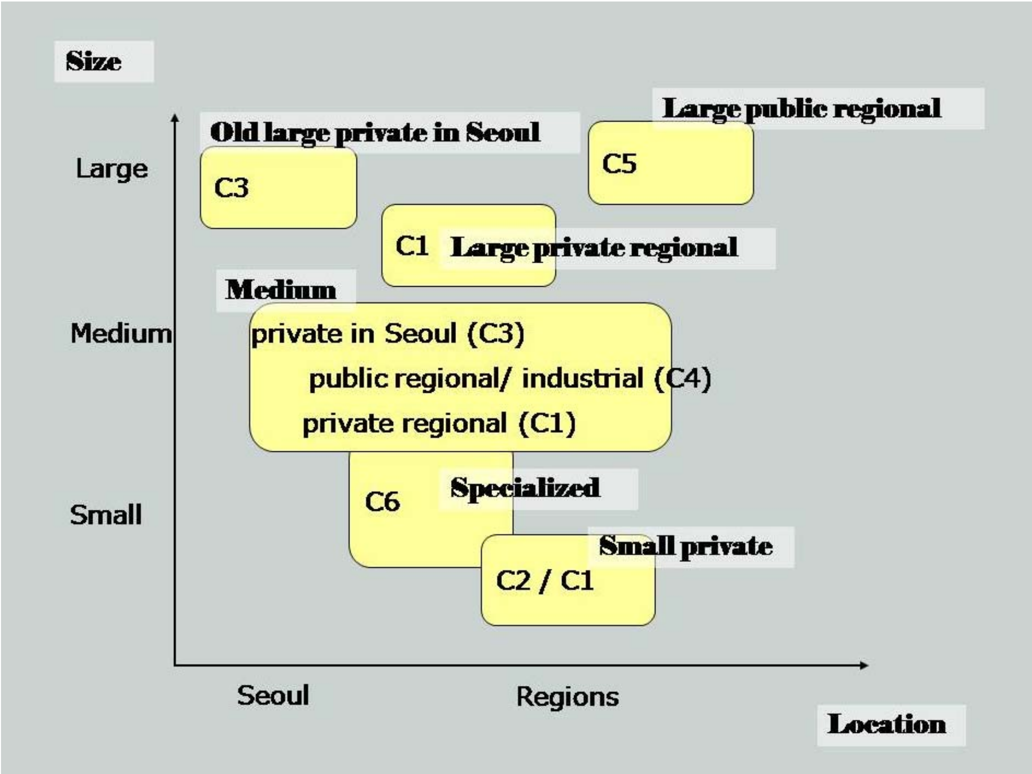
Table 5.10 Comparison of categories between the three approaches

Approaches	Historical Development	Cluster Analysis	Correlations
CATEGORIES	Middle-aged (private) (private) Industrial (older)Young small private regional	Cluster 1	Type D (large private regional) Type H (small private regional)
	(younger)Young small private regional	Cluster 2	Type H (small private regional)
	Old large private in Seoul Old medium private in Seoul	Cluster 3	Type C (large private in Seoul) (a part of) Type G
	(public) Industrial Middle-aged (public)	Cluster 4	*Fails to identify*
	Large public regional	Cluster 5	Type B (large public regional)
	(a part of) (public) Specialsed	Cluster 6	Type F (small public regional)

Source: the author, based on the discussion about comparison of the three approaches

Finally, considering both the strengths and weaknesses of the three approaches, these types can be mapped onto a plane reflecting the three approaches as shown in the figure below. The size and location axis represents the correlation method. The capital letter ‘C’ means cluster analysis. Finally, the name given to the categories includes the characteristics identified in the historical analysis.

Figure 5.5 Final typology



Source: the author, based on a comparison of the three approaches.

As shown in the table below, the characteristics of each category can be summarised as follows.[14] Firstly, large universities can be divided into three subcategories: the old private universities in Seoul, the public regional universities and the private regional universities. The first two subcategories are clearly identified by the three approaches to developing a typology, while the correlation method brings out the last one more distinctively than other approaches. The first group literally consists of very old (average founding year is 1923), all private, large (average size is 463), general (average generality is 5.6) universities in Seoul (0). The universities in the second group are middle-aged (1949), all public, very large (567), very general (6) universities, all located in regions far from Seoul (3). The universities in the third group are middle-aged (1952), all private, large (389), general (5.8) and located in the regions (2.8).

[14] See Appendix Table 5. 1 for more detailed properties of each category

Table 5.11 Final typology based on the comparison of the three approaches

Types / Sub-types	Properties of each type (mean values)					No of Univ.
	Founding year	Legal status	Size no. of prof	Distance	Generality	
Large universities						
- Old private in Seoul (C3)	1923	0	463	0	5.6	9
- Public regional (C5)	1949	1	567	3.0	6.0	8
- Private regional (C1)	1952	0	389	2.8	5.8	13
Medium-sized universities						
- private in Seoul (C3)	1929	0	92	0	4.8	16
- public regional / industrial (C4)	1944	1	177	2.8	4.3	19
- private regional (C1)	1968	0	119	2.3	4.9	26
Specialsed universities (C6)						
- science & engineering	1985	0.3	173	2.1	1.9	9
- teachers' & ministers' training	1966	0.6	14	1.7	1.7	20
Small-sized universities						
- private regional (C1)	1971	0	38	2.4	3.7	38
- private industrial (C2)	1986	0	66	2.8	3.4	9

*Number of universities: 167
**The two universities identified as outliers: Old large public in Seoul and medium-sized public in Seoul.
Source: the author, based on a comparison of the three approaches.

Secondly, the categorisation of medium universities is as follows. The medium and small private universities in Seoul identified partly by the correlation and historical methods; the medium public regional and public industrial universities identified by the historical method and cluster analysis; and the medium private regional universities partly identified by the cluster analysis. The universities in the first group are relatively old (1929), private, medium-sized (92)[15], general and located in Seoul (0). The universities in the second group are old (1944)[16], public (1), medium-sized (177), general (4.3) and located in the regions (2.8). The middle-aged (1968), private (0), medium-sized (119), general (4.9) and regional (2.3) universities belong to the final group.

Thirdly, the specialised universities, which are defined as institutions with a narrow range of academic disciplines, can be divided into two sub groups: those specialised in

[15]In fact, this type consists of ten small institutions with less than 90 academics and six medium-sized institutions with more than 100 academics. However, considering the historical background, their location is more important than size here. Thus, these two subtypes are integrated. (In later analysis, any difference of these two is checked in terms of their activities.)

[16] The 12 public regional universities are middle-aged (1951), while seven public industrial universities are very old (1930). Moreover, the frequencies of this subcategory according to the size are also widely distributed from small to large size (five of them are bigger than 200 academics while one of them is less than 90). However, based on the historical background, these have very similar institutional goals such as meeting local demands, so they are integrated in the same category.

science and engineering, and those specialised in teachers training, ministers training and on-line universities. These universities are identified by the historical approach. The universities in the first subcategory are young (1985), mostly private (0.3), medium-sized (173), all outside of Seoul (2.1) and specialised (1.9). Those in the second group are middle-aged, very small (14), evenly distributed across the country (1.7) and much more specialised (1.7). In particular, excluding the teachers' (from cluster 6) and ministers' training colleges, they are very young (1993) and very tiny (7.4) and mostly come from cluster 2 (six out of eight).

Finally, the small universities consist of two subcategories: the small private regional and the small private industrial universities. The universities in the first categories are middle-aged (1971) and half of them are young (created after 1980), private (0), small (38), regional (2.4) and less general than the others (3.7). Those in the second are young (1986), private (0), small (66), regional (2.8) and also less general than the others (3.4). Therefore, except in terms of age, these two subcategories are very similar. Other differences of their activities, if any, are investigated in the next section.

5.3 Activities of Korean universities according to the typology

Based on the typology developed in Section 5.2, this section looks at the conditions and activities of Korean universities broken down by type. First of all, based on interviews with Korean academics, Subsection 5.3.1 investigates the qualitative conditions of research and industrial collaboration activities according to the typology developed in Section 5.2. Next, based on the survey data from KRF (2006), subsection 5.3.2 investigates the three main activities (i.e. teaching, research and knowledge transfer) of different types of the universities as well as the characteristics of their source of research expenditures (e.g. government, industry and universities themselves).

5.3.1 Environments and strategies of different types of university

Based on the interviews[17], this subsection carries out an analysis of the environments

[17] The analysis of this subsection is based on interviews with the research directors or the directors of industrial collaboration offices, as well as the other academics in each type of university. Most of the directors of the offices of industrial collaboration offices are also the directors of the offices of

and strategies of different types of university with regard to their teaching, research and knowledge-transfer activities. First of all, with regard to the research and knowledge-transfer activities, the recent change to the external conditions (e.g. with regard to their respective advantages and barriers) faced by each type of university as well as their internal organisational efforts in responding to these changes are presented in the following subsections.[18] Next, the relationships between teaching, research and knowledge-transfer activities are suggested according to different types of universities.

Old large private universities in Seoul

In terms of both research output and its quality, these universities are competing with other universities in the same category, as well as prestigious universities in Seoul (the director of both the office of research affairs and the office of industrial collaboration, A7). In terms of knowledge-transfer activity, the universities that are near Seoul enjoy certain advantages due to the geographical proximity to industries (Engineer A4). However, in his opinion, the funding size of individual governmental R&D programmes has tended to grow larger, so the number of programmes has decreased. Moreover, the supply of highly qualified professors and postgraduate students is limited, in spite of the traditional preference for universities in the capital. Consequently, the competition for government funding and with regard to the recruitment of human resources in research has intensified more than ever (The director A7 and Physicist A1 and A2, Engineer A3). The directors mentioned that, in order to strengthen its research capacity and the research environment, their university has recently succeeded in establishing laboratories from prestigious domestic and overseas research institutes such as KIST (the Korea Institute of Science and Technology) and RIKEN (the Institute of Physical and Chemical Research) on its campus. Moreover, it has also provided strong incentives (e.g. a named endowed chair and additional income) for high quality research performances.

Furthermore, according to the same directors' statement, the commercial exploitation of academic potential has recently been adopted as an important mission for the university.

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research affairs. In this case, only one director was interviewed.

[18] The universities representing each type of university identified in section 5.3.1 are chosen mainly for their research and knowledge transfer activities and also on the basis of the five properties of the university.

The university has restructured its organisation recently. The office of research has been integrated with the office of industrial collaboration, which implies that the research activities are being considered in terms of both academic excellence and industrial impact (The director A7). In order to commercialise the research output of the academics, various institutional efforts have been carried out to provide incentives. These include: provision of royalties to academics who have disclosed inventions; recruitment of patent attorneys to evaluate inventions and engaged in consultation; and the inclusion of performance indicators for knowledge-transfer activities in the promotion system[19] (The director A7). Additionally, new departments such as applied biochemical engineering that are mainly aimed at commercial exploitation, have been created recently by the university's strong initiatives (Engineer A5 and A6). Regarding the recruitment of academics, the university prefers academics with industrial experience. The fact that the director himself participates in recruitment suggests that academics with experience of entrepreneurial orientation are likely to have an advantage in being appointed as a new academic member of staff[20].

Large public universities in the regions

The director B7 mentioned that, historically, they have focused on their social and economic responsibility towards the region in which they located. This may be related to the fact that the university (as well as other universities in the same category) has a high degree of generality in order to meet the various educational needs of the region.[21] Compared to the previous type, firstly, these universities are located far from Seoul. Secondly, they have a public legal status. The former tends to create a negative resource condition for their activities (as presented in discussion on the previous type), whereas the latter tends to provide a positive condition. For example, this university enjoys a prestigious status as a base institution for the vitalisation of regional universities through governmental programmes (e.g. NURI (New University for Regional Innovation and HUNIC (Hub University for Industrial Cooperation)). The university has been appointed by the central government as a primary organisation to support

[19] According to p.79 and Table 4.7, many other types of universities have adopted this practice.
[20] During the interview, the director A7 did not deny the possibility that he could influence the decision of the recruitment committee.
[21] See Table 5.5.

specialised regional industry in the fields of agriculture and aerospace.
However, according to the director B7, the overall technological capacity of regional firms is relatively low compared to those near Seoul, so the university focuses on how to complement this weakness of local firms. In the same vein, engineer B5 reported that, in terms of industrial collaboration his university has specialised in certain industrial sectors. Thus, in some cases, spin-out firms in the field of bio-technology (e.g. Bioaegis) have played an important role as a local technological leader (the director B7). It is reported that, 100 million won (about 100 thousand US$ in 2006) of research funding obtained by the academics from industry is equivalent to one paper being published, in terms of performance evaluation for the individual academics involved. Moreover, networking of individual academics with local industry is encouraged through financial support for semi-formal meetings such as RTT (Round Table Talk). In terms of research activities, the director B7 also stated that, at least in several specialised fields based on the 'selection and concentration' principle, the university encourages excellent academic research through strong pecuniary support. For example, an additional income (ten million won for one paper) is guaranteed in the case of publication in SCI journals.

Large private universities in the regions

According to the director C7, and engineers C5 and C6 in this university, the government has shown stronger financial support for large private universities in Seoul and large public universities in the regions than they have shown in other types of universities during the last half century. Moreover, the same academics maintain that these universities are 'suffering' from the relatively 'unfair' funding allocation by the government. Engineer C4 maintains that in terms of the operation of his own laboratory, he is in a very disadvantaged position when attracting highly qualified academics and talented students. Furthermore, the traditional industries of the region such as the textile industry have had a negative effect in attracting firms and human resources in high-tech specialities (engineer C3).

Against this background, this university has tried to be more intensively specialised than the previous two types of universities. In particular, the creation of niche markets in terms of teaching, research and knowledge transfer is a survival strategy enacted by the university, according to the interview with the director. In order to do this, this university established a strong network between local entrepreneurs and academics in order to provide human resources and knowledge closely related to the specific needs of the local economy. Furthermore, various incentives for industrial collaboration such as advantages in promotion (e.g. inclusion of knowledge-transfer activities in performance evaluation of the academics) and additional income have been implemented as at other types of universities (Chemist C2). The director C7 also stressed that professors in departments of natural science had to consider local needs. For example, the university's department of chemistry has been strongly encouraged to support a neighbouring chemical industrial complex in the region in terms of research and teaching.

Medium-sized and small private universities in Seoul

In spite of their advantageous location in Seoul, the director DS7, physicist DS1, engineers DS4 and DS6 complained that 'reverse discrimination' exists between their university and large universities in the regions. In other words, they are provided with relatively lower levels of support from the government in comparison with their competitors in the regions despite their academic and entrepreneurial performance. Furthermore, the expensive rent fee in Seoul is also considered to be a major barrier for the expansion of their research and teaching facilities (Engineer DS2).

Facing these environmental conditions, the university focuses on the production of human resources and applicable knowledge closely related to the sectors of large companies located near Seoul (The director DS7 and Physicist DS1). The university provide a commissioned teaching programme for industrial engineers, based on the external network formed mainly by their graduates working in firms near Seoul (The director DS7). This network has been strengthened by the recruitment of industrial researchers as professors. In terms of organisational efforts, the formation of internal research networks between the laboratories (the majority of them are small compared to others in Seoul) is strongly encouraged in order to carry out large governmental projects (The director DS7). Additionally, the incentives for obtaining external research funding, as well as for the commercialisation of academic inventions, have been formalised as internal rules (i.e. evaluation indicators for individual academics). In particular, the university's special unit provides financial and administrative support for the academics in competition for external research projects with other universities' researchers (The director DS7).

Medium-sized public regional universities

Historically, as discussed in Chapter 4, these universities have been established as special institutions to meet the local needs of medium-sized cities, far from the metropolitan cities. This is the case in most regions after the liberation in 1945, which encouraged the establishment of many other public regional universities. The director DN7 confessed that their appeal is confined to a very small area, so their three missions are also focused on the specific local area, and the majority of their fields are not as competitive. In terms of recruitment, the university prefers academics who are loyal to their institution rather than highly competitive (and, consequently, highly mobile) academics. Therefore, they have formed a close tie with the nearby city. However, the financial resources provided by the government to them are very limited in terms of disciplines and size, compared to that of large public universities in the regions (Engineer DN6). Therefore, the overall research performance is never strikingly distinctive, but the low-tech collaboration with the small local industry can be regarded as quite important and a relatively successful area in their activities (Engineers DN3 and DN6).

Industrial universities

The public industrial universities[22] have extensive historical ties with local industries with a long history in the field of traditional disciplines (e.g. machinery) (The director FN 7). This is also presented in Chapter 4. Thus, they are specialised in the provision of technical training and practical assistance to companies in the regions meeting the day-to-day needs of the companies nearby, but the technology provided by the universities cannot be regarded as that required high-tech sectors such as nano-technology (The director FN 7). Medium-level knowledge exchange is a distinctive characteristic of the

[22] Conditions of private industrial universities are regarded as similar to those of small regional universities (The director FN 7). Accordingly, interviews with the academics of these universities have not been carried out.

linkage between these universities and industries in the same regions (The director FN 7). In particular, the visited university operated 19 research project teams which are all aiming to provide practical knowledge to the industries nearby. Moreover, the university technology centres share R&D equipment and encourage frequent contact by academics with local companies. In the case of recruitment, they prefer academics who can provide students with 'on the job' training that is immediately applicable to the fields of industries (The director FN 7).

Medium-sized private regional universities

'Specialisation' and 'flexibility' are the keywords in understanding this type of university according to the director DP7. That is to say, he puts more stress on focussing on 'niche' disciplines than all the previous types of universities. This is because they are in a more disadvantaged position than the public regional universities in terms of legal status and than the private regional universities in terms of size. For example, graduates from this type of university are likely to move to a postgraduate school in larger public universities nearby or universities near Seoul (The director DP7, Chemist DP2 and Engineer DP5).

In order to attract and keep more students on the campus, through strong specialisation of disciplines, they are leading the reformation of internal institutional setting such as restructuring of department. Moreover, they tend to provide fee exemptions for postgraduate students (The director DP7). Under the strong leadership of the owner, the visited university has abolished traditional disciplines such as physics, mathematics and chemistry; some have been integrated into the engineering department, and some have changed their activities to be more application-oriented (Chemist DP1, Engineer DP4 and DP5). Moreover, most of the disciplines are related to 'medicine' which stem from the historical origin of the university. Even the departments of social science are also adopting this theme (e.g. study of health care). In other words, the university tries to provide 'customer-oriented' programmes focused on the student rather than 'supplier-oriented' or 'discipline-centred' programmes (Chemist DP2).

Specialised universities in science & engineering[23]

The three universities included in this type are all private and are specialised in the fields of medical science, ICT and automotive engineering respectively. The first two universities are located in Seoul and in Daejeon (specifically, in Daedeok science town) and each has had a strong reputation in its own specialised field. In contrast, the last one is located in a region far from Seoul and has a moderate regional reputation.

In their specialised fields, the first two universities enjoy abundant governmental financial support as well as being the students' strong preference compared to other universities, so they are in an advantageous position to provide excellence in both academic research and knowledge-transfer activities. The director EI7 of the university specialising in ICT stated that its reputation in the discipline makes it easy to collaborate with high-tech industry. The director EM7 maintains that they have a nation-wide reputation in the converged (or integrated) area between medical research and bio-science. Their research aims to generate high profits through high quality research (Medical scientist EM6). Therefore, all institutional efforts are focused on maintaining highly productive environments for research (The director EM7 and Medical scientist EM6).

In contrast, even though the university specialising in automotive engineering has more advantages than the other small regional universities focusing on vocational training in general, the extent of this advantage is far weaker than for the first two universities. In this regard, this university can be categorised as a 'small private regional universities'. The director EA7 of the university maintains that 'automotive' is the most frequent adjective for expressing its own survival strategy in the disadvantaged condition that small regional private universities with low nationwide reputations are faced with. Engineer EA4 in the field of 'traditional or low-tech engineering' (according to his expression) in this university confessed that they are good at helping local industry but not so excellent in terms of academic research.

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[23] Interviews with directors and academics in the universities specialising in teachers' and ministers' training and on-line universities have not been carried out in this study. This is because teaching is regarded as those universities' main mission rather than research and knowledge-transfer activities.

Small private regional universities

The relationship between the three missions of these types of universities can be boiled down to 'demand-driven teaching'. The university officially aims to train students to be directly suitable for industrial 'fields', so teaching is directly connected to industrial collaboration, and the organisation of the curricula is very sensitive to local firms' demands for graduates (The director FP7). In order to reflect the demand of local industry efficiently, the university has tried to strengthen both formal and informal linkages between their academics and local entrepreneurs (e.g. through university-industry consortia, informal consulting and meeting). Based on this network, they can encourage firms to recruit their trained students.

The universities categorised as this type tend to show low competitiveness in academic research due to insufficient funding and a shortage of postgraduate students (Engineer FP6). Instead of pursuing academic excellence, the research of this university is being carried out mainly for the purpose of overcoming the difficulties of small and medium-sized local firms (Engineer FP5). Engineers FP3 and FP4 of this university asserted that 'good' research cannot be implemented without close contact with specialists in the local firms. In the same vein, the director FP7 revealed that a specialist from one of local firms, rather than directly from academia, is a preferred form of recruit as a new professor of the university.

Prestigious universities

Two universities categorised in this type are in the most advantaged position to attract financial and human resources to implement teaching and research activities. Compared to other types of universities, prestigious universities are not so seriously concerned about conditions for resource acquirement at the university level, because their individual academics are competitive enough to attract external resources (The directors GD7 and GS7). In spite of these advantages, an institutional reform such as a restructuring of the tenure system has been carried out recently in order to increase the quality of academic research (The director GD7).

According to interviews with the two directors GS7 and GD7 of two prestigious universities, they are very proud of having world-class academics. In particular, the academics at this type of university strongly expressed a view close to 'a linear model of innovation' which means that autonomous basic research benefits society as well as industry in the long run. According to the director GS7 and biologists GS1 and GD1, even though they do not care about the short-term knowledge-transfer, the academic output will eventually turn into commercial outputs. Therefore, this type of university tries to provide strong autonomy and a user-friendly environment for individual academics with regard to research and knowledge-transfer activities. They do not push their academics to collaborate with industry, but assist them through a professional internal consulting agency, only if they want to commercialise their research (The director GS7). However, in spite of these similarities, the prestigious university located regionally is more active in terms of knowledge transfer than the other in Seoul. Several university institutes aiming for development of high-technology has been created as independent legal entities, which implies that the destiny of these institutes' researchers are dependent on their own performances to attract external funding (Biologist GD1).

Summary: the relationship between the three activities and the characteristics of the different types of universities

According to the environments and organisational efforts of the different types of universities presented in the previous subsections, this subsection discusses the relationship between university characteristics (e.g. size, location and legal status) of each type of university and their three missions. This is summarised in Table 5.12.

According to various properties of universities, each type of universities is located in different resource condition. Firstly, large universities are in a better position in terms of resources for research such as funding and postgraduate students than medium-sized and small universities, so research is recognised as more important or at least equally important as other activities. Secondly, the location is also related to resource conditions. In general, more highly qualified researchers, funding opportunities and high-tech firms are concentrated in Seoul. Therefore, research and industrial collaboration activities and their interaction are more dynamic. In contrast, the three missions tend to be separate in universities in the regions. Finally, legal status is important for acquiring financial resources from central government, so public universities are in a more stable condition to conduct the three activities. However, private universities tend to give priority to vocational training or practical industrial collaboration rather than academic research activities that are linked to a direct increase in financial resources.

In Table 5.12, the relationship between the three activities of the different types of universities is summarised according to their organisational characteristics, such as size, location and legal status. Firstly, a stronger stress on academic research than teaching and industrial collaboration is found in one of the prestigious universities and in old large universities in Seoul. Teaching is focused on fundamental research techniques, and industrial collaborations are pursued based on strong academic capacities. Secondly, based on strong support from the central government, the large public universities tend to regard their contribution to local economy as equally important as research and teaching. Thirdly, a survival strategy based on the integration of industrial collaboration in academic research is very important for three types of universities: large private universities in the regions, medium-sized private universities in the regions and medium-sized universities in Seoul. Moreover, they complain about insufficient funding from the government, but get more industrial funding than other types of universities.

Fourthly, training students for local industry is the most important mission for small private universities in the regions. Furthermore, research and industrial collaboration are regarded as one of the means to increase the possibility of graduate recruitment. Finally, in order to meet national needs, according to government policies in certain technological fields, both the development of technology and the training of technicians and highly qualified scientists have been important missions for these types of universities: one of the prestigious universities, specialised universities in science and engineering, and public industrial universities.

Table 5.12 The relationship between the three missions and resource conditions according to the characteristics of different types of universities

Size \ Loc. & Stat.	Universities in Seoul	Universities in Regions	
		Public	Private
Large	- Both T and IC are subordinated to R - Abundant resource condition, due to the government and industry	- T, R and IC are equally important. - Strong support of financial resources from the government for T, R and IC	- IC is important for R, specialisation emerges - In strong competition for funding from the Gov't to do R
Medium	- IC is important for R - In strong competition for funding from the Gov't to do R	- T, R and IC are oriented to the needs of the 'national local' industry - Mild competition for resources and strong network to 'national local' industry	- all T, R and IC are specialised in a few fields - Suffering from the larger and smaller competitors
Small		- T, R and IC are serving a mission given by the government - Mild competition for resources and strong network to 'national local' industry	- R and IC exist for specialised T - IC are oriented to practical needs of small local firms

*T: Teaching, R: Academic Research, IC: Industrial Collaboration.
Source: summarised by the author.

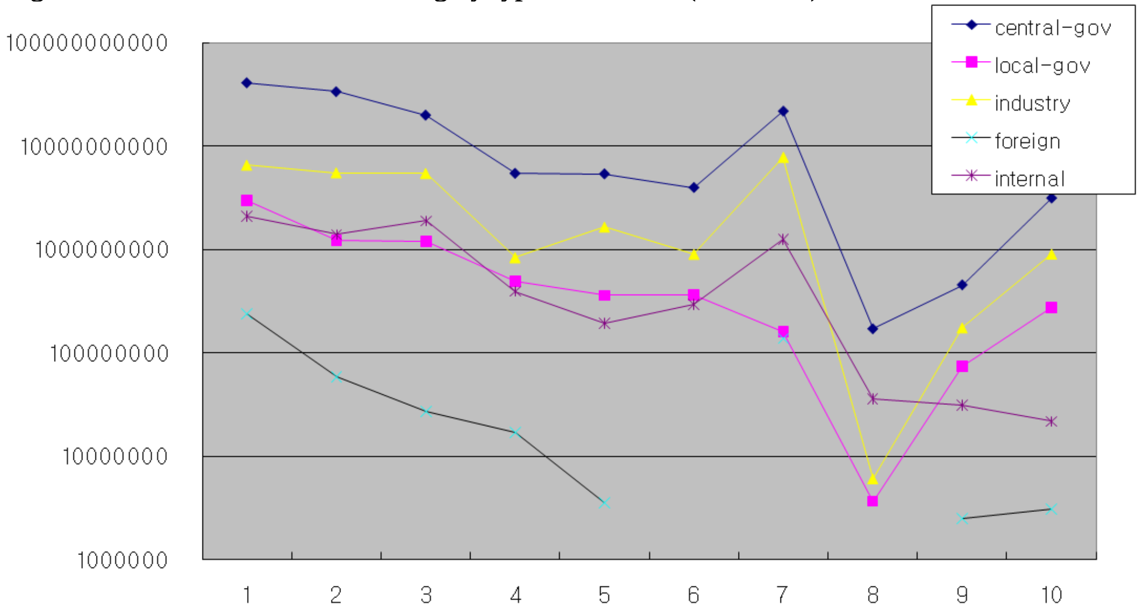
5.3.2 Resources and activities of the universities according to the different types

This section provides a quantitative analysis of the university characteristics and its activities according to the different types of university.

Resources structure of the universities according to the types

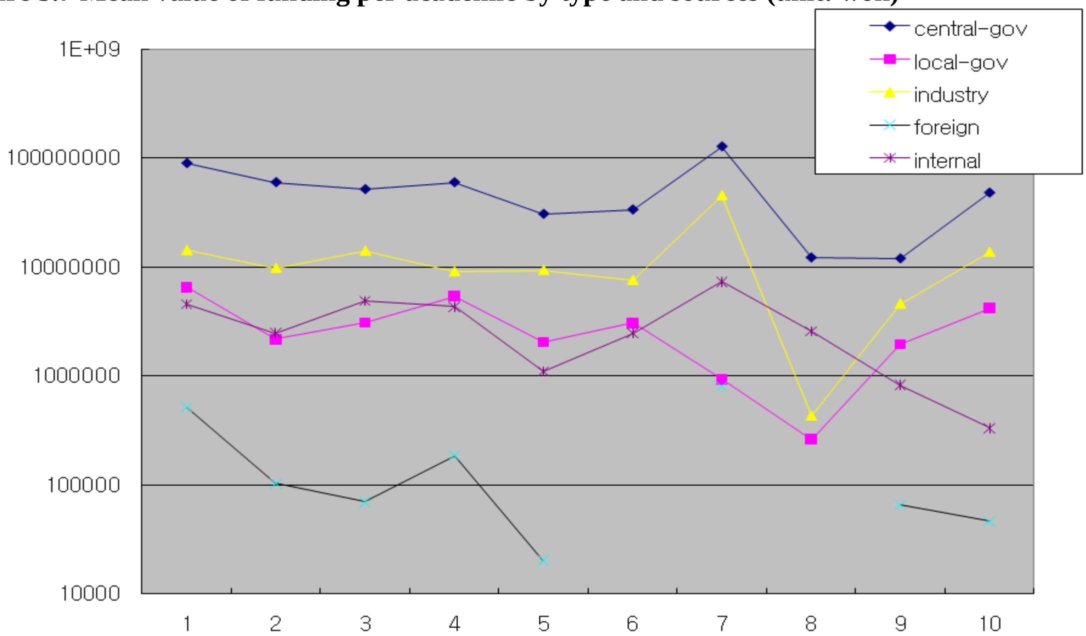
Based on both Figure 5.6 and Figure 5.7, some structural characteristics of research funding of different universities can be presented according to the sources of the funding (e.g. central government, local government, industry, foreign sources and internal funding) as follow. As shown in the figure below, overall, the large universities are more likely to use large amounts of research funds except for type 7 (those specialised in science and engineering). As shown in Figure 5.6, the average research expenditure of the universities categorised in the three types of large universities is about ten times larger than that of those categorised in three medium-sized universities.

Figure 5.6 Mean value of the funding by type and source (unit: won)



Source: the author, data based on KRF survey (2007).
*1: Old large private in Seoul, 2: Large public regional, 3: Large private regional, 4: Medium and small private in Seoul, 5: Medium public regional / industrial, 6: Medium private regional,7: Specialised in science & engineering, 8: Specialised in teachers' and ministers' training/ on-line,9: Small private regional, 10 Small private industrial. Source: the author, data based on KRF survey (2007).

Figure 5.7 Mean value of funding per academic by type and sources (unit: won)



Source: the author, data based on KRF survey (2007).

Firstly, central government funding is concentrated in absolute terms in large universities and universities specialising in science and engineering. Moreover, in terms of the funding per academic, academics in Seoul, in large universities and in universities specialised in S&T are in a more advantaged position than those in other institutions.

Secondly, in terms of local government funding, universities in Seoul are in an advantageous position, as shown in the two figures above. This may be related to their local governments' budget size. In contrast, the universities of type seven and eight are in a relatively unprivileged position. This may be because the official mission of type seven and eight institutions is more related to meeting national needs, such as the development of certain disciplines in technology and the provision of public education.

Thirdly, the university type which most benefited from industrial funding is type seven, whereas type eight is in the opposite position. This may be because type seven universities are specialised in and competent in science and technology, and therefore they attract funding from industry, whereas the activities of type eight institutions are limited to training teachers and ministers. The amount of funding for the type two (large public regional universities) (14 million won/academic) is larger than that (9 million won/academic) of type three (large private regional universities). This may be due to the fact that private universities in the regions are closer to local industry than public universities in the regions, which are dependent on the central government.

Fourthly, the size of the foreign funding is relatively smaller than that of other funding sources. The large universities in Seoul, medium-sized universities in Seoul and those specialising in science and engineering are the top three institutions attracting overseas resources. They may be benefited from the location: the capital.

Finally, overall the size of internal funding is also proportional to other funding. However, large and medium-sized private universities show higher levels of internal funding than public universities, while small private industrial universities shows the lowest level of internal funding. This is related to the organisational inflexibility of public universities. According to a director DN7 of a medium public university, public universities are suffering from various regulations on the budgeting of the organisation, so flexible management of internal research funding is not easy.

Activities of the universities according to the types

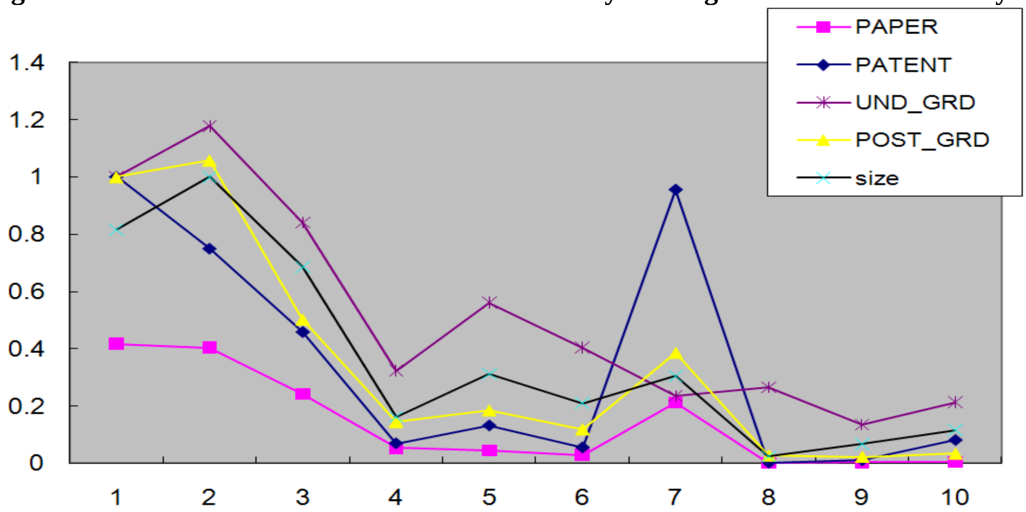
Based on the characteristics of each type of university, activities such as teaching, research, and entrepreneurial activities are analysed according to the type. As shown in the table below, activities such as published papers and patents applied for are presented according to the types identified in the previous section.

Table 5.13 Mean value of the activities of different types of universities

Types*	PAPER-SCI		PATENT		UND_GRD		POST_GRD		SIZE (No. Profs)
	N	N/Prof	N	N/Prof	N	N/Prof	N	N/Prof	
1	425	0.92	123	0.27	9353	20.20	3127	6.75	463
2	412	0.73	92	0.16	11018	19.43	3309	5.84	567
3	247	0.64	56	0.15	7868	20.23	1570	4.04	389
4	55	0.60	9	0.09	3029	32.92	452	4.91	92
5	46	0.26	16	0.09	5246	29.64	578	3.27	177
6	30	0.25	7	0.06	3781	31.77	370	3.11	119
7	217	1.25	118	0.68	2203	12.73	1207	6.98	173
8	1	0.09	0	0.02	2484	177.45	85	6.11	14
9	4	0.11	1	0.03	1266	33.30	70	1.84	38
10	5	0.08	10	0.15	1993	30.20	105	1.59	66

*1: Old large private in Seoul, 2: Large public regional, 3: Large private regional, 4: Medium-sized and small private in Seoul, 5: Medium-sized public regional / industrial, 6: Medium-sized private regional, 7: Specialised in science & engineering, 8: Specialised in teachers' and ministers' training/on-line, 9: Small private regional, 10: Small private industrial, 11: Outliers (SNU: 4540, 410, 10486, 9946, 961; UOS: 392, 61, 3279, 1926, 159).
Source: the author, data based on KRF survey (2007).

Figure 5.8 Mean value of the activities normalised by the largest value of each activity

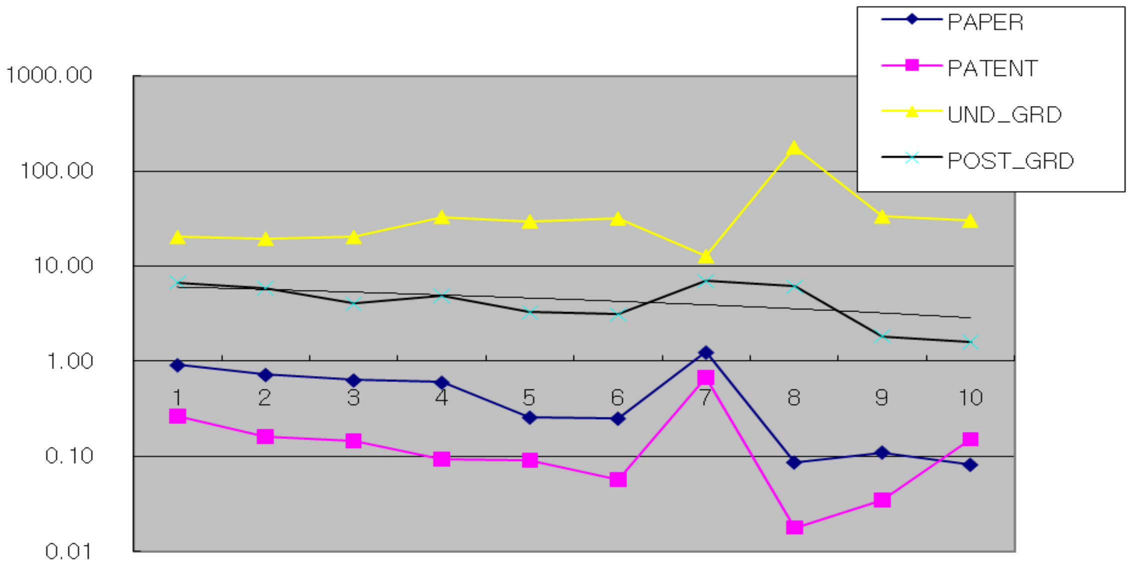


*Y axis represents the relative size of numbers of paper, patent, undergraduates and postgraduates.
Source: the author, based on the Table 5.13.

As shown in Table 5.13 and Figure 5.8, the activities of teaching, research and knowledge-transfer are expressed in terms of the number of both undergraduates and postgraduates, papers published and patents applied for. Overall, the performance of each type of the universities is likely to be proportional to their size. For example, the larger universities published more papers, and applied for more patents, and trained more undergraduates than the smaller ones. However, some small universities such as type seven (i.e. universities specialised in science and engineering) show better performance in spite of their small size. Moreover, the size of the large regional universities is larger than the old large universities in Seoul, whereas the performance of the former in research and industrial collaboration is lower than in the latter.

In order to compare the performance of universities, the output from their activities are normalised by their size, as shown in the figure below. In the following parts, the comparison is implemented on the basis of four categories: large, medium, special and small universities. Firstly, comparing three large universities (i.e. the old large private in Seoul, the large public regional and the large private regional), differences in their performance can be analysed as follows. Among the three universities, the large public universities have the smallest teaching load (19.43). The old large private universities show the best performance in terms of papers (0.92) and patents (0.27). In particular, the number of patents applied for per academic for them is about two times higher than that for the other two types of the universities. Even though the large public regional universities have about two more postgraduates per academic (i.e. 1.8 = 5.84 – 4.04) than the large private regional universities, their activities in terms of publishing and patenting are not as distinctive compared to those in the category of large private universities in Seoul.

Figure 5.9 Mean value of the three activities denominated by the size (activities per academic)



*Y axis represents the numbers of papers, patents, undergraduates and postgraduates on a log scale.
Source: the author, based on Table 5.13

Secondly, compared to the universities in the group of large universities, the academics in the medium-sized universities taught more undergraduate students, and produced relatively few papers and patents. Thus, they can be regarded as being more teaching-oriented institutions. The medium-sized universities in Seoul have shown three times stronger research performance (with 0.60 papers/academics) than the other two universities (0.26 and 0.25 each). This may be not only because they have about two more postgraduate students per academic (4.91 students/academics) than the other two universities (with 3.27 and 3.11 respectively), but also because the size of their total research expenditure is far larger than that of the other two universities, as shown in Figure 5.7. In spite of this larger amount of total research expenditure (see Figure 5.7), the private regional universities produced fewer patents (0.06) than the public regional universities (0.09). Possibly, this may be due to the fact that the former prefer informal channels of knowledge-transfer (e.g. consulting and meeting), while the latter is encouraged strongly by the central government to produce highly visible outputs such as patents applied for.

Thirdly, the specialised universities group consists of the most heterogeneous two sub types of universities. That is to say, the universities specialised in science and engineering show the best research (1.25 papers/academic) and knowledge-transfer (0.68 patents/academic) performance among all types of university, while the others show the lowest publishing (0.09) and patenting (0.02) performance among all types of university. In contrast, in terms of the size of undergraduate student education, the specialised ones in teaching show the highest performance, because this type consists of universities mainly aiming to train teachers and ministers or specialising in on-line training.

Finally, the two subtypes in among the small universities are all teaching-oriented rather than research-oriented, but are different with regard to publishing and patenting activities. That is to say, private industrial universities are better at patenting, whereas small private regional universities are better at publishing. Moreover, the private industrial universities show the third highest performance in terms of patenting and undergraduate teaching among all types of universities. However, these two universities belong to the lowest group in terms of the production of papers. Therefore, they are regarded as being not as competitive in academic research. In spite of this size difference, the public industrial universities have a similar activity pattern to private industrial universities. Specifically, the former have a larger production of papers (0.13), and produced more undergraduates (39.7) and have more postgraduates (2.94), but they have applied for fewer patents (0.10) than the latter.[24]

5.4 Conclusion

In the first part of this chapter, the characteristics of Korean universities engaged in science and engineering were investigated according to their five organisational properties. Firstly, the founding year of the Korean universities engaged in science and engineering is consistent with the results of the analysis of historical development as presented in Chapter 4. For example, the two peaks in Figure 5.1 show the expansion of Korean universities after the liberation in the 1940s and after the deregulation in 1980. Secondly, in terms of legal status, Korean higher education has been more dependent on private universities than on public universities. Thirdly, in terms of size, the majority of the universities (76%) are small, with fewer than 200 academics. Fourthly, in terms of geographical distribution, the universities are not particularly concentrated in a certain area. Finally, in terms of generality, public universities tend to cover a wider range of academic disciplines than private universities.

Next, based on three methods for arriving at a typology (i.e. on the basis of historical development, correlation coefficients, and cluster analysis), ten types of Korean universities engaged in science and engineering have been identified: large old universities in Seoul, large public regional universities, large private regional universities, medium-sized private universities in Seoul, medium-sized public regional universities, young specialised universities in science and engineering, specialised

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[24] Among medium-sized universities, the old public industrial universities produced two times more papers than the middle-aged public regional universities, while the other activities are broadly similar (See Table.5.11). As another 'sub' category, the private universities in Seoul consist of two size groups as indicated in the previous section (see p.121). The ten small private universities in Seoul produce 0.27 papers, 0.01 patents and 36.8 undergraduates per academic. In other words, the production of papers is similar to other medium universities, while patent production is similar to other small universities. In contrast, the six medium-sized universities in Seoul are very similar to large universities. In terms of papers production, they are close to the old large private universities in Seoul. In terms of patents applied for, they are close to the large private regional ones. The small private regional universities also consist of two different 'sub-sub' types: middle-aged and young. However, except for a small difference in the number of students, their other activities do not show any distinctive differences.

universities in training, and small private regional universities. Based on this typology, interviews with academics in these different types of Korean universities have been carried out, in order to investigate the conditions influencing the three activities of the universities. In addition to this qualitative analysis, the quantitative characteristics of the funding structure and activities of different universities have been explored.

According to the interviews with academics in each type of university, we may conclude that in spite of the strong central government policy for vitalising scientific research and academic entrepreneurship, different types of responses from the universities are identifiable. This is not only because different types of university are in different 'local' environments, but also because each university has its own organisational characteristics. In particular, resource endowments such as research funding and highly-qualified academics are essential for carrying out excellent academic research and for meeting sophisticated industrial demands; this is not the case for all types of universities. Usually, only a few types of university near the capital area fully enjoy the dramatic increase in government research funding. In contrast, it is not easy for small regional universities to exploit the opportunities to upgrade their research capacities by absorbing external research resources. Instead, they have chosen a strategy of strengthening vocational education with a view to increasing their students' recruitment opportunities in the local community, which directly contributes to the financial stability of the university. Between these two groups, some intermediate types of universities were identified. The large regional public universities under strong governmental control were regarded as instruments for meeting public interests such as regional development. However, the fact that these universities dominate central government funding in each region has provoked middle-sized universities in Seoul to believe that this constitute a system of reverse discrimination. Moreover, this has also motivated large regional private universities to become more specialised in certain areas of research and industrial collaboration in order to obtain more direct financial resources from industry.

The results of the quantitative analysis based on the KRF survey (2006) on the sources of research funding presented in subsection 5.3.2, are consistent with those of the qualitative analysis based on the interviews with academics. In other words, the amounts of research funding (particularly from central government) are not allocated equally. The three types of large universities in Seoul and the regions have nearly ten times more research funding from central and local government and from industry than medium-sized universities. In particular, the amount of research funding from central government is more concentrated than any other funding sources on large universities. Private universities enjoy more local government and industry support than public universities in terms of research funding.

In terms of their three missions and the relationships between them, the responses of the different types of universities to the environments identified by the interviews can be presented as follows. Firstly, teaching in larger universities tends to be oriented towards fundamental research techniques in the laboratories, while small and regional universities are likely to put more emphasis on technical vocational training. Secondly, large or prestigious universities enjoy abundant research resources such as postgraduates, professors and governmental funding. This tends to create an advantageous environment for producing excellent academic output and further attracting research resources. In contrast to this ‘positive feedback loop’ operating in the large universities, the small regional universities are suffering from a ‘vicious cycle’ between poor research performance and poor resources provided. In order to escape from this trap, the small regional universities have been focusing their research on more commercial and practical areas. Thirdly, large universities and those in the capital area tend to make an effort to exploit the output from their industrial collaboration, seeing it as an opportunity to increase their academic reputation. However, small and regional universities enjoy this collaboration at the expense of academic research, and use it as a local network to increase the likelihood of their students being recruiting in local companies.

The results of the quantitative analysis of the activities of each type of university are also consistent with the results of the interviews. First of all, the larger universities are more focused on research and industrial collaboration, whereas the smaller ones are more focused on teaching. Furthermore, we can distinguish the types that excel in teaching (types 4, 5, 6, 8, 9 and 10) from those (types 1, 2, 3 and 7) that do better in research and entrepreneurial activities. Possibly the first mission and the other two missions are negatively related to each other across the university types. In terms of the relationship between academic research and knowledge-transfer, they seem to be positively related to each other. Regarding this relationship, the number of postgraduate students at each type of university is more closely related to research and industrial collaboration than it is to undergraduate education.

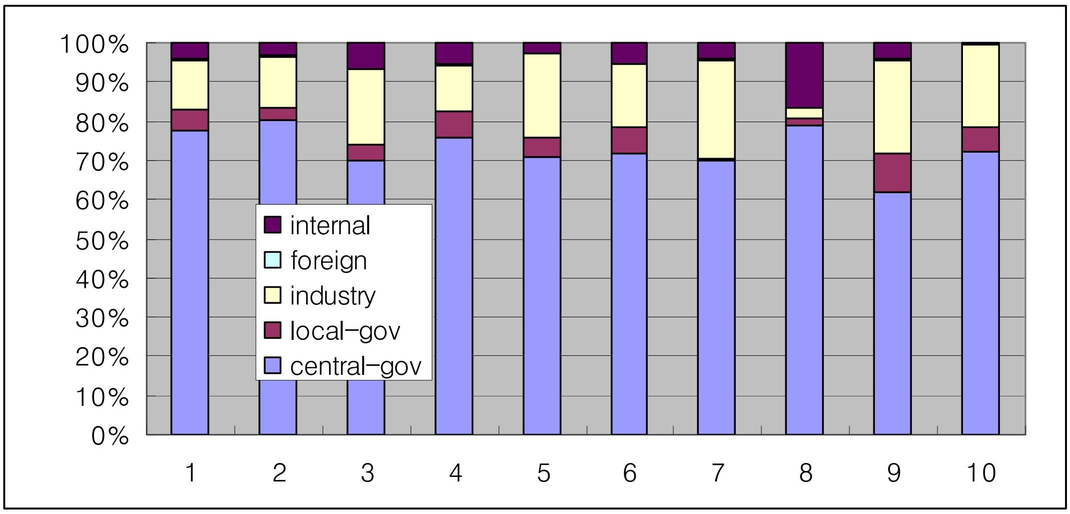
Based on the qualitative and quantitative results summarised above, we can suggest some conclusions, considering the discussion on existing literature (Chapter 2), the characteristics of the Korean higher education system (Chapter 4), and the main research question (Chapter 1).

Firstly, we have found various coexisting ‘species’ of universities in a certain country (Martin, 2003). As Howells et al. (2008) found in the UK university system, the different types of Korean universities act differently in terms of their missions (i.e. teaching, research and industrial collaboration). For example, large private universities in Seoul largely pursue academic excellence, while small private universities in the regions focus more on their local reputations by providing ‘on the job’ training. Furthermore, in terms of interaction with industry, the public universities produce more patents (i.e. formal channel) than the private universities. Therefore, in later studies, ‘universities’ need to be considered to be various ‘actors’ in national innovation system rather that single uniform entity, as different types of universities interact differently with other actors (e.g. government and industry).

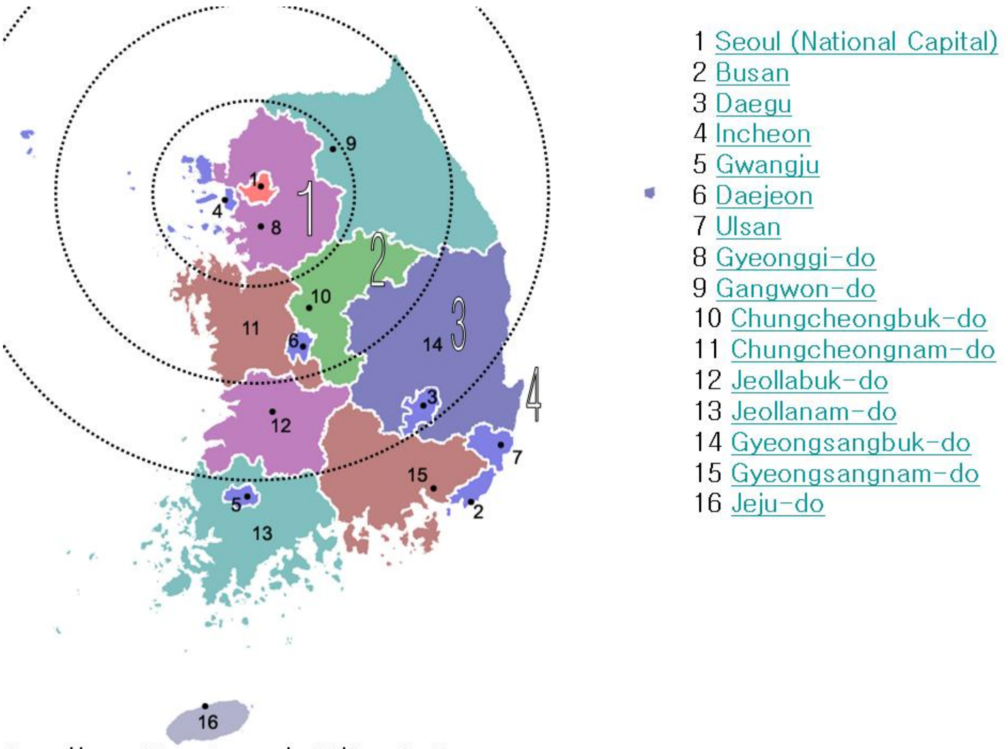
Secondly, the institutional characteristics of the different university types we identified here are closely entangled with the idiosyncratic characteristics of the Korean higher education system. The majority of universities are private, because the government has not enough resources to provide sufficient public higher education. Moreover, during the last half century, the government has supported certain types of universities (particularly large universities), in order to develop the national and regional economy. Therefore, the issue of imbalanced resources among universities has been created by strong government control. As a result, universities that have benefited from the central government programmes can afford to focus on academic research, whereas those that have not must focus more on teaching due to their heavy dependence on students’ fees.

Finally, regarding the main issue of this thesis (i.e. the relationship between academic research and knowledge-transfer activities), we found a positive relationship between the two activities across the different types of university (see Figure 5.9). In addition, the teaching activities (particularly the education of undergraduate students) are negatively related to both research and knowledge-transfer activities. According to interviews with university directors and the KRF survey (2006), one of the critical factors influencing these relationships is the availability of research resources such as funding and researchers. In this vein, the central government can be regarded as the strongest actor involved in this process. Moreover, the positive relationship between research and industrial collaboration may be due to the fact that these two activities are closely and intrinsically entangled with each other; otherwise, the factors from other dimensions may be related to this relationship. However, this needs further investigation on organisational and individual levels. This analysis will follow in later two empirical chapters.

Appendix Figure 5.1 Mean value of the funding expressed in proportion according to the types



Appendix Figure 5.2 Categorisation of the areas according to the distance from Seoul



http://en.wikipedia.org/wiki/South_Korea

Appendix Table 5.1 Descriptive statistics of different types of universities

CATEGORY			PAPER	PATENT	UND_GRD	POST_GRD
Old large private in Seoul	N	Valid	9	9	9	9
		Missing	0	0	0	0
	Mean		1018.9556	123.1711	9353.1111	3126.5556
	Median		876.2500	69.3400	9329.0000	2014.0000
	Std. Deviation		550.34021	113.75487	2725.77129	2358.46195
	Minimum		371.77	23.72	4864.00	898.00
	Maximum		1917.09	329.00	13545.00	6979.00
Large public regional	N	Valid	8	8	8	8
		Missing	0	0	0	0
	Mean		1146.6750	92.2900	11017.6250	3309.2500
	Median		1008.9500	97.7000	10821.5000	3316.0000
	Std. Deviation		587.83050	29.17386	1589.78435	1146.51755
	Minimum		514.63	47.85	8829.00	1686.00
	Maximum		2061.98	121.50	13160.00	4777.00
Large private regional	N	Valid	13	13	13	13
		Missing	0	0	0	0
	Mean		687.0638	56.4569	7868.3846	1570.0000
	Median		641.1200	31.8000	7335.0000	1560.0000
	Std. Deviation		392.63632	76.38616	2248.32202	938.57472
	Minimum		125.48	.00	4320.00	433.00
	Maximum		1423.74	240.00	10906.00	3307.00
Medium and small private in Seoul	N	Valid	16	16	16	16
		Missing	0	0	0	0
	Mean		231.2713	8.5894	3028.8750	451.8750
	Median		263.0100	2.2000	2490.0000	303.5000
	Std. Deviation		122.35747	14.25076	1517.30010	426.63706
	Minimum		20.02	.00	709.00	3.00
	Maximum		411.68	50.00	6396.00	1478.00
Medium public regional / industrial	N	Valid	19	19	18	18
		Missing	0	0	1	1
	Mean		197.1616	16.2700	5270.8333	599.0556
	Median		178.2000	9.9800	4569.0000	527.5000
	Std. Deviation		121.51700	15.01760	2305.92098	461.50400
	Minimum		66.20	.00	2282.00	128.00
	Maximum		555.40	50.00	10945.00	2077.00
Medium private regional	N	Valid	25	25	25	25
		Missing	0	0	0	0
	Mean		185.5672	6.7944	3799.2400	376.4000
	Median		180.5300	4.0000	3505.0000	255.0000
	Std. Deviation		101.23924	7.65416	1275.53689	246.12412
	Minimum		18.69	.00	1268.00	66.00
	Maximum		420.70	27.00	7375.00	866.00
Specialised in science & engineering	N	Valid	9	9	8	8
		Missing	0	0	1	1
	Mean		323.4789	117.7222	2202.7500	1207.0000
	Median		130.8800	17.7000	2123.0000	540.5000
	Std. Deviation		387.96303	185.27718	1825.95038	1414.63524
	Minimum		34.90	.00	306.00	274.00
	Maximum		1155.44	535.15	5653.00	4376.00
Specialized in teachers' and ministers' training/ on-line	N	Valid	21	21	7	7
		Missing	0	0	14	14
	Mean		45.0729	.2381	184.1429	78.5714
	Median		25.3500	.0000	40.0000	.0000
	Std. Deviation		61.64435	.53896	287.04961	207.88046
	Minimum		2.00	.00	.00	.00
	Maximum		257.15	2.00	746.00	550.00
Small private regional	N	Valid	38	38	38	38
		Missing	0	0	0	0
	Mean		55.6134	1.3163	1265.5789	69.9474
	Median		42.5400	.0000	1050.0000	37.0000
	Std. Deviation		41.62822	3.08361	878.65123	98.93485
	Minimum		1.70	.00	.00	.00
	Maximum		159.56	14.00	3551.00	418.00
Small private industrial	N	Valid	9	9	9	9
		Missing	0	0	0	0
	Mean		72.2044	10.0111	1993.1111	105.0000
	Median		43.6200	3.0000	1758.0000	54.0000
	Std. Deviation		60.38859	16.52819	1262.30132	166.34753
	Minimum		17.78	.00	274.00	.00
	Maximum		188.02	51.00	4787.00	536.00
Outliers	N	Valid	2	2	2	2
		Missing	0	0	0	0
	Mean		2466.0850	235.4400	6882.5000	5936.0000
	Median		2466.0850	235.4400	6882.5000	5936.0000
	Std. Deviation		2932.77487	246.27115	5096.11857	5670.99639
	Minimum		392.30	61.30	3279.00	1926.00
	Maximum		4539.87	409.58	10486.00	9946.00

Chapter 6 Determinants of Knowledge Transfer Activities of Korean Universities

6.1 Introduction

The main aim of this chapter is to investigate the relationship between the characteristics of universities engaged in science and engineering and their knowledge-transfer activities. To do this, descriptive statistics, correlation statistics and regression analysis are used in Sections 6.2 and 6.3, based on data from the official census on Korean universities (presented in Chapter 3 in detail).

Firstly, Section 6.2 explores the relationship between the university characteristics and the knowledge-transfer activities of 145 Korean universities engaged in science and engineering. In particular, knowledge-transfer activities such as patenting, technology transfer and revenue creation are investigated according to three categories of their characteristics (i.e. institution and environment, resources, and activities). Furthermore, the relationships between the various sources of research expenditure and knowledge-transfer activities, and between the characteristics of academics and knowledge-transfer activities are also investigated.

Secondly, Section 6.3 focuses on the relationships between scientific capacities (measured by research activities) and knowledge-transfer activities, and between various sources of funding and knowledge-transfer activities, while the previous section attempts to grasp the overall picture of the relationships between various characteristics of the universities and their knowledge-transfer activities. Thus, based on the existing literature, as well as on the peculiar properties of Korean universities, various hypotheses on this relationship are suggested. These hypotheses are tested by a statistical model, and the test results are discussed considering certain characteristics of the Korean academic system identified in Chapters 4 and 5.

Finally, Section 6.4 summarises the findings of the two empirical sections. Based on these findings, some conclusions on the factors influencing the knowledge-transfer activities of Korean universities are provided. Finally, some general characteristics of the relationship between academic research and knowledge-transfer activities specifically at the organisational level can be suggested.

6.2 The Relationship between Universities' Characteristics and their Knowledge-Transfer Activities

The main aim of this section is to provide an overview of the relationship between universities' characteristics and their knowledge-transfer activities. Firstly, university characteristics are categorised as: institutional and environmental properties (subsection 6.2.2), characteristics of human and financial resources (subsection 6.2.3), and research and teaching activities (subsection 6.2.4). Secondly, in terms of knowledge-transfer activities, patent applications and technology transfer are introduced. Before exploring the relationship between universities' characteristics and their knowledge-transfer activities, in the section below, we discuss certain basic properties of the variables addressed in this chapter.

6.2.1 Variables

The descriptive statistics shown in Table 6.1 provide us with **institutional and environmental properties** of Korean universities engaged in science and engineering.[25] The average founding year of Korean universities is 1959; which is due to the enormous increase in the establishment of universities after the liberation in 1945 (see Section 5.2). About 77% of these institutions are private universities. The average size of university as measured by the number of academics engaged in science and engineering is 183. The average size of TTOs as measured by the number of staff is 15 (the number is quite large, because the TTO personnel in Korean universities are involved not only in the business of knowledge-transfer but also in the management of externally-given R&D programmes), and the distribution skews highly, as shown in Appendix Figure 6.3. In terms of region, 20% of universities are located in Seoul. The **human and financial resources** of the universities are also presented in Table 6.1. More than 45% of academics in science and engineering are engaged in engineering, and most (75%) of the research expenditure is funded by central government.

[25] In this chapter, we define 'universities engaged in science and engineering' as universities with at least one department of science and engineering, because the analysis of this chapter is based on the organisational level. Among the 169 Korean universities in science and engineering investigated in Chapter 5, universities specialised in teachers' and ministers' education (type 8 in section 5.3.2) are mostly excluded.

Moreover, the characteristics of the universities' three main activities, **teaching, research and knowledge transfer**, can also be explored based on the descriptive statistics. Firstly, in terms of teaching, the average Korean university engaged in science and engineering has 4,262 undergraduates (i.e. 23 per academic) and 891 postgraduates (4.87 per academic). Secondly, in terms of research, they produce 110 papers in domestic journals and 126 papers in SCI journals per year. Moreover, funding from central government consists of more than 75% of the R&D expenditure of Korean universities. Thirdly, in terms of knowledge-transfer activities, 29 domestic patents and five overseas patents were applied for in 2006, and 61 million Korean won (US$61,000 in 2006) was earned by three technology transfers on average by Korean universities engaged in science and engineering.

Table 6.1 Descriptive statistics of 145 Korean universities engaged in science and engineering

	Mean	S.D.	Min	Max
Founding year	1958.52	28.77	1855	2003
Legal status (Pub=1/Pvt=0)	0.23	-	0	1
Size (No. of academics in S&E)	182.77	190.56	13	987
- Natural Science	38.15	41.35	0	215
- Engineering	83.14	67.02	4	287
- Medical & Pharmaceutical	52.01	100.89	0	580
- Agriculture and Maritime	9.47	16.99	0	98
Teaching (No. of students)				
- undergraduate	4261.58	3327.36	0	13545
- postgraduate	890.92	1462.26	0	9946
Location (in Seoul =1/No=0)	0.20	-	0	1
Number of papers published				
- Domestic journal	109.65	129.90	0	672.06
- SCI journal	125.68	320.18	0	3078.57
- Natural science discipline	49.07	94.14	0	859.77
- Engineering discipline	121.18	200.15	0	1240.66
R&D Exp. by sources* (Total)	151.31	290.78	.35	2306.79
- Cent gov't	113.70	232.47	0	1956.04
- Loc gov't	6.81	13.85	0	102.57
- Industry	24.23	49.34	0	339.17
- Overseas	.35	1.58	0	14.97
- Self	6.21	11.87	0	70.13
TTO size (no. of staff)	15.08	14.65	0	78
Regional BERD*	25101.65	32680.48	197.99	1.03e+5
Patent applications				
- Domestic	28.84	63.27	0	410
- Overseas	4.80	18.46	0	174
Technology Transfer+	3.89	7.36	0	40
Revenue from TT*	.61	1.66	0	13.62

*unit: 0.1 billion won (US$0.1 million in 2006).
+Transfer of ownership regarding intellectual property rights (IPR) created by universities.

6.2.2 Universities' institutional and environmental characteristics and their knowledge-transfer activities

This subsection analyses the relationship between the universities' institutional and environmental characteristics and their knowledge-transfer activities, such as patent applications, technology transfer and revenue creation. The **institutional** characteristics of Korean universities (i.e. legal status, founding year, university size and TTO size) as well as their **environmental** properties (i.e. location and regional BERD) are investigated in terms of their relationship to knowledge-transfer activities.

Firstly, universities' knowledge-transfer activities by their legal status are presented in Table 6.2 below. That is to say, the mean values of the number of domestic and overseas patent applications, the number of technology transfers, and the amount of revenue created by technology transfers are calculated in two groups (i.e. public and private universities). As shown in Table 6.2, the public universities show rather better performance in all four categories of knowledge-transfer activities. In addition, the equality of the two means of each group is tested by an independent sample t-test.[26] According to the test results, the public universities show significantly better performance in terms of the number of domestic patent applications, but not in terms of other activities. However, according to descriptive statistics, the public universities show better performance in all four knowledge-transfer activities.

Table 6.2 Legal status of the universities and knowledge-transfer activities

	Domestic patent applications (No.)	Overseas patent applications (No.)	Technology transfer (No.)	Revenue creation by tech transfer[1]
Public Univ.	57.2	7.7	7.4	130.6
Private Univ.	20.5	3.9	2.9	40.4
Mean Differences	36.7^{**}	3.8	2.8	90.2

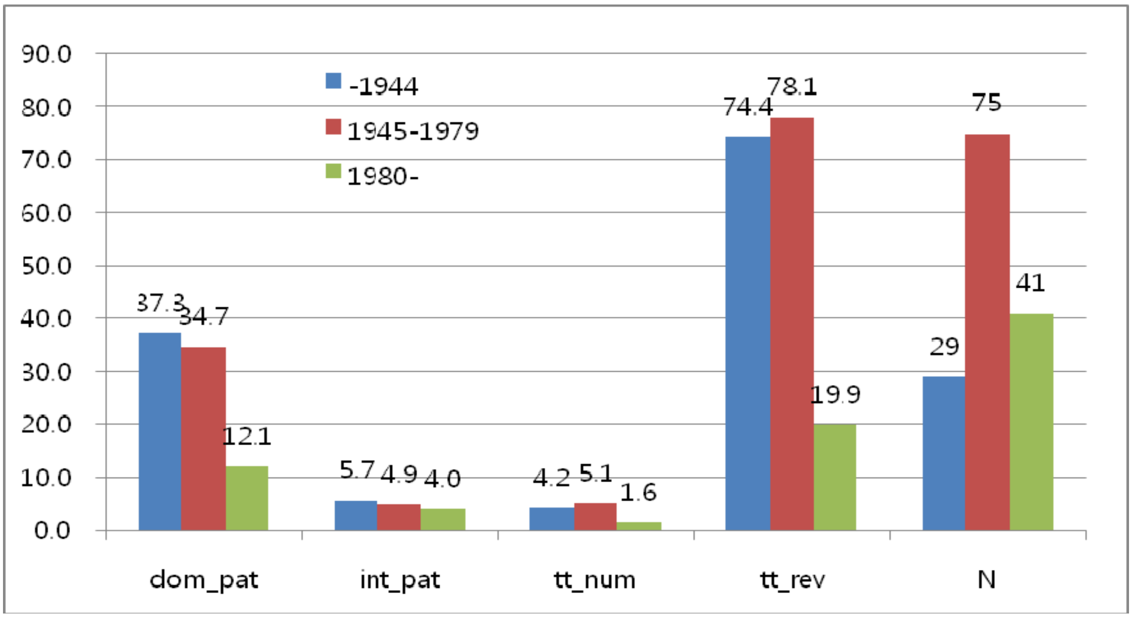
[1]Unit: million won (US$1,000 in 2006), $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$, $^{+}p<0.1$.

Secondly, the relationship between universities' founding year and knowledge-transfer

[26] Because the number of public universities is less than 50, normality test needs to be implemented. After taking log of knowledge-transfer activities, the normalities of three activities except overseas patent application are assumed according to Shapiro-Wilks test. However, in case of private universities, the normality of technology transfer cannot be assumed. Therefore, we can carry out T-test only in case of domestic patents and revenue creation. The distributions of the public universities' two activities with normal distribution curves are presented in Appendix Figure 6.1.

activities are investigated. In order to explore this relationship, the mean values of the knowledge-transfer activities are presented within three age groups (i.e. the categorisation by university founding year as introduced in Chapter 5) in Figure 6.1. The oldest group of universities records the highest output apart from in terms of technology transfer, whereas the youngest group shows the lowest output in terms of the four knowledge transfer activities. According to ANOVA test, significant difference between age groups exists in terms of domestic patents application, technology transfer and revenue creation, but not in terms of overseas patents application.[27]

Figure 6.1 Mean values of the knowledge-transfer activities* for three age groups



*The four knowledge-transfer activities are measured by the numbers of domestic and overseas patents and of technology transfers, and by the amount of revenue generated from technology transfer.
**Frequencies in the figure indicate the numbers of universities in the three groups.
***Unit of revenues from technology transfers: million won (US$1,000 in 2006).
Source: Data based on KRF (2006), figure created by the author.

Furthermore, according to the results of the correlation test shown in Table 6.3 below, the founding year is negatively related to all types of knowledge-transfer activities. In other words, older universities are likely to show a better performance in terms of knowledge transfer than younger universities. In particular, overseas patent applications are the strongest and the most significant variable related to the founding year of the universities.

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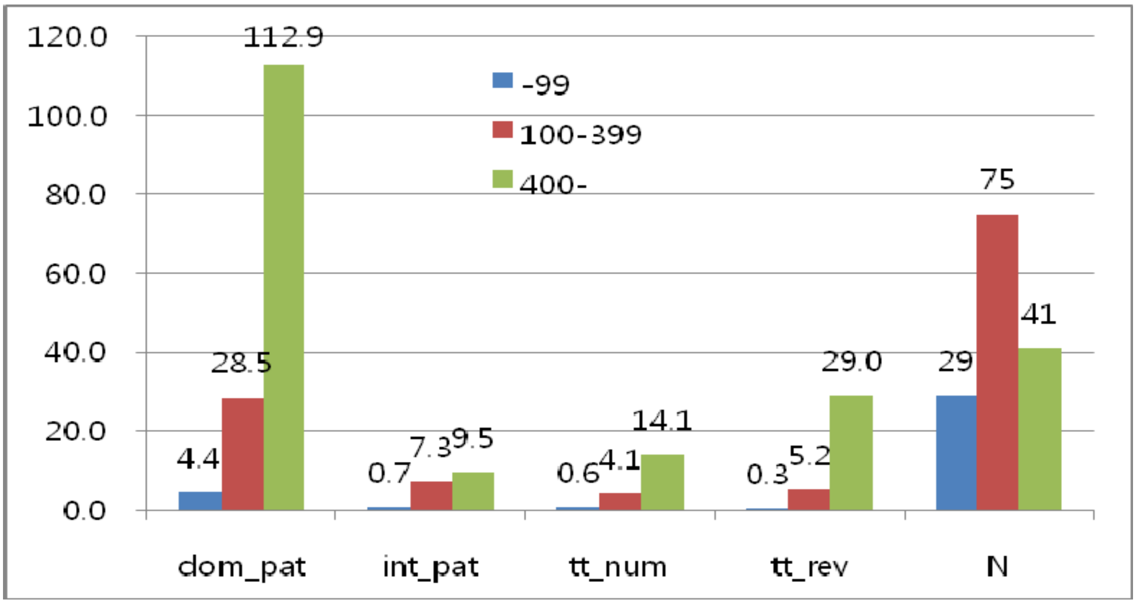
27 According to Shapiro-Wilk test, normality assumed for all four activities. Moreover, according to Levene test, equal variance can be assumed for three activities except for overseas patents.

Thirdly, in order to explore the relationship between the size of the universities and their knowledge-transfer activities, the four activities of domestic and overseas patent applications, technology-transfers and revenues received from these transfers are presented, broken down by the three size groups (i.e. large universities with more than 400 academics engaged in science and engineering, middle-sized universities with more than 100 academics, and small universities with fewer than 100 academics). According to the results shown in Figure 6.2, the large universities produced the largest outputs in terms of the four knowledge-transfer activities, whereas the small universities produced the lowest outputs.[28] According to a t-test, significant differences of knowledge-transfer activities between large and medium-sized groups are observed in terms of domestic patents, technology transfer and revenue creation, but not in terms of overseas patents.

Figure 6.2 Mean values of the knowledge transfer activities* by three size groups



*The four knowledge-transfer activities are measured by the numbers of domestic and overseas patents and of technology transfers, and by the amount of the revenue generated from technology transfers.
**Unit of revenues from technology transfers: 10 million won.
Source: Data based on KRF, figure created by the author.

Furthermore, according to the results of correlation tests, the size of universities is positively and significantly related to the knowledge-transfer activities as shown in Table 6.3. This means that the larger universities are likely to show better performance in terms of knowledge transfer than the smaller universities.

[28] Normality can be assumed only for large and medium-sized groups according to Shapiro-Wilk test, so independent two samples t-test is carried out here.

Fourthly, the size of TTOs (Technology Transfer Offices) has a significant and positive relation to knowledge-transfer activities. In other words, the universities with a larger TTO are likely to be more active in knowledge transfer than those with a smaller TTO.

Table 6.3 Institutional properties (founding year, university size and TTO size) and knowledge-transfer activities

Correlation Coefficient[1]	Domestic patent applications (No.)	Overseas patent applications (No.)	Technology transfer (No.)	Revenue creation by tech transfer[2]
Founding year	-0.206^{*}	-0.353^{**}	-0.224^{**}	-0.252^{**}
University size	0.699^{**}	0.601^{**}	0.675^{**}	0.678^{**}
TTOs size	0.673^{***}	0.560^{***}	0.647^{***}	0.619^{***}

[1]Because the distribution of the knowledge-transfer activities is highly skewed (i.e. likely to be far from the normal distribution), Spearman's rho is calculated as a correlation coefficient.
[2]Unit: million won (US$1,000 in 2006).
$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$, $^{+}p<0.1$

Fifthly, in terms of the **environmental characteristics** of the universities, an investigation has been conducted into the relationship between the location of the universities and their knowledge-transfer activities. In order to do this, universities' knowledge-transfer activities are calculated according to their location (i.e. the distance of the university from the capital). According to a t-test, universities in the capital produce a significant higher number of outputs of knowledge transfer in terms of domestic patents and revenue creation than those in other areas, as shown in Table 6.4. However, if we categorise two groups (i.e. universities near Seoul, and others), there are no statistically significant difference in terms of their knowledge-transfer output. This means that 'located in Seoul' is more important than 'located near Seoul' in terms of universities' knowledge-transfer activities.

Table 6.4 Mean values of knowledge-transfer activities* by the location of the universities

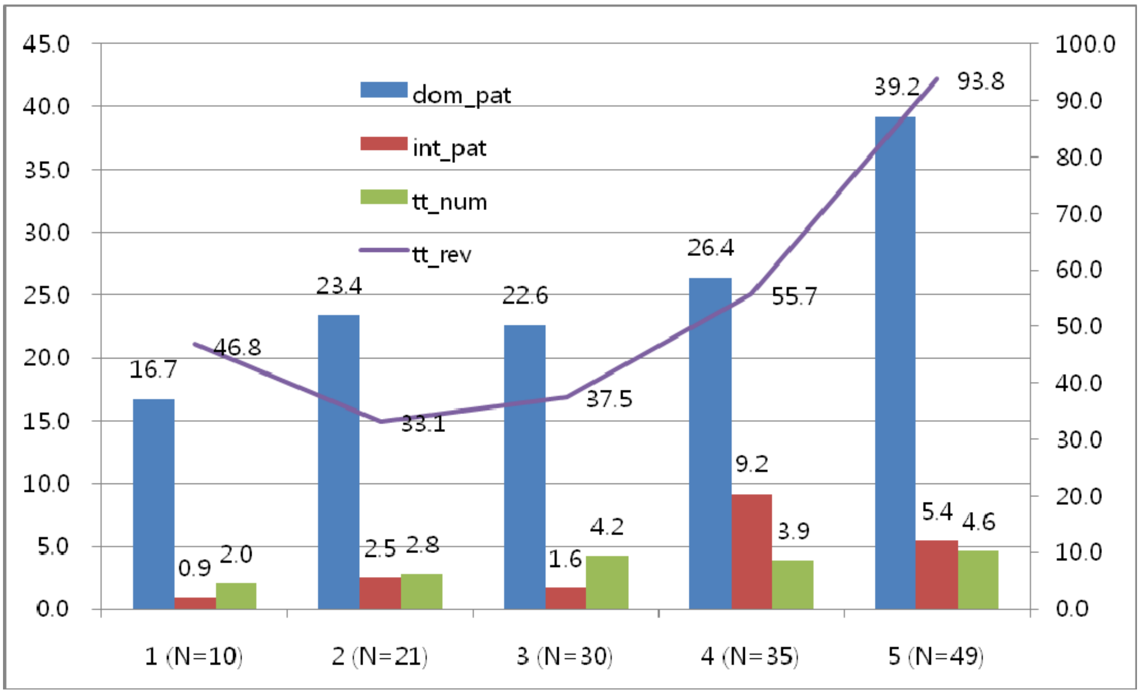
Correlation coefficients	Domestic patent applications (No.)	Overseas patent applications (No.)	Technology transfer (No.)	Revenue creation by tech. transfer[1]
Uni. near Seoul (51)[2]	41.3	5.7	4.9	94.2
Others (94)	22.1	4.3	3.4	42.8
Mean Differences	19.2	1.4	1.5	51.4
Uni. in Seoul (29)[3]	54.8	6.7	6.8	139.9
Uni in regions (116)	22.4	4.3	3.2	41.1
Mean Differences	32.4^{+}	2.4	3.6	98.8^{+}

[1]Unit: million won (US$1,000 in 2006).
[2]'Universities near Seoul' are located in Seoul, Incheon and Kyunggi.
[3]In the case of 'Uni. in Seoul', the number of cases is less than 50. Therefore, by taking natural log of the value of the four knowledge-transfer activities, the normality can be assumed.
$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$, $^{+}p<0.1$

Furthermore, according to the figures in Table 6.5, the location of universities as defined by their distance from Seoul is negatively related to the knowledge-transfer activities. In particular, the location is significantly and negatively related to overseas patent applications, while the other knowledge transfer activities are not significantly related to location. This means that universities closer to the capital are likely to show a higher number of overseas patent applications.

Sixthly, Figure 6.3 shows universities' knowledge-transfer activities according to the levels of regional BERD (Business Expenditure on Research & Development). Overall, the universities in the areas of higher regional BERD produced higher outputs of the four kinds of knowledge-transfer activities. However, according to the results of the correlation tests shown in Table 6.5, regional BERD in the area where the universities are located is not significantly related to any knowledge-transfer activities.

Figure 6.3 Mean values of the knowledge-transfer activities* by the regional BERD**



*The four knowledge-transfer activities are measured by the numbers of domestic and overseas patents and of technology transfers, and by the amount of the revenue generated from the technology transfers.

** Levels of regional BERD (unit: 0.1bilion won or US$100,000 in 2006): 1 (100-1000), 2 (1000-3000), 3 (3000-10,000), 4 (10,000-20,000), 5 (20,000-110,000).

***Unit of revenues from technology transfers: million won (US$1,000 in 2006)

Source: Data based on KRF, figure created by the author.

Table 6.5 Contextual properties (location & regional BERD) and knowledge-transfer activities

Correlation Coefficient[1]	Domestic patent applications (No.)	Overseas patent applications (No.)	Technology transfer (No.)	Revenue creation by tech transfer[2]
Distance from Seoul	-0.002	-0.187*	-0.042	-0.057
Regional BERD	-0.025	0.135	-0.006	0.038

[1]Because the distribution of the knowledge-transfer activities is highly skewed (i.e. likely to be far from the normal distribution), Spearman's rho is calculated as a correlation coefficient.
[2]Unit: million won (US$1,000 in 2006).
*p<0.05, **p<0.01, ***p<0.001, +p<0.1

6.2.3 Universities' human and financial resources and their knowledge-transfer activities

This subsection is more focused on the relationship between the characteristics of the human and financial resources exploited by universities and their knowledge-transfer activities.

First of all, the disciplines of the academics are categorised into four research areas: natural science, engineering, medical and pharmaceutical science, and agricultural and maritime science. Then, the correlation coefficients of the four knowledge-transfer activities are calculated according to the research areas of academics, as shown in Table 6.6. The correlation coefficients and their significance values indicate that all four academic disciplines are positively related to knowledge-transfer activities. In particular, academics in the fields of natural science and engineering are more prominent in terms of knowledge transfer than academics in the other two fields.

Table 6.6 Relationship between characteristics of human resources (number of academics in various disciplines) of universities and knowledge-transfer activities

Correlation coefficient[1]	Domestic patent applications (No.)	Overseas patent applications (No.)	Technology transfer (No.)	Revenue creation by tech. transfer[2]
Natural Science	0.594**	0.568**	0.631**	0.666**
Engineering	0.687**	0.535**	0.582**	0.609**
Med. /Pharm.	0.425**	0.398***	0.468**	0.448**
Agr. /Maritime	0.368**	0.198*	0.377**	0.337**

[1]Because the distribution of the knowledge-transfer activities is highly skewed (i.e. likely to be far from the normal distribution), Spearman's rho is calculated as a correlation coefficient.
[2]Unit: million won (US$1,000 in 2006).
*p<0.05, **p<0.01, ***p<0.001, +p<0.1

Secondly, according to the correlation coefficients presented in Table 6.7, regardless of the source of research expenditure, the level of financial resources is positively related to the output of knowledge-transfer activities. In particular, central government and industrial funding are more strongly related to universities' knowledge-transfer activities than funding from local governments, overseas institutions, and the universities themselves.

Table 6.7 Relationship between characteristics of financial resources (amount of funding from various sources) of universities and knowledge-transfer activities

Correlation Coefficient[1]	Domestic patent applications (No.)	Overseas patent applications (No.)	Technology transfer (No.)	Revenue creation by tech transfer[2]
Central gov.	0.759**	0.751**	0.722**	0.736**
Local gov.	0.590**	0.583**	0.578**	0.570**
Industry	0.747**	0.705**	0.682**	0.721**
Overseas	0.522**	0.503**	0.452**	0.507**
University	0.602**	0.581**	0.545**	0.561**

[1]Because the distribution of the knowledge-transfer activities is highly skewed (i.e. likely to be far from the normal distribution), Spearman's rho is calculated as a correlation coefficient.
[2]Unit: million won (US$1,000 in 2006).
*p<0.05, **p<0.01, ***p<0.001, +p<0.1

6.2.4 Universities' teaching, research and their knowledge-transfer activities

This subsection investigates the relationship between knowledge-transfer activities and both research and teaching activities. Firstly, in order to investigate the relationship between universities' **research** activities and their knowledge-transfer activities, the correlation coefficients between the two activities are calculated. The research activities carried out by the universities can be measured by two different categorisations.

On the one hand, the research activities measured by the number of publications can be subdivided into publications in domestic publications and SCI publications. As shown in Table 6.8, both kinds of publishing activities are discovered to be positively related to knowledge-transfer activities. In particular, the coefficients of domestic publications show a higher value than the coefficiets of SCI publications. This means that the universities publishing in domestic journals are more likely to show better performance than those publishing in internationally qualified journals.

On the other hand, research activities can also be categorised by the number of publications in different disciplines. Table 6.8 presents the correlation coefficients between the number of publications in four disciplines and the output of knowledge-transfer activities. According to the results, regardless of the discipline, the knowledge-transfer activities are positively related to research activities. In particular, the research activities in the area of natural science and of engineering are more strongly related to universities' knowledge transfer activities than those in the areas of medical and pharmaceutical science and agricultural and maritime science.

Table 6.8 Relationship between characteristics of research activities (numbers of papers published) of universities and knowledge-transfer activities

Correlation coefficient[1]	Domestic patent applications (No.)	Overseas patent applications (No.)	Technology transfer (No.)	Revenue creation by tech trans[2]
Domestic Journal	0.736**	0.698**	0.698**	0.713**
SCI Journal	0.655**	0.594**	0.628**	0.640**
Natural Science	0.642**	0.591**	0.641**	0.672**
Engineering	0.724**	0.617**	0.646**	0.668**
Med. / Pharm.	0.480**	0.454**	0.538**	0.511**
Agr. / Maritime.	0.382**	0.223**	0.423**	0.376**

[1]Because the distribution of the knowledge-transfer activities is highly skewed (i.e. likely to be far from the normal distribution), Spearman's rho is calculated as a correlation coefficient.
[2]Unit: million won (US$1,000 in 2006).
*p<0.05, **p<0.01, ***p<0.001, +p<0.1

Secondly, the relationship between **teaching** activities and knowledge-transfer activities is investigated. In order to measure the universities' teaching activities, the numbers of undergraduate and postgraduate students are counted. According to the correlation coefficients presented in Table 6.9, the numbers of both undergraduate and postgraduate students are positively related to the knowledge-transfer outputs of the universities. In particular, the higher correlation coefficients between the number of postgraduate students and output of knowledge transfer mean that the larger size of postgraduate may be related to more active knowledge-transfer activities of universities.

Table 6.9 Relationship between characteristics of universities' teaching activities (number of undergraduate and postgraduate students) and knowledge-transfer activities

Correlation Coefficient[1]	Domestic patent applications (No.)	Overseas patent applications (No.)	Technology transfer (No.)	Revenue creation by tech transfer[2]
Under. Std. (No.)	0.605**	0.504**	0.585**	0.611**
Post. Std. (No.)	0.717**	0.718**	0.715**	0.753**

[1]Because the distribution of the knowledge-transfer activities is highly skewed (i.e. likely to be far from the normal distribution), Spearman's rho is calculated as a correlation coefficient.
[2]Unit: million won (US$1,000 in 2006).
*p<0.05, **p<0.01, ***p<0.001, +p<0.1

6.2.5 Summary and discussions

Based on the descriptive statistics, t-tests and the correlation analysis presented above, we can begin to understand the overall relationship between various characteristics of the universities and their knowledge-transfer activities, such as domestic and overseas patent applications, technology transfer and revenue from technology transfer. Firstly, universities' institutional characteristics in terms of legal status, founding year, and size are strongly related to knowledge-transfer activities. On the other hand, environmental characteristics such as location and regional BERD are weakly related to those activities. Secondly, characteristics of both human and financial resources show a significant and strong relationship to knowledge-transfer activities, regardless of their discipline and funding sources respectively. Thirdly, university activities such as research and teaching are positively related to their knowledge-transfer activities.

However, in spite of easy access to the overall picture of the relationship between variables, both the correlation and the descriptive statistics presented here have some general weaknesses. One of the critical pitfalls is the failure to control other factors influencing the relationship. In other words, if we introduce other controlling variables (e.g. size) to the relationship between the universities' characteristics (e.g. teaching) and their knowledge-transfer activities, the relationship can be changed to a non-significant or even a negative relationship, in contrast to the results presented above. Therefore, in order to see the 'true' (i.e. controlling other conditions) relationship between the universities' characteristics and their knowledge-transfer activities, the next section is mainly based on regression models to test various hypotheses on the relationship.

6.3 Are scientific capacities and industrial funding critical for knowledge-transfer activities of universities in a catch-up country?

Following the suggestion in 6.2.5, this section focuses on the testing of hypotheses on the relationship between universities' characteristics (particularly their scientific capacity and financial structure) and their knowledge-transfer activities. In order to test the hypotheses suggested in subsection 6.3.1, subsection 6.3.2 presents statistical models as well as the data and variables employed. Finally, subsection 6.3.3 provides the results of the estimation based on the model and discusses the results.

6.3.1 Propositions (or hypotheses)

If we consider the systemic characteristics of Korean universities described in Chapters 4 and 5, the implications from reviewing the existing literature presented in Chapter 2, and the preliminary findings in Section 6.2, certain hypotheses regarding the relationship between characteristics of universities and their knowledge-transfer activities can be put forward.

Firstly, the scientific capacity of universities in a catch-up country such as Korea has been strengthened very recently, as discussed in Chapter 4. This change was possible due to the government's strong support for several strategic areas of research linked to human resource provision and commercial exploitation. Therefore, academic research at universities tends to be encouraged in the vicinity of particular areas that are easily exploited commercially. In other words, the scientific capacity of individual universities is closely related to their knowledge-transfer activities. Based on the above argument, the following hypothesis can be suggested.

Hypothesis 1: The universities with a stronger scientific capacity are likely to show a higher level of knowledge-transfer activities.

However, as introduced in Section 6.2, scientific capacity in terms of publications can be measured in a variety of ways, including number of domestic publications, number of SCI publications and number of publications in a certain area of research. Firstly, among the newly industrialising countries in Asia, Korean academic society would seem to have the academic system most significantly based both on Korean and on English (Altbach, 1989). Accordingly, in measuring scientific capacity, we cannot exclude the number of domestic publications. However, as frequently observed in the interviews with Korean academics, the number of SCI publications is regarded as a more reliable measure in terms of a certain level of quality, because of the stricter review process. Moreover, considering the close relationship between the engineering discipline and its industrial contribution in Korea, scientific capacity can be measured by the number of publications in the field of engineering. As a result, by applying various definitions of the scientific capacity in the above hypothesis, the relationship between different scientific capacity and knowledge-transfer activities can be explored.

Secondly, during the last decade, Korean universities' industrial contribution has been strongly encouraged by central government. In particular, in terms of R&D expenditure, Korean universities have become more dependent on central government funding than on other sources, particularly after the late 1990s, as shown in Chapter 4 (see Figure 4.5). Furthermore, the recent increase of total expenditure is mostly due to the increase of central government funding (see Table 6.1). Therefore, the major increase in knowledge-transfer activities of Korean universities is likely to be influenced by the significant increase of central government funding. As introduced in subsection 4.3.1, the various policy measures initiated by the central government in the 2000s support this argument. Based on the above argument, we propose a hypothesis focusing on the positive relationship between the amount of central government funding received by universities and their knowledge-transfer activities.

Hypothesis 2a: The ***amount*** *of universities' research funding from* ***central*** *government positively affects the knowledge-transfer outputs of universities.*

However, the small amount of funding from other sources, such as industry, does not necessarily mean that the sources are independent from the universities' knowledge-transfer activities. Accordingly, not only the effect of central government funding, but also that of other funding sources needs to be investigated in the empirical analysis later on. In particular, industry funding may be a weaker predictor for universities' knowledge-transfer activities than central government funding, if we consider the government's strong financial contribution to the universities' research expenditure.

As introduced in the literature review in Chapter 2 (see subsection 2.3.3), the question of whether not only the absolute size of research funding, but also whether the proportion of research funding in relation to the total amount of funding is a critical factor for knowledge-transfer activities is an undetermined issue that needs more empirical investigation. In a similar vein, if we consider the important role of central government funding in Korean universities' research activities (see Chapter 4), the proportion of central government funding could be significantly related to knowledge-transfer activities. Furthermore, as discussed in Chapter 5 (see Figures 5.6, 5.7, 5.8 and 5.9), according to different types of universities, the proportion of funding from each resource is closely related to not only research and teaching activities, but also knowledge-transfer activities. In particular, according to interviews discussed in Chapter 5, central government funding is critical for universities' research and knowledge transfer activities. Accordingly, an additional hypothesis focusing on this issue can be stated as follows.

Hypothesis 2b: The ***proportion*** *of universities' research funding from* ***central*** *government relative to the total amount of research funding positively affects the knowledge-transfer outputs of universities.*

Finally, as discussed in Chapter 2, the other factors influencing the relationship (e.g. institutional characteristics, entrepreneurial orientation and environmental condition) are also included as control variables in our statistical model. In this way, considering the various characteristics of Korean universities, their activities, and their relationships discussed in the previous chapters, the influence of the other variables excluded in the above hypotheses are investigated according to the empirical results in the following analysis.

6.3.2 Data and model specifications

The data set has been mainly compiled from the KRF (Korea Research Foundation) annual survey on the academic research and knowledge-transfer activities of Korean universities in 2006.[29] The definition of 'the universities engaged in science and engineering' in this section is introduced in subsection 6.2.1 (see footnote 25). The data set contains input and output variables of the individual universities' activities, such as the number of academic staff, the amount of research funds from different sources, the number of internal research institutes and their research expenditure, and the number of papers, books, patents, technology transfers and research projects. In addition to this data set, the website of the Korea National Center for Education Statistics & Information provides the number of undergraduate and postgraduate students.

As introduced in 2.3.3, the economic model using a patent production function as a dependent variable is also adopted here. The **dependent variables** are related to the

[29] The details of this survey are provided in subsection 3.3.2.

universities' industrial collaboration activities in 2006 (i.e. the number of domestic and overseas patents applied for, the number of technology transfers and the revenue from the technology transfers). In terms of the **independent variables and the control variables**, the following factors influencing entrepreneurial activities are employed: scientific capacity, funding sources of universities, institutional characteristics (e.g. size, age and legal status), size of TTOs (personnel or budget), regional business expenditure of R&D, and properties of the universities (e.g. size, location, research expenditure). Alternatively, instead of institutional characteristics, dummy variables representing the universities' characteristics are adopted in order to understand what specific types of university differentiate the extent of entrepreneurial activities

The dependent variables, such as numbers of patents and technology transfer in this study, are count variables (i.e. zero or positive integers). Therefore, a Poisson distribution and negative binomial distribution can be regarded as alternatives for the regression analysis here. According to the descriptive statistics in Table 6.13 and Appendix Figure 6.2, over-dispersion (i.e. the variance is much larger than the mean) is clearly identifiable. This also proved to be statistically significant from the magnitude of the alpha value.[30] Consequently, a negative binomial (NB) model is more appropriate than the Poisson model in this analysis. Furthermore, in the case of domestic patents, the Vuong test result indicates that a standard negative binomial (NB) model has a better fit than a zero-inflated negative binomial (ZINB) model, while in the case of overseas patents and technology transfer, the latter has a better fit.[31]

Based on the above argument, a negative binomial (NB) regression model is employed for predicting the number of domestic patents. A zero-inflated negative binomial (ZINB) model is chosen for the estimation of the numbers of overseas patents and of the number of technology transfers. However, the Tobit model is adopted for explaining the revenue from technology transfer, because the dependent variable (i.e. the value of revenues) can be regarded to be censored in the area of a negative real variable.

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[30] All the alpha values in NB and ZINB models we introduced here are significantly different from zero at the level of 95% confidence.

[31] In case of the estimation of domestic patents in models 1-1, 1-2, and 1-3, Vuong test results of zero-inflated vs. standard negative binomial consistently supports the latter (i.e. all three z-values resulted from the tests are smaller than 1.96). However, Vuong test results in models 2-1, 2-2, 2-3, 3-1, 3-2 and 3-3 support ZINB models, which means that the dependent variables in these models has excessive zeros.

In order to prevent excessive multi-collinearity between the explanatory variables, the variables with a high VIF are excluded.[32] Moreover, highly and significantly related groups of variables are employed in separate regression models. For example, high correlations are observed between variables of the number of papers, those of the number of researchers (i.e. professors and postgraduate students), and those of the amount of research expenditure. In particular, according to preliminary regression analysis on the relationship between independent variables, the number of researchers and the amount of research expenditure are positive and significant predictors for the number of papers. Therefore, these three groups of variables are included in different models, as shown in the following table showing the results of the estimation. This is also well-aligned with the re-categorisation of the explanatory variables (i.e. scientific capacity, financial and human research resource), as discussed in Chapter 2.

6.3.3 Results

Universities' scientific capacity, sources of funding and knowledge-transfer activities

In this subsection, the estimation of the regression coefficients is carried out according to different dependent variables, such as domestic patent applications (models 1-1, 1-2 and 1-3), overseas patent applications (models 2-1, 2-2 and 2-3), technology transfer (models 3-1, 3-2 and 3-3) and the revenues from technology transfer (models 4-1, 4-2 and 4-3).

As shown in Tables 6.10 and 6.11, the regression coefficients of the predictors for knowledge transfer performance such as patent applications, technology transfers and the revenues from technology transfers are estimated by a standard negative binomial (NB), a zero-inflated negative binomial (ZINB) regression model and a Tobit regression model. Furthermore, considering the possibility of a heteroscedasticity problem, robust standard errors are calculated.

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[32] In each model, we exclude several independent variables with larger than 10 VIF (Variance Inflation Factor) value, because those variables are possibly linearly related to other independent variables. In this case, exclusion of significant independent variables could result in the overestimation of the significance of remained independent variables. However, because the three groups of variables are highly and significantly correlated, such possibility can be minimised.

Table 6.10 Negative binomial (NB) and Zero-inflated negative binomial (ZINB) estimation of patents application

Models	Model 1-1 (NB) Domestic Patent	Model 1-2 (NB) Domestic Patent	Model 1-3 (NB) Domestic Patent	Model 2-1 (ZINB) Overseas Patent	Model 2-2 (ZINB) Overseas Patent	Model 2-3 (ZINB) Overseas Patent
Founding year	.007 (.005)	.007 (.005)	.007 (.005)	.001 (.007)	.001 (.007)	-.007 (.007)
Legal status	.609* (.331)	.523* (.218)	.330 (.310)	-.247 (.486)	.084 (.479)	.776 (.496)
Size (No. of academics)						
- Natural Science			.001 (.008)			-.018 (.012)
- Engineering			.007* (.003)			-.002 (.004)
- Med. & Pharm.			-.002* (.001)			-.002 (.002)
- Agri. and Mari.			.0004 (.008)			-.016 (.011)
Location	.073 (.302)	-.012 (.325)	.311 (.410)	-.417 (.781)	.747 (.840)	.263 (.600)
Teaching (no. of students)						
- undergraduate		.00004 (.00007)			-.0001 (.0001)	
- postgraduate			.0005^{+} (.0003)			.001** (.0004)
Research						
- domestic journal		.001 (.001)	*.0009 (.002)*		.001 (.002)	-*.001 (.005)*
- SCI journal			*.0006 (0007)*			*.004* (.002)*
- Natural Science	.005 (.003)			.005 (.005)		
- Engineering	.004*** (.001)			.003** (.001)		
- Med. & Pharm.	-.002^{+} (.001)			-.002^{+} (.001)		
- Agri. and Mari.	.004 (.005)			-.015* (.007)		
R&D Exp (amount/ratio)		Amount[2]	Ratio		Amount[2]	Ratio
- Cent. Gov't		.020 (.020)	.425 (.760)		.017 (.027)	4.382^{+} (2.376)
- Loc. Gov't		.267** (.098)	-1.50 (1.43)		.046 (.154)	
- Industry		.010** (.0370)			.114* (.059)	2.710 (3.088)
- Overseas		-2.72^{+} (1.41)	6.511 (44.620)		-.664 (1.89)	516.404** (168.067)
- Self funding		.208** (0.067)	-.751 (1.431)		.236* (.108)	10.785* (5.087)
TTO size (no. of staffs)	.046*** (.012)	.028** (.011)	.035** (.012)	.0002 (.013)	.014 (.014)	.011 (.012)
Regional BERD[2]	15.6 (42.3)	-72.0* (35.6)	-61.0 (55.0)	58.2 (95.3)	-62.9 (88.5)	49.3 (77.0)
Constant	-14.062 (10.280)	-12.412 (10.710)	-14.567 (10.421)	-1.170 (14.225)	1.671 (13.709)	8.672 (14.388)
Ln-alpha	.569 (.147)**	.408 (.710)**	.507 (.139)**	.217 (.193)**	.593 (.255)**	.784 (.163)***
Log-likelihood	-491.36703	-482.24729	-487.27856	-203.40020	-202.42980	-208.59000
Wald/LR χ^2(deg. of f.)	134.73 (9)***	121.04 (8)***	116.79 (14)***	56.71 (9)***	42.67 (12)***	70.44 (14)***

[1] t-ratios are based on robust standard errors. $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$, $^{+}p<0.1$

[2] Unit of the coefficients is e-9.

Table 6.11 Zero-inflated negative binomial (ZINB) and Tobit estimation of technology transfer

Models	Model 3-1 (ZINB) Tech. Transfer	Model 3-2 (ZINB) Tech. Transfer	Model 3-3 (ZINB) Tech. Transfer	Model 4-1 (Tobit) Revenues from TT	Model 4-2 (Tobit) Revenues from TT	Model 4-3 (Tobit) Revenues from TT
Founded year	.004 (.004)	.007 (.005)	.016 (.006)	.021e+7 (.051e+7)	.018e+7 (.036e+7)	.045e+7 (.049e+7)
Legal status	.287 (.398)	.240 (.343)	.499 (.457)	2.75e+7 (3.24e+7)	2.89e+7 (2.04e+7)	1.27e+7 (3.35e+7)
Size (No. of academics)						
- Natural Science			.012^{+} (.006)			.148e+7* (.060e+7)
- Engineering			.002 (.004)			.038e+7 (.032e+7)
- Med. & Pharm.			-.002 (.001)			-.008e+7 (.016e+7)
- Agri. and Mari.			-.005 (.009)			.046e+7 (.081e+7)
Location	.233 (.359)	.431 (.379)	.425 (.472)	.265e+7 (4.55e+7)	2.23e+7 (3.12e+7)	2.22e+7 (4.31e+7)
Teaching (no. of students)						
- undergraduate		.00001 (.00005)			6243.3 (4478.1)	
- postgraduate						
Research						
- domestic journal		.002 (.001)	.002 (.002)		-.164e+6 (.100e+6)	-.024e+7 (.017e+7)
- SCI journal			.0002 (.0006)			.037e+7*** (.057e+7)
- Natural Science	.0003 (.002)			.391e+6 (.361e+6)		
- Engineering	.002*** (.0006)			.533e+6*** (.107e+6)		
- Med. & Pharm.	.0002 (.0005)			.516e+6 (.121e+6)		
- Agri. and Mari.	-.0007 (.004)			.761e+6 (.540e+6)		
R&D Exp (amount/ratio)		Amount[2]	Ratio		Amount[2]	Ratio
- Cent. Gov't		.007 (.008)	-.329 (1.487)		.005*** (.0007)	4.75e+7 (11.8e+7)
- Loc. Gov't		.057 (.142)			.012 (.010)	1.14e+7 (13.2e+7)
- Industry		.057** (.021)	-1.054 (1.406)		.014*** (.003)	
- Overseas		.762 (.645)	-.721 (44.098)		-.110 (.072)	223.0e+7 (225.0e+7)
- Self funding		.145 (0.109)	-0.837 (2.211)		-.741e-6 (.008)	.058e+7 (15.0e+7)
TTO size (no. of staffs)	.006 (.007)	.006 (.007)	.022** (.009)	.186e+7(.947e+7)	-.012 e+7(.068e+7)	.173e+7^{+} (.094)
Regional BERD[2]	27.5 (47.2)	-102.0^{+} (53.2)	-50.0 (65.0)	1.978 (6.150)	-10.1 (4.77)	-.057 (5.77)
Constant	-6.140 (8.477)	-13.325 (9.710)	-31.237* (12.576)	-5.68e+8 (10.2e+9)	-4.65e+8 (7.07e+8)	-11.1e+8 (9.90e+8)
Ln-alpha/sigma	-.305 (.400)**	-.411 (.503)**	.414 (.157)**	11.7e+7 (1.06e+7)***	7.75e+7 (.696e+7)***	10.7e+7 (.98e+7)***
Log-likelihood	-260.36970	-256.25510	-276.3906	-1270.489	-1260.6913	-1285.3461
Wald/LR χ^2(deg. of f.)	62.21 (9)***	47.41 (12)***	67.59 (15)***	146.52 (9)***	206.12 (12)***	156.81 (15)***

[1] t-ratios are based on robust standard errors. $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$, $^{+}p<0.1$

[2] Unit of the coefficients is e-9.

- The relation of universities' scientific capacity to their knowledge-transfer activities

Scientific capacity as measured by the number of domestic and SCI publications is significantly related to the number of overseas patent applications and to the amount of revenue from technology transfers in models 2-3 and 4-3, while its relationship to technology transfer is not significant in models 1-3 and 3-3.

However, scientific capacity as measured by the number of papers published in different disciplines is observed to be a significant predictor for knowledge-transfer activities in all four models (i.e. models 1-1, 2-1, 3-1 and 4-1). In particular, the number of papers in engineering is strongly significant in all four models, and the number of papers in medical and pharmaceutical sciences is significant in model 1-3, which predicts domestic patent applications. In contrast, any number of papers in natural science and in agricultural and maritime science is not significant in any of the four models.

According to the results given above, the hypothesis 1 is partly supported. That is to say, on the one hand, scientific capacity as measured by SCI publications is observed to be a strong predictor for knowledge-transfer activities, whereas scientific capacity as measured by domestic publications is not. On the other hand, the significance of the relationship between scientific capacity in different disciplines and knowledge-transfer activities is supported in all four models. In particular, scientific capacity in engineering disciplines is a strong and positive predictor for knowledge-transfer activities. In conclusion, universities' scientific capacity influencing their knowledge-transfer activities is dependent on disciplinary scientific capacity (particularly, in engineering) and high-level (SCI publication) scientific capacity rather than low-level (domestic publication) scientific capacity.

These empirical results are somewhat different from those found in developed countries' cases, such as Sapsailis et al. (2006) and Owen-Smith (2003) (see subsection 2.3.2). On the one hand, only a part of the evidence supports the significant relationship of scientific capacity (as measured not by domestic publications but by SCI publications) of Korean universities to knowledge-transfer activities. On the other hand, scientific capacity in different disciplines is important for the universities' knowledge-transfer activities. (The adoption of this variable contributes to the novelty of this research, compared to the previous studies, which do not differentiate between the disciplines of the publications.) The latter result is reasonable in the sense that research in engineering disciplines is more closely related to industrial applications and has been more strongly supported by the central government (particularly in Korea) than that in natural science disciplines. Furthermore, the former result may imply that, as the same variable is observed to be a significant factor in Europe (Sapsailis et al., 2006) and the U.S (Owen-Smith, 2003), scientific capacity (as measured by the number of publications in qualified journals) covering all disciplines is also important for knowledge-transfer activities of universities in catch-up countries.[33] However, scientific capacity as measured by domestic (unqualified or low level) publications is not strong predictor for Korean universities' knowledge-transfer activities.

- *The relation of universities' sources of funding to knowledge-transfer activities*

Overall, the amounts of funding from different sources are observed to be significant in all four models, whereas the proportions of those to the total amount of funding in the three models are not strongly related to the knowledge-transfer activities of the universities, except in the case of the estimation of overseas patent applications.

On the one hand, in terms of the amount of funding, funding from industry shows positive and significant relations to three of the knowledge-transfer activities. Central government funding is only significant for universities' revenues earned from technology transfer (in model 4-2), while local government funding is only significant for their domestic patenting (in model 1-2). Furthermore, overseas funding is also significant for domestic patent applications (in model 1-2). University funding is significant for domestic and overseas funding (in models 1-2 and 2-2), but not significant for technology transfer and the revenue from this (in models 3-2 and 4-2).

On the other hand, the proportion of funding is only positive and significant for predicting overseas patent applications (in model 2-3). In particular, the proportions of central government funding, overseas funding and university funding are significant for

[33] The same result is reported by the Kim and Lee (2007)'s study on Korean universities' knowledge-transfer activities, even though the estimation is carried out based on OLS (Ordinary Least Square) model and the sample size (N=60) is smaller than ours.

the prediction. However, the other proportions are not significant in all three models (1-3, 3-3 and 4-3).

Therefore, hypothesis 2a is only supported by one of four models, which predicts revenue creation from technology transfer (model 4-2), and hypothesis 2b is supported only by model 2-3. The first result in the case of hypothesis 2a is in contrast to our expectations. Therefore, we need another explanation of the important role of central government that we stress in Chapters 2 and 4. This may be related to the characteristics of the funding sources. The funding from the central government has fewer requirements for commercialisation (or is less application-oriented, and longer-term based) than the funding from industry. In addition, in all four models, the amount of funding from industry is more significantly and consistently related to knowledge-transfer activities than that from any other source.

Our finding on the insignificance of central government funding (regarding three out of four knowledge-transfer activities) is in the same vein as the empirical evidence of Foltz et al. (2001). Moreover, the positive and significant influence of industrial funding on knowledge-transfer activities is also found in the empirical results of Powers (2003) and Di Gregorio and Shane (2003) in the case of US universities. However, this result is contradictory to the findings of Payne and Siow (2003) and Foltz et al. (2000) in terms of the effect of central government funding, and also contradictory to Foltz et al. (2000), Foltz et al. (2001) and Powers (2004) in terms of the effect of industry funding. In this regard, this research might be seen as merely contributing to inconsistent empirical 'confusion'. However, as discussed in subsection 2.3.3, unlike previous research, the sample of this research covers all kinds of Korean universities in science and engineering. Furthermore, this empirical test has been carried out in the context of catch-up country, so this result may represent the 'contextualised' relationships in such a country. That is to say, during the last decade the Korean government has invested massive funding in invigorating the commercialisation of academic research, but these efforts have not been effective in terms of Korean universities' patent applications and technology transfer (in models 1-2, 2-2 and 3-2). Even in case of revenue creation from technology transfer (in model 4-2), the magnitude of influence of government funding is three times smaller than that of industrial funding.

Moreover, our findings show that the proportion of each source of funding to total funding failed to be observed as a significant predictor for knowledge-transfer activities except in model 2-3. This is in line with the empirical findings of Di Gregorio and Shane (2003), even though their dependent variable is the creation of spin-off companies. In contrast, the empirical evidence of Henderson et al. (1998) and O'Shea et al. (2005) is inconsistent with our findings, while the dependent variables of the two studies are application-oriented academic research and spin-off activities respectively. However, our dependent variables are patent applications and technology transfer. Therefore, compared with these studies, our evidence investigates a relatively unexplored area, but in a broader sense these dependent variables can be categorised together. This result may imply that the proportion of funding source has not yet become a reliable indicator for informing knowledge-transfer activities of universities in a catch-up country. In spite of a lack of further evidence, we may tentatively conclude that in a catch-up country, absolute size of funding does matter, but the proportion of funding does not. Another unexpected result here is that funding from universities themselves is highly related to their knowledge-transfer activity (in models 1-2 and 2-2). This may indicate that the university at an individual organisational level is exerting an effort to produce transferable knowledge to industry, and the effort is apparently effective, in spite of the need to further investigate the characteristics of the internal funding process and structure in later research.

The institutional and environmental characteristics of universities and knowledge-transfer activities

- The institutional characteristics of universities and knowledge-transfer activities

Aside for the size of universities, institutional and environmental characteristics of universities are not very strongly or consistently related to the knowledge transfer performance of universities. The founding year is not significantly related to the number of technology transfers in any of the models, while the legal status of universities is a significant predictor in two out of 12 models. These two results are different from those of the t-test in subsection 6.2.2 (see Tables 6.2 and 6.3), because the other variables (e.g. size of the universities and TTOs) are not controlled in the t-test. This implies that the legal status itself is not a significant factor for the knowledge-transfer activities of

Korean universities except in terms of domestic patents application. In other words, the three properties (size, age and legal status) are closely related to each other as discussed in Chapter 5, and among these variables, size is more consistent and important than the others. This is related to the idiosyncrasies of the Korean university system. A critic has suggested that a lack of variety within the Korean university system represents a weakness (Han, 2006). Regarding the positive effect of public legal status on domestic patent applications, our results contradict the empirical evidence of Hegde (2005), Sine et al. (2003), Siegel et al. (2003), Thursby and Kemp (2002), and Adams and Griliches (1998), which is discussed in subsection 2.3.4. This reflects the fact that the Korean government has encouraged mainly public universities to produce visible output, such as number of patents by various policy measures as discussed in Chapter 4.

In disciplinary terms, the size of universities as estimated by the number of academics in science and engineering is positively and significantly related to all three kinds of knowledge-transfer activities. This result is in the same vein as the empirical studies of Sapsalis et al. (2006), Powers (2004) and Lach and Schankerman (2003). In particular, while the last two studies include only the total number of academics as representing the size of universities, the first study differentiates the size by the discipline of academics. According to the results of Sapsalis et al. (2006), universities with biomedical and engineering faculties (as dummy variables) are likely to show a larger number of patent applications.

In this vein, as an original factor of this research, our regression model not only differentiates the disciplinary size of universities, but also measures the variable as the number of academics instead of as a dummy. In terms of domestic patenting only (in model 1-3), the number of academics in engineering is a significant and positive predictor, whereas the number of academics in medical and pharmaceutical sciences is a negative and significant predictor. The former result is partly explained by the disciplinary characteristics of engineering disciplines, while the latter result is due to the inclusion of clinical professors in the category. In contrast to the number of academics in engineering, those in natural sciences are significant predictors except in domestic and overseas patenting. A direct interpretation of this result is that the larger size of natural scientists may be related to the higher impact of knowledge-transfer activities (represented as technology transfer and revenue creation). However, this tentative explanation needs more complementary empirical evidence as well as refinement of the disciplinary categorisation (e.g. physical science, life science, etc.).

Regarding the entrepreneurial orientation of universities, compared to the existing literature as introduced in subsection 2.3.3, the intellectual property policies of individual universities are not included due to the difficulty of data collection and quantification, while the size of TTOs is included as a control variable in all the models we adopted. The size of TTOs as estimated by the number of staff is significantly related to domestic patents in models 1-1, 1-2, and 1-3, to technology transfer in model 3-3, and to revenues creation from technology transfer in model 4-3. These results support the findings from others' studies (e.g. Siegel et al. (2003), Carlsson and Fridh (2002)). In later studies, we need to include various specific characteristics of TTOs, such as the structure of their human resources and their main mission given by individual universities.

The numbers of undergraduate and postgraduate students can be interpreted as organisational properties or as another activity (i.e. teaching) variable different from research and knowledge-transfer activities. However, regardless of this activity's categorisation, intuitively the number of undergraduate students is positively related to the teaching load for academics, while the number of postgraduate students can be regarded as one of the resources for both academic research and knowledge-transfer activities. In accordance with this argument, our findings do appear to make sense. The number of postgraduate students is a significant positive predictor for domestic and overseas patent applications in models 1, 2, 3 and 4, and for revenues from technology transfer in model 1-3 and 2-3. However, we fail to identify that the number of undergraduate students is a significant negative predictor for knowledge-transfer activities in models 1-2, 2-2, 3-2 and 4-2. These findings contribute to the investigation of the relationship between the three missions (i.e. teaching, research and economic contribution to society). In other words, our evidence supports the positive relationship between postgraduate student teaching and knowledge-transfer activities (or between the research activities of postgraduate students and knowledge-transfer activities).

- The environmental characteristics of universities and knowledge-transfer activities

In terms of the influence of environmental factors, geography or location (in this case, the distance between Seoul and the region where the university is located) is considered in our model. Our evidence shows that location is not a significant variable for entrepreneurial activities in all 12 models. That is to say, we did not find any statistical evidence supporting our expectations based on Chapters 4 and 5 and the preliminary analysis in 6.2.2. Furthermore, Sohn and Kenney (2007) stress that the Seoul's centrality attracts all the resources from across the country. However, our evidence may imply that in spite of its simplicity of the definition, location defined as distance from Seoul is not a strong indicator with regard to Korean universities' knowledge-transfer activities.

The second environmental factor we adopt is the regional business R&D expenditure of the area in which the universities are located. According to our findings, regional BERD has a significant relationship to knowledge-transfer activities in models 1-2 and 3-2, which predict domestic patent applications and technology transfer respectively. Only this case is in the same vein as the evidence of Chapple et al. (2005), Sine et al. (2003) and Varga (1998). The other ten models support the empirical findings of Sapsalis et al. (2006). Although the unsophisticated categorisation of the level of regional BERD (i.e. the small number of regions and their wide geographical coverage) can be criticised, these results may imply that regional industry R&D intensity is not working so strongly to induce the knowledge-transfer activities of universities in the regions.

Some limitations in interpretation of the empirical findings based on our model

Our interpretation of the empirical results has some of the typical limitations of an econometric model. First of all, the endogeniety problem (i.e. knowledge-transfer activities can encourage scientific publication and can attract research funding) has not been overcome in our model. Therefore, in this case, we need to be careful in terms of the direction of causality. In other words, we can say merely that two variables (i.e. knowledge-transfer activity and scientific capacity) are significantly and closely related to each other, if we do not accept the assumption on which the hypotheses based on (see subsection 6.3.1). Next, our model is based on cross-sectional data; in other words, all the variables (i.e. the knowledge-transfer activity, the amount of research expenditure and the number of scientific publications) were measured in 2006. Therefore, the time lag between the point of funding and the point of patenting (due to the funding) cannot be considered in our model. Accordingly, causality is again not so clear in our discussion of the relationship between the variables we are interested in.

6.4 Conclusion

In this chapter, we have explored the relationship between the various characteristics of universities and their knowledge-transfer activities. According to the results of the descriptive statistics and the calculated correlation coefficients, institutional and environmental characteristics (legal status, founding year, university size, TTO size and location) aside from regional BERD are significantly correlated with the universities' knowledge-transfer activities. Moreover, all the variables measuring the characteristics of human and financial resources, as well as teaching activity and scientific capacities, are significantly related to universities' knowledge-transfer activities. In order to investigate more closely the relationship between the various university characteristics and knowledge-transfer activities by controlling the influence of other variables, an analysis based on regression models has been carried out.

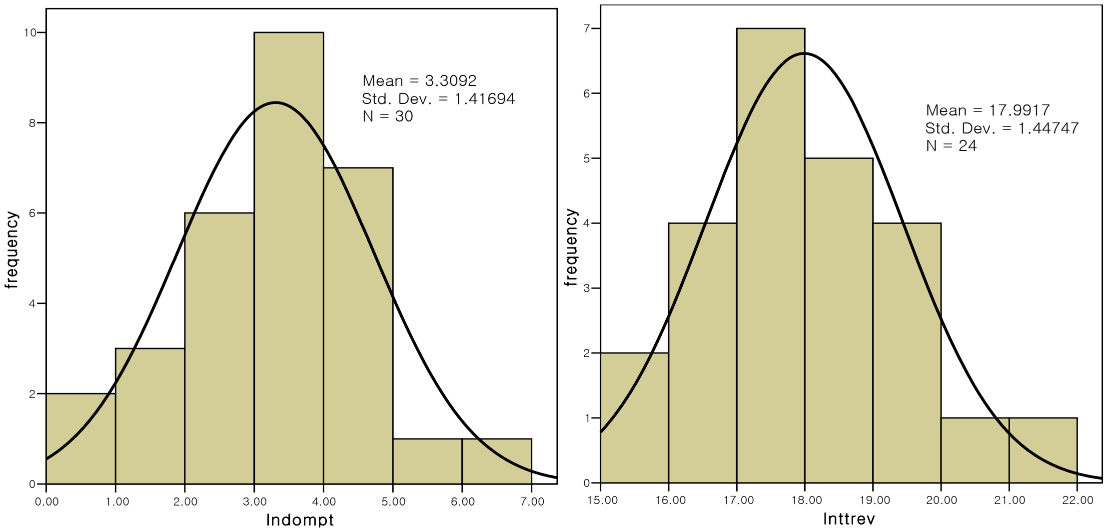
In particular, considering the idiosyncratic characteristics of the Korean university system, as well as those of universities in other catch-up countries, we are more interested in the relationship between the scientific capacity of universities and their knowledge-transfer activities and between funding sources and knowledge-transfer activities. According to the empirical results of the regression analysis, in all four models scientific capacity in different disciplines (particularly in the field of engineering) is important for knowledge-transfer activities, while scientific capacity (regardless of the discipline) is important in only two out of eight models. This evidence is rather different from the results of similar research in developed countries as discussed in subsection 6.3.3. That is to say, scientific capacity in a specific discipline, such as engineering, is important for universities in both developed countries and in Korea, while scientific capacity (regardless of the discipline) is not apparently important for Korean universities, particularly in the case of domestic publication. Furthermore, this result supports the proposition suggested in Chapter 2 that strategically chosen industrial sectors in catch-up countries are closely related to the scientific capacity of universities in specific disciplines. In other words, the second and third missions of universities have seemingly interacted closely.

In terms of funding sources, the amount of funding from industry is strongly related to the knowledge-transfer activities of universities, whereas the proportion of funding relative to the total amount of funding is not as significantly related to knowledge-transfer activities. These results are in the same vein as the existing empirical evidence from developed countries, while the empirical results with regard to central government funding are not. In other words, our hypotheses on the importance of central government funding are not as strongly supported. In spite of this undetermined empirical evidence from developed countries, as discussed in Chapter 2 and subsection 6.3.3, these results help us to understand the specific relationship between sources of funding and universities' knowledge-transfer activities in a catch-up country. The failure to identify a significant relationship between central government funding and knowledge-transfer activities may be due to less strict requirements for commercialisation in central government R&D programmes. Otherwise, central government funding fails to generate knowledge-transfer activities in universities. We need either more empirical and qualitative evidence to confirm these explanations, or we must put forward another, more appropriate one. In spite of this ambiguous result with regard to central government funding, industrial funding shows a more consistent significance to knowledge-transfer activities. Considering the discussion on knowledge-transfer activities of the countries described in Chapter 2, this evidence supports the proposition that, in spite of it being smaller in size than central government, industrial involvement has been significantly stimulating the commercial activities of Korean universities.

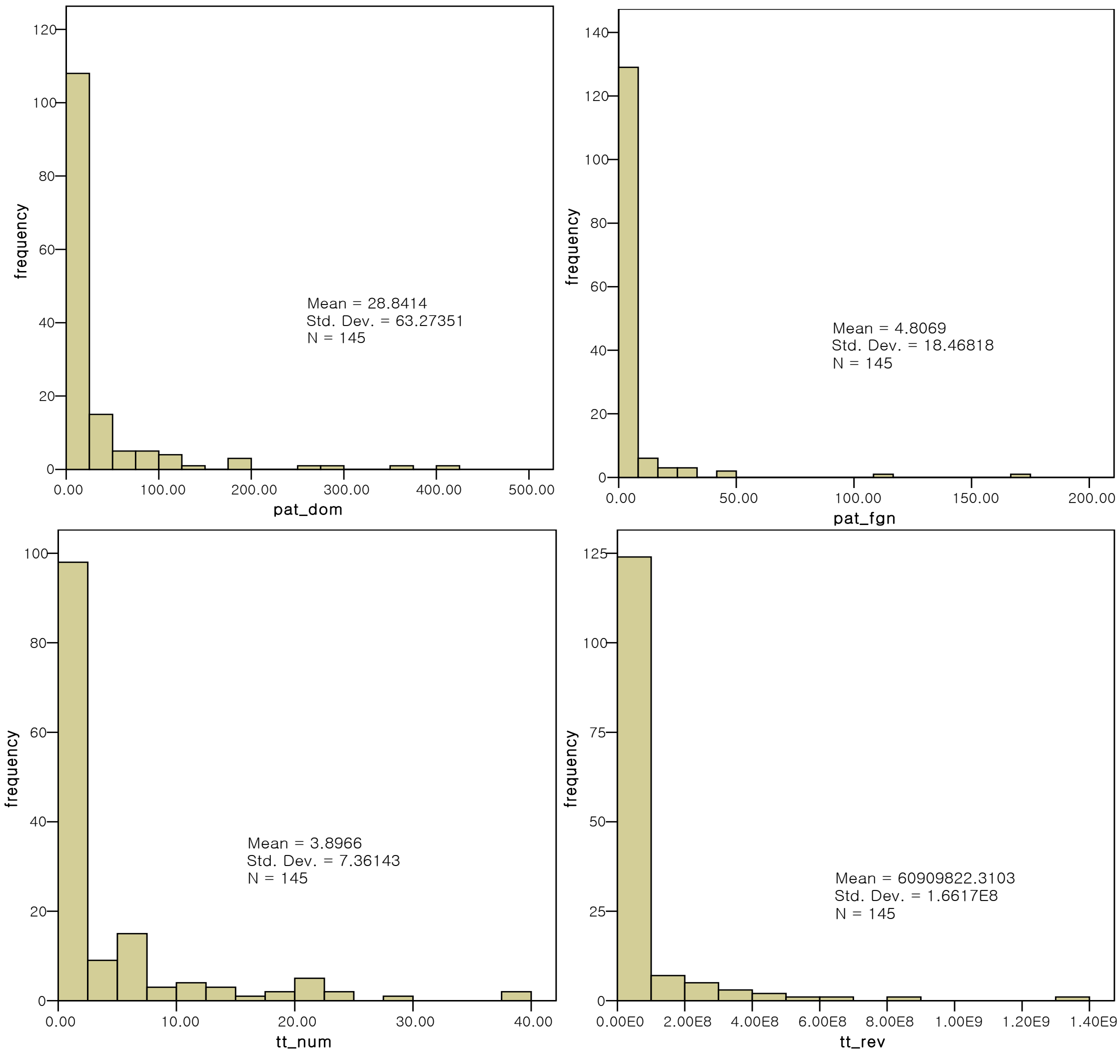
In terms of the institutional and environmental characteristics of Korean universities, various properties are not consistently significant for knowledge-transfer activities, apart from the size of university and the size of TTO. The size of universities (particularly in the field of natural science), and TTO size are observed to be important, whereas the founding year, legal status, location and regional BERD were not important, or important in only two of 12 of the knowledge-transfer activities. The former result is consistent with empirical evidence from developed countries, while the latter result partly supports those in developed countries. However, the centrality of Seoul in terms of universities' knowledge-transfer activities is not supported in our empirical test at all.

In conclusion, we found a positive relationship between academic research and knowledge-transfer activity, which is the main focus of this thesis. At the organisational level, scientific capacity (the second mission) is positively related to knowledge-transfer activities (the third mission), while undergraduate teaching (the first mission) is not significantly related to knowledge-transfer activities (the third mission). In particular, scientific capacity in engineering is the strongest predictor for knowledge-transfer activities. This finding is consistent with our findings at the system level (as discussed in Chapters 4 and 5) and those at the individual level (as discussed in Chapter 7). For example, Chapter 4 shows that the Korean academic system is strong in the field of engineering, and this fact is closely linked to the disciplinary evolution of national patents applied for.

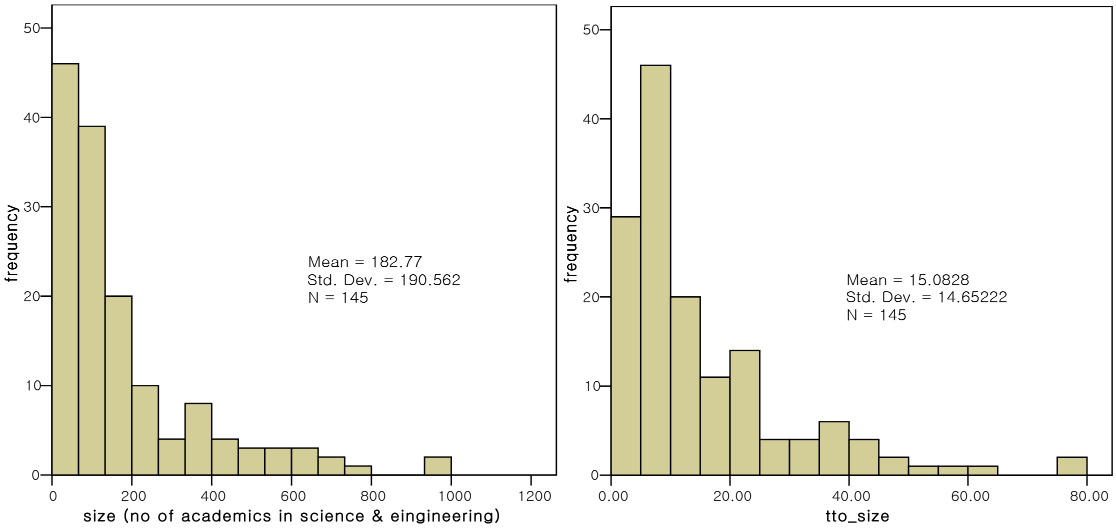
Appendix Figure 6.1 Distribution of natural log values of the number of domestic patent and the amount of revenue from technology transfer with normal distribution curves



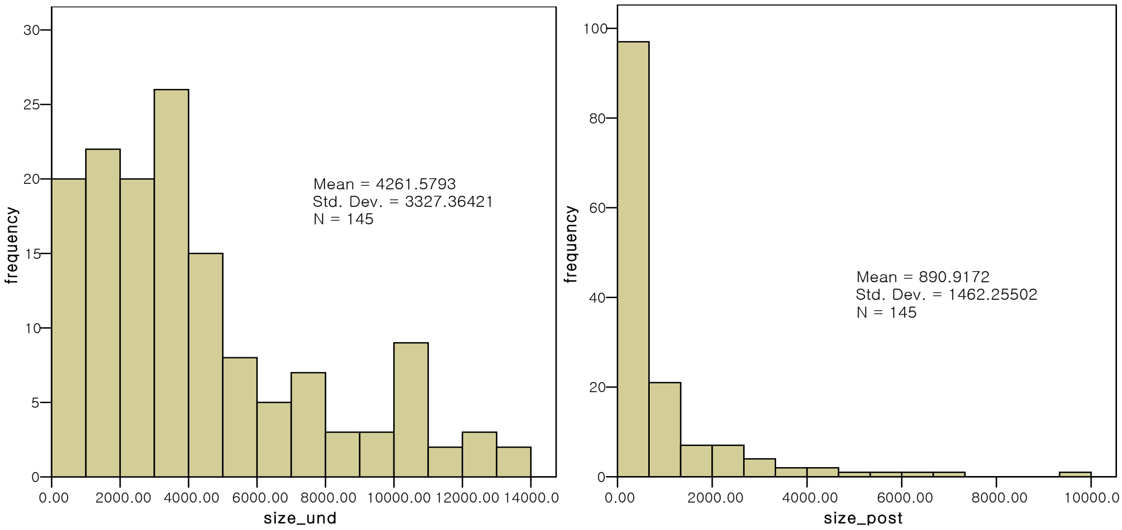
Appendix Figure 6.2 Distribution of domestic and overseas patent application, technology transfer and their revenues of 145 Korean universities in science and engineering



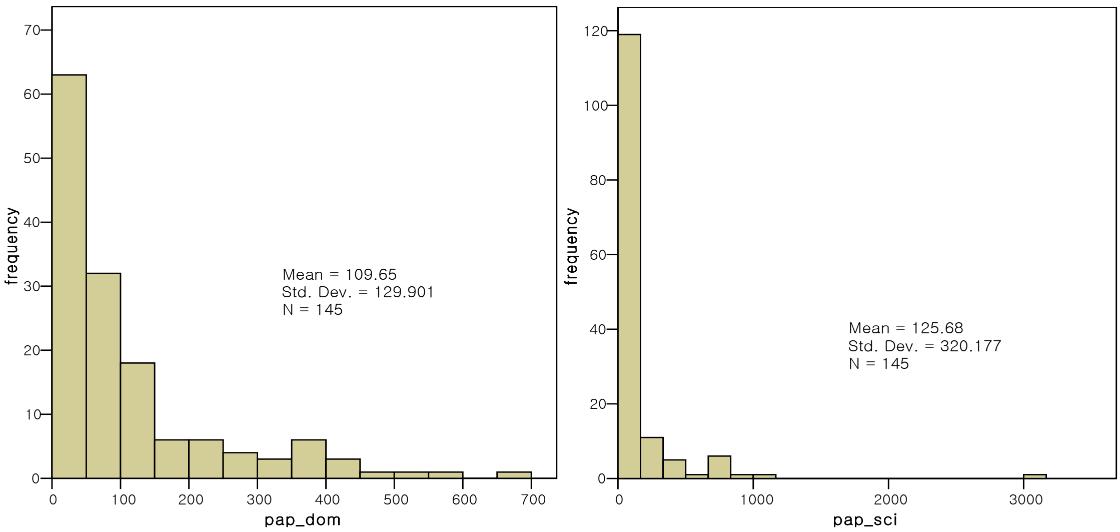
Appendix Figure 6.3 Distribution of the size of universities and their TTOs



Appendix Figure 6.4 Distribution of the size of undergraduate and postgraduate



Appendix Figure 6.5 Distribution of the number of domestic and SCI papers in science and engineering



Chapter 7 Synergy mode or separation mode: the relationship between academic research and industrial collaboration of Korean academics

7.1 Introduction

This chapter focuses on the academic research and knowledge-transfer activities of Korean academics; in particular on the relationships between these two activities at the individual level. First of all, we analyse the interview data with regard to the influence of the individual and the contextual factors on the activities of academic research and industrial collaboration of Korean academics. Next, based on a quantitative method, the determinants of the two modes (i.e. whether the relationship between research and entrepreneurial activities is positive or not) are identified.

In terms of a qualitative approach, Section 7.2 presents the analysis of how various individual and contextual factors influence not only individual academics' research and industrial collaboration but also the relationship between the two activities themselves. This analysis is based on the conceptual framework of the 'synergy and separation mode' suggested in Chapter 2 and the results of interviews with Korean academics introduced in Chapter 3. As a result, we suggest several propositions regarding the relationship between the personal and contextual properties of Korean academics and their two modes.

In terms of a quantitative approach, Section 7.3 presents a statistical test of the propositions suggested in Section 7.2, based on the results from the survey questionnaire introduced in Chapter 3. In addition to these propositions, two other elements are considered in formulating our hypotheses: the historical background of the Korean university system, and previous studies on the determinants of the scientific and entrepreneurial activities of academics. In order to test the hypotheses, we suggest a statistical model adopting the mode of academics as a dependent variable, and the individual and contextual variables as predictors.

Finally, Section 7.4 briefly summarises the findings of this chapter and discusses the implications of the statistical results of Section 7.3, as well as the qualitative findings in

Section 7.2. Moreover, the findings are discussed whilst considering the conceptual framework suggested in Chapter 2 and the characteristics of the Korean higher education system and those universities within the system.

7.2 The Characteristics of Academics and the Two Modes: Relationships Emerging From the Interviews

This section briefly summarises the results of the analysis of the interview data regarding the relationship between research and industrial collaboration of individual academics. Moreover, we investigate how the relationships that emerged from the interviews relate to an individual and to the contextual variables.

7.2.1 Synergy and separation modes: the two modes of relationship between research and industrial collaboration

In Section 2.4, we suggested the conceptual framework with regard to the relationship between academic research and industrial collaboration activities of academics. According to this framework, the discipline of academics is closely related to the determination of the academics' mode. That is to say, academics in disciplines such as biotechnology (i.e. in Pasteur's quadrant) are likely to operate in synergy mode; while those in disciplines such as physics (i.e. in Bohr's quadrant) are likely to operate in separation mode. In addition to an academics' discipline, various individual (e.g. gender, career and the country of training) and contextual (e.g. size and legal status of the affiliated university) characteristics can be regarded as determinants of the two modes.

Among the general individual and contextual characteristics suggested above, we focus more closely on certain variables, considering the idiosyncrasies of the Korean academic system. For example, as shown in Chapters 4, 5 and 6, academic discipline has been an important factor for Korean universities' knowledge-transfer activities at both system level and organisational level. Furthermore, career stage can also be regarded as being related to the academics' two modes, as the academic climate has changed rapidly in Korean universities, as described in Chapter 4.

Against the discussion of the conceptual framework provided above, the interviewed

Korean academics are categorised into two types: those operating in synergy mode (i.e. having a positive relationship) and separation mode (i.e. having a negative relationship).[34] As an example of an academic who operates in separation mode, A1, the senior physicist in one of the large private universities, mentioned that:

> I think the main mission of an academic is teaching. I am very negative about the recent change. Universities are not educational institutions any more. Rather, they have become research institutes. Even though my research field is not strongly industrially applicable, a few years ago, I was involved in a research project contracted with a large company. Actually, the motivations were to provide financial support to my graduate students and to secure operational costs for my laboratory. However, as a side effect, it consumed my teaching and research time, so my own research performance was not so successful, and my teaching quality was not so satisfactory at that time.

According to the statement above, a push that is intended to strengthen industrial collaboration is likely to result in a decrease in the quantity and quality of research and teaching. In other words, the relationship between research and industrial collaboration shows a trade-off pattern in this case.

In contrast to academics operating in separation mode, as set out above, the case of academics in synergy mode can now be introduced. As a representative case, A6, the junior engineer in a large private university, mentioned that:

> The main roles of the professor, I think, are as researcher and trainer for their students who are going to be researchers in the future. In my case, even undergraduate students are encouraged to become involved in research projects in my laboratory when they are supervised for their term projects and theses. My research field has dual properties which are basic research and applied research. Therefore, the research results are easily converted into commercial output. Furthermore, the results of the research can not only be published but also patented. Thus, the students in my lab can benefit from contracted research projects with industry in terms of financial support and job searching.

Based on these two typical but contrasting cases, we can identify the types of mode into which the academics interviewed are categorised. In addition to these two types of academics, academics who can be categorised as hybrid cases are also observed in the interviews. These academics can transfer to one of the two modes under certain circumstances. According to these interviews, the hybrid-type academics are more sensitive to contextual characteristics than individual characteristics. These cases are discussed more intensively at the end of subsection 7.2.2.

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[34]The Appendix Table 7.1 summarises the relationship between research and industrial collaboration (i.e. the two modes) with regard to all the interviewed academics' individual and contextual properties such as career stage, discipline, and the characteristics of the affiliated universities.

According to the interviews, individual characteristics such as discipline and career stage are found to be major factors influencing the two modes of Korean academics, whereas gender and country of training do not emerge as important factors. In addition to these two individual factors (i.e. career stage and discipline), we explore the interaction between the two modes and contextual factors such as laboratory size, the size, legal status, entrepreneurial leadership and location of the affiliated university, and industrial background in the following section.

7.2.2 The relationship according to individual and contextual variables

This subsection focuses on the underlying process of how separation or synergy mode interacts with academics' activities and their environments, while the previous section only relates the two modes to the two disciplines of the academics. In order to investigate an interactive process between academic's two modes and their various characteristics, we need a more detailed analysis of the interview data. The results of the investigation of the operation of the two modes, according to individual and contextual variables of academics, are provided below.

Career stage and the two modes

As shown in the table below, most senior professors (20 out of 27) are regarded as academics operating in separation mode, while about half of the junior professors (13 out of 25) are operating in synergy mode. Furthermore, of the total number of academics in synergy mode (20), two thirds of them (13 out of 20) belong to the younger generation.

According to Chi-square test result[35], p-value is 0.52. This means that career stage has a significant relation to the two modes within a level of 10% significance. This fact, therefore, leads us to explore how career factors are related to the mode in which the academics are identified to be operating.

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[35] Chi-square test can be carried out in order to test the relationship between two categorical variables. This test is based on the difference between observed count and expected count. The lager the difference, the less the two variables are independent.

Table 7.1 Career period and the two modes

Career \ Mode	Separation	Synergy	Total
Junior Count	12	13	25
Expected Count*	15.4	9.6	25
Senior Count	20	7	27
Expected Count	16.6	10.4	27
Total Count	32	20	52
Expected Count	32	20	52

Expected count is calculated by the proportion of the number of cases in a certain group to the total number of cases. For example, the expected count of 'junior in separation mode' (15.4) is calculated by 25(32/52).
Source: by the author, based on the analysis of the interview data.

As addressed in Chapter 4, the younger generation of Korean academics started their academic career in the mid-1990s, which is characterised as 'the first academic revolution', and they have then experienced 'the second Korean academic revolution' in the early 2000s. These macro-level changes at a national level have a correlation with the activities of individual Korean academics, in particular those of the younger generation. For example, during the interviews, most of the junior professors revealed a strong identity as a researcher rather than as a teacher. Furthermore, they recognise industrial contributions as one of the main missions of academics (particularly in the case of academics working in engineering science). Consequently, they are under heavy pressure to deliver research excellence, as well as having a strong motivation for industrial contribution.

According to the interviews, some academics' research orientations are related to a 'role model' or 'division of labour' according to their career stage: research for junior academics and teaching for senior academics. B4, a junior engineer mentioned, 'because I am a junior academic, research is more important than teaching'. Moreover, according to DS6 another junior engineer, industrial collaboration has very recently emerged as an important activity. A4, a junior engineer in Seoul who is observed as having a strong identity as a researcher rather than teacher, stated:

> Due to time limitations, it is not possible to manage all these activities because of the heavy workload not only for research but also for preparation of classes, management of my laboratory, administrative work and industrial collaboration. Furthermore, recently the evaluation criteria of individual research have been strengthened [junior engineer C6 mentioned a similar trend], so some academics who failed to fulfil the minimum level of performance had no choice but to leave their posts.

Consequently, due to these above mentioned constraints, junior professors may look to synergy mode with regard to the relationship between research and industrial collaboration. DS4, a junior engineer, reported:

> Because of the strengthened performance evaluation process requiring a high level of research output, I try to avoid industrial projects far from my research topic that are unlikely to result in academically meaningful output.

In the same vein, A6, another junior engineer, stated:

> Given the recent heavy pressure on young professors, we established the strategy of my laboratory to choose research topics that are likely to produce a research result that is both publishable and patentable.

EI6, a junior engineer, attributed these inclinations to the performance-centred criteria of academic research funded by the national funding agency.

> Recently, industrial collaboration activities have been strongly encouraged by the university authorities and the government, so we can find a large number of industrial projects funded by the government. In order to win these projects, as a junior researcher, quantitative research output rather than industrial experience is considered as an important element of a successful research proposal. Accordingly, I have to make efforts to show a certain level of productivity in terms of academic papers, even when we want to get involved in an industrial project.

In other words, younger academics regarded their identity as that of a 'not fully established' researcher in their institutions. Moreover, the external and internal 'push' for research output encourages them to seek certain types of industrial collaboration that are beneficial to their academic research. This can be corroborated by the fact that the motivations of several junior professors for industrial collaborations are identified as: 'direct application of research results to industry' (junior physicist A2), 'the search for both basic and useful knowledge' (junior engineer A6) and 'exploitation of industrial resources' (junior engineer DS4).

In contrast, the older generation has been relatively 'safe' from the revolutionary changes in academia both at national and organisational levels, because most of the disadvantageous changes mainly apply to the younger generation. For example, the strengthened performance evaluation criteria created by university authorities are mainly applied to newly employed academics. Therefore, senior professors are likely to have preserved their identity as teachers, which has been the main role of Korean academics for the last five decades.

B5, a senior engineer, remarked that the main mission of a professor was teaching. In a similar vein, A1, a senior physicist argued that the recent university evaluation, which was heavily focused on research output, may distort the priority of academic activities (i.e. teaching). Moreover, C1, a senior engineer, reported that after being promoted to a tenured professor, teaching became more important than research. In the same vein, EI5, a senior engineer, confessed that: 'as a senior professor on a tenure track, I don't care about the research performance evaluation so much, compared to the younger generation'.

Accordingly, the older generation tends to regard the three main activities (i.e. teaching, research, and industrial collaboration) as separate from each other. Compared to younger academics, they are more likely to participate in industrial projects that differ from their own research interests or expertise, and are unlikely to generate academic excellence. In addition, in many cases their motivations for involvement in industrial collaborations are maintenance of a laboratory by securing scholarships for students, and provision of practical help for local companies.

A1, a senior physicist, remarked,

> I was in financial need for my laboratory and postgraduate students, so this resulted in my involvement in an industrial collaboration with a major company. However, the topic of this project was barely linked to my own academic research area.

On the other hand, DN3, a senior engineer, commented,

> When meeting the practical industrial needs requested by the local company, I feel self-satisfaction as a true engineer, even though the quality of the need is so low when linked to academic benefit.

In the same vein, EI5, a senior engineer, mentioned, 'I am more interested in helping industry practically than in writing academic papers, so the topics of the research papers I have produced are not necessarily related to the results of industrial collaborations'. Furthermore, B5, a senior engineer, added, 'the main concern of the industrial projects in which I am involved is practical help for local industry, so these projects are located in different areas from my academic research'.

However, we found two counter-examples to the above cases in terms of the relationship between career stage and the two modes. A senior engineer, A3, is operating in synergy mode, whereas a junior engineer, A4, is operating in separation mode. Moreover, a junior engineer, DS5, is operating in separation mode, whereas a senior engineer, DS6, is operating in synergy mode. The occurrence of these counter-examples can be explained by other factors such as accessibility to high-tech firms, the academic exploitability of the industrial collaboration, and the characteristics of the industry sector. Firstly, DS6, a senior engineer, stated, ‘the collaboration with a high-tech firm providing good data was an essential factor for publishing papers’, whereas a junior engineer, DS5, reported he was in the contrary situation. Secondly, A3, a senior engineer, maintained: ‘good academic research based on industry needs never fails to generate good papers’. Thirdly, A4, a junior engineer, stated: ‘industrial collaborations with mechanical industry can hardly generate publishable outputs because of their application-oriented characteristics’.

Disciplines and the two modes

As discussed in Chapter 2, the discipline of the academic is also one of the important factors leading the researcher to operate in either separation mode or synergy mode. In Chapter 3, we categorise academics’ disciplines into three: natural science, traditional engineering and new engineering. Although our categorisation of academic disciplines includes various sub-disciplines (e.g. natural science includes mathematics, physics, biology, chemistry, etc.), according to our findings from the interviews this broad categorisation provides us with a meaningful overall picture of the different relationships between the two modes.

According to the conceptual framework introduced in Chapter 2, academics in the new engineering areas (i.e. Pasteur’s quadrant) tend to be closer to synergy mode than academics in other disciplines, not only because such fields are very close to recently-developing industry, but also because governmental research funding is focusing on this area to generate commercially-applicable results, as shown in Chapter 5. In addition, the disciplines within new engineering developed recently and are strongly supported by the Korean government, so the younger generation is more likely to be involved in these disciplines than the older generation. In contrast, academics in natural science and in traditional engineering are likely to operate in separation mode. Generally, the aims of natural science can be regarded as a quest for fundamental understanding of nature (i.e.

Bohr's quadrant), while traditional engineering is, in terms of its nature, rooted in meeting practical needs (more in Edison's quadrant). Therefore, academics in both disciplines rarely generate a result that is both publishable and patentable, as discussed in Chapter 2.

According to the interviews, as shown in Table 7.2, the academics in natural science are more likely to be operating in separation mode than expected (10 as opposed to 8.6), while those in new engineering are more likely to be operating in the synergy mode than expected (9 as opposed to 7.7). However, in the case of traditional engineers we observe only a slight difference between actual counts and expected counts, so this needs more analysis based on the contents of the interview. Furthermore, according to a Chi-square test, we fail to find a statistically significant relationship between the two modes and the discipline of academics, but we cannot exclude the possibility that this relationship can be changed into a significant one, if we control other variables. As a result, the evidence provided above is not totally consistent with the relationship between the discipline and the mode discussed in Chapter 2. Therefore, in order to understand the relationship more completely, we need more results of the analysis of interview data and the statistical analysis of survey data as follows.

Table 7.2 Disciplines and the two modes

Discipline \ Mode		Separation	Synergy	Total
Nat. Sci.	Count	10	4	14
	Expected Count	8.6	5.4	14
New Eng.	Count	11	9	20
	Expected Count	12.3	7.7	20
Trd. Eng.	Count	11	7	18
	Expected Count	11.1	6.9	18
Total	Count	32	20	52
	Expected Count	32	20	52

Source: constructed by the author, based on the interview data

The academics in natural science remarked that generally their discipline is not suitable for industrial collaboration. DN2, a senior mathematician, stated, 'because of my discipline, it is nearly impossible to get involved in industrial collaboration. Instead, I am focusing on teaching and my own academic research despite having insufficient resources'. DN1, a junior mathematician, commented in the same vein. However, the younger generation in natural sciences, such as a physicist A2 and a biologist B2, stresses a stronger affinity with industrial application than the senior generation in the same disciplines. A2, a junior physicist, comments,

> Personally, I think I have been recruited to this university as a physicist who has not only a mixed academic background both in natural science and engineering, but also a mixed career background both in a governmental institute and a university. This shows, I think, the rapidly changing human resources policy of our university, reflecting the university's role in industrial collaboration, which is more important than in any other period before, even for academics in natural science like me.

Chemists C1, C2, DP1 and DP2, also in natural science departments after recent restructuring reported that their department is very strongly oriented towards industrial applications in terms of curriculum and research activities. They added that natural science departments cannot survive without adopting to the needs of local industry, so even natural scientists are trying to shift their teaching and research focus to be more practical.

The academics in traditional engineering also tend to maintain that usually their discipline is far from pure or basic research motivated by curiosity. Rather, they believe, that their discipline aims to provide practical applications (i.e. the main role of an engineer). DP4, a junior engineer, and DN3, a senior engineer in traditional engineering, declared that:

> Because of the characteristics of the discipline, we usually provide a practical service that the company needs (DP4, a junior engineer).
>
> As an engineer, I have been involved in industrial projects for 30 years. Most of the companies in my region are small or medium-sized and have a low technological capacity, so the projects hardly generate any academic results. However, I think that providing practical assistance to local industry is the role the engineer in our country should play (DN3, a senior engineer).

At the very least, they are unlikely to deny that the ultimate goal of engineering science is to benefit industry and society (FP4, a senior engineer, and FN3, a senior engineer). According to FP4, a senior engineer, this characteristic is linked to the operation of separation mode.

> It is not desirable to research only for the purpose of publishing a paper. Research for a paper and research for industry are located in different spheres (FP4, a senior engineer).

However, as a counter-example, a senior engineer in traditional engineering who is operating in synergy mode pointed out that only academic research based on industrial collaboration can generate excellent academic results (A3, a senior engineer). He adds:

> In the engineering discipline, academics should be in pursuit of publishing of excellent papers not through knowledge for its own sake, but through meeting industry needs (senior engineer A3).

The academics in newly-developed engineering disciplines such as ICT, BT, and NT can be identified as a more privileged group than other academics in natural science and traditional engineering. They are regarded by university authorities and the government as having the potential to be a new 'engine' for the national economy, as discussed in Chapter 4.

> The research funding supported by the government is inclined to focus on the strategic areas linked to emerging industry based on ICT, BT, and NT rather than on the traditional manufacturing industry (A2, a junior physicist, and A3, a senior engineer).

Moreover, according to A5 and B5, senior engineers and B1, a senior biologist, academics in natural science and traditional engineering tend to complain about inequality in terms of scientific resources allocation such as research funding and personnel not only at the organisational level but also at the individual level.

> The university authority established our department five years ago according to the strategy of advancing our university's reputation in cutting-edge research and its industrial application (A5, a senior engineer).
>
> Even in the same university, professors in the natural sciences and traditional engineering are discriminated against in terms of resource allocation (B1, a senior biologist, and B5, a senior engineer).

In addition to its privileged condition regarding resources, characteristics of new engineering such as consideration of both use and fundamental understanding tend to encourage academics to operate in synergy mode.

> Bio-technology is likely to produce research results that are both publishable and patentable (A6, a junior engineer).

More than half of the senior academics identified to be operating in synergy mode (four out of seven, see Appendix Table 7.1) are in the discipline of new engineering as opposed to the other two disciplines (of natural science and traditional engineering), while among junior academics operating in synergy mode, the discipline effect is not so distinctive.

However, as counter-examples, some junior and senior engineers in this discipline are identified as being in separation mode. According to the interviews, this is due to other factors such as accessibility to high-tech firms, and the research capacity of individual laboratories.[36] For example, DP5, a senior professor, in the nano-tech discipline stated that a high-tech company in the nano-field did not want to collaborate with the local university, so synergy mode is not always easy to obtain.

On the other hand, in spite of their discipline being natural science or traditional engineering, some academics maintain that their sub-discipline provides a strong basis for both academic research and industrial application.[37] For example, although the discipline of electrical engineering is categorised as traditional engineering, the sub-disciplines of B3 and B4 (both electrical engineers) are integrated with new materials such as semi-conductors. Therefore, they were able to collaborate with a big high-tech company with a nationwide reputation.

> Because my sub-field is application oriented, I usually aim to produce academic and industrial output whenever a research project starts. In addition, the university authority recruited me, I think, as an exemplar case of a professor in a natural science department who can produce patentable output (A2, a junior physicist)

In contrast, B5 and B6, engineers, in the field of information device technology, categorised as 'new engineering', revealed that they are operating in separation mode because of the characteristics of their specific research topics.

In conclusion, by integrating the effects of the two variables (i.e. career stage and discipline) as addressed in the last two subsections, we can tentatively generalise the above findings as follows. First of all, in traditional engineering and natural sciences, the younger generation is likely to indicate that they are in synergy mode, whereas the older generation are mostly operating in separation mode. Next, academics in new engineering are likely to be operating in synergy mode. In other words, the academics in a junior group or in a new engineering discipline are likely to be in synergy mode, whereas the academics in a senior group or in other disciplines are likely to be in separation mode.

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36 The effect of the other factors is more intensively investigated in the following subsection.

37 This point is also related to the problem of the broad definition of disciplines. Therefore, a more specific categorisation of the disciplines is carried out in Section 7.3.

However, as shown in each type of interview (e.g. senior academic in traditional engineering, junior academic in new engineering, etc.), individual characteristics (i.e. career stage and discipline) are not sufficient to fully explain the determinants of the two modes. This can be completed by introducing contextual variables observed in the interviews such as the properties of the affiliated organisation, the research capacity of the university laboratory, and the characteristics of the company collaborated with.

Contextual variables and the two modes

In Chapters 5 and 6, we investigated how the different organisational resource conditions of universities affect universities' performance in academic and entrepreneurial activities. This subsection carries out an analysis of the influence of different contextual factors on individual academics' activities. As presented in the latter part of the two previous subsections, contextual variables relating to environmental conditions (i.e. accessibility to high tech firms, academic exploitation of industrial collaboration, and the characteristics of the industry sector) in which the academics are embedded are inevitably involved in the determination of the two modes by influencing the activities of individual academics.

In this section, those contextual factors are categorised into two areas on the basis of an organisational borderline: in other words, inside (or internal) and outside (or external) contextual factors. On the one hand, internal contextual factors can be defined as factors influencing individual academics' activities that are related to the characteristics of the affiliated laboratory (e.g. research capacity) and to the affiliated organisations (e.g. size and legal status). On the other hand, external contextual factors can be defined as factors influencing an individual academic's activities that are related to the characteristics of the geographical location and industrial partners.

Based on the categories defined above, we will investigate the relationship between the two modes and the *internal contextual factors*, such as the research capacity of the affiliated laboratory, the size and legal status of the affiliated university, and the entrepreneurial leadership of the affiliated university.

Firstly, the research capacity of the affiliated laboratory, such as research equipment and postgraduate students, is observed to be one of the important factors that influences the relationship between the research and industrial collaboration activities of academics and the two modes. Furthermore, the academics themselves are short of research capacity have difficulties in conducting high-quality academic research and industrial collaboration together.

> I admit that the research capacity of my laboratory is actually insufficient to carry out academic research and industrial collaboration together, because our department has only four postgraduate students and no doctoral students at all (DN5, a senior professor).

> I actually lost my passion for highly-qualified academic research after failing to get funds from government agencies such as KRF (Korea Research Foundation). Therefore, I am spending most of my time on teaching and on low-quality projects for local companies (EA3, a senior professor).

Secondly, depending on the size of the affiliated university, the interviewed professors gave different views on the two modes (i.e. the relationship between academic research and industrial collaboration). Some of the academics belonging to small and medium-sized universities in Seoul implied that they were in a disadvantaged position for obtaining resources because of their size and consequently low visibility and low reputation with regard to potential industrial partners. They are therefore unlikely to turn down an industrial project unrelated to their academic topic because of the difficulties in being funded for their academic research.

> In my experience, one the most important factors for winning funding from governments or industry is the size of a university and its laboratories. It is a prejudice. They tend to doubt whether a small university and its laboratories can complete their project successfully (DS6, a junior engineer in Seoul).

> Small and medium-sized universities are hardly likely to be chosen as a main university to implement projects for big scientific consortia (DS4, a junior engineer in Seoul).

> Because of its small size, my university is in a poorer condition in terms of government research support than large local universities (DS1, a senior physicist in Seoul).

Furthermore, in regional areas, size matters more than it does in Seoul. Accordingly, small and medium-sized universities in regional areas are likely to be in the worst position in terms of resources being allocated.

> Small and medium-sized universities in regional areas are in the most disadvantaged situation, because large regional universities are overwhelmingly not only attracting postgraduate students in the region but also dominating government support for local universities (C4, a junior professor).

> Because of the poor resource condition of small local universities, their research-related

> activities (e.g. maintenance of equipment and administration of the research team) are mainly dependent on the efforts of the professors themselves without postgraduate students' assistance (FP6, a junior professor).

Thirdly, the legal status of the affiliated university can also create a different environment for academics' activities. In terms of financial resources, private universities are more dependent on tuition fees and industry funding, whereas public universities are more dependent on government funding (see Figures 5.6 and 5.7). Due to this different funding structure, academics in private universities may be more inclined to participate in industrial collaborations without academic importance than those in public universities. Furthermore, academics in public universities may be more strongly involved in industrial collaboration and academic research together than those in private universities, because the Korean government stresses the importance of industrial exploitation of academic potential, and supports a large amount of research funding. This is supported by the empirical evidence in Chapter 5 (see Figure 5.8) and Chapter 6 (see Table 6.2).

In the interviews, some academics in private universities revealed that the legal status of their universities has influenced their orientation towards academic research and industrial collaboration through strong and flexible intervention by the university authorities. In contrast, public universities have been relatively slow in following private universities practices due to a more complicated decision-making system.

> The decision-making structure of the private university can be regarded as a 'top-down' approach, whereas that of a public university is a 'bottom-up' approach. In other words, important decision-making such as the restructuring of departments in a public university usually requires a consensus of all academic staff, whereas in a private university directors of the board can initiate reform of the university structure to adapt to the changing environment with which they are faced (B5, a professor in a public university).

> Based on its strength in terms of organisational flexibility, our university has achieved a remarkable performance in terms of such things as application-oriented restructuring of departments and strong support for research students (DP7, a professor in a private university).

Fourthly, in addition to the legal structure, the entrepreneurial leadership of the affiliated university can also be regarded as a factor that influences the university's activities. In particular, private universities tend to show a relatively strong leadership and a flexible governance structure to adapt to local or national industrial needs. In this process, the president of a university has a critical role to carry out in the restructuring of departments and in encouraging certain groups to focus on certain types of research programme.

> Our department's efforts are regarded as one of the best practices within our university, as we have established a research institute to implement a future research strategy initiated by the president of the university (A5, a senior professor).
>
> A series of restructures of natural science departments, particularly in several regional universities, has been implemented by university authorities over the last decade. For example, the physics and mathematics departments merged into an applied computing department, and the chemistry and biology departments are integrated under the medical-bioengineering department. In this process, an identity as a natural scientist who focuses on curiosity-oriented research cannot help them reorient to industry-friendly research and teaching (DP1, a senior chemist in a regional university).

However, if we consider the relatively weak performance both in academic research and industrial collaboration introduced in Chapters 5 and 6, these organisational efforts based on the affiliated university's legal status and entrepreneurial leadership have not developed into a positive relationship between academic research and industrial collaboration (i.e. synergy mode). According to the analysis of these four internal contextual factors, the resource availability of the university and of individual academics can be regarded as an underlying dominant factor.

In terms of the relationship between the two modes and the *external contextual factors*, five factors are identified as important from the analysis of the interviews: location of the affiliated universities, industrial background, characteristics of the firms collaborated with, geographical proximity to high-tech firms, and charactristics of funding sources.

Firstly, the location of the universities is one of the most influential factors in terms of both what was stated in the interviews and one of the critical characteristics of the organisation academics belong to. In general, the location of Korean universities (particularly whether or not they are near Seoul) is widely accepted as a signal that indicates the scientific reputation and resource conditions of a university and its academics, as discussed in Chapters 4 and 5. In other words, the universities near Seoul enjoy an advantageous position in terms of attracting not only the brightest postgraduate students and professors with academic reputations, but also a large amount of research funding from government and industry.

> Most high-tech companies are located near Seoul (i.e. Seoul, Kyunggi and Incheon), so in order to make the most use of this opportunity, we have implemented various programmes: close networking with the companies near our university, and establishment of a techno park and research centres focused on electronic components (DS7, a director of research and industrial collaboration in Seoul).

> Our university is located in a region far from Seoul, so research resources such as postgraduate students are relatively scarce compared to universities near Seoul. To make this situation even worse, our postgraduate students usually want to move to a laboratory near Seoul. Therefore, universities far from Seoul are in a disadvantaged position for acquiring research funding to support postgraduate students, so this can be seen as a 'vicious cycle' (C4, a junior professor in a regional university).

Secondly, in terms of industrial background, the match between academics' disciplines and the sectors of local industry also plays a critical role. Academics in those disciplines overlapping with industrial needs are likely to obtain industrial resources (e.g. funding and equipment) more easily than those whose discipline does not match with local industry. Therefore, the existence of local industries that are close to the academics' research fields could result in synergy mode.

> Academics in our university, particularly in the biology department, have produced distinctive research outputs in the field of bio-technology, because the government chose our university as an organisation to create a leading centre for boosting the emerging regional bio-industry (B7, a director of research and industrial collaboration).

> An electric power supply plant near our university enables us to be in a prestigious position in terms of research and industrial collaboration (B3, a senior professor).

> The auto industry in our region is critical for industrial collaboration and for the employment of our graduates (EA7, director of industrial collaboration).

Thirdly, the characteristics of the firms collaborated with are also an important factor in distinguishing between the two modes of academics. High-tech firms are likely to encourage synergy mode among academics, whereas academics collaborating with low-tech firms are likely to stay in separation mode. Most academics operating in separation mode claimed that they cannot operate in synergy mode because of the low technological understanding of local firms. In contrast, some academics, such as DS6 and EA3, stated that if the technological understanding of the firm is higher than that of the academics, the firm just regards university researchers as cheap assistants for routine work such as testing and data collection.

> Because of the low capacity of the local firms, it is very hard to produce academically meaningful results (FP6 and EA4, regional engineers).

> In the field of the auto industry in our region, usually the capacity of industry is higher than that of the university laboratories, so they do not want to collaborate with a local

> university laboratory that has a low research capacity for high-quality research (A3, a regional engineer).
>
> In the case of a high-tech firm, they tend to ask for a kind of routine work, exploiting low-cost workers such as postgraduate students (DS6, an engineer in Seoul).

Fourthly, geographical proximity to high-tech firms is closely related to the location of the university. In other words, as high-tech companies are mostly concentrated near Seoul, universities near that area are likely to operate in synergy mode. Therefore, according to this point of view, this factor overlaps with the first external contextual factor (i.e. the location of universities). However, if academics have a nationwide reputation in a niche discipline, they can overcome this geographical limitation.

> Because the majority of the firms located in our region have a very low technical capacity, it is not easy to collaborate with a high-tech firm to produce a synergy effect in my own research topic (C6, a regional engineer).
>
> In spite of the geographical disadvantage, my own networking based mostly on alumni helped me to produce academic results through collaboration with high-tech firms with nationwide reputations (FP6, a regional engineer).
>
> I have always collaborated with large major companies based on my past performance indicating a strong scientific capacity (B3, a regional engineer).

Fifthly, government funding is also related to the two modes. Government funding is regarded as an additional option for academics operating in synergy mode who are competent enough to obtain industrial funding. This is because a government-funded industrial project is a preferable way to produce research results that are both publishable and patentable without the intervention of companies asking for a direct financial return.

> If possible, I try to become involved in government-funded projects aiming to produce long-term benefits, which are therefore likely to result in publishable research output (EI6, a junior engineer).
>
> Usually, academics prefer government-funded projects to industrial projects, because the former focus more on academic outputs while the latter are mainly concerned with producing economically meaningful products (DS2, a junior engineer).
>
> In my case, the collaborating company provides me with 'state of the art' research facilities, so a stronger synergy effect can be achieved (DS4, a junior engineer).

In addition, the competition for research funding has been increasing (particularly for junior academics) due to the recent sudden growth in the amount of individual government funding available for universities, in spite of a steady increase in the total amount of government funding. This influences the determination of the academics' modes. Consequently, some younger professors tend to be involved in industrial collaboration far removed from their academic research topic.

> As the size of government-funded projects has recently been massively increased, the opportunities for young professors have decreased (A6, a junior engineer, and A2, a junior physicist).

> The support for new academic staff is not sufficient to produce good research output relatively quickly (DN6, an engineer).

Transition between the two modes: the importance of abundant resources

According to the results from the analysis above, we found that the mode is related not only to the characteristics of individual academics but also to contextual factors. Therefore, it is not surprising that there is a possibility of transition between the two modes. According to the interviews, some academics assert that in spite of their current separation mode, if they are provided with sufficient resources such as postgraduate students and high-quality facilities they can produce research output that is not only academically excellent but also commercially successful (B4, FN4 and DS6, junior engineers).

The contents of the interviews support the view that synergy mode can be transformed into separation mode and vice versa by contextual factors: in particular, the characteristics of the industrial partner, the quality of the industrial project, and the research capacity of the universities and firms.

Firstly, according to B4, a junior engineer, his mode tends to change if the size of the collaborating firm changes. This is also closely related to the quality of the project and the technological capacity of the firm:

> In my case, synergy mode can be produced if a big firm gives me a research project. In contrast, a project commissioned by a small or medium-sized firm is unlikely to produce a synergy effect (B4, a junior engineer).

Secondly, according to FN4, a junior engineer, the characteristics of the project can result in a change of mode, as described below:

> Even though my overall mode can be regarded as separation mode, sometimes my

> research projects from industry operate in synergy mode, generating both useful results for industry and excellent academic papers. This happens in cases when the industrial project requires not just a practical solution to the technical barrier the company faces but also high-quality research linked to academic content (FN4, a junior engineer).

Thirdly, the relative competitive advantage in research capacity between the university laboratory and the collaborating company can be critical for the mode of the academics.

> The determination of the two modes is dependent on who has the power in a research project. If the university laboratory has a stronger technological capacity than the industrial partner, it is likely that the research can produce academically meaningful results (DS6, a junior engineer).

Conclusion: some facts emerged from the interview data

Based on the findings in Section 7.2, this subsection summarises the emerging relationship between the individual and contextual characteristics of the academics and the two modes (i.e. synergy and separation mode). Based on the summary of the findings, some facts are proposed.

First of all, we have found that the determination of the two modes is closely related to individual characteristics such as the career stage and discipline of the academics. In terms of career stage, senior academics are likely to be operating in separation mode, whereas junior academics are more likely to be operating in synergy mode. In terms of discipline, academics in new engineering fields are likely to be operating in synergy mode, whereas those in natural science and traditional engineering fields are likely to be operating in separation mode. If we consider the career stage and discipline of the academics together, senior and junior academics in new engineering fields and junior academics in traditional engineering and natural science are likely to be operating in synergy mode, while senior academics in traditional engineering and natural science are more likely to be operating in separation mode, as shown in Table 7.3.

Next, the determination of the two modes is also likely to be influenced by contextual characteristics. As shown in Table 7.3, academics are likely to be operating in synergy mode if they are working in the following contexts: large and public universities near Seoul, laboratories with a high scientific capacity, universities where the authorities have a strong interest in entrepreneurship and where there is a strong industrial background, and in areas where there are neighbouring large high-tech firms. In contrast, academics in the opposite situation are likely to be in separation mode. In spite of this oversimplification, these two groups of contextual properties can be divided by a criterion: the existence of an abundance of resources, as discussed in previous sections.

Table 7.3 Two modes and characteristics of academics

Variables / Modes	Individual variable	Contextual variable
	Discipline & Career	Internal and External Factors
Synergy: reinforcement between R & IC*	Junior in new eng. Senior in new eng Junior in eng. & nat.	Large/Public uni. near Seoul, High capa. lab., Strong Leadership, Strong ind., Near/Big/High tech firms. → Rich resource conditions
Separation: trade-off between R & IC*	Senior in nat. Senior in trd. eng.	Small/Private uni. local, Low capa. lab., Weak Leadership, Weak ind., Far/Small/Low tech firms. → Poor resource conditions

*R: Research, IC: Industrial collaboration

Source: summarised by the author, based on the analysis in this chapter

7.3 The Determinants of the Two Modes: quantitative test based on the survey results

This section proposes several hypotheses (subsection 7.3.1) based on the findings of Section 7.2 with regard to the relationship between the two modes and the various characteristics of the academics, and then carries out various statistical analyses (see subsection 7.3.2) of the quantitative results of the survey (subsection 7.3.3).

7.3.1 Hypotheses

This section sets out hypotheses on the relationship between the two modes and the contextual and individual properties of the academics based on three elements: characteristics of the Korean academic system, factors influencing productivity in terms of publications and academic patenting identified in the previous literature, and the relationships emerging from the interviews.

Firstly, if we consider the characteristics of the Korean academic system, several variables can be suggested as influencing factors with regard to the two modes. Due to the rapid expansion and transition of the main mission of Korean universities, the age variable is important. Moreover, due to the government's strong control and imbalanced growth policy in favour of public universities, the legal status of the affiliated universities and the discipline of academics may also influence individual academics' activities. Finally, in terms of highly-qualified scientists and engineers, the Korean academic system has been heavily dependent on overseas institutions (see Chapter 4), so the country of training can also be considered as a possible critical factor.

Secondly, the factors influencing academics' productivity in terms of publishing and patenting have been investigated in Section 2.4. According to these previous studies, academic performance as well as knowledge-transfer performance of academics is significantly related not only to individual properties such as career stage, discipline and gender, but also to contextual characteristics such as the size of the laboratory, the location of the university and the characteristics of the local industry.

Thirdly, based on the interview data, the relationship of the two modes to individual and contextual factors is explored as shown in Table 7.3. Junior researchers in all disciplines and senior researchers in new engineering fields tend to operate more in synergy mode, whereas senior researchers in the fields of natural science and traditional engineering tend to operate in separation mode. In the light of the three arguments suggested above, a number of hypotheses are suggested as follows.

Career stage of the academics

The interviews with junior academics tend to imply that they are searching for a synergy effect with industry likely to produce a research output that is publishable and patentable. Furthermore, considering the recent policy changes of Korean universities (particularly, those after 2000), the government has begun to strongly stress the need for the exploitation of academic potential. Therefore, those academics who have been recently employed tend to be exposed to an environment encouraging strong linkages to industry. Based on these arguments, one hypothesis can be suggested as follows:

Hypothesis 1: junior academics with a shorter career are more likely to operate in synergy mode than senior academics.

Discipline of the academics

According to the discussion in Chapters 4 and 5, Korean universities have developed their teaching and research systems in close relation to industrial development since the early catch-up stage. Therefore, at the systemic and organisational levels (see Chapters 4, 5 and 6), two missions (academic research and knowledge-transfer activities) of Korean universities (particularly in the discipline of engineering) interact strongly with each other. Consequently, individual academics in engineering fields are also likely to have more intensive linkages with firms, and they are more likely to show synergy effects with industry than those in natural science. Therefore, those academics closely linked to industry tend to operate in synergy mode, suggesting a second hypothesis as follows:

Hypothesis 2: academics in the engineering disciplines are more likely to operate in synergy mode than those in other disciplines.

The size of the laboratories

In terms of resource effects, academics in bigger laboratories are likely to attract more funding from industry as well as from government, so they have enough resources to produce both academic and industrial outputs. Furthermore, academics in the bigger laboratories may have some advantages such as those stemming from a division of labour and knowledge-sharing between researchers and from higher visibility to potential industry partners compared with those in smaller laboratories. According to the interviews with academics in small laboratories, they claimed that they are suffering from a ‘vicious circle’ in terms of a lack of financial and human resources and high-quality contacts with industry producing synergy. Based on this argument, the third hypothesis can be stated as follows:

Hypothesis 3: the size of the laboratories that the academics are affiliated with is positively related to synergy mode.

Characteristics of the universities

Some universities are more focused on industrial collaboration, while some specialise in teaching, and some specialise in high-quality academic research. Furthermore, some universities are in an advantageous resource condition for generating synergy mode, while the others are not. For example, large prestigious universities are more likely to attract industrial attention from a high-tech company or a large company, and this contact tends to produce a synergy effect for both partners in terms of high-quality collaborative research. Therefore, these kinds of organisational orientation and environmental conditions can influence the choice of mode of the academics affiliated to these institutions. This argument suggests a hypothesis on the relationship between the characteristics of the universities and synergy mode:

Hypothesis 4: the characteristics of the university such as its size, legal status, location, year of foundation and generality (or the types of the university suggested in Chapter 5) have a significant relation to the synergy mode of the academics affiliated with it.

Local R&D intensity

One of the most important environmental conditions for the generation of a synergy effect with regard to the academics' interaction with industry is the business R&D intensity of the region in which the academics are located. This factor can influence the mode of the academics, as the R&D orientation of the local companies may encourage a synergy mode among the academics in the region as one of the 'pull' factors. If the firms in a region are investing highly in R&D, the universities located in that region are likely to benefit from collaborative research with industry:

Hypothesis 5: the R&D intensity of local industry is significantly related to the synergy mode of the academics located in the region.

7.3.2. Dependent variable and independent variables

In the previous section, starting with the two-mode framework considering both individual and contextual variables, we have developed various hypotheses on the basis of that conceptual framework and the interview data. In this section, the dependent variable and independent variables are introduced. Furthermore, based on these variables, the statistical model is presented in order to test the hypotheses suggested in the previous section.

Dependent variable – synergy mode / separation mode

The dependent variable is whether an individual academic is operating in synergy mode or in separation mode. In order to measure this 'dichotomous' variable, two methods are suggested.

In terms of a quantitative method, counting the number of papers and patents produced by academics can be considered as one possible method. Those professors with high performance both in terms of papers and patents production can probably be categorised as academics operating in synergy mode, while those with lower performance are assumed to be in separation mode. In order to identify these two types of academics, the number of papers and patents produced were collected through the survey questionnaire. As shown in the table below, we can separate a group of academics who belong to the upper 20% in terms of both patent and paper production. In order to check the consistency of the regression results, the upper 10% and 30% groups are also regarded as academics operating in synergy mode.

Table 7.4 Number of academics according to the level of patents and papers production

		No. of Patents Produced last 3 years					Total	%
		0	1	2	3-4	4-52		
No. of Papers Produced last 3 years	0	158	13	10	6	3	190	8.1
	1-2	257	49	32	18	17	373	15.8
	3	156	29	16	18	9	228	9.7
	4	102	26	23	14	11	176	7.5
	5	119	30	23	13	20	205	8.7
	6-7	161	27	20	18	16	242	10.3
	8-10	153	56	26	27	34	296	12.6
	11-13	90	21	16	18	21	166	7.0
	14-20	116	36	30	45	43	270	11.5
	21-100	72	20	24	37	56	209	8.9
Total		1384	307	220	214	230	2355	100
Percentage (%)		59.0	13.1	9.3	9.0	9.7	100	

Source: tabulated by the author, using data based on the survey.

In terms of a qualitative approach, a second method to identify the academics operating in synergy mode is based on the existence of mutual benefits between academic research and industrial collaboration. In order to identify the academics operating in synergy mode and those operating in separation mode, the survey questionnaire included several questions to estimate the synergistic effect between the two activities. Among the response options to the questions, the academics who ticked 'partly agree' or 'strongly agree' for the three questions regarding the academic benefits of industrial collaboration are those who are probably operating in synergy mode. As a result, the group of academics so chosen is regarded as operating in synergy mode.

As shown in the three questions below, the synergy can be assessed qualitatively in terms of three types of benefits from industrial collaboration: strengthening of research capacity (i.e. researchers and equipment), generation of research ideas, and enhancement of academic reputation. In order to calculate the dependent variable (here, the binary variable), the academics who ticked 'partly agree' or 'strongly agree' among the given choices for all the three questions are identified as academics who operate in synergy mode. However, in order to check the appropriateness of this choice, the other options for the choice of the academics operating in synergy mode (i.e. academics who ticked at least one positive choice in these three questions) are also considered and compared with the others in later statistical tests.

Table 7.5 Two questions asking whether the surveyed academics are operating in synergy mode

Q13. What are your direct outputs resulting from the industrial collaborations you have been involved in since 2004?

	Strongly disagree	Partly disagree	Neutral	Partly agree	Strongly agree
- enhancement of my research capacity	1	2	3	4	5
- generation of new ideas for my own research	1	2	3	4	5

Q15. To what extent do you agree with the following statement on the industrial collaboration you have experienced?

	Strongly disagree	Partly disagree	Neutral	Partly agree	Strongly agree
- It has contributed to my academic career and reputation	1	2	3	4	5

Source: constructed by the author

Independent variables and control variables

- *Individual characteristics of the academics*

Based on the personal profiles provided by KRF (the Korea Research Foundation) and on replies to the survey, variables such as career stage, discipline, gender, the country of training and productivity in terms of patents and papers are included in the models as variables representing individual characteristics.

Firstly, the time-span between the current year and the year of starting employment is estimated as a measure of career stage, because it is a better measure than the age of the academics. However, age is not excluded from the model. Secondly, the disciplines of the academics are divided into six categories: natural science (e.g. physics, mathematics, statistics, etc.), chemistry, bio-technology, engineering, medical science and agricultural science. Thirdly, the gender of the academics based on the KRF data is encoded as a binary variable. Even though the gender effect has not emerged as a critical effect from our interview data, gender differences could be seen as possible social factors such as the degree of networking with industry (Murray & Graham, 2007), which may influence the modes of the academics. Fourthly, the country of training may influence the two modes of activity. In particular, those academics who studied overseas can be regarded as productive professors in terms of research as well as industrial collaboration. Furthermore, the academics who trained in the US (a country that had already introduced academic entrepreneurship during the 1980s) may be more likely to have been exposed to a strong culture of university linkages than domestically trained academics. Finally, the productivity of academic research and knowledge transfer, estimated in terms of the papers and patents produced over the last three years, could influence synergy mode.

- *Contextual characteristics of the academics*

The data collected from the personal profiles as well as the replies to the questionnaire provide us with contextual variables such as the size of the laboratory, the characteristics of the universities affiliated with (or the type of university), and the intensity of business R&D in the region. These variables are employed as predictors rather than as control variables.

Firstly, the size of the laboratory is measured by the sum of the number of postgraduate students and postdoctoral students in the laboratory operated by the academics. Secondly, characteristics (e.g. founding year, legal status, location, size) of universities can influence the modes of the academics. Furthermore, the type of university, as developed in Chapter 5 is also adopted as a dummy variable. Thirdly, the business R&D intensity of the region is measured by the expenditure on business R&D, based on data from the MOST (Ministry of Science and Technology) survey (MOST, 2007). The regions are classified into 16 categories consisting of the capital, six metropolitan cities, and eight provinces.

Estimation and model specification

A logit regression model is employed, because the dependent variable is a binary categorical variable. This variable has one of two values: synergy mode (1) or separation mode (0). The multicollinearity has been checked by VIF (Variance Inflation Factor) values in each model, and robust standard errors are calculated.

7.3.3 Results

Table 7.4 below presents descriptive statistics for the variables included in the sample. First of all, before constructing specific models testing the hypothesis suggested in subsection 7.3.1, we carry out a preliminary analysis on the relationship between the dependent variable (i.e. synergy or separation mode) and the independent variables (i.e. individual factors and contextual factors influencing the two modes) based on descriptive statistics and basic statistical tests such as a Chi-square test. These results are briefly provided in Appendix Figures 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7 and 7.8.

In terms of individual factors, firstly, the number of male academics operating in synergy mode, as well as the proportion of the number of male academics operating in synergy mode to the total number of male academics as measured by quantitative and qualitative definitions (176 and 8.3%), is larger than those of female academics operating in synergy mode (5 and 1.8%). Furthermore, the two modes of academics and gender are statistically significantly related to each other. Secondly, in terms of age, aside from the academics in their sixties, the relationship between age and the two modes is positive. However, the relationship is not statistically significant, particularly in terms of the quantitative approach. Thirdly, the proportion of the number of junior academics operating in synergy mode as measured by quantitative and qualitative definitions to total junior academics (8.2%) is larger than that of senior academics (7.0%), but this is not statistically significant. Fourthly, the academic's discipline (particularly engineering) is important for the generation of synergy mode, and the relationship is statistically significant. Fifthly, the academic's country of training (particularly Japan) has a significant relationship to the determination of the two modes. Finally, in terms of contextual factors, laboratory size and university type are significantly related to the two modes, whereas the regional BERD is not.

Table 7.6 Descriptive Statistics

Variable	Observations	Mean	S.D.	Minimum	Maximum
Gender	2392 (1=male)	0.89	0.318	0	1
Age	2395	46.55	7.415	30	77
Career	2392	11.30	8.449	0	40
Discipline	2395				
- Nat. Sci.	279	0.11		0	1
- Chem.	142	0.06		0	1
- Bio.	219	0.09		0	1
- Eng.	1015	0.42		0	1
- Med.	581	0.24		0	1
- Agr.	159	0.06		0	1
Cnt. trained	2395				
- Korea	1335	0.55		0	1
- US	723	0.30		0	1
- Japan	211	0.09		0	1
- EU	95	0.04		0	1
- others	31	0.01		0	1
Papers	2355	8.75	9.769	0	100
Patents	2383	1.50	3.442	0	52
Lab. size*	2383	4.90	4.383	0	33
Uni. Cha.					
- Size	2395	469.30	239.87	49	987
- Legal status	2395	0.47	0.50	0	1
- Location	2395	1.74	1.62	0	4
- Found. year	2395	1940.83	29.91	1855	1998
- Generality	2395	5.47	1.06	1	6
Uni. type**	2395				
- type 1	463	0.19		0	1
- type 2	705	0.29		0	1
- type 3	465	0.19		0	1
- type 4	142	0.06		0	1
- type 5	254	0.11		0	1
- type 6	125	0.05		0	1
- type 7	112	0.05		0	1
- type 8	11	0.01		0	1
- type 9	10	0.004		0	1
- type 10	108	0.05		0	1
Reg.BERD***	2394	2171963.6	2753790.71	19799	1028630
Syn_qual	2395 (1=Syn)	0.15	0.358	0	1
Syn_quan	2395 (1=Syn)	0.08	0.264	0	1

*Number of researchers in the laboratory (sum of research students and postdoctoral researchers)
**1: Old large private in Seoul, 2: Large public regional, 3: Large private regional, 4: Medium-sized or small private in Seoul, 5: Medium public regional / industrial, 6: Medium private regional, 7: Specialised in science & engineering, 8: Small private regional, 9: Small private industrial, 10: Outliers. ***unit: million won. Source: tabulated by the author, based on the survey data.

Next, in order to test the hypotheses using different combinations of the variables, various models have been constructed. Firstly, the dependent variables of models 1, 2 and 3 are based on quantitative data (i.e. academics who have a better performance both in publishing and patenting than others), whereas those of models 4, 5 and 6 are based on qualitative data (academics who replied to the questions asking whether they are operating in synergy mode). Secondly, the numbers of papers and of patents produced by individual academics are adopted as control variables in models 4, 5 and 6, whereas those variables are excluded from models 1, 2 and 3. Thus, we can control the influence of publishing and patenting productivity on the determination of the two modes measured qualitatively. Thirdly, in models 1 and 4, characteristics of the universities such as the founding year, legal status, size, location and generality are included, while in models 2 and 5, the variable based on the typology of university affiliated with (see subsection 5.2.2) is employed as an organisational factor. Finally, in models 3 and 6, the age variable (the age of the academic) is included, while in the other models (1, 2, 4 and 5), the career stage variable (the time span between the year of starting employment and 2007) is used.

The reference groups of the dummy variables are specified as follows. Firstly, in terms of the disciplines, natural science is regarded as the reference discipline. Secondly, the academics who have been domestically trained are set as the reference group. Finally, the large old universities in Seoul are also regarded as the reference group amongst the ten types of universities.

Tables 7.7 and 7.8 on the next two pages show the results of the regression analysis according to the six different models. In order to have more robust results, the estimation of the regression coefficients has been carried out by the adoption of alternative definitions (i.e. we can change the definition of the academics operating in synergy mode from ‘upper 20%’ into ‘upper 30%’ in terms of patens and papers production[38]). In the following section, comparing the results of the first three models based on quantitative dependent variables with those of the last three models based on qualitative dependent variables, we discuss the test results of the hypotheses suggested in subsection 7.3.1.

[38] In this case, we have identified only a small amount of change in regression coefficients. In terms of another alternative definition, see footnote on p.213.

Table 7.7 Estimation of the two modes measured quantitatively

Models Variables	Model 1 (Synergy mode)	Model 2 (Synergy mode)	Model 3 (Synergy mode)
Gender	1.660 (.505)***	1.639 (.511)***	1.690 (.5209)***
Age			-.012 (.012)
Career	-.025 (.011)*	-.025 (.011)*	
Discipline			
- Chemistry	1.389 (.405)***	1.434 (.407)***	1.453 (.407)***
- Biology	.344 (.455)	.296 (.449)	.354 (.448)
- Engineering	.653 (.358)+	.657 (.357)+	.676 (.359)+
- Medical	.694 (.400)+	.681 (.399)+	.708 (.399)+
- Agricultural	.084 (.514)	1.093 (.513)	.120 (.514)
Country of training			
- US	.353 (.206)+	.281 (.216)	.321 (.217)
- Japan	.511 (.301)+	.539 (.298)+	.550 (.301)+
- EU	.442 (.394)	.409 (.384)	.453 (.390)
- Other	-.134 (.773)	-.205 (.768)	-.214 (753)
Papers			
Patents			
Laboratory size	.169 (.017)***	.163 (.017)***	.159 (.017)***
Uni. characteristics			
- Size	.0008 (.0005) +		
- Legal status	.465 (.211)*		
- Location	.069 (.067)		
- Found. year	-.002 (.004)		
- Generality	-.176 (.085)*		
Uni. types[1]			
- type 2		-.348 (.284)	-.395 (.284)
- type 3		-.148 (.274)	-.205 (.273)
- type 4		.086 (.380)	.052 (.378)
- type 5		-.798 (.413)*	-.849 (.410)*
- type 6		-.416 (.527)	-.439 (.525)
- type 7		.383 (.349)	.316 (.350)
- type 8		[3]	[3]
- type 9		.607 (.969)	.672 (.980)
- type 10		-.072 (.422)	-.134 (.419)
Regional BERD	-2.07e-8 (3.52e-8)	-1.23e-8 (3.82e-8)	-7.54e-9 (3.81e-8)
Constant	-.335 (7.150)	-5.375 (.422)***	-5.113 (.901)***
Log p-likelihood	-540.42988	-538.85468	-542.54425
Wald chi[2] (d. of f.)	150.79 (18)***	162.04 (21)***	160.45 (21)***
No. of observations	2376	2366	2369

[1]the names of the university types are listed in the notes of Table 7.6.
[2]regression coefficients are calculated based on robust standard errors.
[3]type 8 is omitted due to the small number of observations.
*p<0.05, **p<0.01, ***p<0.001, +p<0.1

Table 7.8 Estimation of the two modes measured qualitatively

Models Variables	Model 4 (Synergy mode)	Model 5 (Synergy mode)	Model 6 (Synergy mode)
Gender	.905 (.261)***	.841 (.260)***	.832 (.261)***
Age			.017 (.009)*
Career	.008 (.008)	.009 (.008)	
Discipline			
- Chemistry	.002 (.415)	-.006 (.415)	-.025 (.416)
- Biology	.176 (.363)	.182 (.361)	.178 (.360)
- Engineering	1.360 (.259)***	1.339 (.260)***	1.347 (.260)***
- Medical	.513 (.295)+	.571 (.296)+	.559 (.295)+
- Agricultural	.807 (.338)*	.780 (.339)*	.769 (.337)*
Cnt. trained			
- US	-.099 (.153)	-.028 (.153)	-.058 (.152)
- Japan	.260 (.199)	.263 (.196)	.231 (.197)
- EU	.039 (.310)	.089 (.307)	.050 (.307)
- The others	.635 (.485)	.695 (.498)	.648 (.500)
Papers	-.011 (.007)	-.009 (.007)	-.008 (.006)
Patents	0.058 (.016)***	0.059 (.016)***	0.059 (.016)***
Laboratory size	0.052 (.014)***	0.058 (.014)***	0.054 (.014)***
Uni. characteristics			
- Size	-.00007 (.0004)		
- Legal status	-.191 (.161)		
- Location	.023 (.047)		
- Found. year	-.005 (.003)+		
- Generality	-.003 (.070)		
Uni. types[1]			
- type 2		.504 (.237)*	.508 (.237)*
- type 3		.396 (.230)+	.397 (.230)+
- type 4		.535 (.321)+	.552 (.321)+
- type 5		.759 (.266)**	.765 (.266)**
- type 6		.440 (.343)	.438 (.340)
- type 7		-.085 (.355)	-.100 (.356)
- type 8		.618 (.783)	.598 (.785)
- type 9		.891 (.724)	.887 (.724)
- type 10		.292 (.352)	.312 (.352)
Regional BERD	1.39e-8 (3.06e-8)	2.13e-8 (2.89e-8)	2.09e-8 (2.90e-8)
Constant	4.94 (5.10)	-4.31 (.428)***	-4.98 (.579)***
Log p-likelihood	-912.90216	-909.00372	-908.22142
Wald chi[2] (d. of f.)	145.15 (20)***	147.32 (24)	150.62 (24)
No. of observations	2348	2348	2351

[1]the names of the university types are listed in the notes of Table 7.6.
[2]regression coefficients are calculated based on robust standard errors.
*p<0.05, **p<0.01, ***p<0.001, +p<0.1

On the one hand, the results from the models employing the quantitative dependent variable are different from those of the models employing the qualitative dependent variable.[39] Firstly, age is significantly related to synergy mode in the latter models (models 4, 5 and 6), whereas career stage is significantly related to synergy mode in the former models (models 1, 2 and 3). Secondly, among the disciplines of academics, chemistry is a significant predictor in the former models, while agricultural and maritime science is a significant predictor in the latter models. Thirdly, the country of training variable (particularly for those trained in Japan) is significantly related to synergy mode in the former models, but not in the latter models. Fourthly, in terms of the characteristics of the universities, the size, legal status and generality are significantly related to synergy mode in the former models, while in the latter models, only the founding year is related to synergy mode. Finally, in the latter models, papers production over the last three years has a significant relationship with synergy mode in the former models, whereas patents production is a highly positive significant predictor for synergy mode.

The difference in the results presented above is mainly due to the difference in the data base of the dependent variable. In other words, the dependent variable of the first three models is more focused on the quantitative performance in both academic research and knowledge transfer of the academics, whereas that of the last three models focuses on the benefits from industry to academic research in terms of research capacity, ideas and reputation, as discussed in the first part of subsection 7.3.2. Therefore, the two dependent variables are measuring different aspects of synergy mode. That is to say the first one measures the quantitative output of the operation of synergy mode, while the second one relates to the qualitative aspects of the process and the outcome of synergy development. Furthermore, the synergy effect that resulted in both papers and patents does not necessarily coincide with the synergy effect from the qualitative process and the outcome of industrial collaboration. Not all academics who are good at both patenting and publishing are operating in synergy mode. Some of them may show a high performance because of their talents and rich resources. Conversely, the academics who are experiencing a synergy effect from collaboration with companies demonstrate synergy not only in the form of papers and patents, but also in the forms of meetings,

[39] On the other hand, discussions on the consistent or common results across the six models are provided on p.213.

facility sharing and exchange of the students supervised.

By comparing the regression results of the first three models, we can focus more intensively on the last three models than in the discussion above, and discuss the test results for the hypotheses, because these models are based on the qualitative aspects of synergy mode. In particular, the three variables (i.e. career stage, discipline, and the country of training) with regard to the related hypotheses and paper productivity are discussed.

Firstly, **hypothesis 1** is supported by the results of the regression analysis based on models 1 and 2, but not by models 4 and 5. The career length of academics is found to be a significant predictor of synergy mode measured quantitatively, whereas that is not found to be a significant and positive predictor of synergy mode measured qualitatively. Furthermore, in model 6, the age of academics is found to be a significant and positive predictor for synergy mode measured qualitatively. Even in the case of the presence of the two variables (i.e. age and career stage) at the same time in a model, the result is the same, except for a marginal change in the beta coefficients of the variables. Therefore, age may be more important than career stage in generating synergy mode measured qualitatively.[40]

The signs of the coefficients in models 1 and 2 are consistent with the findings based on the interview data. In other words, we expected that junior academics would be more likely to operate in synergy mode than senior academics. This is probably because junior academics are under greater pressure to produce academic outputs as well as experiencing a stronger desire for enhancing their academic reputation than senior academics, so 'output' synergy (i.e. the production of papers and patents at the same time) is more important than 'process' synergy (e.g. the generation of new ideas from industrial collaboration). In terms of the academics' life-cycle, the creation of a synergistic environment in the process of collaboration with industry may take more

[40] This result may be explained by the recent recruitment policy of Korean universities. According to interviews with several directors of the office of research and industrial collaboration, universities prefer academics with industrial experience rather than those without such experience when it comes to the recruitment of professors. Industrial researchers in their fifties are now recruited as professors, which was quite rare before 2000. Therefore, comparatively junior academics in their middle age are not difficult to find on campus. This fact may reduce the significance of career stage in models 4 and 5.

time than one might have expected. Therefore, only 'older' academics with a longer research experience or stronger social network may be allowed to pursue qualitative synergy rather than quantitative synergy.[41]

Secondly, the results of the regression analysis support **hypothesis 2**. The discipline of the academic (particularly engineering and medical science) is found to be a highly significant predictor for synergy mode across the six models. This result is consistent with the explanation of the operation of the two modes based on the conceptual framework considering only the type of research suggested in Figure 2.2 (see Section 2.4). This is also confirmed by the interviews with academics in different disciplines. In particular, compared to the reference group (academics in natural science), the group of engineering researchers is more strongly and positively related to synergy mode than the other groups. This is also due to one of the characteristics of engineering in academia, in that it is based on both theoretical and practical knowledge. According to one interviewee in the field of engineering, good academic research cannot be implemented without addressing the practical needs of industry. However, we need more evidence to explain the result that academics in biotechnology do not tend to operate in synergy mode, whereas those in chemistry are far more likely to operate in synergy mode. However, this may be related to the lack of a strong bio-industry in Korea and the relatively small proportion of business R&D expenditure, compared to the Korean chemical industry. For example, only 5.8% of total Korean R&D expenditure is invested in bio-technology R&D, and two-thirds of this is allocated to universities rather than to industry (MOST, 2007).

Thirdly, the country of training is not significantly related to synergy mode in the last three models, whereas training in Japan (compared to domestic training) are

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[41] In this analysis, we focus on the relationship between the career variable and the two modes in models 1, 2, 4 and 5. In the discussion, we interpret the academics' choice between the two modes as being related to the period of academics' recruitment to universities (i.e. junior and senior groups), and to academics' age. However, it is impossible to distinguish whether synergy mode is determined because they belong to the junior group in universities, or because they belong to a later cohort group equipped with a superior knowledge base. As a result, due to the confounding career and cohort effect, the 'pure career' effect cannot be identified. Moreover, in models 3 and 6, the confounding age and cohort effect can be discussed in the same vein. Therefore, in this discussion, career and age variables are interpreted as only whether they belong to the 'senior' group and 'older' group rather than career effect and age effect respectively. In later studies, by collecting pooled data consisting of several groups of cohorts, we will be able to separate age and career effects from cohort effect.

significantly related to the synergy mode in the first three models. In spite of the lack of further evidence, this may be related to the climate of the Japanese higher education system. However, academics trained in the US are likely to be poorer in terms of generating synergy than those trained in domestic institutions. If we change the range of the group of academics operating in synergy mode by using another definition,[42] training in US institutions has a significant negative effect on the generation of synergy mode when measured qualitatively. In contrast, according to another regression model on productivity, academics trained in the US show significantly better performance in terms of academic paper production than domestically-trained academics (Oh et al., 2009). Therefore, we could expect that academics trained in the US focus more on academic research than on generation of 'qualitative' synergy with firms.

Finally, in all three models estimating the 'qualitative' synergy mode, the patent productivity of academics is significantly related to synergy mode, while paper productivity is not significantly related to synergy mode. This implies that the synergy mode measured qualitatively is significantly related to patent production rather than to scientific paper production. Therefore, we may conclude that patent productivity is a better predictor in the search for academics operating in synergy mode.

On the other hand, across all the models we have observed consistent or common regression results (i.e. the significant or non-significant relationship between the two modes and the predictors such as gender, discipline, laboratory size, type of universities, and regional BERD). Based on these results, we can also discuss the test results of the last three hypotheses suggested in subsection 7.3.1.

First of all, the two individual characteristics of gender and discipline are significantly related to the two modes in all six models. Firstly, some gender difference exists in the operation of the two modes, even though considering the fact that female academics are relatively rare in engineering science in Korea, we control discipline effect on the mode. However, in our interviews, gender difference has not emerged as a critical factor influencing the determination of the two modes. Although we do not have a strong

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42 Alternatively, we can change the qualitative definition of synergy mode from 'academics who replied positively to all three questions' to 'academics who replied positively to at least two questions.

theory, this interesting result may be partly due to the fact that for Korean academics, the gender issue is not easy to mention during official interviews, if not asked directly. However, these explanations need further investigation because of the lack of interview data and other evidence to explain the apparent gender bias. Secondly, as discussed on the previous page, the two disciplines of engineering and medical and pharmaceutical science (aside from chemistry and agricultural and maritime science) are significant positive predictors for synergy mode in all six models. Thus, hypothesis 2 is consistently supported across all the models.

Next, in terms of contextual factors influencing the two modes, in all six models, laboratory size and university type are significantly related to the two modes, whereas regional BERD is not significantly related to the two modes. Firstly, **hypothesis 3** is strongly supported in all six models. In other words, the size of the laboratory affiliated with is a highly significant positive predictor for synergy mode with minor changes in the magnitude of the coefficients across all six models. This means that the research resource such as research students and postdoctoral researchers are important for the encouragement of academics' synergy mode in both quantitative and qualitative terms. This is consistent with the statements of academics (who are in an unprivileged condition with regard to resources) operating in separation mode that if the resource condition improved, their mode could transfer to synergy mode.

Secondly, **hypothesis 4** is also supported by the results of the regression analysis in all four models. In terms of the type of university, the affiliation with Type 5 universities (public regional universities) is found to be a consistently significant predictor with regard to the reference group (Type 1 universities – i.e. large private universities in Seoul), while Type 2, Type 3 and Type 4 universities (large public universities in the regions, large private universities in the regions and middle-sized private universities in Seoul) are significant only in the last two models. Therefore, two types of universities as an internal environmental factor are significantly related to the individuals' synergy mode. Therefore, we may conclude that the typology of universities based on their organisational properties is a significant factor influencing the determination of individual academics' modes. Next, regarding the various individual properties of universities, in model 4, only the founding year is significantly and negatively related to the individual choice of mode. In terms of the sign of the regression coefficient, this somewhat contradicts the results of the model employing the typology of the university instead of the properties of the university (i.e. younger public regional universities are more likely to be related to the synergy mode of their academics than older public regional universities). In spite of the contradiction, this result may indicate that universities with a long history of working with the regions create a positive environment encouraging a 'qualitative' synergy mode among academics. Additionally, the sign of the coefficient with regard to size is consistent with our expectations based on the interviews, but the signs of the coefficients with regard to legal status and generality are not.

Finally, **hypothesis 5** is not supported by the results of the regression analysis at all. In other words, the business R&D intensity of the region is not strongly and significantly related to the modes of academics across all six models. Even though academics may be located in regions with intensive business R&D activities, these activities are not necessarily linked to the encouragement of the choice of synergy mode. This means that the amount of R&D expenditure in the region does not necessarily induce mutually beneficial relationships between university and industry. In all probability, the determinants of synergy mode may be closer to the supply side (university) than the demand side (industry).

In order to strengthen the persuasiveness of our discussion provided above, we need to discuss the effect of some methodological caveats on the empirical results. Here, we discuss the problems of omitted variable, control of international patent, and response bias.

Firstly, academics' willingness to publish papers and to apply for patents, possibly, varies according to different university policies providing financial incentives (e.g. the size of royalty share for academics, and the amount of additional income for publication in prestigious journals). In order to control these various incentives, we need to collect data on the 56 universities' various incentive system which, unfortunately, is lacking in our survey data. Therefore, we need to discuss whether the absence of the variables controlling these incentives affects our empirical results or not.

Basically, this is the problem of omitting a relevant variable which could result in biased coefficients estimated by the econometric model. Our model does not include an independent variable controlling different incentives for publication and patenting activities, so the magnitude and significance level of other regression coefficients might be different from 'true' values. Nevertheless, we can argue that this possibility is minimised due to the inclusion of other variables. According to the interviews with Korean academics discussed in Chapters 5 and 7, the characteristics of the incentive system are closely related to the characteristics of universities to which the academics are affiliated. For example, academics in big private universities in Seoul are more likely to be strongly encouraged to publish and to patent than those in other types of universities. Our model includes several variables controlling universities' organisational properties and types of universities. Moreover, according to regression results (see Tables 7.7 and 7.8), the effect of these factors is not stronger than that of the individual characteristics of the academics. Therefore, we may argue that the characteristics of the incentive system are not fully omitted in our model. In other words, to some extent, our model succeeds in excluding the possibility of biased estimation resulted from the omitted variable.

Secondly, in our model, patenting activity is measured by the sum of the numbers of domestic and international patents applied for. Here, we suppose that a unit of domestic patents and that of international patents applied for have an equal value. However, the quality or the potential financial benefit of the international patents applied for might be far better than that of domestic patents applied for. Therefore, we can investigate whether the outcome of our results is different or not if we control the international patenting activity only. In order to do this, we have estimated the regression coefficients by adopting an alternative definition of synergy mode (i.e. the academics that published more than 13 papers and applied for at least one international patent) and control variable based on international patenting activity.

On the one hand, according to the results, compared to the previous results we discussed, we found consistent results across models 1, 2 and 3. Firstly, the significance levels of disciplines such as engineering and medical science are shifted into a non-significant area (i.e. larger than 10%). Moreover, academics trained in Japan are not significantly related to synergy mode based on the number of international patents applied for. As discussed above, these changes are related to the fact that the scientific productivity of academics (i.e. the academics trained in the US and in the field of chemistry, who are inclined to show better publishing performance) intertwines with their operation in synergy mode. Therefore, quantitative measures such as numbers of patents and papers provide a less appropriate definition of synergy mode than the qualitative measure such as survey questionnaire responses.

On the other hand, according to the results in model 4, 5 and 6, we have found that the control variable as measured by international patenting activities is non-significant for predicting academics' synergy mode based on qualitative measures. This means that international patenting activity has a weak relationship with the generation of synergy effect between academic research and industrial collaboration. In other words, synergy mode based on qualitative measures is likely to occur in the case of low-quality industrial collaboration as measured by the sum of domestic and international patents, rather than at the high-quality level of industrial collaboration.

Finally, according to the response analysis (see Appendix 7.1), our responding group is biased with regard to their individual and contextual characteristics and to their publishing and patenting activities.

In terms of individual and contextual characteristics, young professors trained in overseas institutions now working in local middle-sized public regional universities were more inclined to respond to our survey. According to the interviews discussed in Chapters 5 and 7, these academics are likely to be located in an intermediate range regarding their resource conditions, compared to the academics in big universities in Seoul or in small regional universities. Moreover, other academics with opposite characteristics are also included in our sample on a significantly large scale, so the characteristics of these academics can be included in our econometric model as predictors. In terms of the extent of the bias, the response rates according to different individual and contextual characteristics are calculated to be located between 9% and 20% (see Appendix 7.1), which means that our sample is equally distributed and, in other words, is not extremely biased in terms of the two characteristics.

In terms of publishing and patenting activities, the academics with a higher record in the two activities may be more likely to respond to the questionnaire. Therefore, our sample can be regarded as a biased group in terms of paper and patent production. Some may argue that we could have only one type of academic who excel in publishing and patenting. However, admitting this is true, our definition of synergy mode based on a quantitative measure enables us to select academics excellent both in publishing and patenting. Therefore, our sample succeeds in including academics operating in two modes. In conclusion, we may argue that the possibility of this affecting our econometric results is quite low.

7.4 Conclusion

This section provides a summary of the main findings and conclusions. Based not only on a qualitative approach (i.e. interviews) but also on a quantitative method (i.e. the survey questionnaire), this chapter has identified the individual and contextual characteristics of academics operating in synergy mode and in separation mode.

First of all, according to the analysis of the interviews, the determination of the two modes is related to various individual characteristics of academics such as career stage and discipline. Moreover, contextual characteristics, such as the affiliated universities' characteristics and laboratories, the characteristics of industrial partners and geographical properties are also related to the academics' two modes. Next, according to a statistical test of the hypotheses, it has been discovered that synergy mode is significantly related to gender, discipline, and to certain types of universities, to the size of the laboratory and to patent outputs in all models tested. Moreover, this is significantly related not only to individual characteristics such as age, career stage and the country of training, but also to size, legal status, age, and generality of universities in a few models. However, the location of the university and the business R&D expenditure of the region fail to show any significant relationship to synergy mode.

Thus, the image of academics operating in synergy mode emerging from the interviews is somewhat different from the results of the statistical tests. That is to say, according to the interviews, the most typical academics operating in synergy mode are junior professors in large universities near Seoul or public universities in regions (see Table 7.3). However, if we consider the common results across the six models, the regression results indicate that the academics most likely to be operating in synergy mode are male academics in the fields of engineering and medical and pharmaceutical science who are affiliated to medium-sized public universities in the regions (see Tables 7.7 and 7.8). According to the first three models based on a quantitative definition of synergy mode, junior academics in the field of chemistry trained in Japan are likely to be operating in synergy mode. In contrast, in the last three models which estimate synergy mode qualitatively, older academics in agricultural and maritime science that are affiliated with old and large universities are likely to be operating in synergy mode.

This discrepancy may be explained by the two different approaches to synergy mode: the qualitative and quantitative approaches (i.e. the interviews in Section 7.2 and the surveys in Section 7.3). Furthermore, the quantitative approach again consists of two different definitions of synergy mode (i.e. papers and patents production, and the generation of synergy through collaborating with firms). As a matter of fact, we adopt three different approaches to synergy mode: synergy mode as identified by academics themselves, synergy mode as measured by papers and patents outputs, and synergy mode as measured by the questionnaire asking whether academics have experienced some academic benefits from industrial collaboration.

Firstly, the quantitative analysis in Section 7.3 differentiates the qualitative and quantitative synergy modes, whereas the qualitative analysis in Section 7.2 does not. In other words, the academics interviewed mentioned synergy in terms of both formal output (i.e. papers and patents production) and informal benefits (e.g. increase of academic reputation) interchangeably. Therefore, the analysis of the interviews has some common results with the second approach (i.e. the analysis based on the academics' quantitative outputs) and with the third approach (i.e. the analysis based on questionnaire on the generation of synergy mode). Firstly, regarding the commonality between the results from the first and the second approaches, junior academics in chemistry are likely to be in synergy mode. Secondly, regarding the commonality between the results from the first and the third approaches, academics in agricultural and maritime science who are affiliated with large universities or medium-sized universities in Seoul are likely to be in synergy mode. Additionally, the positive effect of the size of the laboratory and being in the discipline of engineering on the two modes is found in all three results.

Secondly, the definition of synergy mode based on academics' quantitative outputs is focused on the formal results of academics' industrial collaboration. If we consider the different results of this approach from those of the other approaches, the regression results based on this definition (i.e. synergy mode as high performance both in patents and papers production) are closely connected to the productivity issue (see Table 7.7). In other words, because synergy mode is based both on the number of papers and of patents, a possible third factor of talent in scientific research and its application cannot be excluded in the estimation. The minus sign of the regression coefficient of career stage and university Type 5 (in model 1), and the relatively high significance level of the variable of the discipline of chemistry (in models 1, 2 and 3) can be explained in this vein. However, in order to explain this more persuasively, we need more empirical evidence on the influencing factors on the papers and patents productivity of Korean academics.

Thirdly, we also investigated various factors influencing synergy mode based on the results from the questionnaire asking whether academics have experienced synergy effects through industrial collaboration or not. This is closely related to the broader benefit (e.g. enhancement of research capacity) from academics' industrial collaboration rather than with formal output such as papers and patents.[43] This definition of synergy mode is reflected in the regression results (see Table 7.8). In particular, the plus sign of the coefficient of academics' age and the minus sign of that of universities' founding year are identified as significant predictors, because the benefit may require a relatively long period of industrial collaboration at both an individual and organisational level. Moreover, patent outputs are significantly related to synergy mode, whereas paper outputs are not, which means that patenting propensity rather than scientific research capacity is important in indentifying the academics operating in synergy mode.

In conclusion, regarding the main research question of this thesis, we have found not only two different groups of academics who have positive and negative relationships between academic research and knowledge-transfer activities at an individual level, but also factors influencing these two kinds of relationships. In particular, the determination of the relationship (i.e. academics' two modes) is influenced by factors not only at an

[43] If we exclude the productivity variables (i.e. the numbers of papers and patents) in models 4, 5 and 6, the regression coefficients and the level of significance are changed within a negligible range.

individual level but also at the organisational and system levels. As discussed above, individual characteristics such as gender and discipline and organisational characteristics such as laboratory size and the affiliated universities' organisational properties are strongly related to the determination of academics' mode. In terms of system level characteristics, the country of training is also related to the two modes.

Finally, regarding the conceptual framework developed in Chapter 2, the findings in this chapter enable us to develop a more sophisticated conceptual framework. In other words, we can include not only the academics' discipline (as shown in Figure 2.2) but also their other characteristics (e.g. gender, career stage and resource condition) as influencing factors on the determination of the two modes.

However, some issues of methodological weakness can be suggested. Regarding the operationalisation of factors influencing the two modes, gender difference is missing in from the interview questionnaire, because it did not emerge as one of the major factors. This is also due to the fact that the survey and the interviews were carried out simultaneously during the field work. Disciplines are not specified more specifically in the quantitative analysis. That is to say, with regard to engineering disciplines, new engineering and traditional engineering cannot be categorised, because the existing categories of academics' disciplines make it difficult to identify categorised in new engineering disciplines (e.g. nano-technology and bio-technology are hard to find in academics' personal profiles based on KRF data). Additionally, the quantitative analysis of this chapter is mainly based on cross-sectional data. Therefore, we need to carefully interpret the relationship between the two modes and the factors influencing the two modes regarding the causality of the relationship.

Appendix Table 7.1 Two modes and the various characteristics of the interviewed academics

Uni. Type	Dis.	Career & Code	Mode	Main Reasons for the Mode Reported by the Academics
Large Private Seoul	Nat. Sci.	Senior A1	Separation	Discrepancy between the **discipline** & industrial projects commissioned
		Junior A2	Synergy	Consistency between the sub-**discipline** and industrial application
	Trd. Eng.	Senior A3	Synergy	**The firm** collaborated with inspires academic topics for paper publishing
		Junior A4	Separation	The **low capacity of the industry** related to the discipline
	New Eng.	Junior A5	Separation	**The firm** collaborated with only interested in product not in papers
		Junior A6	Synergy	The characteristics of the **discipline** are close to synergy mode
Large Public Regional	Nat. Sci.	Senior B1	Separation	**Resource shortage** makes me collaborate with non-academic projects
		Junior B2	Separation	Discrepancy between the **discipline** & industrial projects commissioned
	Trd. Eng.	Senior B3	Synergy	The **high capacity of the big firm** related to my sub-**discipline**
		Junior B4	Synergy	The **high capacity of the big firm** related to the new sub-**discipline**
	New Eng.	Senior B5	Separation	The low scientific capacity of the **regional firm** & the quality of the project
		Junior B6	Separation	The low capacity of the **regional firm**, focus on **training** & recruitment
Large Private Regional	Nat. Sci.	Senior C1	Separation	The low quality of the project commissioned by the firm
		Junior C2	Separation	Unlike small **regional firm,** big high-tech firms rarely want to collaborate
	Trd. Eng.	Junior C3	Separation	**Resource shortage** makes me collaborate with non-academic projects
		Junior C4	Synergy	Consistency between the sub-**discipline** and industrial application
	New Eng.	Senior C5	Separation	The low capacity of the **regional firm** in spite of potential synergy mode
		Junior C6	Separation	Collaboration not in technology but in training, **local firm** of low capacity
Middle Private Seoul	Nat. Sci.	Junior DS1	Synergy	Sub-**discipline**, commissioned by big **high-tech company** near Seoul
		Junior DS2	Synergy	Sub-**discipline**, prefer to be publicly funded because of the low pressure
	Trd. Eng.	Senior DS3	Separation	Collaboration through the simple **project** given by the industry
		Junior DS4	Synergy	The high quality research facility of the collaborating **company**
	New Eng.	Senior DS5	Synergy	Industrial projects with small **firms** usually generate publishable output
		Junior DS6	Separation	Prefer synergy, but low capacity of the **firm** results in separation mode
Middle Public Regional	Nat. Sci.	Senior DN1	Separation	Characteristics of the **discipline are** not suitable for the collaboration
		Senior DN2	Separation	Characteristics of the **discipline are** not suitable for the collaboration
	Trd. Eng.	Senior DN3	Separation	Collaboration **topic** differs from academia, consumes research time
		Junior DN4	Synergy	Prefer to involve an industrial **project** to generate academic results
	New Eng.	Senior DN5	Separation	Collaboration with **local firm** generates only the funds for my laboratory
		Senior DN6	Synergy	In spite of poor resources, involved in a high-quality **project**
Middle Private Regional	Nat. Sci.	Senior DP1	Separation	Low scientific capacity of small local firms and low-quality **projects**
		Senior DP2	Synergy	Sufficient funds from **governments** helps high-quality practical research
	Trd. Eng.	Junior DP3	Synergy	The quality of the **project** is a critical factor for the mode
		Junior DP4	Separation	Characteristics of the **discipline are** likely to be linked to simple **projects**
	New Eng.	Senior DP5	Separation	Low capacity of **university** cannot attract high-quality **projects**
		Junior DP6	Synergy	Dependency on the requirements of the industrial **project**
Specialised	Trd. Eng.	Senior EA3	Separation	Low-level industrial collaboration **projects** and focus on industrial **training**
		Senior EA4	Separation	Low quality of the **project**, shortage of resources for basic research
	New Eng.	Senior EI5	Separation	Focus on **practical applications** originating from personal history
		Junior EI6	Synergy	Prefer to be funded by the **government** due to low pressure for product
	New Eng.	Senior EM5	Synergy	**Use-inspired research** is encouraged by the university & the government
		Senior EM6	Synergy	**Use-inspired research** is encouraged by the university & the government

(The table continued)

Uni. Type	Dis.	Career & Code	Mode	Main Reasons for the Mode Reported by the Academics
Small Private Regional	Trd. Eng.	Senior FP3	Separation	Focus on informal & **practical collaboration**, characteristics of discipline
		Senior EP4	Separation	Characteristics of practical **discipline**, low research capacity
	New Eng.	Senior FP5	Separation	Neutral, focus on informal and **practical collaboration**
		Junior FP6	Synergy	Network to big high-tech **firms** in spite of regional capacity and resource
Small Public Regional	Trd. Eng.	Senior FN3	Separation	Focus on **practical needs,** organisational orientation for industry
		Junior FN4	Separation	Industry-oriented sub-**discipline** in spite of synergy preference
	New Eng.	Senior FN5	Separation	Focus on **training** programme for employment funded by the government
		Junior FN6	Synergy	Characteristics of **discipline** oriented for application
Prestigious	Nat. Sci.	Junior GS1	Separation	**Contamination** of academic agenda by the industrial needs
		Junior GD1	Separation	**Contamination** of academic agenda by the industrial needs

* This table summarises the content of the interview data in terms of the relationship between the two modes and various facts. In addition, in the last column, the effect of the strengthened pressure for industrial collaboration on the activities of academics is summarised.

** The senior/junior allocation is determined using a career duration of 11 years, which means that junior professors began their career during the last half decade of the ’90s. Furthermore, after 11 years, Korean academics are usually promoted to a tenured position. However, because some departments have been established very recently, both professors in the department are assigned to the junior group. Some other departments have recruited no additional junior professors during last decade, so all the professors in the department are regarded as senior professors.

Appendix Table 7.2 List of Interviewees (13 universities, 65 professors, 07/05/07 – 27/06/07)

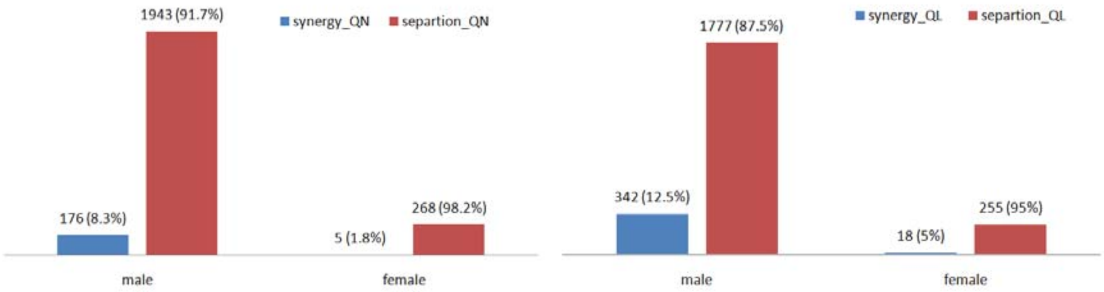
Type	Location	Discipline & Field	Name and Career period	Code
SBP	*S*	Physics	C. H. Oh (13), Y. G. Han (1)	A1, A2
		MecEng	K. S. Lee (27), S. Song (4)	A3, A4
		LifeEng	Y. H. Kim (3, D), H. Shin (2)	A5, A6
		IUCF	H. Lee (also Res. Dir.)	A7
RBN	*J*	Biology	N. E. Huh (18), S. H. Lee (8)	B1, B2
		ElclEng	S. H. Kim (19), T. H. Kim (3)	B3, B4
		InfoDev	Y. Y. Yang (18), S. G. Kang (5)	B5, B6
		ORIC	Y. L. Ha (also Res. Dir.)	B7
RBP	*D*	Chemist.	C. S. Lee (17), J.Y. Bae (1)	C1, C2
		ElcnEng	Y. Y. Chai (10), S.W. Kwak (5)	C3, C4
		Chemsys	H. K. Park (14), B. Lee (2)	C5, C6
		IACF	M. S. Han (also Res. Dir.)	C7
Mid	*S*	ElcPhys	Y. K. Kim (5, D) B.J. Park (2)	DS1, DS2
		RadEng	H. K. Yang. (15), H. Shin (4)	DS3, DS4
		EnvEng	N. C. Kim (18), K. S. Yoo (9)	DS5, DS6
		RIIC	K. Chung (also Res. Dir.)	DS7
	K	Math.	T. S. Jang (27), Y. J. Yoon (14)	DN1, DN2
		MecEng	B. M. Heo (20), G. Choi (3)	DN3, DN4
		MatEng	S. H. Lee (20, D), J. H. Joo (16)	DN5, DN6
		IACF	Y. H. Kim (No Res. Dir.)	DN7
	K	BmChe	J. Y Lee (24), B. J. Lee (21)	DP1, DP2
		CivEng	B. S. Cho (11), D. Y. Kwon (5)	DP3, DP4
		NanEng	G. S. Cho (23), K. H. Han (2)	DP5, DP6
		IACF	H. K. Choi (also Res. Dir.)	DP7
Spc.	*D*	Eng	M. S. Lee (12), J. Park (5)	EI5, EI6
		R&ICG	M. Kim (also Plan. Dir.)	EI7
	S	MolBio	J. J. Ko (22, RD), K. A. Lee (16)	EM5, EM6
		IACF	Y. G. Choi (Psnt of K-Cha Hsp.)	EM7
	W	AutoEng	S. K. Jo (13), S. H. Kang (12)	EA3, EA4
		IACF	S. G Jang (also Res. Dir.)	EA7
Sml.	*K*	TFTech	M. S. Park (23,D), W. K. Sung (18)	FP3, FP4
		DCEng	Y. T. Park (30), S. W. Ham (11)	FP5, FP6
		IACF	J. H. Yoo (No Res. Dir.)	FP7
	D	MecEng	B. C. Kwon (19), J. M. Choi (8)	FN3, FN4
		ComEng	K. H. Ahn (23), Y. C. Kim (10)	FN5, FN6
		IACF	B. K. Koo (No Res. Dir.)	FN7
Prst.	*S*	Biology	J. H. Seol (4)	GS1
		SNUIF	Y. Kuk (also Res. Dir.)	GS7
	D	Biology	D. Y. Lee (1)	GD2
		OUIC	S. H. Han (under O of Res. Dir)	GD7

* 7 types of universities: SBP (Seoul Large Private), RBN (Regional Large National), RBP (Regional Large Private), Mid. (Middle-sized), Spc. (Specialised), Sml. (Small), Prst. (Prestigious).

*** Names of the office of research affairs or industrial collaboration: IUCF (Industry-University Cooperation Foundation), OR&IC (Office of Research and Industrial Cooperation), RIIC (Research Institute for Industrial Cooperation), R&ICG (Research and Industrial Cooperation Group), IACF (Industry Academic Cooperation Foundation), SNUIF (Seoul National University Industry Foundation), OUIC (Office of University-Industry Cooperation)

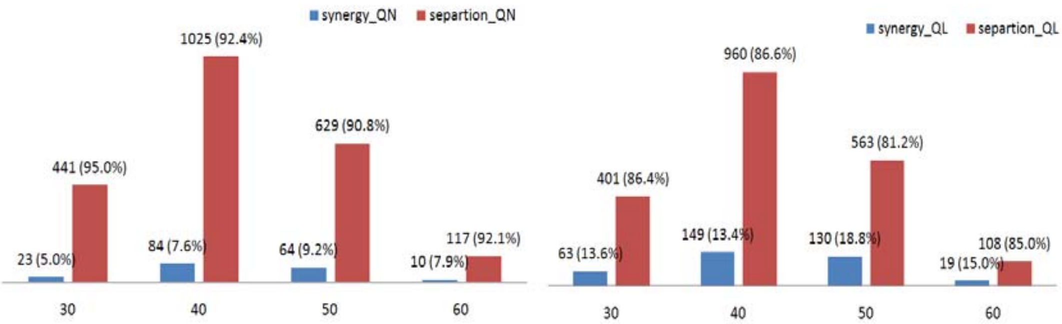
**** Names of departments and majors: MecEng (Mechanical Engineering), LifeEng (Life Engineering), ElclEng (Electrical Engineering), InfoDev (Information Technology Devices), ElcnEng (Electronic Engineering), Chemsys (Chemical System Technology), ElcPhys (Electrophysics), RadEng (Radio Science and Engineering), EnvEng (Environmental Engineering), MatEng (Material Engineering), BmChe (Biomedicinal Chemistry), CivEng (Civil Engineering), NanEng (Nano Engineering), MolBio (Molecular Biology), AutoEng (Automotive Engineering) TFTech (Textile and Fashion Technolgy), DCEng (Display and Chemical Engineering), ComEng (Computer Engineering)

Appendix Figure 7.1 Gender and the two modes



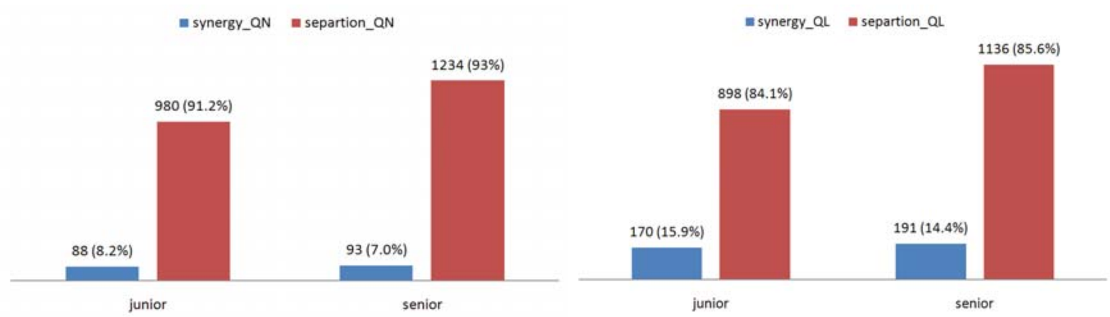
*According to the results of a Chi-square test, gender and the two modes both in qualitative and quantitative terms have a significant relationship within 0.1% significance level.
Unit: number of academics.
Source: constructed by the author, based on the survey data.

Appendix Figure 7.2 Age and the two modes



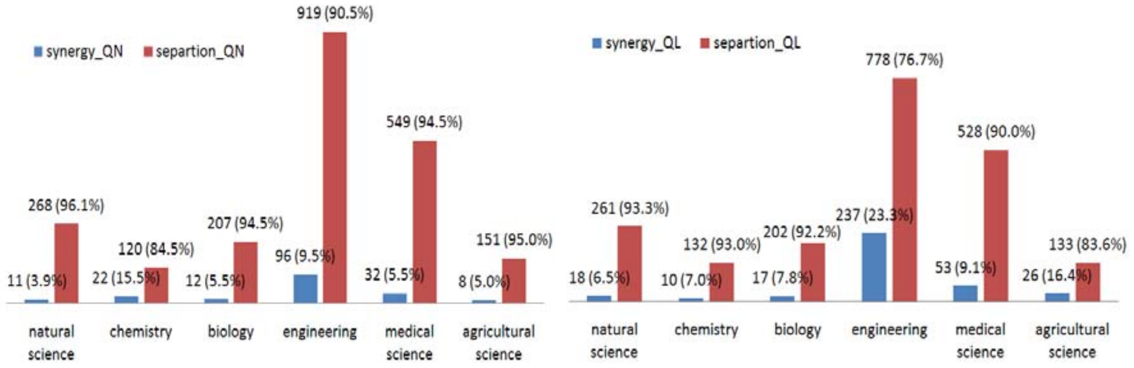
*According to the results of a Chi-square test, age and the two modes have a significant relationship within 5% significance level in quantitative terms, but no significant relationship in qualitative terms.
Unit: number of academics.
Source: constructed by the author, based on the survey data.

Appendix Figure 7.3 Career stage and the two modes



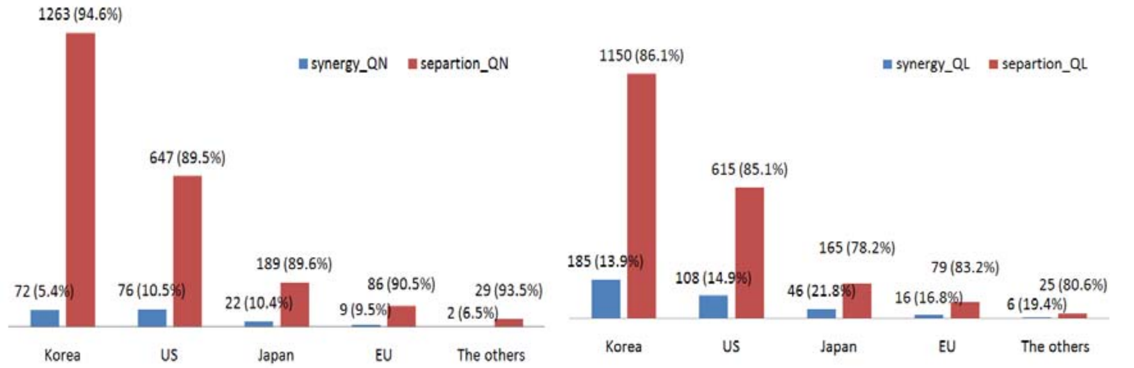
*According to the results of a Chi-square test, career stage and the two modes do not show a significant relationship within 5% significance level either in qualitative or quantitative terms.
Unit: number of academics.
Source: constructed by the author, based on the survey data.

Appendix Figure 7.4 Discipline and the two modes



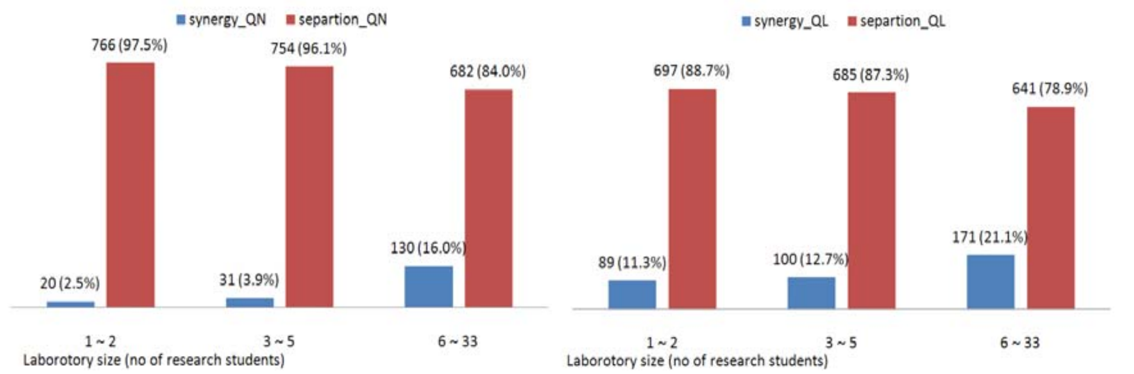
*According to the results of a Chi-square test, discipline and the two modes have a significant relationship within 0.1% significance level both in qualitative and quantitative terms.
Unit: number of academics.
Source: constructed by the author, based on the survey data.

Appendix Figure 7.5 The country of training and the two modes



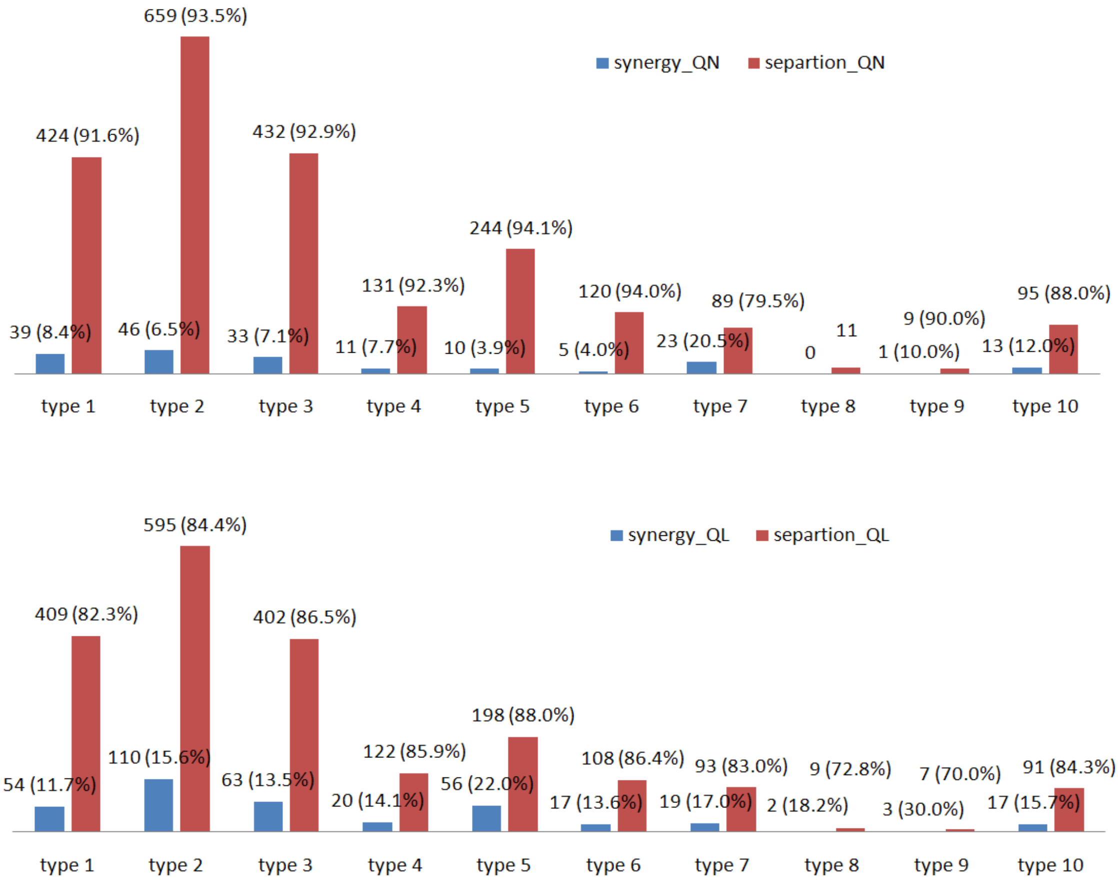
*According to the results of a Chi-square test, the country of training and the two modes have a significant relationship within 5% significance level both in qualitative and quantitative terms.
Unit: number of academics.
Source: constructed by the author, based on the survey data.

Appendix Figure 7.6 Laboratory size and the two modes



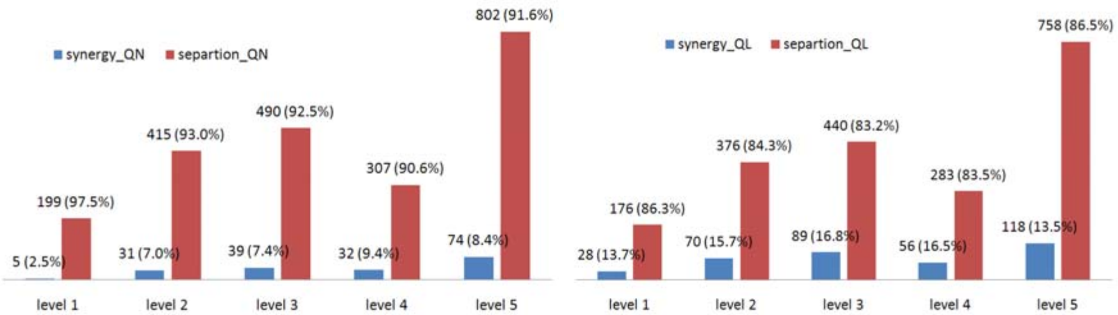
*According to the results of a Chi-square test, laboratory size and the two modes have a significant relationship within 0.1% significance level both in qualitative and quantitative terms.
Unit: number of academics.
Source: constructed by the author, based on the survey data.

Appendix Figure 7.7 University type and the two modes



*According to the results of a Chi-square test, university type and the two modes have a significant relationship within 0.1% significance level both in qualitative and quantitative terms.
**1: Old large private in Seoul, 2: Large public regional, 3: Large private regional, 4: Medium-sized and small private in Seoul, 5: Medium-sized public regional / industrial, 6: Medium-sized private regional, 7: Specialised in science & engineering, 8: Small private regional, 9: Small private industrial, 10: Outliers
Unit: number of academics.
Source: constructed by the author, based on the survey data.

Appendix Figure 7.8 Regional BERD and the two modes



*According to the results of a Chi-square test, regional BERD and two modes have a significant relationship within 1% significant level both in qualitative and quantitative terms.
** Levels of regional BERD (unit: 0.1bil won): 1 (100-1000), 2 (1000-3000), 3 (3000-10,000), 4 (10,000-20,000), 5 (20,000-110,000).
Unit: number of academics.
Source: constructed by the author, based on the survey data.

Chapter 8 Conclusion

8.1 Introduction

Chapter 8 summarises the main conclusions to emerge from this thesis. Based not only on the findings from the previous empirical chapters but also on the implications from the review of existing literature, we identify characteristics of the three missions of Korean universities and how they are related to one another. After summarising the empirical findings, we synthesise and discuss the implications of these findings.

Firstly, the main research interest of this study is discussed. In order to address this research interest, a summary of the research methodology is provided. Secondly, Section 8.3 summarises the main findings from the four empirical chapters. Based on these findings, we discuss the characteristics of the Korean academic system and its three main activities: teaching, research and knowledge transfer. In Section 8.4, the factors influencing the relationship between academic research and knowledge-transfer activities are discussed. Based on the factors involved in this relationship, the linkages between the different levels are investigated.

Finally, Section 8.5 gives an indication of the empirical and theoretical contributions (e.g. generalisation of the findings in a particular context to the wider world) as well as weaknesses of this study. Based on this critical assessment, we provide some suggestions for future studies. Additionally, some policy implications are suggested.

8.2 Research interests and methodology

The main research interest of this thesis lies in the identification of the relationship between universities' academic research and knowledge-transfer activities in a catch-up country, and the factors influencing this relationship. In particular, we have tried to explore the positive and negative relationships between the two major missions of academia by the various factors suggested theoretically and empirically at the three levels of analysis (i.e. system, organisation and individual). Based on the results of this exploration, we can extend our theoretical understanding (as well as our empirical knowledge) about university-industry and science-technology linkages in the context of a catch-up country, a topic that is more intensively discussed in Section 8.5.

In order to address the aims of the study, various approaches have been adopted in this research. First of all, at the system level, in terms of qualitative methods, we interviewed Korean academics and collected a large number of related documents. The interviews focused on Korean universities' teaching and research and their contributions to the national economy. Moreover, quantitative data were analysed to investigate the relationship between the academic research and knowledge-transfer activities of Korean universities as a whole.

Next, at the organisational level, the interviews focused on the organisational changes and environmental conditions influencing the three main activities of Korean universities. In particular, the directors of industrial cooperation offices and research affairs offices were interviewed about these issues. In order to complement this qualitative data, quantitative data collected from the annual national census on the activities of Korean universities were analysed.

Finally, at individual level, academics were questioned about their three main activities. In particular, the interviews focused on what sorts of conditions were influencing the positive and negative relationships between their academic research and knowledge-transfer activities. In the light of the responses to this interview question, statistical tests of the relationship between the two modes (i.e. separation and synergy modes) and various related factors were conducted.

8.3 Summary of findings and conclusions

8.3.1 Evolution and current status of the Korean university system

The revolutionary changes in western universities can be characterised by the adoption of research and its exploitation as central missions, i.e. the integration of teaching and research, and subsequently the direct economic contribution of universities. If we agree with this definition of the two 'academic revolutions' suggested earlier in Chapter 2, revolutionary changes in Korean universities can be said to have taken place during the last two decades. However, some characteristics of these revolutionary changes are significantly different from those in western universities, as they were influenced by the pre-existing and path-dependent systemic features of Korean higher education. For example, in Korea, as with other developing countries, the government has played a much stronger role in the catch-up process.

Furthermore, as a part of a rapidly-expanding university system, Korean universities share some characteristics with universities in developed countries, while some characteristics are more similar to those of universities in developing countries. For example, the research capacity of Korean universities was not a high-priority policy concern before the 1990s, as in other developing countries. However, unlike in other developing countries, Korea established a scientific infrastructure, including public research institutes and universities, early in the catch-up period (Albuquerque, 2001), while universities' mission focused largely on teaching and supplying standardised industrial labour. Therefore, these kinds of macro and historical conditions (both cross-sectional and longitudinal) have undoubtedly influenced the activities of Korean universities at the organisational level as well as at the level of individual researchers.

Chapters 4 and 5 investigate the evolution of the Korean higher education system. Historically, the Korean higher education system was strongly influenced by the US during the opening era and around the time of the Korean War, and by Japan during the earlier colonisation period, in terms of institutional forms and their subordinate relations to the government. Since the economic catch-up began in the 1960s, Korea has strongly encouraged the activities of its higher education system in serving industrial development as it has progressed through various developmental stages. At the 'strong regulation' stage, universities focused on the provision of technicians. As the need for higher education grew, the 'massive expansion' stage emerged. Finally, most recently, university research and its direct contribution to the economy have been invigorated by strong governmental support.

The strong control of the government over the Korean higher education system is a key factor in enabling us to understand its evolution. Even though the majority of Korean universities are private universities, the Korean university system has developed largely according to the government's education policy. In particular, the three main activities of the universities have been influenced by various government programmes, as well as by legal regulation. For example, as shown in Figure 4.5, the main source of universities' research funding is the government. Due to this active involvement of the government in universities' activities, Korea has developed its own rather idiosyncratic academic system. If we consider the tentative model of universities' historical paths in catch-up countries proposed in Chapter 2, Korean universities have evolved from the Humboldtian model into technical universities (i.e. having a strong interaction with other spheres of society following a high dependence on the state), and most recently, some evidence of a transition to 'entrepreneurial universities' (i.e. with growing independence from the state) has been observed.

In addition to the characteristics discussed at the system level, the organisational properties of Korean universities and the individual characteristics of Korean academics (investigated in Chapters 6 and 7 respectively) reveal the idiosyncratic characteristics of the Korean higher education system. First of all, in terms of organisational characteristics, the establishment of Korean universities has been heavily concentrated in two historical periods (i.e. around the Korean War in the 1950s, and later around the 'massive expansion' stage in the 1980s). More than 70 percent of universities are private due to an abrupt increase in the need for higher education, and to inadequate government support. More than half of the universities have fewer than 100 academics in science and engineering. Public universities have more varied departmental structures than private universities. If we take account of the relative population of the regions, the geographical concentration of Korean universities (particularly around Seoul) is not so disproportional.

Based on their institutional properties, ten main types of Korean universities are identified in Chapter 5. This typology enables us to identify certain characteristics of Korean universities in terms of their organisational resources and activities.[44] In terms of resources, as revealed by the development of the Korean higher education system through a number of different stages, the large private universities near Seoul would seem to be in a more advantageous position for attracting students and research funding than small universities in the regions. Furthermore, among the universities in the

[44] The activities of the different types of Korean universities are discussed in subsection 8.3.2.

regions, public universities are in a better condition than other types of universities. However, we have failed to find a significant and consistent relationship between funding from the central government (the major source of funding for universities' research activities) and knowledge-transfer activities, whereas funding from industry is a significant and consistent predictor for knowledge-transfer activities. In terms of organisational and environmental characteristics, the size of the universities and their TTOs were observed to be significant predictors for their knowledge-transfer activities.

Next, the individual characteristics of Korean academics (e.g. gender, career stage, discipline and country of training) in science and engineering, as discussed in Chapter 7 (see Table 7.6 and Appendix 7.1), also enable us to understand Korean universities at the system level. According to the distribution of career stage, we can identify three peaks of recruitment in the 1980s, 1990s and 2000s. The last two peaks coincide with the two academic revolutions in Korea. In particular, regarding the third peak, around 40 percent of current academics were recruited after 2000, which implies a recent need for academics in Korean universities. About half of the academics are working in public universities, despite the fact that more than 70 percent of Korean universities are private. This fact is related to public universities being more focused on science and engineering than private universities. 40 percent of academics in science and engineering are in the discipline of engineering, reflecting the government's encouragement of the strengthening of the discipline, which is closely related to its emphasis on industrial exploitation. More than half of all academics work in the capital area. If we consider the population of the area (20 million, out of 40 million in Korea as a whole), the proportion of academics in the capital is not over-concentrated. About 40 percent of the academics were trained in overseas institutions, and 70 percent of those were trained in institutions in the US. This reflects Korean universities' continuing dependence on overseas institutions in terms of producing highly-qualified scientists. However, the proportion of domestically-trained scientists recruited in Korean universities has started to increase very recently.

8.3.2 Three activities of Korean universities and their relationship at three levels

The three missions of Korean universities were developed in order to meet national goals set by strong government initiatives and interventions. Based on the empirical findings outlined in this section, we can find a close relationship between the three missions, particularly at the three levels examined (i.e. system, organisation and individual levels). Throughout the four empirical chapters (Chapters 4, 5, 6 and 7), the three activities of teaching, research and knowledge transfer have been investigated at these three levels.

Firstly, at the **system** level, the appropriate supply of human labour has been an important factor in the development of the Korean innovation system, as shown in Chapter 4. In this respect, the government recognised that controlling the teaching activity of Korean universities was an important policy measure in meeting changing industrial demands as the country engaged in different stages of industrialisation. Accordingly, at the system level, we observe a co-evolving relationship between teaching (as measured by the number and disciplines of graduates) and industrial structure (as measured by different sectors of industry), which has been mainly mediated by government education policy. Furthermore, both the research and the knowledge-transfer activities of Korean universities at the system level are closely related to the industrial structure. As shown in Chapter 4, research activity has been invigorated since the 1990s, while knowledge-transfer activity was strongly activated after 2000. Both these activities were also part of the government's higher education policy, orienting universities towards industrial usefulness. Therefore, over time the disciplinary changes of both research activities (as measured by the number of publications) and knowledge-transfer activities (as measured by the number of patents) have been closely matched to the sectoral changes taking place in industry. This is more thoroughly discussed later in Section 8.4.

Secondly, according to the analysis based on the typology of universities developed in Chapter 5, teaching activity (as measured by the number of undergraduate students) is likely to be negatively related both to research activity (as measured by the number of scientific papers) and to knowledge-transfer activity (as measured by the number of patents and technology transfers). However, according to the interviews, certain types of universities have made various efforts to integrate teaching into both research and knowledge-transfer activities. In other words, not only teaching but also research and knowledge-transfer activities are carried out in order to produce directly-applicable outputs for industry. Therefore, in this case, teaching is not in conflict with research and knowledge-transfer activities. Furthermore, as shown in Chapter 6, at the **organisational** level, academic research (as measured by the number of papers) and knowledge-transfer activities (as measured by the number of patents and technology transfers) are positively and significantly related to each other. This implies that scientific capacity can be regarded as an important factor with regard to knowledge-transfer activities. This is discussed further in Section 8.4. In addition, the size of universities (as measured by the number of academics) and the amount of funding from industry is also important for knowledge-transfer activities, whereas teaching activity (as measured by the number of undergraduate students) is not significantly related to knowledge-transfer activities.

Finally, at the **individual** level, according to the interviews, the focus of teaching activities seems to have changed during the last few decades. In terms of teaching, laboratory research skills and improvements in the practical curriculum following requests from industry are considered more important than mastering textbooks. Furthermore, teaching activities are regarded as constraints by academics who need free time for research and knowledge-transfer activities. Therefore, if academics are intensively involved in research activities, this can be regarded as a negative factor for teaching and knowledge-transfer activities. By contrast, some academics located in less privileged institutions, such as small universities in regional areas, have developed their teaching curriculum to be more practical. This increases their students' chances of being recruited by companies, and teaching can therefore be integrated into knowledge-transfer activities based on industrial needs.

Academics closely involved in knowledge-transfer activities tended to report that it was hard to allocate time for academic research, whereas others tried to focus on the research area most likely to generate results for both academic research and knowledge-transfer activities. We focus more closely on the relationship between academic research and knowledge-transfer activities, and the factors influencing the relationship. According to the results of statistical analysis in Chapter 7, not only individual characteristics (i.e. the gender, age, disciplines of academics, patenting activity, etc.) but also contextual characteristics (i.e. laboratory size and type of university) are significantly related to the generation of 'synergy mode' (i.e. a positive relationship between academic research and knowledge-transfer activities) among academics. This is discussed further in the following section.

8.4 The close relationship between the second and the third missions of Korean universities

This section focuses on the close relationship between the second and third missions (i.e. academic research and knowledge-transfer activities) at the three levels. Subsection 8.4.1 focuses on the relationship between the two missions and the factors influencing the relationship, and subsection 8.4.2 discusses the interaction between different levels according to the factors discussed in subsection 8.4.1.

8.4.1 Factors involved in the relationship between academic research and knowledge-transfer activities at the three levels

Firstly, at the **system** level, the characteristics of the three main actors – government, industry and universities – can be regarded as major factors involved in the relationship between academic research and knowledge-transfer activities. The most important factor influencing this relationship is apparently government policies; this is outlined in Section 8.3. Government policies have created conditions in which the academic disciplines, the age of the institution and the academics, and various other characteristics of institutions have influenced the relationship at both organisational and individual levels. This is discussed further in subsection 8.4.2. Based on these conditions, Korea has developed its academic system in harmony with the pursuit of industrial growth. In this process, the role of government has been important as a leader as well as a coordinator. As a result of various governmental policy efforts to mobilise academic potential for industrial application, Korean universities' outputs of science and technology are quite similar to each other in terms of discipline. The recent sudden expansion of publications and patents, as well as the similarity between them in terms of discipline, implies that the two missions have been relatively closely coupled, as shown in Chapter 4.

Next, the direct financial influence of industry on universities' knowledge-transfer activities has emerged as an important factor, as shown in Chapters 4 and 6. This is partly because industry's demand for R&D capacity has increased with the production of highly competitive products, and firms lacking a strong R&D capacity have begun to recognise universities as possible research agents. Therefore, if industrial influence on universities grows stronger than before, the relationship between academic research and knowledge-transfer activities may be positively affected. In other words, the structural similarity between university output and industry sectors could be strengthened according to the needs of industry. On the other hand, the government's weakened institutional control could increase the institutional autonomy of universities to reorganise the relationship between academic research and knowledge-transfer activities. However, this autonomy could also result in a strengthened relationship between them.

Finally, in addition to government and industry as external factors, at the system level the characteristics of universities themselves are also an important factor with regard to the relationship between their second and third missions. Their direct dependence on external resources such as research funding has weakened the development of their own research agenda. If academics want to undertake research, they have very little option but to carry out research projects closely related to industrial usefulness as directed by government officials. Furthermore, to date financial dependence on government funding has increased rapidly, while industry funding has also grown steadily. This condition has partly contributed to the closeness of the two missions. Therefore, if this state of weak financial autonomy (in spite of improved institutional autonomy) remains in the future, the close relationship between academic research and knowledge-transfer activities may well be strengthened in accordance with the government's research agenda.

Secondly, at the **organisational** level, scientific capacity, in terms of both quality and disciplinarity, is significantly related to knowledge-transfer activities. The knowledge-transfer activities of universities are related to institutional properties such as legal status and size, as well as to other activity variables such as teaching load and academic research, as shown in Chapter 6. According to the analysis of activities based on the university typology in Chapter 5 (see Figure 5.5), universities with a higher level of academic research output also show a higher level of knowledge-transfer activities, except for small private industrial universities. Furthermore, the levels of both academic research and knowledge-transfer activities are positively related to university size (as measured by the number of academics). However, in the case of small private industrial universities, they are better at applying for patents than publishing papers when compared to other types of university. This means that organisational characteristics have some influence on the relationship between academic research and knowledge-transfer activities. According to the interviews carried out, certain types of universities are more focused on (practical) knowledge-transfer activities than (highly-qualified) academic research.

In addition to organisational properties, contextual characteristics such as location, proximity to industry, and regional business expenditure on R&D are also involved in the relationship between academic research and knowledge-transfer activities. According to the interviews discussed in Chapter 5, universities located near large industrial complexes, or located near Seoul, or in a region with higher levels of business expenditure in R&D are more likely to exhibit a positive relationship between academic research and knowledge-transfer activities. However, as we discussed in Chapter 6, this involvement was not confirmed by statistical tests. This is discussed in the following subsection.

Finally, at the **individual** level, based on the interviews introduced in Chapter 7, we found a type of academic benefiting from industrial collaboration (those academics operating in synergy mode). One determinant of this type is related to individual properties such as the career stage and the discipline of the academic. According to the interviews, some senior academics (who are likely to have relatively abundant research resources) tend to operate in synergy mode. This finding is somewhat consistent with the statistical results based on model 6 in Table 7.8. On the other hand, according to the interviews, they are also likely to operate in separation mode because of the generation effect. In other words, considering that academic behaviour and culture cannot easily be changed and that it is supported by the internal rules of universities, we can regard the senior academics recruited before the 1990s as academics operating in separation mode. This argument is consistent with the statistical results based on models 1 and 2 in Table 7.7. Next, the disciplines of academics are also related to the determination of synergy mode according to both the interview results and statistical tests of all the models in Tables 7.7 and 7.8. In particular, academics in engineering are more strongly related to synergy mode than those in other fields.

In terms of contextual variables, the characteristics of affiliated organisations (such as size, legal status and location) and the research capacities of interacting companies are related to the determination of synergy mode according to the interviews. This relationship is discussed in depth in the following subsection addressing interaction between different levels.

8.4.2 Interaction between actors at different levels according to various factors

The concluding part of Chapter 4 outlines the constraints imposed on the Korean academic system affecting the three missions both at organisational level and individual level. In summary, the characteristics at the system level have created conditions related to several variables (e.g. discipline, age of institutions and individual, organisational characteristics of institutions, and characteristics of the system) influencing the behaviour of both organisations and individuals in terms of academic research and knowledge-transfer activities. This subsection explores these influences, whether positive or negative, in more detail. In other words, the interaction between the actors at the three levels is the central topic of this subsection.

Firstly, within different time periods, different types of universities, as well as different types of academics have been created. As discussed in Chapter 4, the founding year of a university is an important indicator to understanding its behaviour. Based on their long history, the older universities (established before the liberation in 1945) are more likely to be independent (most of them are private) and prestigious than other universities. Middle-aged universities (established just after the liberation from Japan) were established in Korea’s early period of industrialisation. Therefore, they are likely to have been mobilised to provide industrial labour by a ‘strong’ government. Finally, young universities (created around the 1980s) were established in the period of mass education, so they are likely to focus on vocational training addressing the practical needs of students rather than on academic research. This has been confirmed by the analysis of the activities of universities according to the typology set out in Chapter 5, and by the analysis at the organisational level in Chapter 6.

Different time periods have also created different types of academics. Senior academics recruited by universities before the 1990s are likely to focus mainly on teaching due to both the strong government policy of encouraging the supply of industrial labour, and to the partial deregulation of admissions. Furthermore, research and knowledge-transfer activities are recognised as a personal activity by academics themselves as well as by policy-makers; however, the resources available for academics are not adequate. In contrast, academic research and knowledge-transfer activities have been strongly recommended to junior academics who joined academia after the 1990s. In terms of the external environment, the policy-makers set up a system to exploit academic potential for the purpose of industrial development. In terms of internal conditions, universities strengthened the incentive system for academic research and knowledge-transfer activities. This was confirmed by both interviews (see Table 7.3) and statistical analysis (see Tables 7.7 and 7.8) in Chapter 7.

Secondly, besides being important at the system level, research disciplines are also important for the relationship between academic research and knowledge-transfer activity at the organisational level as well as at the individual level. Therefore, certain disciplines provide a key to understanding the relationship between academic research and knowledge-transfer activities across the three different levels. At the system level, the Korean government has supported several disciplines (particularly in the area of engineering) that are closely related to industrial applications (see Figures 4.7 and 4.8 and Table 4.16). These characteristics are linked to universities' knowledge transfer activities at the organisational level. The universities' scientific capacity in engineering is important for knowledge-transfer activities (see Tables 6.10 and 6.11). At the individual level, disciplines have again proved to be an important factor for the relationship between academic research and knowledge-transfer activities. According to both the interviews (see Table 7.3) and statistical analysis (see Tables 7.7 and 7.8), academics in application-oriented disciplines such as engineering are more likely to show a positive relationship between academic research and knowledge-transfer activities than those academics in other disciplines.

Thirdly, interaction between the system and individual levels can be observed in terms of the organisational and environmental characteristics of universities, such as their size, legal status and location. These characteristics are also closely related to the 'imbalanced' higher education policy of the Korean government, as explained in Chapter 4, where we saw how the policy provides more resources to larger universities.

Based on this policy, universities owned by the government, located in Seoul, and large in size have benefited most from government resources. Therefore, these privileged universities have been able to respond better to a new environment (the second and third academic revolutions) than less privileged universities (those that are private, small and local), by producing high-quality research output and actively transferring the knowledge they create. This is confirmed by the analysis based on the typology of universities in Chapter 5, and the analysis based on the properties of individual organisations in Chapter 6.

Furthermore, these organisational characteristics are also related to the activities of individual academics. In interviews, academics asserted that their level of research resources, such as funding and postgraduate students, is likely to be influenced by the reputation of the institution to which the individual is affiliated. From another point of view, this could be regarded as an excuse for their weak research capacity in attracting resources. However, various organisational characteristics, such as the type of university based on several organisational properties (i.e. size, legal status, founding year, generality and location), as well as the organisational properties themselves, have turned out to have a significant effect on the relationship between the academic research and the knowledge-transfer activities of individuals (see Tables 7.7 and 7.8).

Finally, the country of training, which is an individual characteristic closely related to higher education policy at the system level, is also related to the relationship between academic research and knowledge-transfer activities. As outlined in Chapter 4, this is based on a historical dependence on overseas institutions in terms of the training of highly-qualified scientists since the 1950s. In terms of both patents and papers (i.e. synergy mode measured quantitatively), academics trained in Japan proved to be significantly more productive than academics trained domestically. However, we cannot find any evidence for a significant difference between domestically-trained academics and academics trained overseas in terms of the relationship between academic research and knowledge-transfer activity (i.e. in terms of synergy mode measured qualitatively). Furthermore, synergy mode as measured qualitatively is negatively and weakly related to the production of papers, but positively and strongly related to applications for patents, as shown in Chapter 7 (see Tables 7.7 and 7.8). These two empirical results imply that, regardless of the location of training, academics with a strong patent performance are more likely to be operating in synergy mode (particularly when measured by qualitative indicators). Therefore, we may argue that the policy encouraging or allowing dependency on overseas institutions at the system level has been successful in terms of academic excellence, but unsuccessful in generating close relationships between academia and industry, even though the quality of the relationship varies widely.

8.5 Contributions and future studies

In this section, we discuss the theoretical and empirical contributions of this study at the three levels. The weaknesses and flaws of this research are then critically examined. Finally, based on these discussions, some policy implications are suggested.

8.5.1 Contributions of this study

The most significant contribution of this study is not only the investigation of an unexplored area, but also the uniqueness of the methodology adopted. First of all, in terms of the novelty of the area investigated, this research has separated the role of universities from that of public research institutes instead of dealing with public science as a whole in catch-up countries, something which has only rarely, if ever, been done before. Regarding this newly-proposed research area (i.e. the activities of universities in a catch-up country), an identification of the factors influencing the relationship between academic research and knowledge-transfer activities has been carried out at three levels. Next, in terms of the overall methodology adopted, as far as we know, such a detailed analysis of a single academic system based on the integration of different levels (i.e. system, organisation and individual levels) and on the integration of qualitative and quantitative approaches has rarely been done before. As shown in subsection 8.4.2, the integration of the multi-level analysis based on a cross-cutting variable (i.e. the relationship between the two missions of universities) is also a part of the uniqueness of this thesis and of its original contribution.

More specific discussions of the contributions of this study in both theoretical and empirical terms are addressed according to the three levels. Moreover, we discuss how far we can generalise from these empirical and theoretical understandings of the Korean case to other countries' academic systems. The discussion of this generalisation is based on the comparison of both the similarities and differences which exist between Korea's and other countries' academic systems, as well as the environments which the systems operate.

Firstly, at the **system** level, this study provides a possible starting point for a conceptual framework to better understand the close relationship between academic research and knowledge-transfer activities of universities in catch-up countries such as Korea and other East Asian countries.

In the case of Korea, strong government intervention has been one of the critical factors influencing this close relationship (see Chapter 4). Chapter 2 discusses the fact that the East Asian governments strongly control not only industry but also academia. Based on this, we propose a historical pathway of the development of East Asian universities, as opposed to universities in other developing countries. This study provides an empirical basis for this model at least in the case of the Korean university system by investigating the interaction between Korean universities and the policy environment according to different development stages. As long as other East Asian universities (e.g. Taiwan and Singapore) have similar conditions to those of the development of Korean universities (i.e. a strong government encouragement of universities' provision of human resources in the early catch-up stage, and a mobilisation of university research for the national innovation system in the final stage) (see Chapter 2), we can generalise this model not only to universities in other East Asian countries, but also to universities in other rapid catch-up countries.

Our findings also contribute to the enrichment of theoretical issues developed in universities in western countries. This study empirically supports the idea that the application of the concept of a 'republic of science' or 'open science', and its conflict with industrial involvement in the context of developing countries has some limitations. The Korean academic system has developed its own norms, which are somewhat different from those of western countries (such as Mertonian norms). In other words, Korean academics are relatively willing to participate in industrial collaboration, and the institutional setting encourages them to develop their knowledge-transfer activities. This explains the way that the close relationship between teaching and economic contribution, and between academic research and knowledge-transfer activities has evolved in Korea during the last half-century. These findings may be extended to certain academic systems in western countries which have similar conditions to those of the Korean academic system mentioned above. Moreover, in western countries, certain types of universities that strongly interact with government policy (e.g. technical universities in France and Germany) may also develop such a close relationship between academic research and knowledge-transfer activities.

Secondly, at the **organisational** level, we also confirm the close relationship between academic research and knowledge-transfer activities in Korean universities. Regarding various organisational factors influencing knowledge-transfer activities, we focused on scientific capacity and government funding, considering the context of developing countries (i.e. efforts aimed at the industrial exploitation of the certain disciplines of academic potential). According to the empirical results, the disciplinary effect of scientific capacity on universities' knowledge-transfer activities is significant. Thus, we found that not only scientific capacity itself (Sapsalis et al, 2006; Owen-Smith, 2003) but also the disciplinary variation of scientific capacity is important for universities' knowledge-transfer activities. This suggests a subsequent research question with regard to disciplinary differences for universities in developed countries. Next, in terms of funding sources, empirical results from this study corroborate some of the findings from studies in developed countries (i.e. the absolute size of each funding is more important than the proportion of each funding to total funding). However, as the specific characteristics of funding sources differ according to the different national funding systems of universities, we need to be careful in terms of generalising these findings.

Thirdly, at the **individual** level, based on the conceptual argument in Chapter 2 and the evidence provided in Chapter 4, a conceptual framework based around the notion of a 'synergy mode' is suggested at the individual level. Based on this conceptual framework, we can not only identify the academics carrying out research closely related to industrial collaboration, but also investigate the factors influencing the relationship between academic research and knowledge-transfer activities. In other words, in an epistemological sense, this concept helps us to proceed from the existing question: 'Is academic research in conflict with knowledge-transfer activity?' to the new question: 'What is important for creating a positive relationship between academic research and knowledge-transfer activity?' This shift, we would argue, is valid not only for catch-up countries, but also for developed countries. In the case of a catch-up country, gender, discipline, laboratory size, and type of university were found to be very important factors influencing the two modes. In particular, gender, discipline and laboratory size are positively, consistently and very strongly related to the synergy mode of academics. These factors may well also be important in the case of academics in developed countries.

In terms of the sophistication of our conceptual framework, in Chapter 2 we start from a simple conceptual framework that adopts only academics' discipline as a single factor influencing the determination of the synergy mode. In Chapter 7, we found that other individual factors as well as contextual factors are involved in this process. In other words, we developed a more sophisticated framework that enables us to understand the operation of the synergy mode. Moreover, we measure the synergy mode in three different ways: interviews, quantitative data, and qualitative questions posed by means of a survey. By comparing the results from these three approaches, we can arrive at a more enriched understanding of the synergy mode. This may contribute to future discussions of how to operationalise and estimate the synergy mode.

8.5.2 Limitations and further studies

Some limitations of the present study, and suggestion for further studies to address these limitations, can be outlined. After the discussion of the overall weaknesses of this study, specific limitations are considered according to the different analysis levels (i.e. the system, organisation, and individual levels).

First of all, the overall weaknesses of this study will be discussed. In terms of the generation of a new conceptual framework, if firm-related data could be integrated, the factors relating to the synergy mode of companies as well as to the synergy mode of both academics and industrial entrepreneurs could perhaps be identified. Therefore, in order to understand the influence of demand-side (industry) factors on the synergy mode of academics, a further study of the characteristics of collaborating firms needs to be conducted. Moreover, at the organisational level, firm-side factors influencing universities' knowledge-transfer activities could be added to our statistical model.

In terms of empirical novelty, at the organisational level, data based on the census of all Korean universities have been analysed for the first time. Moreover, at the individual level, analysis based on a large amount of data (i.e. more than 2,000 cases) has increased the reliability of the statistical analysis. However, those statistical data that were analysed are mostly cross-sectional, so the scope for the interpretation of the results in terms of causality is quite limited. In further studies, if one were to add multiple-year data to the existing data, a more advanced statistical analysis based on time-series data could be implemented. This might enable us to provide more robust answers to our research questions.

Next, let us discuss the limitations and potential further studies according to the three levels. Firstly, at the system level, this study focused on a single country, so despite there being some generalisable patterns with other catch-up countries as discussed in the previous subsection, the extent to which one can generalise is still quite limited. If one were to carry out comparable case studies on the development of universities' activities in other catch-up countries, the generalisablity of our findings could be substantially increased. Based on the framework (i.e. the two contrasting historical paths of universities, and the distinction between the synergy and separation modes) suggested in this study, comparison with other catch-up countries as well with as certain developed countries could generate richer findings. Thus, comparative studies with other catch-up countries, such as Taiwan and Singapore, as well as on industrialised countries could provide a richer understanding of academics in these countries.

Secondly, at the organisational level, as discussed in subsection 6.3.3, the endogeniety problem limits our interpretation of the statistical findings in terms of the direction of causality of the two variables (i.e. knowledge-transfer activities and scientific capacity). Therefore, in later studies, a specific method to overcome this problem needs to be adopted. For example, instead of the number of publications, an instrumental variable representing scientific capacity could perhaps be included as one of the predictors in a statistical model. Panel data would also help in solving this problem.

Thirdly, at the individual level, owing to the parallel process of the two approaches of the data-collection (i.e. survey and interviews), one variable (i.e. gender) that proved to be significant in the statistical analysis is not included in the qualitative analysis (see

Section 7.3). Therefore, interviews on gender difference and its involvement with the synergy mode need to be carried out in later studies. Moreover, due to the confounding career and cohort effect, the 'pure career' effect cannot be identified. In later studies, the collection of pooled data consisting of several groups of cohorts will enable us to separate age and career effects from cohort effect. Finally, the categorisation of the disciplines of academics needs to be more clearly specified in later studies. In particular, a new way of categorising engineering fields perhaps needs to be introduced.

8.5.3 Policy implications

The findings of this study provide the basis for a number of policy recommendations for supporting the activities of academics and universities in other catch-up countries and developing countries, as well as for the invigoration of the innovation system at the national level, as we shall now discuss.

Firstly, at the system level, the Korean case can provide other catch-up countries and developing countries with lessons in terms of the role of their universities. The challenge that those countries are facing is how to set up and invigorate the two main missions of universities in their national innovation system. In the case of Korean universities, after completing the vitalisation of provision of industrial labour, the time gap between the first academic revolution and the second academic revolution was too short to fully complete the first one, so two revolutionary changes occurred almost simultaneously. These two revolutions were made possible because the allocation of scientific resources has been largely dependent on government decisions based on industrial practicality, rather than on independent decisions of scientists based on scientific excellence.

Considering the generalisation issue discussed in subsection 8.5.1, we can suggest certain issues with regard to the implementation of the 'benchmarking' of the Korean case. On the one hand, as long as certain conditions of the initial developmental stage (as Korean universities experienced) are fulfilled, policy-makers in other countries might expect similar growth to that of Korean universities. In particular, in order to strengthen the universities' role as 'an engine for the economy', the government needs to implement policy measures designed to harmonise the activities of industry and academia. Such a policy would be effective only if higher education policy is consistent with other policies such as industrial policy and science and technology policy, as shown in the Korean case. On the other hand, we need to consider that the current external situation of universities in developing countries is different from that of Korean universities in the 1960s. For example, we need to consider the fact that the chosen path of industrial development might be (or might need to be) different from that of Korea. Therefore, governmental support needs to be focused on those academic disciplines that are closely related to strategic sectors of their national industry. However, the continuing substantial gap of scientific resources between the developed and the developing countries could be a negative factor for in terms of enhancing research activities meeting local demand from industry.

Secondly, based on the findings at the organisation level, various policy recommendations (mainly for the Korean government) can be put forward. If the government desires programmes of university-industry collaboration (particularly aimed at the production of patents and revenues from technology transfer) to be carried out more efficiently, the size of universities, in terms of both the number of academics and their scientific performance in specific disciplines, needs to be seriously considered. Moreover, an indirect policy measure to attract and to increase the amount of industrial funding is very important. According to our findings, the size of TTOs is more consistently related to the number of domestic patent applications than to overseas applications for high-quality patents, technology transfer and revenue creation. This might indicate that the current TTOs are more focused on short-term (or highly and easily visible) performance than on generating more innovative and commercially meaningful outputs. Therefore, additional policy measures needs to be considered in order to encourage TTOs to more intensively involve in long-term and high value-added knowledge transfer.

Finally, at the level of individual academics, a policy encouraging knowledge-transfer activities based on only highly visible outputs such as patents and papers could distort the behaviour of academics. In other words, as shown in Chapter 7, if we define and encourage the synergy mode based only on a quantitative approach, the effect of the policy measures might be limited, because the factors influencing the synergy mode have only been partially identified. Therefore, we need to consider the factors identified based on qualitative synergy as well. Moreover, programmes supporting those academics generating synergistic university-industry linkages can be promoted in a more effective way. For example, a programme of research funding aiming to strengthen university-industry linkages focused on junior academics with strong publication records in large universities near Seoul needs to be considered. Furthermore, in spite of certain negative opinions about the promotion of university-industry linkage programmes by supporting regional public universities such as NURI (the New University for Regional Innovation), the synergy mode of academics is found to be significant in such types of universities. This may indicate that the programme has had an effect on the formation of mutually beneficial relationships between academics in regional universities and industry.

In summary, this study adopts a mixed research design integrating not only the three analysis levels (i.e. national, organisational and individual levels) but also the quantitative and qualitative methods (i.e. survey and interviews). Based on the data collected by this research design, we investigate the relationship between universities' academic research and their knowledge-transfer activities. According to the results, we identified a close and positive relationship between the two activities and various factors involved in the relationship at the three analysis levels.

Firstly, at the national level, strong government control over the higher education system has been the most critical factor for the co-evolution of the Korean university system and industry, as observed in the structural similarity between the two actors' activities and between universities' academic research and knowledge-transfer activities. Secondly, at the organisational level, regarding the positive relationship between universities' two activities, scientific capacity (i.e. academic research activities) is positively and significantly related to knowledge-transfer activities. In particular, scientific capacity in the discipline of engineering is a strong predictor for universities' knowledge-transfer activities. This is also related to the selective development of universities' research activities in a catch-up country as discussed at the national level. Thirdly, at the individual level, the career stage and discipline of academics are significantly related to their knowledge transfer activity in relation to their academic research activity. This result is also in the same vein as the findings from the analysis at the two upper levels in terms of the close interaction between the universities' two activities and the selectivity of the activities resulting from strong government intervention.

Based on these findings, we can conclude that in contrast to the concerns raised by the ‘new economics of science’ or ‘open science’ approach, universities’ academic research activity has not been contradictory to their economic contribution to society in rapid catch-up countries. Moreover, ‘national innovation system’ and ‘triple helix’ approaches cannot fully explain the historical formation and development of academic society in catch-up countries, such as a harmonious evolution of university and industry. This is due to the fact that in catch-up countries, universities’ research capacity across academic disciplines and their autonomy have not been fully developed, whereas government control has exerted a strong influence on universities’ activities. This implies that, unlike universities in other developed and developing countries, those in catch-up countries have developed their own highly-interacting but easily-mobilised academic system by the government.

Appendix 7.1 Response Analysis of the Survey Results

In this response analysis, we are going to investigate whether the responding group represents the selected group well in several aspects, such as career stage, gender, affiliation, discipline, and the country in which the final degree was given.

A. Career Stage

A career stage is defined as the term after the individual was hired as a tenure-track professor. As shown in the table below, younger professors tend to show a higher response rate, whereas the older professors show a lower response rate, in spite of their bigger proportion in the selected population. Moreover, according to a t-test, the mean value of carer stage responding group (11.30) is significantly smaller than that in selected group (14.42) within 5% significance level.

Career Period*		1~5	6~10	11~15	16~20	20~	No Rsp.	Sum
Rspnd	Freq.	687	430	490	313	440	35	2395
	%	28.68	17.95	20.46	13.07	18.37	1.46	100
Slctd.	Freq.	3307	3252	3934	2758	4251	1021	18523
	%	17.85	17.56	21.24	14.89	22.95	5.52	100
Rsp. Rate (%)		20.8	13.2	12.5	11.3	10.4	-	12.9

*Unit of career stage: year.

B. Gender

In terms of the gender of the professors, the response rate shows only a slight difference between male and female professors. Moreover, according to a t-test, the proportion of male academics in responding group (0.89) is not significantly different from that in selected group (0.88) within 5% significance level.

Gender		Male	Female	No Rsp.	Sum
Rspnd. group	Freq.	2119	273	3	2395
	Rate (%)	88.48	11.40	0.13	100
Slctd. group	Freq.	16271	2188	64	18523
	Rate (%)	87.84	11.81	0.35	100
Rsp. Rate (%)		13.02	12.48	-	12.9

C. Characteristics of affiliated universities

- Legal status

Professors affiliated to public (national and prefectural) universities tend to show a higher response rate. Moreover, according to a t-test, the proportion of public universities in responding group (0.41) is significantly smaller than that in selected group (0.48) within 5% significance level.

Legal Status		Public	Private	No Rsp.	Sum
Rspnd. group	Freq.	1150	1245	0	2395
	Rate (%)	48.00	52.00	0	100
Slctd. group	Freq.	7852	10941	0	18523
	Rate (%)	40.9	59.1	0	100
Rsp. Rate (%)		14.65	11.38	-	12.93

- Size of university

The professors affiliated to middle-sized universities (500 – 700 academics) show the highest response rate, while those in the biggest universities show the lowest response rate. Moreover, according to a t-test, the mean value of university size of responding group (469) is significantly smaller than that in selected group (550) within 5% significance level.

Size*		~100	~200	~300	~400	~500	~600	~700	~800	~1000	~1100	Sum
Rsp.	Freq.	65	288	181	343	188	438	260	398	56	178	2395
	Rate	2.7	12.0	7.6	14.3	7.8	18.3	10.9	16.6	2.3	7.4	100
Slct.	Freq.	565	2100	1299	2816	1358	2730	1544	3118	562	2431	18523
	Rate	3.1	11.3	7.0	15.2	7.3	14.7	8.3	16.8	3.0	13.1	100
Rsp. Rate		11.5	13.7	13.9	12.1	13.8	16.0	16.8	12.8	9.9	7.3	12.9

*Unit of size: number of professors in science and engineering
**There is no professor affiliated to a university with between 800 and 900 academics.

- Location

The professors in universities near the capital area (Seoul, Incheon and Kyunggi) show a lower response rate that those in regional universities. Moreover, according to a t-test, the proportion of academics in Seoul in responding group (0.29) is significantly smaller than that in selected group (0.35) within 5% significance level.

Location		Seoul	KI	KW	CC	KS	JL	Jeju	No Rsp	Sum
Rspnd. group	Freq.	687	237	162	250	726	290	42	1	2395
	Rate(%)	28.68	9.90	6.76	10.44	30.31	12.11	1.75	0.04	100
Slctd. group	Freq.	6504	2254	1178	1627	4381	2300	247	32	18523
	Rate(%)	35.11	12.17	6.36	8.78	23.65	12.42	1.33	0.17	100
Rsp. Rate (%)		10.56	10.51	13.75	15.37	16.57	12.61	17.00	-	12.93

*KI:Kyunggi and Incheon, KW:Kangwon, CC:Chungcheong, KS: Kyungsang, JL:Jeolla

D. Discipline

The professors in natural science departments show the highest response rate, while those in medical science and pharmacy departments show the lowest rate. Moreover, according to a t-test, the proportion of academics in the discipline of engineering in responding group (0.41) is significantly smaller than that in selected group (0.38) within 5% significance level.

Discipline		Eng	Agr	Med	Nat	No Rsp.	Sum
Rspnd. group	Freq.	971	159	581	684	0	2395
	Rate(%)	40.54	6.64	24.26	28.56	0	100
Slctd. group	Freq.	6977	987	6194	4365	0	18523
	Rate(%)	37.66	5.32	33.43	23.56	0	100
Rsp. Rate (%)		13.91	16.11	9.38	15.67	-	12.93

*Eng: Engineering, Agr: Agricultural and Maritime Science, Med: Medical Science and Pharmacy, Nat: Natural Science

E. The country where the final degree was awarded

The professors trained abroad, except those in the category 'other abroad area' show a higher than average response rate, while those trained domestically show a slightly lower rate than average. Moreover, according to a t-test, the proportion of academics trained in Korea in responding group (0.56) is significantly smaller than that in selected group (0.58) within 5% significance level.

Country		Korea	US	Japan	EU	other	No Rsp.	Sum
Rspnd. group	Freq.	1334	739	210	100	8	4	2395
	Rate(%)	55.7	30.86	8.77	4.18	0.33	0.17	100
Slctd. group	Freq.	10738	5507	1119	661	69	429	18523
	Rate(%)	57.97	29.73	6.04	3.57	0.37	2.32	100
Rsp. Rate (%)		12.42	13.42	18.77	15.13	11.59	-	12.93

F. Publishing and patenting activities

Unfortunately, our data on personal details of 18,523 academics in 56 Korean universities (i.e. the selected group) lack information on their publishing and patenting activities. Instead, based on an official census of all Korean academics' activities in 2007, we have collected data on these two activities of 20,728 Korean academics in the same 56 Korean universities. By comparing these data with the data about the two activities of 2,395 Korean academics, we can indirectly investigate the response bias of the responding group. According to the results, distribution of the two activities within responding group is likely to be concentrated on relatively high-performance areas compared to that of the selected group. In other words, academics with higher performance were more likely to respond to our survey than those with lower performance in terms of papers and patents.

G. Conclusion

In summary, young professors trained in overseas institutions and affiliated to local, middle-sized public regional universities are inclined to respond to the survey at a higher rate than those who do not fall into these groups. If we consider this result in analysis of the data, we can avoid a serious fallacy. In other words, when we analyse and conclude from the response data of each question by considering the characteristics of this biased responded group, the risk of misinterpretation of the results can be minimised as much as possible.

Appendix 7.2 Interview Questionnaires for Activities of Korean Academic Staff

A. Characteristics and changes of activity of universities

1. [Environment] **What has been the environment (or condition) of your university for activities such as teaching, research and service to society over the last two decades?**

- Is your university satisfied with the recent institutional and environmental nationwide changes, such as the government's policy supporting your activities?
- How do you evaluate your regional environment, such as local industry structure, population growth?
- How is the competition with other universities? Is it getting harder?
- What are your main opportunities and threats recently in terms of the three missions?

2. [Identity and strategy] **What have been the characteristics and strategies of your university compared to other universities in the last two decades?**

- Do you have any specialised discipline in terms of teaching, research, and industrial collaboration?
- Are you stimulating your academic staff to work in a certain direction? If so, what is your rationale to persuade them to do so?
- Is there any conflict between basic research and commercial research in your university? If so, what is your solution for that?
- What future strategy or direction do you have in terms of resource acquirement such as budget and academic staff? What types of research funds and new academic staff are you looking for?

3. [Organisational and Institutional Change] **What changes have you implemented to adapt to your recent environment?**

- Have you established any new organisations or divisions in order to facilitate research and industrial collaboration?
- What functions and services do you have in your Industry Academic Collaboration Foundation?
- In order to invigorate research and industrial collaboration, what kind of incentives do you have, such as bonuses for paper publications and sharing profits for patent licensing?

B. Characteristics and changes in activity of individual professors:

1. In terms of t*eaching*, what kind of quantitative and qualitative changes can you identify since recruitment?

- Do you prefer teaching to research? If so, why?
- Are you putting emphasis on research skills and vocational training in your teaching? Can you give me examples of formal and informal programmes for research skills and vocational training in terms of educational facilities and media, and individual supervision?
- What is the usual route to help your students be hired by a company?
- Does teaching integrate with research at your university? Has the Accreditation for Engineering Education been successfully implemented at your university? If not, why?

2. Has *research* been invigorated at your university since the start of your career?

- How are the resource conditions for research, such as funding, postgraduate students, and facilities? Is it getting harder or easier? What was the reason for that?
- Has the research evaluation system been strengthened? Are there any unintended influences from quantitative performance indicators? Do they decide your reward fairly?
- What is your opinion on the government's programmes to support academic research, such as NURI (New University for Regional Innovation) and BK (Brain Korea) 21?

3. How have university-*industry collaborations* invigorated your university?

- What have been your collaboration activities since being recruited by your university? (e.g. programmes supported by the government, direct contracts with companies, consulting)
- What were the motivations and incentives for the collaboration?
- Has it influenced your selection of research topics? Has it undermined your research capacities? Or have new academic research topics emerged from the collaborations?
- What were main difficulties during the collaborations? Have the characteristics of your department, such as discipline and region, influenced the success of the collaboration?
- What types of collaboration do you think need to be strengthened in the future?

4. *Environmental* and *institutional* change

- Has the research environment at a national level been enhanced since your recruitment?
- Do the university authorities drive you to be more active in research and university-industry collaborations? If so, how?
- If you trained abroad and had the chance to get a job there, what was the main reason for coming back to a Korean university?

Appendix 7.3 Survey Questionnaires for Activities of Korean Academic Staff

※ **Please fill in the blank regarding your teaching and research activities.**

(1) The number of students supervised: [ ]
(2) The number of post-doctoral researchers supervised: [ ]
(3) The number of papers published in journals listed on the Science Citation Index (henceforth, SCI) from 2004 to 2006 (if co-authored, count it as one) [ ]
④ The number of patents registered within Korea: [ ] and abroad: [ ] from 2004 to 2006 (if the same patent is registered in different countries, count it as one)

1. Recently, what types of research have you been involved in?

① Basic research
② Applied research
③ Development
④ Research for education
⑤ None of the above

2. To what extent do you emphasize technical skills for industry in your teaching?

		Undergraduate	Postgraduate
①	Not important at all		
②	Not very important		
③	Fairly Important		
④	Very Important		
⑤	Dependent on situation		

3. Please tick the degree of importance in terms of the missions of universities.

		Not important at all	Not very important	Neutral	fairly Important	Very Important
(1)	Teaching	1	2	3	4	5
(2)	Research	1	2	3	4	5
(3)	U-I collaboration & Commercialisation	1	2	3	4	5
(4)	Service to society	1	2	3	4	5

4. In the case of your university, what is your opinion on the following categories?

4-1. degree of university-industry collaboration compared to other universities

		Very weak	Fairly Weak	Neutral	Fairly strong	Very strong
(1)	Before the year of 2000*	1	2	3	4	5
(2)	After the year of 2000	1	2	3	4	5

* Question only for staff hired before 2000

4-2. If you ticked 1 (very weak), 2 (weak) or 3 (neutral) in the previous question, what do you think is the most important reason for that? (You can choose only

one for each period)
(1) Before the year of 2000 [ ]
(2) After the year of 2000 [ ]
① Lack of academic capability and interest
② Lack of industrial capability and interest
③ Inappropriate government policies
④ Insufficient infrastructure for university-industry collaboration
⑤ If none of the above for (1), describe: [ ]
⑥ If none of the above for (2), describe: [ ]

5. Please choose appropriate types of university-industry collaboration for each question
(You can choose two answers for (1) and (2), and any answer for (3))
(1) What types of collaboration are frequently implemented in your university? [ ] [ ]
(2) What types of collaboration should be considered important from now on? [ ] [ ]
(3) What types of collaboration have you participated in? [ ] [ ] [ ] [ ] [ ] [ ] [ ]

① informal consultancy including special lectures for companies
② attendance and discussion at conferences hosted by industry
③ contracted consultancy for companies
④ commissioned teaching for the industrial labour force
⑤ patent application and paper publication after non-contracted research collaborations
⑥ sharing research facilities
⑦ commissioned or cooperative research by contract with industry
⑧ dispatch of student to industry
⑨ participation in a company as a member
⑩ starting up a company by myself
⑪ none of the above

6. If you are less active in university-industry collaboration, which of the following factors have hindered your involvement in collaboration? (You can choose multiple answers)
① research and teaching is more important than university-industry collaboration
② my personal research field is not appropriate for university-industry collaboration
③ governmental policy and institutional support for university-industry collaboration is insufficient
④ there has been no appropriate company in terms of research goals, time period, etc.
⑤ there are conflicts regarding paper publication and intellectual property issues
⑥ personal negative views on university-industry collaboration
⑦ if none of the above, describe: [ ]

7. If you are active in university-industry collaboration, which of the following factors have motivated you to be involved in collaboration? (You can choose multiple answers)
① research funding and equipment from the company
② knowledge transfer and application through patenting and consulting
③ personal research interest and its applicability
④ pecuniary incentive
⑤ in order to be chosen as a governmental research contractor
⑥ education and support for students

⑦ expectation from the university and the department
⑧ in order to start to be involved in a venture company
⑨ reputation
⑩ if none of the above, describe: [ ]

8. In terms of institutional issues for university-industry collaboration, please choose the appropriate answer.

		Strongly disagree	disagree	neutral	agree	Strongly agree
(1)	I know about the reward incentives and supporting systems for U-I collaboration, such as patent application and registration, and evaluation criteria.	1	2	3	4	5
(2)	I am satisfied with the infrastructure for U-I collaboration, such as the TLO and Business Incubation Centre, in my university.	1	2	3	4	5
(3)	Academic staff should be loyal to the university in the case of the start-up of a company based on the technology developed by them	1	2	3	4	5

9. What do you think is the best way to exploit academic potential for both universities and society?

① strengthening the research and problem-solving capacity of universities
② supporting academic staff by rationalising allocation of intellectual property rights and incentives for starting up companies
③ increasing the amount of research funding and pecuniary incentives from industry
④ strengthening universities' organisational capacity for university-industry collaboration
⑤ if none of the above is appropriate, describe: [ ]

10. Who do you think should own the intellectual property resulting from publicly funded research? (Please give a number according to priority)

(1) Universities [ ]
(2) Academic researchers [ ]
(3) The government or the funding agency [ ]

11. In your case, what have been the major difficulties during university-industry collaborations? (You can choose a maximum of two answers)

① limited time for research given by industry
② industry's low level of understanding of technology
③ insufficient rewards and unfair allocation of profits from the research
④ conflict in the process of co-publication
⑤ negative industrial prejudice (or evaluation) of academic research
⑥ negative academic prejudice (or evaluation) of industrial research
⑦ strong regulation by university authorities
⑧ insufficient evaluation system for university-industry collaboration activities
⑨ strong regulation by the government and improper law and rule
⑩ decrease of academic reputation, academic activity, and knowledge-sharing in academia
⑪ overload when added to pre-existing duties such as teaching, research, and obligations to the university
⑫ if none of the above, describe: [ ]

※ Only answer the next question if you have been involved in any university-industry collaboration. If not, you can finish this survey now.

12. Where are the companies that you have collaborated with located? (Choose a maximum two answers)

① Seoul ② Busan ③ Daegu ④ Incheon ⑤ Ulsan ⑥ Daejeon ⑦ Kwangju ⑧ Kyunggi ⑨ Kangwon ⑩ Chungnam ⑪ Chungbuk ⑫ Kyungnam ⑬ Kyungbuk ⑭ Chonnam ⑮ Chonbuk ⑯ Jeju ⑰ Abroad

13. What have been your direct outputs resulting from the university-industry collaborations you have been involved in since 2004?

		Strongly disagree	Fairly disagree	Neutral	Fairly agree	Strongly agree
(1)	Effective education for student	1	2	3	4	5
(2)	Enhancement of research facilities and capacity	1	2	3	4	5
(3)	Generation of new ideas for my own research	1	2	3	4	5
(4)	Increase of pecuniary incentives	1	2	3	4	5
(5)	Increase of profits for the university and the department	1	2	3	4	5

14. How many patents and papers have resulted from the university-industry collaborations you have been involved in since 2004? (Co-authorship can be counted as one)

(1) Number of papers produced: [ ]
(2) Number of patents applied for: [ ]

15. To what extent do you agree with the following statements on the university-industry collaborations you have experienced?

		Strongly disagree	Fairly disagree	Neutral	Fairly agree	Strongly agree
(1)	It contributed to my academic career and reputation	1	2	3	4	5
(2)	It influenced the orientation of my research to adopt to the needs of industry	1	2	3	4	5
(3)	It contributed to the development of companies	1	2	3	4	5
(4)	Overall, I am satisfied with my U-I collaboration experience	1	2	3	4	5
(5)	Conflicts between myself, colleagues, the university authorities and industry occurred due to U-I collaboration	1	2	3	4	5
(6)	The U-I collaboration stimulated my drive for future U-I collaboration	1	2	3	4	5

※ This is the end of the survey. Thank you for your answers.

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