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**Institutional Conditions for National Technology Capabilities:
A Comparative Study of Technology Catch-up
in Korea and Japan.**

**A Thesis Submitted by
Hee Sun Kim
Birkbeck College
University of London**

**Thesis Submitted for the Degree of Doctor of Philosophy in
Management
University of London**


2013

Declaration

The work presented in this thesis is the candidates (Hee Sun Kim) own.

Date: 07 JUNE 2013

Signed:

A handwritten signature in black ink, appearing to read 'Hee Sun Kim', written over a horizontal line.

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ABSTRACT

What determines technology capabilities and catch-up of countries? Why do the patterns, speed and performance of innovation differ across countries? This thesis seeks to address these questions by linking institutional, organisational and sectoral features of innovation in Korea and Japan which are regarded as the most successful cases of technology catch-up. Despite the widespread recognition that innovators are susceptible to institutional conditions and contextual influences, previous empirical studies have not used contextual factors as determinants of innovation. On the other hand, institutional analysis of innovation has addressed national diversity and historical patterns of change based on thick description and qualitative evidence. This thesis provides a new way of explaining the underlying dynamics of innovation by empirically examining direct correlations between country-specific institutional characteristics and technology capabilities and by testing causal relationships between technology input and output. This thesis employs the national innovation system (NIS) and the late industrialiser perspectives to perform three sets of empirical analyses. The first identifies key institutional and policy determinants of national technology capabilities based on five sets of cross-sectional data, consisting of 37 high-income countries and 32 middle-income countries. The second examines specific institutional conditions for causal relationships between technology input and output based on time-series data of Korea and Japan. The third investigates technological catch-up occurrence, speed and performance to identify productivity and technology gaps as well as delaying and contributing factors. The findings of the thesis have significant relevance to innovation strategy and policy of other catching-up countries in the process of building indigenous technology capabilities.

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CHAPTER 1

Introduction

1.1 Background and Motivations

What determines technology catch-up and capabilities of countries? Why do the patterns, speed and performance of innovation and sectoral specialisation differ across countries? Under what condition is rapid technological catch-up of countries undertaken? This thesis seeks to address these questions by linking institutional, organisational and sectoral features of Korea and Japan to their economic and technology catch-up performance. Given that an institution could be defined as the formal structure or mechanism for political rule-making and enforcement to govern cooperative human behaviour (Schotter, 1981; North, 1990), this thesis examines the trajectory of institutional reform and its effects on technology capability of two most rapidly catching-up economies in East Asia, Korea and Japan. The analysis of institutional change in terms of National Innovation System (NIS), industrial structure, financial system and intellectual property (IP) regime show how the countries control and adjust the allocation and distribution of resources for economic and technological growth.

Despite previous academic efforts to examine idiosyncratic features of innovation systems and activities at various levels, there is little satisfactory explanation for the dynamics of institutional reform and its effect on technology capabilities empirically in innovation literature. Existing studies on innovation, adopting the institutional perspective and NIS approach, address institutional and policy factors as important sources of economic growth, but do not attempt to examine their impacts on technology catch-up and innovation performance empirically. This thesis fills the gap by empirically analysing how county-specific institutional and policy frameworks contribute to the development of technology and innovation activities. The institutional and policy factors contributing to

technology capabilities and innovation performance, including economic policy, trade policy, finance system, organisational structure, national innovation system (NIS) and sectoral innovation system are introduced in the theoretical framework and empirical research design. They are operationalised to analyse their consequences of catch-up pattern, sectoral specialisation and innovation performance in the contexts of Korea and Japan.

There are a number of studies based on an institutional perspective in social sciences that identify determinants of technology progress. Industrial organisation economics literature mainly stresses on market size, concentration, integration and diversification the underlying of industrial structure as important sources of the growth in terms of income, finance and technology (Acs and Audretsch, 1987; Bain, 1956; Kamien and Schwartz, 1975; 1982; Scherer, 1965, 1990; Sutton, 1998 Williamson, 1965). Strategic management literature emphasises on the development of firm specific capabilities and governance structure as the main determinant of innovation and competitiveness (Barney, 1989; Rumelt, 1991). In this sense, these two streams of research do not provide a proper treatment of the role of government and public institutions in the process of technological innovation (Malerba, 2002), without a proper regard to different institutional and sectoral contexts. Therefore, the variations in technology catch-up patterns, sectoral specialisations and innovation capabilities across firms, industries and countries cannot be sufficiently explained (Freeman, 1995, 1997; Lundvall, 1992; Nelson, 1993; Edquist, 1997). Also, most of these studies are based on the context of advanced countries, while paying little attention to the context of emerging or developing countries.

The NIS literature examines the patterns of innovation and growth strategies across countries by looking at the country-specific institutional governance as an important source of innovation performance. A specific institutional configuration that shapes NIS leads to distinctive coordination mechanisms, learning processes and roles of

players (Kogut, 1991; Nelson, 1993; Lundvall, 1998). It highlights a complex set of relationships among the key players in the country specific system of stock and flow of knowledge (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997; Archibugi and Lundvall, 2001). In this sense, the NIS approach provides an insightful framework to explain a dynamic relationship between institutional arrangements and technology development. However, the NIS approach shows some weaknesses in addressing my research questions. The NIS approach has limitations in analysing the contexts of the latecomers countries, since the principles and configurations of the NIS are modelled on the systems of advanced countries. It proposes universal formula which is developed by technologically advanced economies and hence emphasises strong institutional links and professional networks (State-University-Industry relationship) as logical premises for effective creation and diffusion of new knowledge. Therefore, this approach cannot capture the distinctive features of innovation systems of Korea and Japan in a satisfactory way (e.g., extensive government supports and close ties between government and business). Despite a weak State-University-Industry relationship due to the lack of university R&D capabilities, the countries have achieved a rapid economic growth and technological catch-up. Further, the NIS approach suggests that technological change is determined by inside factors of the system, but it is often influenced by outside factors of the system (Viotti, 2002). This implies that a great part of innovative products and services are generated not only by home-grown capabilities, but also by global activities, such as foreign direct investment (FDI), internationalisation of R&D, cross-border strategic alliance (Patel and Pavitt, 1998; Archibugi and Lundvall, 2001; Archibugi and Pietrobelli, 2003). Their global activities in turn blur the boundaries of NIS.

Such weak points underlying the NIS approach could be complemented by the late industrialiser perspective. The late industrialiser perspective focuses on the significance of country-specific structural and institutional conditions for resource accumulation as

critical elements in spurring rapid industrial and economic growth in the contexts of latecomers or developing economics (Amsden, 1989; Wade, 1990; E. Kim, 1997; Mathews and Cho, 1999). This perspective addresses not only the role of national endowment of science and technology (S&T), but also the role of institutional configurations and contextual factors in the processes of industrialisation and innovation. However, both the NIS and the late industrialiser perspectives provide static descriptions of national institutional devices and endogenous mechanisms for learning and coordination, without proper regard to the trajectory of institutional change and special regional and sectoral contexts. Therefore, this thesis extends these perspectives and tries to build a more dynamic account of country-level technological change.

Largely based on the NIS and late industrialiser perspectives, this thesis provides three sets of empirical analyses to examine the determinants of technology capabilities across countries on the one hand, and the determinants of technology catch-up performance in Korea and Japan as case studies on the other. The first analysis identifies key determinants of technology capabilities based on five sets of cross-sectional data, consisting of 37 high-income countries and 32 middle-income countries. Looking at the big picture using cross-sectional data is crucial for generalising the importance of institutional framework on innovation and assessing the relative significance of institutional factors before examining the details. This study examines the impact of institutional and policy factors related to economic freedom and liberal regulatory system on the national technology input and output. The findings of the negative effect of liberal economic system for domestic market entry and capital flow provide new explanation and theoretical implications since the statistical outcome derived from the cross-national research do not conform to many economic and management theories, including resource-based view, transactions cost economics and varieties of capitalism. In addition, I found that the size of government acts as a moderator of regulation and foreign trade effects on

national technology capabilities, indicating that small government size in the combination with the liberalised domestic market and foreign trade systems facilitates technology investment and creation. However, most previous macro-empirical studies on innovation mainly examined its close correlation with the growth in terms of productivity, economy and competitiveness, even though catch-up process and innovation performance are seriously affected by socio-economic and institutional conditions. The possible reasons why they have not attempted to examine these relationships across countries are due to difficulties in moderating countries' huge technology gaps, different levels of economic development, and various institutions. In this sense, this country-level analysis is a new attempt to empirically examine these linkages by controlling various institutional and organisational characteristics of countries.

The second analysis examines specific institutional conditions for the technology input–technology output relationship based on time-series data by employing the triple-helix indicators within NIS and the contextual factors in Korea's and Japan's innovation systems. With the causality test, similar or different patterns of technological development in Korea and Japan are discussed. In both countries, the governments have played a pivotal role in coordinating and supporting innovation activities for rapid economic growth, while embracing the role of private sector R&D and foreign technology transfer over time. Compared with Japan's innovation system, Korea's innovation system shows more effective public R&D and dependent on foreign techniques in the creation of national technology. However, most previous studies on NIS looked at the country-specific institutional setting in a historical approach, and descriptively analysed its role technology capabilities and innovation.

Also, I could not find any empirical studies employing the causality test to examine the causal relations between innovation output variables, say patent production, and innovation input variables, say R&D expenditure. Most empirical studies on

innovation address technology investment as an important determinant of economic growth and innovation performance, looking at their relationship through correlation test. The greater part of this area examined the direction of causality between economic and financial variables. The representative studies are the causal relations between financial development (e.g., stock market volatility and capitalisation) and economic growth (e.g., GDP) (Arestis and Demetriades, 1997; Calderón and Liu, 2003), between FDI and economic growth (Hansen and Rand, 2006; Hsiao and Hsiao, 2006), between capital investment and economic growth (Vanhoudt, 1998; Elena and Gaetano, 2001) and between international trade (e.g., export and import) and productivity (Awokuse, 2008; Harrison, 2007). Therefore, this empirical analysis provides a new way of explaining the underlying dynamics of rapid technology catch-up and innovation progress in Korea and Japan by testing the causal relationship of technology investment with respect to technology creation.

The third analysis examines the level of technology capabilities and competitiveness of Korea and Japan by analysing in which industrial sectors Korea rapidly caught up with Japan through the estimation of the productivity gap between the two countries, given that technical progress and innovation are directly related and contributed to the growth of TFP. By introducing institutional and policy factors, the key determinants of technology catch-up occurrence, speed and performance that influence on latecomer countries' technology capabilities and innovation are identified to compare distinctive catch-up patterns between the two countries. The distinctive patterns and determinants of Korea's catch-up also are analysed by comparing those with other catch-up countries, particularly Taiwan. As a comparative bench mark of Japanese firms, this analysis highlights that industrial sectors required for explicitness of knowledge and embodied technology transfer, and in monopolistic market structure and export-oriented growth are more likely to occur catch-up at fast face. It implies that knowledge regime,

finance system and trade policy are important factors facilitating technology catch-up and competitiveness in the contexts of catch-up countries. Based on this empirical analysis, the two path-creating catch-up models of biotechnology and wireless telecommunications technology in Korea and Japan, implying that latecomer firms explore their own path of technological development and innovation, are selected as case studies. It attempts to find the delay factors (biotechnology) and the contributing factors (wireless telecommunications technology) affecting technological catch-up and innovation, as well as policy measures for improvement from the view point of NIS.

Do the selected cases meet the criteria for case section and the condition for a comparative analysis? To choose the cases, this thesis adopts both a positivist approach (69 developed and developing economies) and a phenomenological approach (Korea and Japan). In a positivist approach that selects many cases as possible from similarity of case background, the cross sectional research using such large numbers of 69 countries can reduce the risk of case-biased findings and generalisability (Saunders *et al.*, 2003), but tends to omit intrinsic importance of cases as well as their contextual background conditions (Yin, 1994). To complement the methodological shortcomings in the positivism, I choose Korea and Japan as representativeness in a phenomenological approach that provides in-depth understanding of the phenomenon with a detailed contextual analysis and an examination of the outlier characteristics (Stake, 1994; Gerring, 2004). However, a phenomenological approach has the weakness in conceptualising and generalising the findings from a few cases (Stake, 1994), hence the clustering method is used for a rational choice of case countries. In high-income economies, Korea and Japan share similar backgrounds of technological development, institutional characteristics, and socio-economic contexts. For systematic comparison, this thesis uses the method of agreement or positive comparison between the cases that are somehow similar in characteristics.

What similarities do Korea and Japan have in common? First, Korea and Japan have similar background of economic and technological developments. Both Korea and Japan are most rapidly technology catch-up countries and now the world top scientific technology-oriented countries, breaking from subsistence agricultural society and war-torn nation (OECD, 2004). Korea has followed the Japanese growth patterns in some ways for economic recovery and technological catch-up. The success story of these countries are attributable to high investment and accumulation of growth factors (Nadri, 1994), effective government industrial technology policies, government intervention in domestic market and an export-led industrialisation strategy (Chang, 1993; World Bank, 1993; Woo, 1999). The dynamic change of growth strategies in Japan according to the level of economic development (from labour-intensive industries to heavy and chemical industries and then R&D-intensive industries) reflected Korea's economic and industrial policies to transform its industrial structure in the same way (Stern *et al.*, 1995). It has enabled Korea to enter the same market as Japan as a competitor. Second, Korea and Japan share similar features of finance system, such as a strong government intervention in financial sectors, a strict regulation on the allocation of financial resources, and a significant government subsidisation of the cost of borrowing in the product and process of innovation. The governments act as a risk-sharing partner with industry and banks to facilitate R&D expenditures in high-yield industries in which income elasticity of demand has been high and technological progress has been rapid. Third, there is a strong resemblance between Korea's and Japan's innovation systems. Government and large industrial firms are key contributors to their innovation system, while universities and high-tech start-ups have relatively lower R&D capabilities compared with the technologically advanced countries. Fourth, Korea's large business group (chaebol)-centred system and their close ties with government are much more similar to Japan's than any other business models within high-income countries and other East Asian Newly

Industrialised countries (e.g., Taiwan and Singapore). Korean chaebol is analogous to Japanese Zaibatsu (family-owned conglomerate), which is different from the current Japanese corporate ‘families’ centred on a bank, namely Keiretsu (Chang; 2003). Therefore, the selected cases in this thesis satisfy the criteria of case selection and the condition for a comparative analysis. The case studies of Korea and Japan allows us to test the usefulness of existing innovation studies and theories that have primarily been developed in Western advanced countries, while providing important implications for emerging or catch-up countries in relation to the question of in what ways they should manage their indigenous innovations.

1.2 Research Purpose and Questions

This thesis has four research questions in relation to determining factors for national technology capabilities. The first is to investigate the role of government regulation and policy in the development of technology capabilities, since innovative activities of actors within the NIS are very sensitive to the governance capability of the administration that changes market structure and trade policy and consequently the stock and flow of capital (Friedman, 1993; Lee and Yoo, 2007). Globalisation causes institutional transformation such as the change of ownership structure and regulatory policy (Goyer, 2003; Hoskisson *et al.*, 2004), forcing countries to conform to market mechanisms and undertake legal reforms to attract more FDI (Kogut and Macpherson, 2003). To allocate and utilise resources such as R&D efficiently, the government reduces the tax burden for technology trade and investment abroad, while easing regulations in local credit, labour and business markets to facilitate cooperation among economic actors rather than dependence on the State (Hall and Soskice, 2001). This gives rise to a heated debate on neo-liberalism versus state coordination (Evans, 1997; McMichael, 1996).

If it is so, does the liberalisation of trade and capital movement (labour, credit and

businesses) always make a positive contribution to the stock and flow of knowledge and technology? Does a heavy regulatory policy impede the dynamics of innovation activities? What makes the state-led economies, such as Korea and Japan, rapidly catch up and develop technology capabilities then? Economic freedom and free capital flow in a more liberal regulatory system is expected to have positive effects on technological catch-up and innovation performance since a lower regulatory burden on market entry and trade increases entrepreneurial opportunities and R&D cooperation (Goh, 2005; Grossman and Helpman, 1991; Jameson and Soule, 1991). Therefore, this leads to question 1.

Research Question 1:

In what ways do government regulation and policies affect technology catch-up and technology capabilities of Korea and Japan?

The second is to investigate institutional conditions for technology capabilities from the view point of NIS. Given that different NIS leads to differences in learning process, patterns of technology catch-up and innovation performance across countries, it is important to examine how key players within the NIS and contextual factors have contributed to rapid technology catch-up and in the contexts of Korea and Japan. Previous studies on innovation systems of Korea and Japan highlight that government, large firms and universities play a central role in shaping the NIS as driving the rapid catch-up in both Korea and Japan. The Korean government has stronger leadership in the process of technology catch-up as a financier and a performer of R&D compared to the Japanese government that plays the role of a mediator or a facilitator. Large industrial firms have been the dominant players while universities have still lower level of research capabilities and lower contribution to innovation systems in both countries compared with the frontier countries (Harayama, 2001; Rhee, 2004; Park, 2004; ISI *et al.*, 2008).

If it is so, how much of the current technology output (or technology input) can be

explained by past values of technology input (or technology output), whether adding lagged values of technology output (or technology input) can improve the explanation, and which researcher performers are more effective and innovative in technology investment and creation in the contexts of Korea and Japan. This leads to question 2.

Research Question 2:

In what ways do key actors within the NIS and contextual factors affect technology catch-up and technology capabilities of Korea and Japan?

The third is to investigate the role of technology regime, sectoral innovation system and institutions related to S&T in the process of technology catch-up and the development of national technology capabilities. Technical innovation is stressed in various academic fields, because of the persistent disparity between the poor and the rich in the world, as well as the stunted growth of middle-income countries (Esterly, 2001; Jung and Lee, 2010). However, Korea and Japan have shown remarkable achievements of economic growth and technological catch-up. The rapid and sustained economic growth of these countries is attributable to their innovation-based growth strategy focusing on distinctive mechanisms of knowledge creation, learning process and technological innovation (Hobday, 1995; Rodrik, 1999; Kim and Nelson, 2000; UNCTAD, 2003). The institutional conditions conducive to the accumulation and diffusion of technological capabilities underpin the economic miracle of Korea and Japan. The countries have been often cited in various fields of academic literature as successful examples of the state-led capitalist model. Korea has followed the Japanese route to industrialisation, internationalisation and innovation processes with similar characteristics of political and institutional frameworks, while Japanese firms serve as a model to Korean firms in terms of corporate governance (e.g., ownership concentration), institutional arrangement (e.g.,

business groups), overseas expansion, technological catch-up and innovation system.

Given the similar patterns and mechanisms of catch-up, which industrial sectors of Korea have rapidly caught up with those of Japan? What determines the occurrence, speed and performance of Korean firms' catch-up in successful industries? What are the key institutional conditions for the catch-up success? This leads to question 3.

Research Question 3:

What determines the occurrence and speed of technology catch-up and the level of technology capabilities in Korea and Japan?

The fourth is to investigate the role of sectoral policy and institutional framework, and their contributions to the development of radically innovative capabilities, with particular reference to biotechnology and wireless telecommunication industries in Korea and Japan. Biotechnology and wireless telecommunication are radically-innovating sectors associated with entrepreneurial business model (i.e., Silicon Valley model), which have particular distinguishing features of '*the management of high-risk finance*', '*the development of human resources within a competency destroying environment*' and '*the creation of sufficiently high-powered motivational incentives of personnel*' (Casper, 2009, p.365).

A large comparative political economists that propose a direct theory linking institutions to firms' innovative capabilities and sectoral specialisation analyses how differences in corporate governance, organisational types, labour market system, financial system and firm relations influence patterns of innovation, technology changes and sectoral specialisation across countries. National financial and business systems, in which firms develop innovative capabilities internally with long-term investments in the accumulation of a stock of organisation-specific knowledge, tend to promote incremental

and customer-focused innovations involved in a cumulative and path-dependent technology change within an established paradigm (Caspar, 2000; Hall and Soskice, 2001; Haake, 2002; Tylecote, 2007). Reliance on such a cumulative and collective knowledge in the development of innovative capabilities makes it difficult firms to reconfigure their organisational structures, while locking in current trajectories (Whitley, 2002). Based on this, Korea's and Japan's financial and business systems (i.e., high levels of industry embeddedness, high dependence of inter-firm and in-house R&D, non cooperative with external organisations) are conducive to incrementally-innovating sectors, such as consumer electronics, machine tools and cars, while providing little incentives for firms to perform discontinues and radical innovations, such as biotechnology and ICT sectors (Tylecote, 2007; Tylecote and Vistintin, 2008; Casper, 2009). Given that highly specialised entrepreneurs could rapidly acquire and use new knowledge in pursuing distinctive research agenda (Hall and Soskice, 2001; Whitley, 2002; Tylecote, 2007), the countries' systems dominated by large firms can be a obstacle to developing innovative capabilities in fast-growing and newly-emerging industries, because of low degrees of labour mobility, the availability of venture capital and university-spin offs. The absence of the availability of expert finance for new firms limit the reconfiguration of their structures to rapidly use of new knowledge and acquiring radically new opportunities responding to the rapidly changing environment — a complete trajectory shift for a new technological paradigm (Caspar, 2000; Hall and Soskice, 2001; Lazonick; 2007; Tylecote and Vistintin, 2008).

In the idealised types proposed by varieties of capitalism (VoC) framework, hence the two coordinated economies (state-coordinated system in Korea and business groups-coordinated system in Japan) tend to adopt high-quality incremental innovation strategies, since their institutional frameworks are unfavourable for the industries involved in radical shifts direction in absence of market-based institutions and venture capital (Whitley,

2002; Tylecote, 2007; Tylecote and Vistintin, 2008). However, Korea and Japan get abreast of liberal-market economies as radical innovators in many high-tech sectors by successfully harmonising the contradictory forces of market-based restructuring (individualism) and relationship-based innovation (communitarianism) (Lee and Yoo, 2007; Tylecote and Vistintin, 2008). Such an inconsistency in this dichotomy in the application to the contexts of Korea and Japan suggests that variations in the rate and types of technical changes across countries should be explained by integrating variations in government S&T policies, NIS and sectoral innovation system. Differences in Government policies and innovation systems can reflect firms' actions in the development of distinctive innovative competences and strategies.

In this sense, it is critical to analyse how effectively government policy facilitate radical innovation by coordinating institutional complementarities operating within their financial and business systems and how sectoral-specific policies interact with economy-wide institutional incentives and constraints in the countries. Whilst Korea and Japan have achieved rapid catch-up in the wireless telecommunications industry, they have not shown any significant success in biotechnology industry. Why have Korea and Japan experienced a pathetic return on a large scale of government funding and corporate R&D for biotechnology? How have Korea and Japan managed to catch up rapidly with wireless technologies of advanced countries at higher speed than biotechnology, even though the policy priority has been placed on attaining developments in both wireless technology and biotechnology? Why have ICT capabilities of Korea surpassed that of Japan in terms of new technology creation, despite smaller investments and funding? Is the Triple helix paradigm appropriate for explaining the development of the biotechnology and wireless telecommunications industries? This leads to question 4.

Research Question 4:

What are the contributing and delaying factors affecting the catch-up success in biotechnology and wireless telecommunication industries in Korea and Japan?

This thesis jointly uses quantitative and qualitative methods to operationalise the research questions and test the validity of the arguments. After indentifying the existence or absence of causations though the correlation tests between institutional factors and national technology capabilities in 69 countries, a comparative historical research through typological analysis and process analysis and Ganger causality test are employed to demonstrate the empirical validity in case studies. The statistical findings derived from the cross-country regression are appraised within the specified contexts by providing fine-grained and convincing evidence within Korea and Japan.

1.3 Structure of the Study

This PhD thesis is organised in eight chapters: introduction, review of innovation literature, theoretical framework, methodology and research design, institutional conditions for national technology capabilities (a cross-county study), institutions, government policies and technology capabilities (a case study on Korea and Japan), technology catch-up and sectoral innovation system (a case study on biotechnology and wireless telecommunication industry in Korea and Japan), and discussion and conclusion.

The chapters of this thesis are outlined as follows. Chapter one (Introduction) provides the research background, motivations and questions, and the methodological approach and research contributions are stated.

Chapter two (review of innovation literature) provides a critical review of theoretical and empirical literature on innovation focusing on determinants of technology catch-up and capabilities. After a discussion of the concept of innovation and technology

capabilities, the second section reviews previous theoretical studies on generations of innovation models and NIS. The previous empirical studies on determinants of technology capabilities and innovation performance are critically reviewed to assess their main contributions and limitations in the third section. The last section reviews the specific literature on innovation in the contexts of latecomer economies for the contextual understanding the characteristics of their technological catch-up, particularly attention to Korea and Japan. This chapter clarifies the theoretical and empirical gap in understanding institutional change in NIS, industrial structure, IPRs and finance system, and its influence on technology capabilities and innovation.

Chapter three (Theoretical Framework) develops a theoretical framework for a systematic and empirical analysis of technological catch-up and innovation by incorporating NIS approach with the institutional theory and the late industrialiser perspective. The second section provides a broad theoretical background on a critical assessment of how government public policy and NIS influence national technology capabilities and innovation in Korea and Japan. The third section discusses the usefulness of institutional theory and NIS perspective in addressing the technological catch-up and dynamics of innovation of Korea and Japan. The last section concludes with discussion for empirical analyses based on the newly suggested theoretical framework and its strengths. In the theoretical framework, institutional effects of innovation are operationalised at the national level and sectoral level to capture the role of government regulation and policy, and finance system, industrial structure, IPR and NIS in the process of technology catch-up and development of technology capabilities. The empirical investigations are performed in chapters 5 and 6.

Chapter four (Methodology and Research Design) discusses research design, method and data for the empirical study. The first section presents the basic research strategy of this thesis to develop an appropriate research design and appraise the worth of

my methodological framework. The second section justifies the rationale for the choice of case countries of Korea and Japan, and data reliability of this study. Then, I address the key issues of methodology that have been used in the existing innovation studies to decrease the risk of method effect. In the methodological framework, a cross-sectional analysis is performed to examine the role of institutions and policy in technology capabilities across countries. With the findings from a cross-sectional analysis, a comparative approach is taken to investigate the distinguishable institutional characteristics of Korea and Japan, and examine their effects on technology catch-up performances.

Chapter five (Institutional Conditions for National Technology Capabilities: A Cross-County Study) provides empirical analysis in relation to determinants of technology capabilities across countries to find answers to the research question 1. This empirical study investigates the effects of economic freedom and liberal regulatory system in the national technology input and output on the assumption that the stock and flow of knowledge, and R&D cooperation/competition are directly affected by institutional conditions for market entry, voluntary exchange of capital and foreign trade. After a discussion of estimation result, the methodological limitations and future research are followed by the end of this chapter.

Chapter six (Institutions, Government Policies and Technology Capabilities: A Case Study on Korea and Japan) explores a historical background of technological development and innovation in Korea and Japan. It provides the contextual understanding the extent to which they have achieved the rapid economic and technological catch-up with the advanced countries. After the brief outline of historical characteristics of S&T policy in Korea and Japan, I evaluate the effectiveness of their S&T policy and institutional framework. Furthermore, this chapter provides the historical and contextual analysis of specific institutional arrangements and policy change in industrial structure,

NIS, finance system and IPRs in Korea and Japan. By introducing the triple indicators within NIS and the contextual factors, different institutional conditions for technology input–technology output relationships and the patterns of technological development in Korea and Japan are compared through the causality test.

Chapter seven (Technology Catch-up and Sectoral Innovation system: A Case Study on Biotechnology and Wireless telecommunication Industry in Korea and Japan) discusses the level of technology capabilities and competitiveness by analysing in which industrial sectors Korea and Japan rapidly caught up. Also, different patterns of catch-up between the two countries are analysed by examining determinants of occurrence, speed and performance of catch-up. Furthermore, two cases studies, biotechnology and wireless technology, are performed to indentify key contributing (or delay) factors affecting technological catch-up performance and capabilities.

Chapter eight (Conclusion) provides a summary of key arguments in the findings, contribution, limitation and further research directions of this thesis, along with managerial, policy and research implications.

1.4 Research Contribution

This thesis links a comparative institutional analysis at the country level and a sectoral level analysis based on the NIS and late industrialiser perspectives. To address a series of research questions in relation to technology capabilities and innovation, it examines the extent to which technological catch-up performance and innovation capabilities of industries and countries are influenced by institutional changes in government regulation, policy and finance system and innovation system. The new perspective developed here is shown to have relevance to and provide more evidence on an on-going debate on institutional and organisational conditions for innovation and technology capabilities.

The theoretical framework of this research indentifies political, economic and

institutional characteristics of high-income and middle-income countries and their impacts on technology capabilities so as to find policy measures for improvement. This provides new theoretical and empirical insights that may be of interest to institutional theorists, strategic and technology management scholars and policy makers. Also, a series of empirical investigations on distinctive contexts of the East Asian latecomer countries (Korea and Japan) provides a new analytical model of determinants of technology capabilities and industrial catch-up performance. The case studies of Korea and Japan fill the gap of conventional theories. Since conventional economics and management theories are derived from the advanced Western countries' experiences of industrialisation, internationalisation and innovation processes, there remains a question whether the theories are applicable to the contexts of emerging or latecomer economics, especially the East Asian State-led capitalist countries (Korea and Japan). There is no doubt that the governmental leadership and institutional embeddedness in Korea and Japan are directly related to their success in industrial reform, overseas expansions and innovation. However, the conventional theory insignificantly addresses political, institutional and sociological factors as the leading determinants to succeed (Boisot and Child, 1996; Peng, 2000; Warner *et al.*, 2004), which may lead to the question whether the extant business theories are a pertinent indicator to the context of the East Asian State-led capitalist countries.

The contribution of this thesis is as follows. First, it empirically views a direct correlation of the country-specific institutional characteristics with technology capabilities. The previous empirical studies on innovation did not address contextual factors as determinants of innovation in spite of the widespread recognition that innovators are susceptible to institutional conditions and contextual influences. Although there is no doubt that the success of the country's technology capacity-building and innovation depend on its inherent administrative legislation and institutional framework, the majority of empirical studies addressed the institutional and policy factors as

determinants of economic variables, such as total factor productivity, national income and growth (e.g., La Porta, 1999; Arestis and Demetriades, 1997; Calderón and Liu, 2003; Awokuse, 2008). Therefore, this study is a new attempt to empirically examine the effects of government regulation and policy on technology capabilities across countries. Since the mobility of capital and labour, venture business and FDI play the important role in innovation performance, countries' liberal regulatory regime in credit market, labour market and businesses, as well as foreign trade are particularly focused in this study in order to examine their linkages with the national technology creation and investment. With the empirical testing, this thesis fills up the gap in the existing innovation studies. Second, it provides a new way of explaining the underlying of dynamics of innovation by testing the causal relationship between technology input and output in contrast to the previous studies that looked at their linkages through the correlation test. Third, it attempts to empirically analyse the specific institutional conditions of technology creation and investment relationships by using indicators in NIS and the contextual factors in contrast to the existing NIS literatures that analysed these linkages and the influence of each triple helix indicators on innovation, either historically or descriptively. Fourth, it provides a comprehensive evaluation of catch-up models which enable us to compare significant determinants and levels of technology capabilities with other catching-up countries or advanced countries. The findings of the thesis have significant relevance to innovation strategy and policy in other countries, particularly catching-up countries which are in the process of building indigenous technology capabilities. These contributions are discussed in more detail in Chapter 8.

CHAPTER 2

Review of Innovation Literature

2.1. Introduction

Technological innovation is regarded as an engine of national economic growth. Due to the persistent disparity between the poor and the rich throughout the world, innovation is a topic of interest in a wide range of disciplines, including economics, business, sociology and engineering. In business and economics, a number of studies have highlighted technological capabilities and innovation as key sources of economic development (e.g., Freeman, 1995; Kobrin, 1995) and competitiveness (e.g., Cantwell, 1989; Kogut, 1991; Porter, 1990). The increase of capital and labour, or the growth of multi-factor productivity, is the key source of economic development in the neoclassical economic growth model. Also, some studies based on an institutional perspective have focussed on different patterns of technological trajectories and sectoral specialisations of countries (or firms) in different institutional contexts (e.g., Dosi *et al.*, 1990; Shan and Hamilton, 1991; Lundvall, 1992; Bartholomew, 1997; Malerba, 2002). The institutional conditions conducive to the accumulation and diffusion of knowledge reflect the creation of new technical sources influencing the comparative advantages of a country (also see Etzkowitz and Leydesdorff, 2000).

This chapter critically reviews the extant theoretical and empirical studies on innovation and determinants of technology capabilities at the national, sectoral and firm levels. The structure of this chapter is as follows: Section 2.2 reviews earlier theoretical and empirical studies on innovation with an emphasis on the concepts of innovation and technology capabilities, the generation of innovation models and key determinants of innovation performance. In section 2.3, I bring together the body of innovation studies in the

context of latecomer economies with the specific literature on Korea and Japan to better articulate my research theme.

2.2 Theoretical Studies on Innovation and Technology Capabilities

Several definitions of innovation exist in various fields since it is difficult to conceptualise innovation with one standard definition because of the inherently complex nature of innovation activities, which are risky, time consuming, indirect and uncertain. Innovation refers to new concepts, products and inventions derived from individuals' ideas, learning and scientific research used for invention, translation and commercialisation.

The first notion of innovation appeared in Joseph Schumpeter's book, *The Theory of Economic Development* (1912). Schumpeter was the first economist to draw attention to the significance of innovation in economic and industrial development. In the 1930s, he defined innovation as: "... (1) *The introduction of a new good ... or a new quality of good* (2) *The introduction of a new method of production ...* (3) *The opening of a new market ...* (4) *The conquest of a new source of supply of raw materials ...* (5) *The carrying out of the new organization of any industry ...*" (Schumpeter, 1934, p.66). In 1998, the Organization for Economic Cooperation and Development (OECD) articulated the notion of innovation as the creation of new knowledge, and the application and diffusion of existing knowledge, categorised by a technological product innovation and a technological process innovation: "A *technological product innovation can involve either a new or improved product whose characteristics differ significantly from previous products. The characteristics may differ due to use of new technologies, knowledge or materials. A technological process innovation is the adoption of new or significantly improved production methods, including methods of product delivery*" (OECD, 1998, p.7). Another explanation is that innovation is not considered until

it is implemented or commercialised to create added value, in contrast to invention which is not directly associated with the application or the commercialisation (Gibbons *et al.*, 1994; Freeman and Soete, 1997). This highlights the importance of technology capability in the creation and commercialisation of new (or improved) products and processes. Technology capability conducive to the transformation of knowledge into new products, processes and services enables a firm and a country to strengthen their competitive advantage and attain sustainable growth economically, socially and intellectually (Porter and Stern, 1999, p.12).

Technological capability is defined as the ability to generate new ideas, know-how and technologies with accumulated knowledge (Archibugi and Coco, 2005; Fagerberg and Srholec, 2008). It is built and developed using several heterogeneous ingredients; (i) visible knowledge (e.g., capital goods, infrastructures) and invisible knowledge (e.g., human skills and expertise); and (ii) explicit knowledge (e.g., patents, scientific articles) and tacit knowledge (e.g., know-how by learning) (Lundvall and Johnson, 1994; Evangelista, 1999; Archibugi and Coco, 2004, 2005).

Explicit/visible knowledge is related to the ease of its translation into information using formulas, diagrams, numbers and words, implying an ease of codification and transfer among people (Archibugi and Coco, 2004; Jung and Lee, 2010). On the other hand, tacit/invisible knowledge cannot be easily codified and described, and consequently the transfer of tacit knowledge is costly and uncertain (Grant, 1996; González-Álvarez and Nieto-Antolín, 2007). In this regard, the firm or organisation that depends on tacit knowledge is more likely to seek secrecy than a patent (González-Álvarez and Nieto-Antolín, 2007). Therefore, consistent training and learning that require long-term research and development (R&D) investment and strategic alliances across borders are the major channels for technical innovation, especially in high-tech sectors where the involved knowledge is more tacit, such as biomedical, micro-machine and next-generation automobiles (Archibugi and Pietrobelli,

2003; Rycroft, 2002; Jung and Lee, 2010). Table 2.1 shows that Korea is the most innovative country in the world and also has advanced national technology capabilities with the world's largest technology input and output. As a component of national technology capabilities, technology input encompasses fiscal policy, education policy and other policies relating to innovation and science and technology (S&T) development, while patents, technology transfer and other R&D results are included as sub-components of technology input (INSEAD, 2009).

Table 2.1 Top Ten Countries by Global Innovation Index, 2009

Rank	Country	Overall	Innovation Input	Innovation Output
1	Korea	2.26	1.75	2.55
2	United States	1.80	1.28	2.16
3	Japan	1.79	1.16	2.25
4	Sweden	1.64	1.25	1.88
5	Netherlands	1.55	1.40	1.55
6	Canada	1.42	1.39	1.32
7	United Kingdom	1.42	1.33	1.37
8	Germany	1.12	1.05	1.09
9	France	1.12	1.17	0.96
10	Australia	1.02	0.89	1.05

Note: (i) Innovation input covers fiscal and education policies and the innovation environment (e.g., ICTs); (ii) innovation output includes patents, technology transfer and other R&D results (e.g., business performance, such as labor productivity and total shareholder returns); (iii) The indicators of innovation inputs and outputs are measured by GDP.

Source: Compiled by the data from INSEAD of The Global Innovation Index 2011.

http://www.globalinnovationindex.org/gii/GII%20COMPLETE_PRINTWEB.pdf

Different mechanisms and channels for technology capabilities also exist in three technological development stages - immature, intermediate and mature. Immaturity is linked to low-income countries that possess basic manufacturing skills in underdeveloped technology infrastructures and feeble network-based innovation systems. The intermediate class involves many middle-income countries in the factor-driven and investment-driven phases. The mature class includes high-income countries in the innovation-driven growth

phase (Lall, 1999; Porter, 1998; UNCTD, 2003a). This suggests that foreign direct investment (FDI) and absorbing capacity are key drivers of national technology capabilities in the earlier stage of technology development, while R&D cooperation and internationalisation of R&D are key channels for progress in the mature stage (UNCTD, 2003a).

2.2.1 Generation of Innovation Models

Five generations of innovation models exist: the technology push model, the need pull model, the coupling model, the integration and parallel lines model and the system integration and networking model. The models broadly divide into linear and non-linear approaches to innovation. The linear form of innovation comprises the technology push model and the need pull model. The former was generated in the 1950s. This model suggests that new technology brings opportunities to acquire, learn and transfer new knowledge, and the consequent pull innovative activities for creating new industries (Rothwell, 1994). The role of government laboratories and universities is emphasised so as to spur the development of new technologies that are pushed into the market (Rothwell, 1994). In contrast, the latter model highlights the importance of the demand side factors in promoting industrial innovation, suggesting that the market is the source of ideas for directing innovative activities (Rosenberg, 1974). In the need pull model, the need for innovation is determined by customers, and new technologies are created in response to customers' need. This model evolved from the mid-1960s through the early 1970s (Rothwell, 1994; Tidd *et al.*, 2005). Both innovation models address innovation as a simple linear sequence of functional activities, emphasising important sources of product innovation, but not the process of innovation. However, in practice, the inherent nature of innovation is associated with a complex, risky, uncertain and interactive process with various stakeholders. Likewise, innovation is affected by a threshold of

opportunity and external shocks (Tidd *et al.*, 2005). Therefore, non-linear approaches to innovation emerged to compensate for the weak points in linear models.

The third generation of coupling model appeared from the early 1970s to the mid-1980s. This model outlines innovation as the combination of technology push and market demand, emphasising the research interaction between different sectors and the feedback loops between them in the process of innovation (Rothwell and Zegveld, 1985). The fourth generation of the integration and parallel lines model (from the early 1980s to the early 1990s) focuses on integration within the firm, upstream with suppliers and downstream with demanding customers. As success factors of innovation, this model emphasises a close link between suppliers and customers and a cooperative relationship among various actors (Rothwell, 1994). The fifth generation of innovation model (integration and networking) emerged in the early 1990s through an extension of the fourth generation model. This model focuses on a strategic partnership with suppliers and customers, as well as integration at both intra- and inter-firm levels on the basis of information technology (IT)-based networking in the process of innovation (Tidd *et al.*, 2005). To succeed in innovation, this model suggests (i) a flexible organisational structure and customised response; (ii) extensive networking for the speed of development and external data links; (iii) a policy quality control; and (iv) continuous innovation focusing on high quality and other non-price factors (Rothwell, 1994).

As mentioned above, the models of innovation have evolved with different public policies and corporate practices in response to market conditions and technical changes since the 1950s, shifting from the linear model to the parallel and integrative innovation models. However, the linear models of innovation still trigger innovation in many industries. For example, the technology push model applies to newly emerging and highly basic scientific research-dependent industries, such as biotechnology and pharmaceuticals (Rothwell, 1994, p.23). Meanwhile, the need pull model that focusses on new markets and active customers is

appropriate for innovating in the electronics and automobile industries (Pavitt, 1984).

2.2.2 National Innovation System Models

The concept of a national innovation system (NIS) was first introduced by Christopher Freeman and Bengt-Åke Lundvall in 1985 when a point in dispute in the European industrial growth strategy was raised (Sharif, 2006). Their idea has been taken up by several scholars in several areas of the literature. The various definitions of NIS are shown in Table 2.2.

Table 2.2 Definition of NIS

Freeman, 1987, p.1	“The network of institutions in the public and private sectors, whose activities and interactions initiate, import, modify and diffuse new technology”
Lundvall, 1992, p.2	“A set of institutions whose interactions determine the innovative performance...of national firms”
Nelson, 1993, p.4	“The elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge...and are either located within or rooted inside the border of a nation state”
Metcalf, 1995, p.38	“The set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies”
Patel and Pavitt, 1994, p.78	“The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country”

In a nutshell, NIS is a set of institutions supporting the stock and flow of knowledge to develop national technology capabilities and overall national competitiveness. The NIS leads distinctive coordination mechanisms, learning processes and roles of players, as well as contextual factors within the system, which significantly affects various patterns of innovation process and growth strategies across countries (Kogut, 1991; Nelson, 1993; Lundvall, 1998).

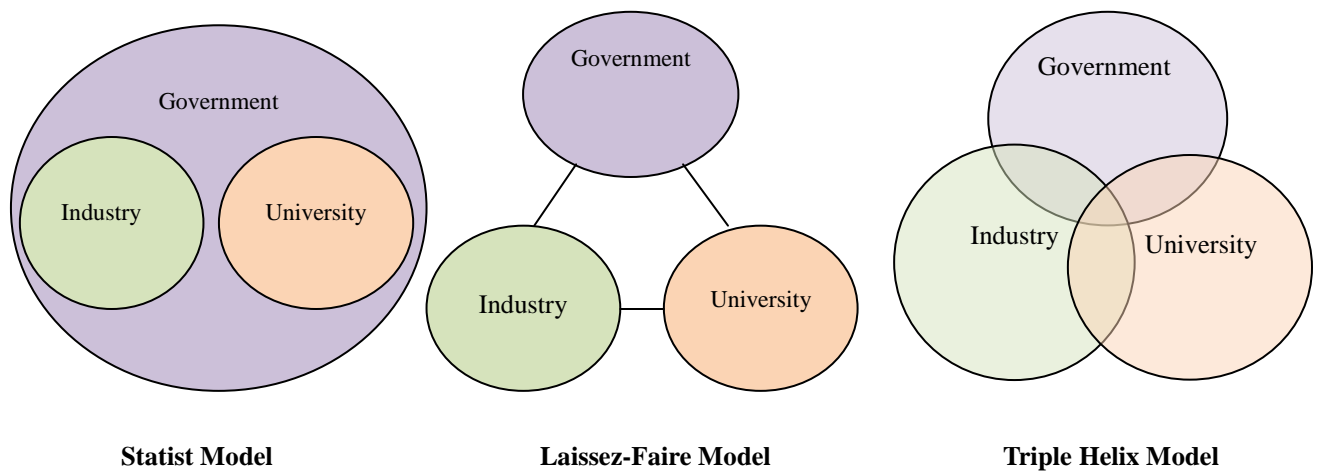
The contextual factors and actors in NIS as significant sources of technology capabilities are highlighted in much of the innovation literature. Freeman (1995) stressed the roles of innovation policy, corporate R&D, educational system and industrial structure in shaping NIS in economic and technological development of Japan. Lundvall (2002) focused on four factors that influence the technology capabilities of countries - government structure, finance system, R&D system and inter-firm linkage. From the institutional perspective, Nelson and Rosenberg (1993) emphasised the importance of institutions and organisational characteristics as the key factors contributing to technology capabilities and innovation - the national education system for schooling, training and retraining, the patterns of labour-management bargaining and negotiation, the degree of mutual commitment of firms, workers and financial institutions and the structure of corporate governance.

Also, several theoretical and empirical studies have focussed on cooperative activities between universities and industry as important contexts of technology transfer (Albino, 1998; Robinson, 1988; Stewart and Gibson, 1990; Mowery and Oxley, 1995), as well as the positive effect of interaction among endogenous and foreign firms on technological spillovers (Cantwell, 1989, 1995; Perez, 1997; Álvarez and Molero, 2005). More recently, Chang and Shin (2004) addressed informal relations, networking capabilities of institutions and personnel as significant sources of innovation success in the context of transition economies, particularly China.

NIS has evolved through three models: statist model, laissez-faire model and triple helix model, as shown in Figure 2.1. The statist model is characterised by top-down bureaucratic coordination, the dominant role of government in knowledge creation and primarily teaching-based universities (Benner and Sandstrom, 2000; Leydesdorff and Fritsch, 2006). In the laissez-faire model (interface units across strong boundaries), government has limitations in addressing market failures, universities act as providers of human capital and

basic research and firms are strongly linked in the market (Etzkowitz and Leydesdorff, 2000; Inzelt, 2004). The role of the university becomes larger as inventor and R&D performer in the triple helix model, evolving from teaching university to research university and entrepreneurial university, which shifts from the secondary to the primary institutional sphere in a knowledge-based society (Etzkowitz and Leydesdorff, 2000; Leydesdorff and Fritsch, 2006; Marques *et al.*, 2006).

Figure 2.1 NIS Models



Source: Compiled by authors from Etzkowitz and Leydesdorff (2000); Leydesdorff, and Fritsch (2006).

In the triple helix paradigm, knowledge creation and innovation are stimulated at the focal point at which they (the triple indicators) affect each other or have links with each other (Etzkowitz and Leydesdorff, 1995; 2000). The role of the university is highlighted with the mission of (i) accumulating and creating knowledge through constant research; (ii) training through knowledge transfer from the teaching staff to students; and (iii) facilitating new products and innovation processes through the transfer of ideas or know-how to other organisations (e.g., government laboratories, research institutes, firms) and joint R&D. The

triple helix is an appropriate model for the biotechnology industry, which in contrast to other industrial technologies (e.g., electronics, automobile) is distinguished by heavy dependence on basic scientific research and close ties to market-induced applied research. Such scientific research-based technology is needed to build up the capacity of universities and their close ties to research institutes and industry (Mowery and Rosenberg, 1993; Lehrer and Asakawa, 2004; Casper and Kettler, 2001).

The NIS has five major agents: administrative organisations, public/private research institutes, higher education institutes, industrial firms and intermediaries. Administrative organisations include government agencies and ministries related to science and technology. They act as S&T policy planners, performers and coordinators, as well as sponsors and facilitators for firms' innovative activities (Senker, 1996; Chang and Shih, 2004). Higher education institutions (i.e., universities and public/private technical training centres) are engaged in knowledge diffusion and technology transfer, as well as fostering human capital (Park, 2004; Lehrer and Asakawa, 2004). Research institutes and industrial firms are major R&D and innovation performers for creating and utilising technologies (Chang and Shih, 2004). Intermediaries promote the dynamics of R&D cooperation among public research institutes, universities and firms through the formation and implementation of joint R&D projects and programmes (OECD, 1997).

2.2.3 Interplay between Corporate Governance System and National Innovation System

Innovation success largely depends on the quality of national finance system and corporate governance system. The importance of corporate governance as the key source of innovation is first recognised by Joseph Schumpeter. He suggested an advantage for corporate governance of large firm, allowing the reinvestment of profits into a routinised innovation, whereas a disadvantage for new entrepreneurs (based on external finance) in the development

of new equipment and the improvement of the existing one (Schumpeter 1911; 1942), given that innovation is generally associated with “*non-negligible time and outlay*” (Schumpeter 1939, p.68). After Joseph Schumpeter, there were a number of studies focusing on organisational characteristics as determinants of industrial competitiveness and innovation: top management GEO’s age (Khan and Manopichetwittana, 1989); firm size (Bertschek and Entorf, 1996); foreign ownership in Scottish manufacturing industries (Love *et al.*; 1996); innovative established firms versus new firms in semiconductor and biotechnology industries (Sørensen and Stuart, 2000); international diversification of large firms (Hitt *et al.*, 1997).

More recently, William Lazonick and Mary O’Sullivan focused on ‘*social conditions of innovative enterprise*’ that provided systematic analysis the role of finance and corporate governance systems in the learning process required for innovation. “*A system of corporate governance supports innovation ... provide the institutional support ... support organisational control in contrast to market control ... Reflected in the operation of employment, financial, and legal institutions, social conditions constitute norms according to which business enterprises seek to make strategic decisions concerning the allocation of resources.* (O’Sullivan, 2000b, p.59-67). They highlighted the significance of ‘financial commitment’ to overcome the nature of innovation (e.g., high uncertainty, time-consuming), and consequence need for ‘organisational integration’, allowing collective and cumulative learning (Lazonick and O’Sullivan, 2000a; 2002). The organisational integration might arise in the established firms. Financial commitment that provides the conditions for recycling profit into investment in innovation depends on shareholder/financier engagement and management autonomy as a response to low visibility and slow pay-off innovation (Tylecote, 2007).

Given that firms are the main research performer and financier within national innovation system (NIS), corporate governance system that directly affects their strategic

actions for the allocation, investment and acquisition of resources, as well as the mechanism for the distribution of returns is interrelated to national technology capabilities in the product and process of innovation. The interplay between NIS and corporate governance system and its profound effect on innovation patterns, outcomes and sectoral specialisation across countries have been highlighted by many financial economists, mostly varieties of capitalism (VoC) scholars (Lazonick; 2004; 2010; Tidd *et al.*, 2005; Tylecote, 2007; Tylecote and Vistintin, 2008).

The absolute and relative technological advantage and industry-specific competitiveness of nation largely rely on characterisation of the shareholder-manager relationship and the manager-manager relationship — who directly (or indirectly) controls firms, how promotes their value creations, and what mechanisms are used for the improvement. In radical differences in national business systems of corporate financing, equity ownership and corporate control, economies are broadly divided into the two types: stock exchange-based and bank-based financial systems (La Porta, *et al.*, 1998; Allen and Gale, 2000; Levine, 2002); in other words, outsider-dominated and insider-dominated corporate governance systems (Franks and Mayer, 1997; Whitley, 1999; Hall and Soskice, 2001; Tylecote, 2007). Such different national systems of finance and corporate governance produce different preferences toward firms R&D and innovation activities (Hoskisson *et al.*, 2002).

In categorisation from VoC perspective, stock exchange-based financial system (or outsider-dominated corporate governance system) is consistent with liberal market economies (LMEs), characterised by dispersed equity ownership, external equity financing, diversified portfolios and high liquid, as well as a dominant conflict of interest between all shareholders over management. The main shareholders include pension funds, mutual funds, insurance companies and households (Berglöf, 1997; Tylecote, 2007). Coordinated market

economies (CMEs) parallels bank-based financial system (or insider-dominated corporate governance system), which have distinctive features of more concentration of equity (or debt) ownership by large block-holders, higher share of control-oriented finance, less liquid of financial market and a conflict of interest between minority shareholders against controlling. The main shareholders include family owners, banks, government and cross-holding firms (Berglöf 1997; Dore *et al.*, 1999; Tylecote and Vistintin, 2008).

Until at least 1990s, English-speaking countries were placed in the former category, and other non English-speaking countries were assigned in the latter category (Edwards and Fischer, 1994; Berglöf 1997; La Porta *et al.*, 1999; Levine, 2002). Such the classification, grouping non English-speaking countries into insider-dominated corporate system economies (CMEs), hardly seems robust and plausible due to the heterogeneity of financing and governing innovation, embracing labour market condition, role of financial market, role of state, polarity control, inter-firm linkage, firm-bank linkage, and ownership concentration and others. This leads to an emergence of alternative taxonomy, which proposes the four types, distinguishing stakeholder-capitalist, state-led capitalist and family/state capitalist from non-stock exchange-based economies (Tylecote, 2007; Tylecote and Visintin, 2007)

First, shareholder capitalism is characterised by a high stock market capitalisation, large role in private equity (less reliance on bank loans), low employment protection, low inter-firm linkage, and the consequent the availability of expert finance for new firms (e.g., venture capital), in which there is pressure from expert owners for higher value added in the areas affected by radical innovation (Lazonick and O'Sullivan, 2000; Aguilera and Jackson, 2003; Young and Scott, 2004). The USA and the UK are representatives of this model in which only shareholders play the role in management with little intervention from government and other stakeholders, as well as little use of bank finance (Tylecote and Visintin, 2008). However, part of the differences between the countries is the dominance of

family-controlled firms and widely held firms in the USA and the UK, respectively (Claessens *et al.*, 2000; Faccio and Lang, 2002). The UK in which there is “*indirect control through share price movements and the market for corporate control*” (Tylecote and Vistintin, 2008, p.87) seems to more perfectly fit as the stereotypical shareholder capitalism than the USA based on a large number of firms controlled by founding entrepreneurs and their families.

Second, Germany, Japan and other countries in which employees and other related businesses can have share of control or influence over management decisions are categorised into stakeholder capitalism. The key distinctive features are “*considerable non-market coordination directly and indirectly between countries, with the state playing a framework-setting role*” (Soskice, 1999, p.103). Under the pressures and interests of stakeholders in management, bank finance, inter-firm cooperation, financier engagement and stakeholder spillovers play the central role in firm performance and innovation (mostly incremental innovation). Compared with Germany, Japan’s bank directorships in large firms are appeared only in crisis, and lending to industry is much higher to govern technological change (Aguilera and Jackson, 2003; Tylecote and Vistintin, 2008). Also, families play little role in Japan than in Germany, because of its relatively high-trust culture and institutions that allow Japan to successfully govern and manage organisational problems without family control (Claessens *et al.*, 2000; Faccio and Lang, 2002). Such different ownership structures could produce different cooperation mechanism — stronger inter-firm cooperation within sectors and stronger inter-sectoral cohesion among firms in Japan (Tylecote, 2007; Tylecote and Vistintin, 2008).

Third, state-led capitalist countries, namely Korea and France, rely on bank finance more than stock market finance, like the stakeholder model, but strong central government influence over the banking system exists. The unique features are larger government role in

coordination, stronger employee protection and inter-firm cooperation among large firms and close ties between the privileged firms and bank (poor access to bank finance for SMEs and start-ups). A small numbers of very large firms that fit into the aims and policies of the government could receive state-direct loans and cheap bank loans, while small firms rely on external finance (Lee and Yoo, 2007). Compared with France, Korean firms have higher level of family control and there is less state direct control and ownership in high-tech sectors in Korea (Edwards and Fisher, 1994; Goyer, 2001; Lee and Yoo, 2007). The Korea firms are better performance than the French firms in rapidly innovative areas involved in high opportunity and high risk, which can be attributable to a small number of family-controlled conglomerates, chaebol. *“Grouping creates financial synergies which enable the chaebol to mobilise large-scale investment funds effectively ... grouping also helps the chaebol firms invest more aggressively in new technologies by enabling them to share risk with their member firms”* (Chang and Park, 2004, p.42). Tylecote and Vistintin (2008) pointed out that Korean firms have followed the style of American corporate governance system, whereas French firms are shifting toward the British shareholder model in the development of high-tech sectors.

Fourth, family/state capitalism is distinctive from the above three types due to high shareholder engagement, low financier engagement and lack of external finance, in which there is a huge direct state subsidy for few large firms and state-owned firms with relatively high degree of state ownership and control. Italy and China belong to this category (Tylecote and Visintin 2002; Tylecote, 2007). The family capitalism can limit the dynamics of innovation since the countries’ legal systems, such as Italy, provide ineffective protection of minority investors (La Porta *et al.*, 1998). Although government interference in management exists in both state-led and family/state capitalisms, its influence is much more positive to the state-led economies because of effective government intervention and close ties with family

capitalists (Tylecote, 2007). Table 2.3 summaries distinctive features of national financial and business systems governing innovation across countries.

Table 2.3 Taxonomy of Financial and Corporate Governance system for Innovation

	Outsider System		Insider System	
Main Shareholders	Pension/mutual funds, insurance companies, households		Families, banks, other firms, government	
Shareholder-Management	Arms-length		Control-based	
Share of Control-oriented Finance	Relatively low		Relatively High	
Ownership (Equity and Debt)	Dispersed		Concentrated	
Equity Market	<i>Shareholder</i> Strong	<i>Stakeholder</i> Weak	<i>Sate-led</i> Weak	<i>Family-Sate</i> Weak
State Role	Background	Cooperation with business	Close ties with large firms	Larger sate-sector
Poles of Control & Directness	Uni-polar; Indirect control	Muti-polar; Direct control	Bi-polar; Indirect control)	Uni-polar; Direct control)
Employee Protection	Weak; no codetermination	Moderate; codetermination ,	Strong; no codetermination	
Dominant Types of Firms	Family holdings ⁽¹⁾ ; Dispersed holdings ⁽²⁾	Family holdings ⁽³⁾ ; Financial/Non-financial holdings	Family holdings; Non non-financial holdings; Dispersed holdings	State holdings, Dispersed holdings (especially Taiwan);
Countries	Australia, Canada, UK, USA, Switzerland, etc.	Netherland, Sweden, Germany, Japan, etc.	France, Korea etc.	Italy, Spain Taiwan, etc.

Note: ⁽¹⁾ and ⁽²⁾ type is dominant in the US and the UK, respectively. ⁽³⁾Germany has the highest share of family control in the stakeholder model.

Sources: Compiled by the data from Berglöf (1997); Whitley (1999; 2003); Tylecote (2007); Tylecote and Vistintin (2008).

These types lead to different trajectories of innovation and sectoral specialisations.

Corporate ownership structure decidedly affects investment behaviours toward industrial competitiveness and innovation (Jensen and Meckling, 1976). Agency theory has provided many other theoretical frameworks to explain these relationships by suggesting effective monitoring mechanisms to control opportunistic of agents. From the agency theory, dispersed ownership structure generates the conflicts between principals (i.e., shareholders) and agents (i.e., managers) interests, and often produces the unbalanced structure (such as powerful managers and powerless owners), while leading to managers' opportunistic behaviour for self-interest as well as the high monitoring costs (Jensen and Meckling, 1976; Eisenhaedt, 1989; Roe, 1994). However, dispersed ownership structure allows risk bearing, diversified portfolio and specialized management (Porter, 1992). Meanwhile, stewardship theory have highlighted that ownership structure controlled by large block-holders can lessen the principal-agent problems and prevent the agent's opportunistic behaviours by efficiently monitoring managers (Aoki *et al*, 1994; Davis *et al.*, 1997; Lee and O'Neill, 2003). The definition of stewardship theory is that "*... situations in which managers are not motivated by individual goals, but rather are stewards whose motives are aligned with the objectives of their principals*" (Davis *et al.*, 1997, p.21).

From technological perspective, the dispersed ownership (normally the shareholder model) that allows risk-hedging in diversified portfolios and increasing venture capital should be beneficial to the sector where '*competence-destroying change*' (Tushman and Anderson, 1986) needs for radical reconfiguration of its organisational structure in the development of radically new products. Rapid technological change leads a complete trajectory shift, moving to a new technological paradigm. "*In rapidly changing environments, there is ... value in the ability to reconfigure the firm's asset structure and to accomplish the necessary internal and external transformation*" (Teece, 1998, p.201).

Due to the limitation of external capital availability, on the other hand, concentration

of ownership (normally the stakeholder model) should be disadvantageous to the sector involved in radical shifts direction, but advantageous to the sector in which technological change is cumulative and path-dependent, implying that learning and knowledge environment is associated with ‘*competence-enhancing change*’ (Tushman and Anderson, 1986; Malerba 2004). “*Where technological change is progressing within an established paradigm ... established firms should be able to carry it forward, enhancing their competences, without much change in their organization*” (Tylecote, 2007, p.1465). Lee and O’Neill (2003) and Carney (2005) proved a positive effect of ownership concentration on R&D investment in medium-high technology industries. Tylecote and Vistintin (2008) highlighted the significance of industry-wide-expertise in governing radically technological change, and the large role of management autonomy in the incremental shift direction.

Hall and Soskice (2001) pointed out that shareholder capitalism are superior to the other capitalisms in radically innovative sectors, since the stock market and equity finance based structure can raise expert risk capital and more R&D under a high market uncertainty (Will does it work?) and a technological uncertainty (Will does it sell?) caused by the rapid technological change. Although the rest of capitalist countries involved in relatively low level of availability of external finance fail to effectively respond to the radical technological change, but their organisational structures in which there are cooperative relationship between stakeholders (firm-firm or firm-bank or firm-sate) are advantageous of incrementally innovative sectors (also see Franks and Mayer, 1997). However, Taylor (2004) critically examined VoC theory and extended Hall and Soskice’s approach by using both simple patent counts and citations-weighted in longitudinal time frame, and found that Japan and Korea are radical innovators, especially in hardware related to information and communication technology (ICT), next of the US.

The countries’ innovative capabilities of ICT in which diverse technologies are partly

attributable to the inter-sectoral based cooperation among the large firms, although they have different characteristics of corporate governance systems — large family-controlled firms-oriented (chaebols) and government-coordinated systems in Korea; network of cross-shareholdings among large firms-based (horizontal industrial groups, keiretsue) and business-coordinated systems in Japan (Soskice, 1999; Allen and Gale, 2000). In selected major areas of state interest, involving especially low visibility and slow pay-off, government encouraged firms to adopt new technologies by forming shareholder/financier engagement and interacting with other institutions of various kinds, which can improve the availability and acceptability of risk finance (Tylecote and Vistintin, 2008).

2.3 Empirical Studies on Innovation, Technology Capabilities and Catch-up

This section provides a critical review of empirical innovation studies on determinants of technology capabilities and innovation performance. To articulate my research themes in better detail, I also introduce the extant research for latecomers' technology and productivity catch-up, using specific literature on technological and economic development in Korea and Japan. Innovation studies on Korea and Japan provide the contextual understanding of distinctive sources and mechanisms of technology catch-up and capabilities.

2.3.1 Literature on Determinants of Technological Capabilities and Innovation

A large body of studies is devoted to identifying determinants of technology capabilities and innovation at various levels - firm, industry and country - in the social sciences. First, traditional innovation research derived from economic studies has argued that R&D expenditure and knowledge stock increase the probability of innovation (Scherer, 1965; Bound *et al.*, 1984; Ettl *et al.*, 1984; Hausman *et al.*, 1984; Pakes and Griliches, 1984; Hall

et al., 1986; Crépon *et al.*, 1998; Decarolis and Deeds, 1999; Licht and Zoz, 2000; Greve, 2003; Beneito, 2006). Despite different contexts, measurements and issues, these studies have commonly regarded in-house R&D and indigenous capabilities as main determinants of technology capabilities and innovation.

Second, management studies have highlighted the role of human capital (Rhyne *et al.*, 2002; Romijn and Albaladejo, 2002; Michie and Sheehan, 2003) and firms' marketing capabilities and managerial skills (Hobday, 1995; Souitaris, 2001; Koschatzky *et al.*, 2001) in innovation and firm performance. Other organisational studies have argued that innovation performance is influenced by firms' internal elements, such as size, age and assets (Schumpeter, 1942; Galende and De la Fuente, 2003; Bertschek and Entorf, 1996; Sørensen and Stuart, 2000), corporate finance and ownership structure (Francis and Smith, 1995; Dixon and Seddighi, 1996; Love *et al.*, 1996; La Porta *et al.*, 1999; Shleifer and Wolfenzon, 2002; Tylecote, 2007). Given those different shareholders' interests and risk management, types of financial system and corporate ownership structure produce different strategic actions in the product and process of innovation (Lazonick and O'Sullivan, 2000; Aguilera and Jackson, 2003; Tylecote and Vistintin, 2008). As case studies, Love *et al.* (1996) discussed the positive impact of foreign ownership on firms' value creation, performance and product innovation using a sample of Scottish firms and English firms, respectively. Francis and Smith (1995) empirically examined the relationship between firms' ownership structure and innovation performance, and concluded that the firm with a highly concentrated management ownership than the diffusely held firm is more likely to undertake long-term oriented investment, considering firm stability and future prosperity. In many emerging economies, firms are controlled by founders and their families (Prowse, 1992; Shleifer and Vishny, 1997; Claessens *et al.*, 2000). However, excessive firm ownership concentration and insiders dominated system have a harmful effect on firms' performance due to arbitrary

owner decisions, less liquidity in markets and fewer opportunities to negotiate the firm's values (La Porta *et al.*, 1999; Shleifer and Wolfenzon; 2002). A strong possibility exists for information asymmetry between owners and managers in diffusely held firms, implying that the separated management structure is likely to result in conflict of opinion among managers regarding innovation projects and allocating R&D resources (Francis and Smith, 1995). More recently, Lee and O'neill (2003) examined how distinctive characteristics of national culture affect the organizational ownership structure, with particular attention to the US firms and Japan firms. They argue that the separated corporate ownership structure in the USA is associated with individualist culture, whereas the collectivist culture in Japan affects the concentrated ownership structure. The collectivist culture values trusts and long-term relationship, as well as attaches a great importance to groups' interests relatively to individual ones (also see Aguilera and Jackson, 2003). Lee (2005) also compared the different ownership structure between U.S and Japanese firms and its direct influence on R&D activity rested on the basis of agency and stewardship theoretic perspectives.

Third, international business studies have stressed the crucial roles of external linkages and networks of knowledge involving multinational corporations (MNCs), as well as central and regional government policies promoting inward FDI investments in the products and processes of innovation (Vernon, 1977; Hunt, 1992; Cantwell, 1995; Meyer-Krahmer and Reger, 1999). They have commonly pointed out that innovation performance depends on the ability to attract knowledge-intensive R&D investments from foreign MNCs and to connect to the global value chain of these firms. Vernon (1977, p.39) asserted that *"multinational enterprises see special virtues in innovation partly because that activity tends to go hand in hand with a rapid increase in sales and profits."* Hunt (1992, p.192) argued that the *"multinational firm is an extension of the multidivisional form. It is more complex because two common differentiators (function and product) are joined by a third-geography."*

Dunning (1993) informed us of two main contributions of economists to the understanding of foreign production and multinational enterprise (MNE) growth, this being identification and explanation of the ‘*unique characteristics of the MNE qua*’ and attempts to explain various “*determinants of the foreign value-added activities of MNEs irrespective of whether they are due to their multinationality*” (Dunning, 1993, p.36). Cantwell (1995) said that “*in more recent times technology leaders have altered the nature of international technology creation by pioneering the international integration of MNC facilities into regional or global networks*” (Cantwell, 1995, p.171).

Meyer-Krahmer and Reger (1999) examined changes in innovation strategy in twenty-one multinational corporations with a focus on internationalisation. Their result showed that “*triadization*” still occurs in research and technology among European, Japanese and US corporations. Significantly, Meyer-Krahmer and Reger (1999, p.754-755) noted that R&D location decisions can be attributed to change and development in “*the internationalisation of management and corporate culture, and the type of cross-border coordination and interaction*” observed. In addition, Meyer-Krahmer and Reger (1999, p.758) signalled that “*creation of technological knowledge in foreign countries has become an important part in the on-going trend towards internationalization*”. They went on to argue that “*an increasing need for international solutions is necessary in global problem fields*”. This affects the emerging and appropriate division of labour in policy and strategy at the regional, national, European and international level (Meyer-Krahmer and Reger, 1999, p.758). In this respect, Ghoshal and Bartlett (1988) addressed the significance of norms interconnecting with socialisation in multinationals. Morgan (2003, p.1) confirmed the MNC to be a “*social ‘construction’ that arises out of ‘specific national, institutional contexts’ that mould how it will ‘internationalize’*”.

Fourth, institutional studies on innovation have underlined the importance of

institutional factors, such as industrial structure, finance system, sectoral and national innovation system and public policy as determinants of technology capabilities and innovation performance. Recently, political economists have pointed out that cross-industry and cross-country differences in catch-up patterns and sectoral specialisation result from distinctive institutional-setting and policy frameworks (Taylor, 2004; Tylecote and Vertova, 2007; Lazonick, 2007; Breznitz, 2009; Freeman, 1995; Lundvall, 2002; Leydesdorff and Fritsch, 2006) and different technological regimes, such as technological opportunities, appropriateness of innovation, and cumulative technical advances (Pavitt, 1984; Archibugi *et al.*, 1991; Mowery and Nelson, 1999; Breschi *et al.*, 2000; Park and Lee, 2006).

Fifth, a large body of innovation studies has highlighted the role of a collaborative/competitive innovation network and clustering process in the development of technological capabilities and improvement of innovation performance at sectoral, regional and national levels from various perspectives (Castells and Hall, 1994; Hsu *et al.*, 2003; Koh *et al.*, 2005; Roberts, 1998; Storey and Tether, 1998; Vedovello, 1997). Porter (1990) argued that interrelated industries in regional clusters are a localised source of customers, employment, exports, incomes and networks in which corporate innovation can be enabled with a regional competitive advantage (RCA). The RCA refers to the capacity of a region to succeed and provide strategically significant offerings that are cheaper or finer than those in other regions, not a country-specific advantage (CSA) or a firm-specific advantage (FSA). Porter's (1990) '*Diamond of National Advantage*' model comprises *industry rivalry*, *strategy* and *structure* (inadequate rivalry will undermine innovation and adequate rivalry will revive innovation); *factor conditions of basic resources* (climate, demographics, resources and size) and *advanced resources* (communications, infrastructure, specialists and technology); *demand conditions* (domestic catalysts can drive innovation); and *related* and *supporting industries* (collaborative or competitive in their offerings). In addition, government policy

can affect innovation in various ways, including antitrust regulations, rousing early demand for advanced products and services and stringent standards for products and services. Porter (1998; 2000) analysed different determinants of innovation clusters and competitiveness across countries, including government policy, legal institutions and market potential, factor conditions (e.g., human resources, technology infrastructure) and others (e.g., firm strategy, demand conditions). Based on Porter's model, Lai and Shyu (2005) examined distinctive sources of innovation performance in national industrial clusters located in China and Taiwan. Dodgson (2008) discussed different patterns of innovation in industrial and technology clusters by employing the two theories of varieties of capitalism and NIS in the context of Korea and Taiwan.

The literature reviewed here suggests that technology capabilities and innovation performance are determined by not only the accumulation of internal and external sources around firms, but also by institutional, policy and contextual factors. The next section reviews specific literature focusing on idiosyncratic sources of technology catch-up and capabilities in the contexts of East Asian latecomers, with particular attention to Korea and Japan.

2.3.2 Literature on Technology Catch-up

The importance of technical innovation is stressed in various academic fields because of the persistent disparity between the poor and the rich throughout the world, as well as the stunted growth of middle-income countries (Esterly, 2001; Jung and Lee, 2010). Cameron (1998) highlighted the role of human capital based on creativity and originality in narrowing productivity and technology gaps because slowdowns are caused by the depletion of imitation or copy possibilities. The newly industrialised countries (NICs) in East Asia (i.e., Korea, Singapore, Taiwan) have shown remarkable achievements in economic growth and

technological progress. These countries are often of interest to researchers because their growth patterns have demonstrated the inadequacy of the Anglo-American model and because of changes in general economic theory. The rapid and sustained economic growth of East Asian economies is attributable to effective institutional reforms and policy changes regarding technology catch-up with countries advanced in high technology fields. The institutional conditions conducive to the accumulation and diffusion of technological capabilities underpin the economic miracle of Korea, Taiwan and Singapore (Hobday, 1995; Rodrik, 1999; Kim and Nelson, 2000; UNCTAD, 2003).

“‘Catch-up’ relates to the ability of a single country to narrow the gap in productivity and income vis-à-vis a leader country, ‘convergence’ to a trend towards a reduction of the overall differences in productivity and income in the world as a whole” (Fagerberg and Godinho, 2005, p.514:2). The NICs refers to the latecomers and catch-up countries that are moving fast enough to attain the same technological progress and innovation performance as the leader (Park and Lee, 2006). However, there are different catch-up patterns and mechanisms in the East Asian latecomer countries. The World Bank (1993) argued that distinctive institutional framework (e.g., political-commercial links), industrial structure (e.g., export-oriented) and fiscal policy (e.g., saving rate, investment in education) produce different evolutionary paths and strategies for technology catch-up in the NICs.

The countries differences in catch-up strategies, patterns and performance are also caused by distinctive organisation structures; (i) the pursuit of a reverse product life cycle strategy in Korea’s large firm internalisation model; (ii) the pursuit of a reverse value chain strategy, process specialist strategy and product pioneering strategy in a Taiwanese small and medium-sized enterprise (SME)-centred innovation network model; and (iii) the pursuit of a process specialist strategy, reverse value chain strategy (smaller scale) and application

pioneering strategy that is strong among service firms in Singapore's FDI-leveraging model (Wong, 1995). The Korean chaebol-oriented structure parallels a Schumpeterian scale-based technological development, whereas the Taiwanese industrial structure based on SMEs associated with a neo-Marshallian network-based technological development (Wang, 2005). Among the East Asian latecomer countries, Korea has the background and institutional framework behind its rapid economic and technological catch-up most similar to Japan. The Korean political-commercial link and large firm-centred structure and innovation system (e.g., in-house R&D, home-grown talent) are much more similar to the Japanese model than any other business and innovation models within high-income countries and other East Asian NICs, such as Taiwan and Singapore (Forge and Bohlin, 2008).

Regarding sectoral technology catch-up performance, a technology paradigm shift enables latecomers to easily leapfrog forerunners, specifically in newly emerging industries characterised by high income elasticity of demand, rapid technique change and short life cycle of product (Lee *et al.*, 2005). The concept of leapfrogging was first developed by Perez and Soete (1988). They explained the phenomenon that a new techno-economic paradigm or the period of paradigm shift enables latecomers to capture new technological opportunities in emerging industries (also see Dosi, 1982). Lee and Lim (2001) suggested different catch-up models across industries; (i) path-following catch-up - the latecomer follows the forerunner's path; (ii) skipping catch-up - the latecomer follows the path to an extent but leapfrogs some stages; and (iii) path-creating catch-up - the latecomer creates its own path of technological development and innovation. Sectoral technology catch-up performance depends on the technology regime, uncertainty regarding a technological trajectory and accessibility to external knowledge flows and initial stock of accumulated knowledge (Lee and Lim, 2006; Park and Lee, 2006; Catellacci, 2007). Park and Lee (2006) provided evidence for the argument that catching-up countries can attain higher technology capabilities and

competitiveness in industrial sectors involving shorter cycle time, easier access to knowledge and higher appropriability in case studies of Taiwan and Korea.

To investigate distinctive technological accumulation processes and innovation patterns in the context of catch-up economies, the next section reviews more specific literature on determinants of technology catch-up and capabilities in Korea and Japan.

2.3.3 Literature on Innovation in Korea and Japan

Researchers have established that sustainable economic growth is attained by “*a process of acquiring technological capabilities and translating them into product and process innovation in the course of continuous technological change*” (Kim and Nelson, 2000, p.IX). Since Korea and Japan are the economies with the fastest technology catch-up in the world, a large body of studies on determinants of technology capabilities and innovation patterns in these countries has used various perspectives, methods and levels of analysis.

At a country level, the role of government in setting up effective policy measures for national technology capabilities and institutional reform in response to technological change was highlighted in much of the previous innovation studies on Korea and Japan. They commonly demonstrated the causal relationship between government intervention and the pace of industrial and technological progress in the state-led capitalist model, such as Korea and Japan (Koo, 1987; Amsden, 1989; Haggard and Moon, 1990; Freeman, 1995; L. Kim, 1997).

Freeman (1987; 1995) identified the national education system, industrial relations, technical and scientific institutions, government policies and cultural traditions as key determinants of national technology capabilities in Japan. L. Kim (1997) argued that effective export-oriented policies and close ties between political institutions and big business groups in the build of national strategic industry are major contributors to the rapid economic growth

in Korea (also see Koo, 1987). Hobday (1996) and Carney (2000) formed a similar conclusion that successful technological catch-up in East Asian economies is a result of government leadership, technological leaning derived from activities in export market and arrangement between government and industrial firms. However, Sakakibara and Cho (2002) pointed out the problems associated with low levels of knowledge sharing and cooperative R&D activities between universities and industry in Korea and Japan.

At an industry level, Mowery and Nelson (1999) discussed key sources of industrial leadership and factors behind cross-national and cross-industry differences in innovation patterns in seven industries in the US, Japan and Western Europe. Cefis and Orsenigo (2001) empirically analysed the persistence of innovation activities and its role in knowledge stock and innovation performance using patent data of manufacturing firms in Japan, France, Germany, Italy, the UK and the US. Cohen *et al.* (2002) identified appropriability conditions and intra-industry R&D spill-overs as critical success factors for technical innovation in Japanese manufacturing sectors.

Amsden (1989) suggested that government intervention, chaebol-centred industrial structure and shop-floor management explain why Korea has grown so much faster than other emerging economies. S. Kim (1998) argued that Korean semiconductor success is the result of political-institutional processes, the state-chaebol relationship based on reciprocal subsidy and chaebol governance. A good partnership between government-sponsored research institutes (GRIs) and firms with the government priority policy for intensively fostering ICTs enable Korea to be the most powerful ICT country in the world (Lee and Yoo, 2007). Meanwhile, the rapid growth of biotechnology in France is attributable to a strong research capacity of university and its close linkage with public/corporate research institutions, as well as the priority policy for biotechnology sectors (Lee and Yoo, 2007).

Furthermore, Bartholomew (1997) indentified several external sources around firms

as determinants of biotechnology and other basic scientific research-dependent industries: tradition of scientific education, patterns of basic research funding, linkages with foreign research organisations, degree of commercial orientation of academia, labour mobility; venture capital system, national technology policy, and technological accumulation (Bartholomew, 1997, p.246). A number of researchers argued that low levels of labour mobility, availability of venture capital and international partnership, as well as a weak R&D capacity of universities negatively affected the progress of biotechnology in Korea and Japan (Rhee, 2003; Park, 2004; Lehrer and Asakawa, 2004). More recently, Lee and Jung (2010) examined productivity gaps between Korean firms and Japanese firms in the manufacturing sector, highlighting the role of knowledge regime, sectoral innovation systems and market structure as determinants of productivity catch-up.

At the firm level, Damijan *et al.* (2003) investigated 8,000 firms in the top 10 transition countries and stressed the important role of FDI in technology transfer and its direct effect on local firms' productivity. Amsden and Hikino (1994) argued that the improvement of firms' capacity to successfully master foreign techniques and transform them into organisational know-how is essential for the latecomer firms. The role of organisational learning in productive and innovative activities was highlighted in much of the innovation literature on the latecomer firms (Hobday, 1995; Mathews and Cho, 1999; Cho *et al.*, 1998; 2001).

Lee and O'Neill (2003) examined the effect of corporate ownership structure on R&D investment of US and Japanese firms. By employing agency theory and stewardship theory, they argued that the different owner-management relationships, such as ownership concentration, result in disparities in R&D investments between the US and Japan. Hobday (1995) discussed success cases of East Asian latecomer firms' innovation strategies for electronic technologies. He pointed out Taiwan's SME innovation cluster model, Singapore's

leapfrogging strategy and Hong Kong's laissez-faire technological development strategy. The inter-organisational relationships (*e.g.*, business groups, strategic alliances, joint ventures, partnerships, research consortia) are the key drivers of catch-up success, since the arrangements empower the organisations to achieve economies of scale and scope, allot risk and share resources in the absence of financial, technical and managerial assets (Powell, 1990; Contractor and Lorange, 1988). Amsden and Hikino (1994) argued that business groups contribute to the progress of technology at both a firm and a country level because the diversified groups can efficiently transfer and diffuse know-how, ideas and skills into their affiliates in Korea and Japan. Furthermore, the formation of business groups may allow the flexibility of turnover capital for technology investment among their subsidiary companies, which serves technology capacity building and upgrading. However, particularly in the time of transition, a close relationship with government may be the necessary condition to grow firms and cope with the frequent fluctuation in public policies and institutions (see Hoskisson *et al.*, 2000; Peng and Heath, 1996). Korean and Japanese economies are the typical model of government-initiated industrialisation and innovation and large firm-centred countries.

All innovation studies listed here have mentioned that an extensive intervention of government and government's close ties with large industrial firms contribute to the current status of technology competitiveness in both Korea and Japan (also see Johnson, 1982; 1987; Wade, 1990; Evans, 1995). Government policies are a vital engine for changing from factor-driven to innovation-driven growth through their facilitation of various institutional and financial supporting schemes and incentives for innovation (Kim and Dhalman, 1992; Kim and Nelson, 1999; Sakakibara and Cho, 2002).

2.4 Conclusion

This literature review on innovation, which mainly focuses on determinants of national

technology capabilities and sectoral catch-up performance, contributes to the development of theoretical and analytical frameworks in an appropriate research design for this thesis. Theoretical views on innovation clarify the concepts of innovation, technology capabilities and NIS, while offering a useful lens through which to view sources and processes of innovation. Recognising that innovation is a key source of competitiveness (Porter, 1994) and business success (Schumpeter, 1964), numerous studies have examined determinants of innovation from various angles, for example, corporate governance, NIS and finance market system. The previous empirical studies commonly concluded that firms' internal factors are significant (e.g., R&D efforts, organisational and strategic factors), but de-emphasised external factors (e.g., institutional conditions, government policies, international factors) in the development of technology capabilities. In reality, political and economic instability, including government debts, inflation and external shocks (e.g., oil), hinders the dynamics of innovative activities (Allard *et al.*, 2012). Likewise, institutional reform and policy change that shape NIS and R&D systems can produce cross-country, cross-industry and inter-firm differences in innovation and catch-up patterns. However, only a few case studies have examined the interface between institutional factors and technology capabilities, mostly offering a historical and descriptive analysis. The theoretical and empirical gaps are discussed in detail in Chapters 3 and 4.

CHAPTER 3

Theoretical Framework: Determinants of Technology Capabilities and Technological Catch-up

3.1 Introduction

This chapter develops a theoretical framework to answer research questions concerning *why innovation pattern, speed and performance, and sectoral specialisation differ across countries and in what way the latecomers have achieved rapid economic growth and technological catch-up*. For the empirical analysis of the country-level and sector-level dynamics of innovation and its consequences on technological advancement and competitiveness, the framework is based on the institutional theory while drawing on national innovation system (NIS) and late industrialiser perspectives. As noted earlier, this thesis explores two major issues: (i) the determinants of technological catch-up and innovation performance, especially the effects of the country-specific institutional condition, policy framework and sectoral context on technology capabilities and (ii) the casual relationship of actors within NIS and the contextual factors with respect to technology capabilities. Therefore, this thesis attempts to create an integrated theoretical framework by addressing specific institutional, policy and contextual factors as significant sources of technological advantage. From a new angle on the link between institutional characteristics and technology capabilities, it analyses the emergence of new technological trajectories, as well as the variations in catch-up patterns, innovation performance and sectoral specialisation across countries, with particular reference to the most successful Asian countries, namely Korea and Japan. In this sense, the policy and institutional contextual effects are investigated to capture

the county-specific characteristics of the innovation environment and its link to technology capability by extending and operationalising an institutional approach to innovation in the NIS literature.

This chapter is structured in the following way. Section 3.2 provides a broad theoretical background for a critical assessment of how institutional and policy factors influence national technology capabilities and innovation in Korea and Japan. The usefulness of institutional theory and the NIS perspective in addressing technological catch-up and the dynamics of innovation of Korea and Japan is also discussed. Section 3.3 develops the theoretical framework to propose how the country-specific institutional features determine technology capabilities and innovation performance by linking institutional, policy and contextual factors to innovation themes. Section 3.4 concludes with a discussion of the empirical analyses based on the newly suggested theoretical framework and an evaluation of the strengths of the framework.

3.2 Background of Theoretical Framework: Perspectives on Institution, NIS and Late Industrialiser

The remarkable economic growth of Korea and Japan has attracted academic and policy interest in the idiosyncratic features of policy and institutional frameworks, and their impacts on industrial science and technology (S&T) progress. The rapid technological catch-up of Korea and Japan is partly attributable to successful policy and institutional change, including NIS, sectoral innovation system (SIS), education system, fiscal policy, S&T policy and intellectual property rights (IPRs) regime in response to technological change. Aoki and Kim (1998) discussed the unique institutional and organisational arrangements behind the government-business relationship as a key contributor to the rapid economic growth in Korea

and Japan. The unique political and legal systems that make policy top priority might also contribute to different patterns of innovation activities and sectoral specialisation across industries and countries. Looking at the development of information and communications technologies (ICTs), for example, the Japanese government placed top priority on developing its own mobile technology standards to deploy high-speed information technology (IT) networks in the local market, whereas Korean policy and institutional frameworks were of benefit to IT firms concentrating on exporting and internationalised research and development (R&D) (Breznitz, 2009). Although numerous researchers have demonstrated the policy and institutional factor effects on industrial expansion (e.g., production system, labour division, major industries), only a few studies have focused on the relationship from the innovation point of view. The distinctive institutional contexts might cause the cross-country variations in technology capabilities and S&T progress supported by the distinctive top priority.

An institution refers to “*the rules of game*” (North, 1990, p.43:7), which include norms, routines, common habits, established practices, rules, laws and standards (Edquist, 2005). The comparative institutional perspective highlights the role of institutions and political-economy structures in contrast to the conventional approach that focuses on the relative factor costs as crucial elements of comparative advantage (Aoki and Kim, 1998; Casper *et al.*, 1999; Hall and Soskice, 2001). The diversity of institutional arrangements that shape economic behaviour produces various styles of resource accumulation, firm growth strategy and corporate governance around the world. From this perspective, Casper *et al.* (1999) argued that the German institutional arrangement is hardly conducive to radically innovative industries, while it helps to continue process innovations and product innovations in mature, established technologies. The new institutional economics has attempted to analyse different patterns of growth across firms, industries and countries by focusing on the

role of the evolutionary process and the role of social norms and legal rules that govern individual behaviour and structure social interactions (North, 1997; Aoki and Masahiko, 2001; Easterly, 2001; Alston, 2008; Dixit, 2008). Although this perspective has contributed to the development of many other theoretical frameworks in addressing differences of socio-economic and institutional environments and their linkages with economic and financial development across countries, it has resulted in little attention to policy change or the variance of technology capabilities and innovation performance in the country-specific institutional setting.

The NIS approach emphasises the significance of NIS configurations and national institutional networks as key sources of the variety in patterns of the product and process of innovation at various levels (Kogut, 1991; Nelson, 1993; Lundvall, 1998). It suggests that distinctive paths towards technology development and innovation are the result of a complex set of relationships among the key players in the country-specific system of the stock and flow of knowledge (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997; Archbugi and Lundvall, 2001). The NIS has evolved through three models: statist model, laissez-faire model and triple helix model, as discussed in Chapter 2. Over time, it can directly reflect different growth policies according to economic development stages, from factor-driven growth (statist model) through investment-driven growth (laissez-faire model) to innovation-led growth (triple helix model). The government is the key NIS player in factor-driven growth focused on the building of infrastructure and institutions related to science and technology. In the stage of investment-driven growth, S&T policy focuses on the construction of effective innovation systems for the private sector's R&D and its linkage to government. The dynamics of R&D cooperation among government, academia and firms becomes the key factor contributing to the development of indigenous technology capabilities in the stage of innovation-led growth (Motohashi, 2005; Park and Leydesdorff, 2010).

However, the NIS approach has some theoretical shortcomings in explaining contextual issues, including socio-political contexts and business external/contextual environments, and their impacts on technological development and innovation in Korea and Japan. It is “... *theoretically too modest ... observations, much like a country fixed effect, that show that institutional environments in the form of nations matter: we do not have a theory that explains why or that seeks to group these effects into categories of national systems*” (Kogut, 2003, p.158).

The underlying limitations of the NIS approach are summarised below. First, the theory of NIS has the weakness of being pressed into the contexts of latecomer countries, particularly state-led capitalist economies where close ties between government and business play an important role in technology catch-up and innovation. The principles and configurations of NIS are modelled on the systems of advanced countries, but technological change of the latecomers is often determined outside the system (exogenous variables) (Viotti, 2002). In other words, this perspective suggests a universal formula that is created in the strong professional networks and institutional links in technologically developed economies as the logical premise for the creation and effective diffusion of new knowledge. In this sense, it does not seem sufficient to explain the rapid economic and technological catch-up of Korea and Japan, where many weaknesses exist in innovation systems, such as a weak State-University-Industry relationship. Second, the NIS approach provides static descriptions of national institutional devices and mechanisms for learning and coordination processes among the key players, without proper consideration of the special characteristics of regional and sectoral innovation systems, the distinctive paths and mechanisms of S&T development in unique regional and sectoral contexts or their interactions with NIS (Gu, 1997). Also, it considers neither an evolutionary process of NIS that changes and develops along with technological change nor tools for predictions (Archibugi *et al.*, 1999). Third, the rapid

growth of foreign direct investment (FDI), internationalised R&D and cross-border strategic alliances produce blurred NIS boundaries (Patel and Pavitt, 1998; Archibugi and Lundvall, 2001; Archibugi and Pietrobelli, 2003); since a great proportion of innovative products and services is generated not only by in-house R&D and home-grown capability, but also by improving imported technologies and joint R&D with foreign organisations (Johnson, 1987).

To complement these limitations in applying the theory of NIS to the contexts of latecomers, this thesis employs the late industrialiser perspective, highlighting the importance of country-specific structural and institutional conditions for resource accumulation as critical elements in spurring rapid industrial and economic growth in the contexts of developing economies (Amsden, 1989; Wade, 1990; E. Kim, 1997; Mathews and Cho, 1999). The famous Amsden book, *Asia's Next Giant: South Korea and Late Industrialization*, identified different patterns of industrial and technological growth in different policy and institutional frameworks by extending the insights of Alexander Gerschenkron's economic backwardness (Gershenkeron, 1966). Amsden (1989) identified an invention-based structure in the UK (the first industrial revolution), an innovation-based structure in Germany and the US (the second) and the basis of learning by using borrowed technology in late industrialisers. Korea, Taiwan, Brazil, India, Mexico, Turkey and Japan were classified as late industrialisers and learners in her book of late industrialisation (Amsden, 1989). Also, a number of studies have argued that the route to technology progress in latecomers is not identical to that of advanced countries (or firms). A new techno-economic paradigm or the period of paradigm shift enables latecomers to quickly move into mature markets and provide new technological opportunities, particularly in newly emerging industries such as biotechnology and ICTs (Dosi, 1982; Freeman, 1994; Lee *et al.*, 2005; Park and Lee, 2006). In this sense, the late industrialiser perspective underscores not only the role of national endowment for S&T, but also the role of institutional and contextual environments in industrialisation and innovation.

However, both perspectives on the NIS and late industrialiser interpret institutional change as an evolutionary process, while merely descriptively analysing how distinctive policy, institutional and contextual factors affect the stock and flow of knowledge in the contexts of Korea and Japan. This thesis attempts to fill the gap of theoretical and empirical shortcomings in previous innovation studies by extending perspectives on the NIS and late industrialisation.

3.3 Theoretical Framework: Determinants of Technology Capabilities and Innovation

My theoretical framework builds on the idea that the rapid economic growth and S&T catch-up of Korea and Japan are attributable to effective state intervention, the policy framework and institutional change responding to technological change. By developing the institutional perspective on innovation, this thesis sheds new light on the discussion regarding the determinants of technology catch-up and the capabilities. It is associated with an institutional structure of a particular environment that provides players with advantages for engaging in innovative activities in that environment. Innovation research for technology catch-up and capabilities is integrated with existing studies based on new institutionalism, NIS and late industrialisation, while reflecting the peculiarities of the Korean and Japanese contexts.

No definitive studies on determinants of innovation performance have provided a proper theoretical framework for understanding policy, institutional and contextual issues related to improving technology capabilities and competitiveness. In the resource-based view (RBV), many strategy and management studies have highlighted the strategic resources that defy imitation as determining factors in boosting innovativeness and performance, and thereby a sustained competitive advantage (Barney, 1989; Rumelt, 1991; Mahoney and

Pandian, 1992). The strategic resources embrace several heterogeneous ingredients that form technological capability building, such as visible/invisible knowledge and tacit/codified knowledge (Barney, 1991; Peteraf, 1993; Archbugi and Pietrobelli, 2003). Although the RBV is still widely used as a tool in building theoretical frameworks in business management studies, it has been criticised for ignoring the process of resource development and the contextual factors (Teece *et al.*, 1997; Eisenhardt and Martin, 2000).

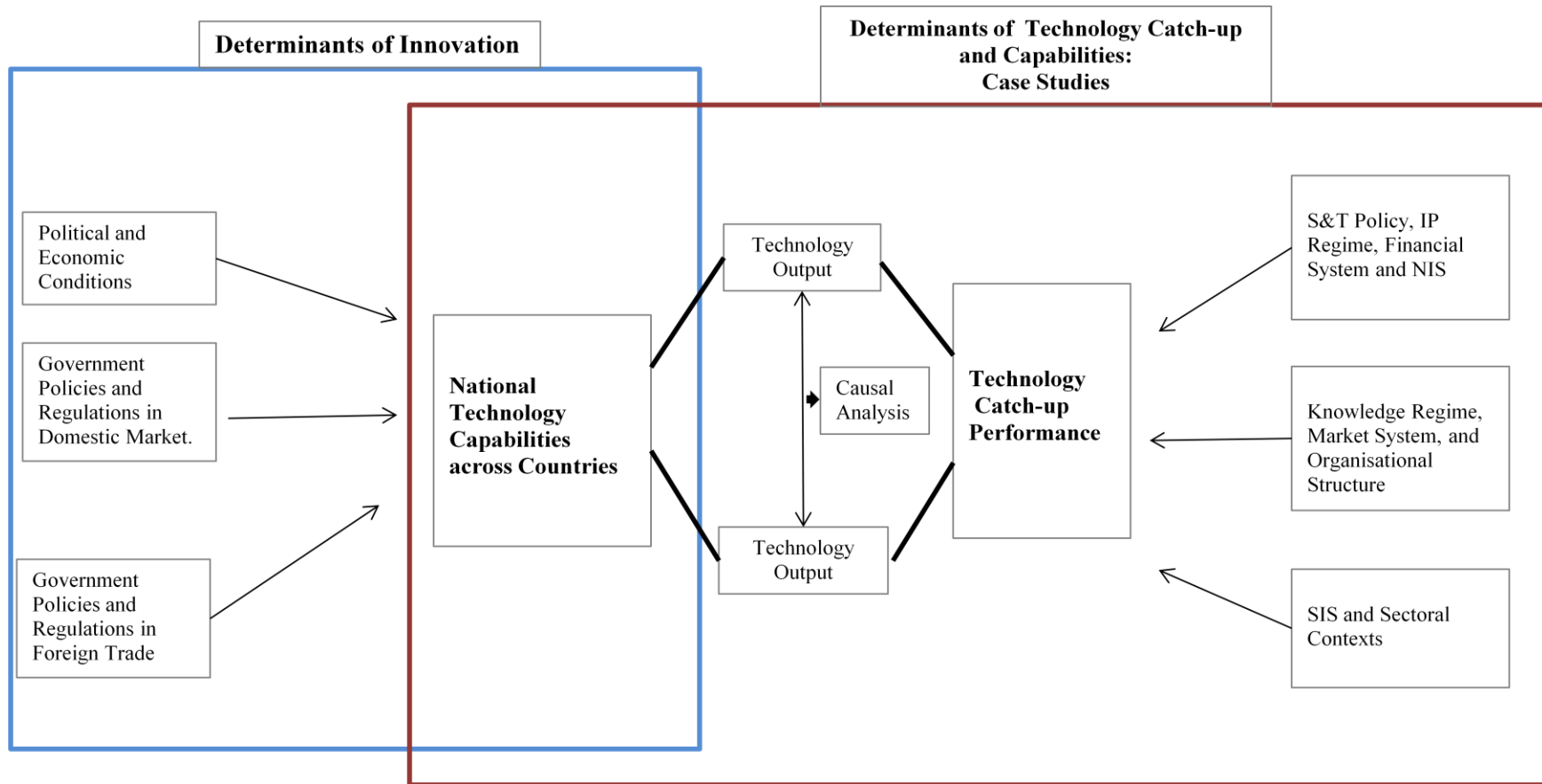
The dynamic capability view (DCV) attempts to compensate for a shortcoming of the RBV. Dynamic capability refers to “*the firm’s ability to integrate, build and reconfigure internal and external competence to address rapidly changing environments*” (Teece *et al.*, 1997, p.516). In contrast to the RBV that stresses the capacity to select appropriate resources, the DCV focuses on the specific capacity for resource development and renewal in response to a changing business environment as a key determinant of competitive development. This may imply that successful innovation is driven not only by the revolutionary radical innovation associated with the development of new products and technologies, but also by evolutionary incremental innovation based on the process of improving and renewing existing knowledge and resources. Incremental innovation seems to be more influential in catching-up countries. In this sense, dynamic capability is neither easily imitable nor completely substitutable without considerable investment of time and effort, and thus it is a key driver for developing technology capabilities. Since technical innovation is inherently uncertain and increasingly dynamic, dynamic capability is the driving force of technological growth and competitiveness in a knowledge-based economy.

However, the DCV provides little help in understanding how political systems and government capacity that shape distinctive institutional frameworks and innovation environments affect national technology capabilities, despite the government being a major contributor to the NIS in the contexts of state-led capitalist countries, namely Korea and

Japan. Korea and Japan, along with Finland and Switzerland, are the world's top performers in terms of government expenditures and grants in R&D (OECD Statistics). Strategic government intervention in Korea and Japan is a crucial driver of productive growth and rapid technology catch-up, particularly in precision manufacturing and newly emerging industries, such as ICTs. Therefore, the rapid catch-up and technology capacity-building in Korea and Japan are driven not only by the stock of capital (the RBV) with the mechanism for resource development and renewal (the DCV), but also by successful institutional reform and policy change that directly influence the flow of valuable resources and investments for future innovation.

There is no doubt that the dynamics of innovative activities relies on not only internal sources, but also external sources around firms, such as political and economic stability, which create sound monetary and taxation systems, trade policy, IPRs regime as well as favourable climates for R&D investment (Allard *et al.*, 2012). In this sense, this thesis addresses institutional and policy factors that affect political, economic and innovation environments as important determinants of the national technology capabilities and the catch-up success of Korea and Japan. Figure 3.1 presents the conceptual framework of this research. Based on an institutional perspective on NIS and late industrialiser, this analytical framework is structured to incorporate existing innovation research on institutional, organisational and sectoral features of Korea and Japan. Empirical investigations have been performed to examine the key determinants of technology capabilities across countries on the one hand, and determinants of technology catch-up performance in Korea and Japan as case studies on the other.

Figure 3.1 Analytical Framework



The first analytical framework was developed under the assumption that cross-national diversity in political and economic environments is the key factor in explaining the heterogeneity of institutional-settings and policies that lead distinctive innovation patterns and sectoral specialisation, as well as different technology capabilities across countries. It assumes that national technology capabilities and innovation performance depend on a strong government capacity supporting economic freedom to the stock and flow of capital, a low regulatory burden on foreign trade and a sound monetary system and legal structure, including IPRs.

The second analytical framework was developed under the assumption that specific institutional conditions for the technology input-technology output relationship cause the distinctive paths and channels for technology progress, with particular attention to Korea and Japan. It also attempts to evaluate the effectiveness of triple-helix indicators' innovation activities by empirically analysing the time required for a return on technology investment for each indicator in the contexts of Korea and Japan. The use of an appropriate lag is an important issue in innovation research because of the inherently complex and risky nature of innovation activities (Tidd *et al.*, 2005). Hence, this empirical investigation tested how much of the current technology output of each player within the NIS (e.g., the public sector, the private sector, foreign investor) can be explained by its past values of technology input, and the other way round.

The third analytical framework was developed under the assumption that specific institutional and policy frameworks play an important part in reducing productivity and technology gaps between a latecomer and a forerunner (a leader). The unique characteristics of industrial structures, S&T policies, knowledge regimes, and sectoral innovation systems in Korea and Japan are employed to explain distinct catch-up patterns, speed and performance. It also attempts to identify key institutional and policy factors influencing productivity

growth and rapid technology catch-up at a sectoral level. With case studies on biotechnology and wireless telecommunication technology in Korea and Japan, the delay factors and the contributing factors affecting technological catch-up are investigated in distinct sectoral innovation systems. This helps in understanding why the catch-up performance and speed of the wireless telecommunication industry is better and faster than that of the biotechnology industry despite the same catch-up patterns (the path-creating catch-up model). A detailed discussion follows in the rest of this section.

3.3.1 Government Policy and Technology Capabilities

The dynamics of innovative activities are significantly dependent on both the national context (e.g., political and economic conditions) and the international context (e.g., globalisation) because the *“creation of new knowledge and the innovations that transpire from such knowledge are influenced by many factors both within and beyond the boundaries of the nation”* (Howells and Roberts, 2000, p.259).

The importance of national conditions is underlined in Porter’s diamond model for the competitive advantage of nations. The diamond model is used to investigate the impact of national conditions on the global competitiveness of industries to explain why some countries (or industries within countries) are more competitive than others. In contrast to the classical theories of international trade that focus on inherited factors (e.g., land, natural resources, labour, size of local population) as key determinants of competitiveness, recent management theories have emphasised the significance of new advanced factor endowments (e.g., skilled labour, a strong S&T base, culture) by considering national conditions. The creation of new advanced factor endowments relies on four endogenous variables (factor conditions, demand conditions, supportive and related industries, and firm strategy, structure and rivalry) and two exogenous variables (government and technological change) (Porter, 1990, 1998). All

endogenous variables are affected by government and political decisions, subsidies, education policies, quality standards, public procurement, taxation and anti-trust laws (Porter, 1990). In this sense, government acts as a catalyst and a challenger to encourage firms to innovate and invest for specialised factor creation, while providing the supportive infrastructure for increases in productivity and innovative activities (e.g., industrial cluster) (O'Donnellan, 1994; Porter, 1998). Government does not participate in product innovation and new technology creation in a straight line, but plays a pivotal role in improving the competitive and cooperative R&D environment to facilitate innovative activities (see Jameson and Soule, 1991; Goh, 2005). In this sense, government policy can affect innovation in various ways, including antitrust regulations, rousing early demand for advanced products and services and stringent standards for products and services.

The diamond model can apply to the contexts of latecomer countries, because their industries are strongly influenced by government policies and economic conditions. However, the diamond model is inappropriate for analysing the dynamics of innovation since this model does not include important factors that affect national and industrial competitiveness in the contexts of latecomers. First, this model considers innovation as a new commodity or product created under the pressure of competition, but pays no direct attention to the nature and types of innovation, especially “*the interactive nature of innovation process*” (Lundvall, 1999, p.62). With an absence of resources, building and developing technology capabilities through the process of learning and cooperative relations among actors within the NIS are essential for latecomers to move from the imitation to the innovation stage (Lundvall, 1999). Second, this model based on market relations fails to capture close ties between big business groups (e.g., chaebols) and government (non-market relationships) in latecomer countries. Non-market organisations, such as governments, and their relationship with market organisations play the leading role in the development of industries in developing countries.

For example, Korea's government made and changed its policy and structure to benefit chaebols in the allocation and utilisation of resources, which resulted in successful economic and technology catch-up in Korea. Third, this model ignores the importance of international factors, especially the globalisation process, and their impacts on innovative activities despite the absorption of foreign knowledge being the core of learning innovation systems in developing or latecomer economies (Viotti, 2002). Therefore, the present study attempted to compensate for these theoretical shortcomings in Porter's diamond model by considering the dynamics of innovation, and both national and international conditions, which extend perspectives on the NIS and late industrialisation.

Globalisation refers to *"the closer integration of the countries and peoples of the world which has been brought about by the enormous reduction of costs of transportation and communication, and the breaking down of artificial barriers to the flows of goods, services, capital, knowledge, and (to a lesser extent) people across borders"* (Stiglitz, 2002, p. 9). From a technological perspective, an increase of border-crossing promotes the liberalisation of capital flow, technology trade and R&D cooperation across countries through various channels, such as FDI, internationalisation of R&D and strategic alliances (Freeman, 1991; Kobrin, 1997; Rycroft, 2002; Castells and Himanen, 2002). By eliminating the national border under globalisation, resources become more mobile due to reductions in transaction and information costs that create the dynamics of innovation activities for acquiring, learning and transferring knowledge (Kleinknecht and Wengel, 1998).

These advantages produce large institutional reforms towards a relaxation of previous government regulatory policy, while stimulating firms to undertake organisational restructuring, such as ownership structuring (Sassen, 1998; Gulati and Gargiulo, 1999; Lee and Yoo, 2007). The current status of economic development in high-income countries is attributable to effective institutional reform and policy change in response to the

technological change caused by globalisation. As a primary step in sustainable growth, high-income countries introduced an open-door policy, including privatisation, stabilisation and liberalisation in terms of finance, trade and investment to strengthen market mechanisms and a seize profitable status in international markets. At that time, their markets were exceedingly buoyed by political and institutional changes that led to private and public firms' restructuring (Arnold and Quelch, 1998). However, rashly opening domestic markets to the world entails economic dislocation, stagnation and marginalisation in the face of fierce competition that yields falling-off prices, shortening product cycles and rapid technology changes (Chew and Goh, 1993; UNCTAD, 2003; Goh, 2005). The best example is Latin American economies.

The increasing globalisation causes changes in government ownership and regulation policy, forcing institutional transformation to conform to market mechanisms (Friedman, 1993; Lee and Yoo, 2007). To efficiently allocate and utilise valuable resources (e.g., R&D), the government reduces the tax burden for technology trade and investment abroad, while easing regulations in local credit, labour and product markets to encourage economic actors to actively cooperate with each other and with the state (Hall and Soskice, 2001). In this sense, a liberal regulatory regime can improve technology capabilities and innovation performance by promoting the dynamics of information flow, technology transfer and joint-R&D across firms, industries and countries (Gilpin, 1987; Kobrin, 1997; Castells and Himanen, 2002; Kogut and Macpherson, 2003), which gives rise to a heated debate on neo-liberalism versus state coordination issues (McMichael, 1996; Evans, 1997).

The present study attempted to prove that policy and institutional factors affecting national and international conditions have an important impact on national technology capabilities and innovation, because the creation of competitive factors for the growth might strongly depend on liberal (or regulatory) government policy and structure. Given the fact

that government policy seriously affects the mobility of capital, availability of skilled labour and venture capital, as well as FDI., direct intervention in the market mechanism and restrictive policy on foreign trade might hinder the stock and flow of knowledge and R&D cooperation in the creation of new advanced factor endowments.

3.3.2 Legal Structure, Intellectual Property Regime and Technology Capabilities

In recent research based on the institutional approach to innovation, IPRs have become increasingly important in the sustainable development strategy of a firm and country. The intellectual property (IP) regime is the specific institution through which to legally secure exclusive rights for intangible assets, such as ideas, knowledge, inventions and discoveries (Song, 2006). IPRs protect owners that are granted monopolies against the utilisation or reproduction of innovations without a license for a certain period of time. IPRs include patents, trademarks, copyrights, industrial design rights and trade secrets in various fields (Boldrin and Levine, 2004).

IPRs have been frequently discussed and debated in the area of social science in relation to various topics, such as international trade, human resources, finance, innovation and industrial development, including biotechnology and media industries (Maskus, 2000; Lesser, 2001; Lall, 2003; Schneider, 2005; Branstetter *et al.*, 2007). IPRs are broadly categorised by two objectives in the process of technical innovation: pro-creation and pro-diffusion. The creation of novel ideas and innovative technologies is the main agenda in the former, whereas the latter focuses on the diffusion of existing knowledge and technologies with the channel of imitation or licensing (also see Song, 2006). In developing countries, the pro-diffusion role of IPRs tends to be given a great deal of weight in the improvement of innovation capabilities over pro-creation, which plays a significant role in developed countries, because of a lack of financial, technical and organisational resources in the process

of technical innovation (Maskus, 2000; Lall, 2003). In the absence of intellectual assets, Hobday (1995) underscored the significance of technological linkages with multinational enterprise (MNEs) or firms in advanced economies as an important channel of knowledge learning, transfer, diffusion and spillover in emerging economies.

The large body of research on innovation provides discussion of the positive effects of tough IPRs on the development of technology capabilities through the promotion of knowledge generation and diffusion, technology transfer and private investment flows. Policy makers have reinforced IPRs with the aim of making active research capital investments in the generation and diffusion of knowledge in the local market by supporting technology proprietors (Maskus, 2000; Song, 2006). Also, tough IPRs target the increase of FDI inflows and innovation processes of technologically advanced countries (i.e., the United States) in host countries, because they are unlikely to enter into licensing contracts with firms and conduct R&D spending in countries with weak IPRs (Mansfield, 1994; Song, 2006); *“weak property rights in many emerging markets mean that firms have only limited ability to negotiate enforceable arms-length contracts. Fearful that they will lose intellectual property, firms from developed economies may hesitate to license technology in emerging economies”* (Mahmood and Mitchell, 2004, p.1350:1). Based on this view, the World Bank (1998) highlighted the importance of FDI, stronger IPRs and openness as significant factors influencing knowledge acquisition and foreign technology imports in developing countries.

However, strong IPRs can negatively affect local technology capabilities with the high likelihood of delays in the innovation rate in emerging economies, especially heavily FDI or foreign technology-dependent nations (Kim, 2002; Falvey *et al.*, 2006; Branstetter *et al.*, 2007; Lee and Kim, 2008). Falvey *et al.* (2006) pointed out the positive effect of a soft IP regime on economic and technological growth in low-income countries by facilitating technology transfer and FDI, but their negative links in middle-income countries because of

the difficulty of technology catch-up through imitation. Lall (2003) emphasised the importance of the level of development in terms of industry, technology and economy in producing a beneficial result in local markets under a tough IP regime (also see Lesser, 2001).

“Weak IPRs can help local firms in early stages to build technological capabilities by permitting imitation and reverse engineering. This is certainly borne out by the experience of the East Asian ‘Tigers’ like Korea and Taiwan that developed strong indigenous capabilities in an array of sophisticated industries. The available historical and cross-section evidence supports the presumption that the need for IPRs varies with the level of development. Many rich countries used weak IPR protection in their early stages of industrialization to develop local technological bases, increasing protection as they approached the leaders” (Lall, 2003, p.1661:2). From the perspective of pro-diffusion, the strong protection of IPRs obstructs the flows of foreign capital and technology transfer in early industrialisation due to the high costs of imitation and technology import (Helpman, 1993; Maskus, 2000). Kim (2003) highlighted the point that *“a) IPR protection would hinder rather than facilitate technology transfer to and indigenous learning activities in the early stage of industrialization when learning takes place through reverse engineering and duplicative imitation of mature foreign products; b) only after countries have accumulated sufficient indigenous capabilities with extensive science and technology infrastructure to undertake creative imitation in the later stage that IPR protection becomes an important element in technology transfer and industrial activities”* (Kim, 2003, p.7:3).

This suggests that weak IPRs could benefit countries with a small domestic R&D base and scant talent, especially when entering the immature technology stage. Existing studies on technological advanced countries have shown the casual relationship among strong IPRs and innovative research capacity (Park and Ginarte, 1997; Song, 2006), and among strong IPRs and high-quality human capital (Helpman, 1993; Branstetter *et al.*, 2007). To

benefit from IPRs in the context of developing countries, the development of autonomous R&D capacity and human capital are urgent for the improvement of imported techniques and further development of new products and technologies.

Therefore, the present study has analysed effective policy measures supporting IPRs as an important determinant of national technology capabilities, and by extension how the Korean and Japanese governments have tried to facilitate R&D and innovative activities in the creation, protection and utilisation of IP, the main driving forces for the reform of IPRs, especially patent-related policies, toward strong IPRs to accelerate patent registration and faster commercialisation; it has also analysed how policy measures and IP regime facilitate patented technology transfer, as well as the role that IPRs play in catching -up and developing technology capabilities.

3.3.3 Finance System, Business System and Technology Capabilities

The role of national conditions and their causal effects on industrial and technological competitiveness have been variously addressed in a large number of comparative studies on national capitalisms (Hall and Soskice, 2001), national business system (Whitley, 1992; 1999), national governance system (Hollingsworth *et al.* 1994), social system of production (Hollingsworth and Boyer 1997), national innovation system (Lundvall 1992) and sectoral innovation system (Malerba, 2002). These studies commonly point out that national variations in trajectories of innovation and patterns of technological change come to characterise countries with institutional arrangements, which produce contrasting styles of sectoral specialisation across countries (also see Sorge, 1991; Kitschelt, 1991; Soskice, 1997; Caspar, 2000).

A number of political economists have demonstrated that different types of capitalism reflecting diverse forms of coordination, patterns of authority or governance produce

idiosyncratic innovation paths for industrial-specific competitiveness by illustrating the industrial competitive profiles of liberal-market economies (LMEs) and coordinated-market economies (CMEs). “*The institutional structure of the political economy provides firms with advantages for engaging in specific kinds of activities ... each economy displays specific capacities for coordination that will condition what its firms and government do*” (Hall and Soskice, 2001, p.32-35). LMEs have a strong competitiveness in revolutionary and radically-innovating industries that need the quick reallocation of firm-unspecific and transferable knowledge, as well as flexible adoption of external knowledge through a reconfiguration of social relationships. CMEs, in which there are closely knit corporate communities, on the other hand, enjoy a comparative advantage in evolutionary and incrementally-innovating industries with firm-specific process of knowledge accumulation developed by an idiosyncratic set of organisational routines (Hall and Soskice, 2001; Haake, 2002; Taylor, 2004; Lazonick, 2007; Tylecote and Vertova, 2007; Jackson and Deeg, 2008).

Differences in national financial systems generate contrasting styles of state science and technology (S&T) policies: government ‘*diffusion-oriented*’ policies aimed at incrementally upgrading innovative capabilities through strong collaboration between firms, industry associations and state agencies; government ‘*mission-oriented*’ policies aimed at radically developing new competences with large numbers of highly skilled human capital. “*Diffusion-oriented ... as the state often involve them in diffusing technological knowledge, developing research programmes and establishing standards. Mission-oriented policies and agencies ... encourage flexibility in public science systems when combined with decentralization of resource allocation decisions through a peer-review system*” (Whitley, 2002, p.521). One important implication of the two models of national financial system is that institutional complementarities particular to each type of capitalism constrain the path of sectoral specialisation by promoting different types of innovative capabilities: more

explorative and revolutionary capabilities of LMEs; more exploitative and evolutionary capabilities of CMEs .

National business systems that generate organisational types and firms' relationships with labour, financial sectors, the state and other organisations are also interrelated with national financial systems. “ *National business systems ... distinctive patterns of economic organization that vary in their degree and mode of authoritative coordination of economic activities, and in the organization of, and interconnections between, owners, managers, experts, and other employees*” (Whitley, 1999, p.33). Different characterisations of business systems, such as individualism and communitarism, lead ‘*relational requirements*’ for developing innovative competences, and result in prevailing patterns of innovation and sectoral specialisation in different societies (Soskice, 1997; Caspar, 2000). The ‘*relational requirements*’ involved in pursuing distinctive innovation strategies and priorities can be explained in contrasting ways in terms of more reliance on internal resources (or external resources), collective organisational capabilities (or individual specialist skills) and path-dependent technology changes (or radical technology change) in the development of innovative capabilities (Whitley, 1999; 2002).

Individualistic business systems in which individual autonomy is guaranteed through a loose interface between a changeable set of parties parallel LMEs’ market-based financial systems that favour radically-innovating sectors, such as life science and ICT sectors. Individualistic business systems and market-based financial systems share similar institutional features, such as short-term employment relationship, firms’ arm's-length relationship to financial investors and the state, deregulated labour markets, strong inter-firm competition, as well as the limited role of government in regulating the economy (Hall and Soskice, 2001; Tylecote, 2007; Tylecote and Vistintin, 2008; Jackson and Degg, 2008). Relying on the specialist skills of particular individuals involved in high levels of

appropriability and modularity of innovations, as distinct from firm-specific knowledge that are more organisational and institutionalised into routines, firms are able to alter organisational skills radically and easily change their organisational contexts to develop radically new products, implying an institutional advantage in generic and transformational innovations (Teece, 1986; Langlois and Mowery, 1996; Whitley, 2002). In such circumstances, specialist experts and venture firms play the central role in the development of national technology capabilities by setting up short- to medium-term innovation strategies due to the high levels of market and technical uncertainties and network externalities in fast-growing and newly-emerging industries (Shapiro and Varian, 1999; Tylecote, 2007).

In contrast, communitarian business systems based on tight interface between an idiosyncratic set of parties closely resemble CMEs' bank-based financial systems, in which there are long-term employment relationship, cooperative relationships with banks and the state, cooperative industrial relations, vocational and firm-specific training, as well as cooperation in technology and standard-setting across firms (Hall and Soskice, 2001; Tylecote, 2007; Tylecote and Vistintin, 2008; Jackson and Degg, 2008). Tight relationships with labour, banks and the state on a continuing basis facilitate the long-term finance for the accumulation of a stock of organisation-specific knowledge in continuous innovation, while reducing the appropriability risks and uncertainties surrounding these long-term investments through long-term alliances between them (Haake, 2002). The high levels of industry embeddedness, involvement of industrial collaboration and dependence of inter-firm also promote cumulative and collective knowledge production in pursuing incremental and customer-focused innovation strategies involved in competence enhancing (Whitey, 2002; Tylecote, 2007). In business systems approach, individualism embraces two types: '*fragmented systems*' dominated by small firms (e.g., the UK); '*compartmentalised systems*' oriented by large integrated firms (e.g., the US). Communitarianism covers four types:

'highly coordinated systems' based on horizontal alliances between large firms (e.g., Japan); *'collaborative systems'* based on sectoral associations (e.g., Germany); *'state-organised systems'* based on close ties with government and large firms (e.g., Korea); *'industrial districts'* (e.g., Italy) (Jackson and Deeg, 2008, p.547).

In theory, national business systems, in which firms' innovative activities are mainly performed by their own organisational resources and in-house R&D, can be a major obstacle to developing newly-emerging industries that need incorporation of varied kinds of new knowledge and different skills in various fields, as well as active cooperation with external organisations responding to rapid change of technological trajectories (Whitey, 2002; Haake, 2002; Taylor, 2004; Tylecote and Vistintin, 2008; Casper, 2009). Hence, communitarian business systems generating fewer opportunities to change the organisational context, with limited openness to new knowledge from outsiders, provide fewer incentives to invest in incrementally-innovative sectors, but stronger incentives in incrementally-innovating sectors. Incrementally-innovative sectors, where appropriability is difficult and technological change is systemic, embrace consumer electronics, machine tools, cars and other assembly manufacturing products (Tylecote, 2007; Tylecote and Vistintin, 2008).

These comparative studies on national financial systems and business systems provide the critical linkages between institutional arrangements, firms' strategies and patterns of technological changes in two idealized types of economy. In this stylised comparison, Japan is the representative of CMEs with communitarian business systems focusing on incremental innovation (Hall and Soskice, 2001). In recent years, however, many CMEs, including Japan and Germany, have adopted LME-style institutions and Silicon Valley model of entrepreneurship through the mission-oriented S&T policies for radical innovation, particularly in biotechnology, since their reliance on long-term commitments from employees and collaboration with internal business partners make it difficult to move a new

technological paradigm for radical reconfiguration of their organisational structure (Dore *et al.*, 1999; Whitely, 2002; Hoskisson *et al.*, 2004; Casper, 2009). Meanwhile, Korea is often lumped together with CMEs from the VoC typology due to the lack of market-based institutions and venture capital (Lee and Yoo, 2007). Although recent research distinguishes Korea's financial system (state-led capitalism) from Japan's innovation system (stakeholder capitalism) in stronger central government influence over the banking system (Lee and Yoo, 2007; Tylecote, 2007; Tylecote and Vistintin, 2008), firms in both countries more rely on bank finance than private equity (stock market financing) in the process and product of innovation (Whitely, 1992; Kneller, 2007; Casper, 2009). The bank-oriented financial system can lead relatively conservative investment portfolios, since venture business are owned and controlled by banks or insurance companies (Casper, 2009). A detailed explanation on the countries' distinctive institutional characterisations was presented in section 2.2.3 in Chapter 2.

However, in reality, many countries have showed pluralistic business systems and hybrid technological paths for national technology capabilities in distinctive sectoral contexts. For example, Korea's ICT industry has more individualistic labour relations with a more communitarian financial system. Armed with large venture financing and government funding, also firms' relationships with banks become looser in Japanese biotechnology industry (Dore, 2000; Lee and Yoo, 2007; Kneller, 2007; Tylecote and Vistintin, 2008). Although VoC approach suggests the adoption of new institutions is associated with high costs and risks due to an incremental and path-dependent institutional change, based on the existing institutional endowments (Lether, 2000; Hall and Soskice, 2001; Talyor, 2004), Korea and Japan have experienced drastic institutional changes toward Silicon Valley styles developing entrepreneurial high-tech firms to strengthen competitiveness in radically-innovating sectors (Lee and Yoo, 2007; Jackson and Deeg, 2008; Casper, 2009). Successful

institutional changes in the countries might be attributable to effective government science and technology (S&T) policies, regulatory rules and technology regime toward targeted industries in promoting radical innovation.

Hence, the rigid interpretations of this dichotomy, in which contrasting types of strategy and form innovation are driven by different financial systems and organisational structures operating within the two different systems of economy, should be further developed by combining with differentiating features of government S&T policies (i.e., clustering), NIS and sectoral innovation system. Differences in government strategic policies (i.e. clustering, sectoral supporting programmes) and innovation systems provide incentives for individuals and firms to seek distinctive innovative competence and strategies, and hence generate differences in patterns of technological development and sectoral specialisation (Whitley, 2002). “... *just as sectoral differences in technology and market conditions give rise to differences in industrial order within countries, national differences produce different governance regimes within sectors. Differences in governance within sectors are often recognizable as national differences in that they follow a similar logic across sectors*” (Hollingsworth *et al.*, 1994, p.272).

Despite different institutional arrangements proposed by VoC perspective, both Korea and Japan show the state-led innovation system, in which actors within NIS and their innovative activities are coordinated and performed by state initiatives and policies in pursuing radical innovation, which might result in similar types of industrial concentration between the countries. “*Even though they are substantially adapting to market forces, especially in financial and employment systems, to support radical innovation ... the global trend of cooperation among the state, academia, and industry strengthens the rationale for the state-led coordination of innovation activities through legislations and government policies*” (Lee and Yoo, 2007, p.460-461). Compared with Japan, Korea is more active in

industrial restructuring and institutional change to increase venture entrepreneurship and shareholder value in financial market in the development of radically innovative capabilities, particular in ICT sectors, while more effectively coordinating the contradictory forces of market-based restructuring and relationship-based innovation by state initiatives (Lee and Yoo, 2007; Tylecote and Vistintin, 2008).

Hence, this thesis investigates how government sectoral-specific policy and institutional frameworks promote radical innovation in Korea and Japan, particularly attention to biotechnology and wireless telecommunication industries. It is also critical to analyse how sectoral-specific rules and technology regimes interact with broader institutional incentives and constraints proposed by VoC scholars in the contexts of Korea and Japan.

3.3.4 Sectoral Innovation System and Technology Capabilities

Technological change is highly affected by different sectoral characteristics in knowledge and learning processes (technology regime), demand conditions (market regime), networks and institutions, which shape the specific system of sectoral innovation; *“A sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral system has a knowledge base, technologies, inputs and an existing, emergent and potential demand”* (Malerba, 2002, p.250:2). In short, the sectoral innovation system (SIS) suggests that sector differences in knowledge base, actors and processes can produce various patterns of innovation across the sectors.

The SIS perspective is rooted in the basic concepts of institutional theory and the NIS perspective that highlight the importance of the country-specific institutional setting and networks of agents in national growth; *“Agents are characterized by specific learning processes, competencies, beliefs, objectives, organizational structures and behaviors. They*

interact through processes of communication, exchange, co-operation, competition and command, and their interactions are shaped by institutions (rules and regulations)” (Malerba, 2002, p.250:2). Agents within the SIS are firms (suppliers, producers, customers) and non-firm organisations (universities, financial institutions, government agencies, trade unions, technical associations). In both market and non-market relations, they interact through five channels, “*communication*”, “*exchange*”, “*cooperation*”, “*competition*” and “*command*”, to create, absorb, distribute and utilise knowledge and technology. (Malerba, 2004, p.24-26). This departs from the traditional concept of sector used in industrial economics that focus on the industry size, concentration and uncertainty as key determinants of the growth (Williamson, 1965; Sutton, 1998), without proper consideration of the dynamics of SIS. However, recent research on the SIS has provided a dynamic view of sectors, focusing on the co-evolution of different aspects of sectors (knowledge base, actors, network, demand and institutions) which are affected over time by social factors and institutions (Nelson and Winter, 1982; Pavitt, 1984; Malerba and Orsenigo, 1996).

Sectoral characteristics are linked to different knowledge bases of production and innovative activities (Winter, 1984; Malerba and Orsenigo, 1996; Breschi *et al.*, 2000), basic technologies, inputs and demand (Rosenberg, 1982; Grandstand *et al.*, 1997; Bresnahan and Malerba, 1999), types and structure of interactions among heterogeneous agents (Nelson and Winter, 1982; Dosi *et al.*, 1998; Malerba, 2002) and institutions, such as standards and regulations in markets (Levine *et al.*, 1987; Dosi and Malerba, 1996). More specifically, Catellacci (2007) identified five factors related to sectoral innovation systems as important determinants of innovation: appropriability conditions, levels of technological opportunities, education and skill levels, degree of openness to foreign competition and size of the market. Park and Lee (2006) employed eight variables related to the technological regime and other country-specific institutional or policy factors affecting knowledge creation, learning process

and spillovers to identify important determinants of technology capabilities at a sectoral level. These eight variables are property of the knowledge base, technology opportunity, cumulateness, appropriability of technological innovation, relative technological cycle time and accessibility to external knowledge flows, initial stock of accumulated knowledge and uncertainty of a technological trajectory.

The study of SIS provides an understanding of how the innovation process takes place in a sector by focusing on sector structure and boundaries, interaction among specific agents and sectoral transformation. It differs from Porter's diamond model, which analyses how national conditions influence the international competitiveness of industries. Despite both attempts to identify key factors that produce differences between industries, the former emphasises a specific knowledge base characterised by technology regime (i.e., appropriability, opportunity, accumulateness) that determines the boundaries of sectors, and the latter highlights the degree of dependency on factor conditions, supportive and related industries and specific industrial structures.

The SIS concept is more suitable for analysing which industrial sectors of Korea rapidly caught up with those of Japan and what factors affected technological catch-up occurrence, speed and performance of Korean firms, since national conditions in Korea are similar to those in Japan within high-income countries and other East Asian NICs. As mentioned in section 3.2.1, the national conditions comprise *industry rivalry*, *strategy and structure* (inadequate rivalry will undermine innovation and adequate rivalry will revive innovation); factor conditions of *basic resources* (climate, demographics, resources and size) as well as *advanced resources* (communications, infrastructure, specialists and technology); *demand conditions* (domestic catalysts can drive innovation); and *related and supporting industries* (collaborative or competitive in their offerings) (Porter, 1990). Given similar national institutional conditions, the present study analysed why some industries in Korea are

more competitive and innovative than those in Japan, and vice versa, by considering different technology regimes, financial market structures, institutional arrangements and sectoral contexts.

3.4 Conclusion

This chapter has developed a theoretical framework for analysing the key factors influencing national technology capabilities across countries and technology catch-up performance in the contexts of Korea and Japan. By elaborating on previous research on institutions, industrialisation and innovation, the analytical framework conceptualised the successful catch-up and innovation in Korea and Japan as a co-evolutionary process of acquiring the properties of technological capabilities supported by political and economic instability and efficient policy and institutional frameworks. This theoretical framework is rooted in three main theoretical bases - institutional economics, NIS, late industrialisation - and tries to suggest a synthesised model for latecomer countries by compensating for these theoretical shortcomings.

The main strengths of this theoretical framework are as follows. This thesis employs new institutional economics that mainly focus on the role of institutions and the political-economic structure in technological growth and competitiveness (North, 1997; Aoki and Masahiko, 2001; Easterly, 2001). However, the new institutional economics pays little attention to the role of institutions in national technology capabilities and innovation, despite that unique political and legal systems are important in producing different patterns of innovation activities and levels of technology capabilities across countries and industries within countries. To compensate for these weaknesses, I employed the NIS approach to address NIS configurations and national institutional networks as key sources of the variety

in patterns of the product and process of innovation at various levels (Kogut, 1991; Nelson, 1993; Lundvall, 1998). In contrast to new institutional economics focused on the role of social norms and legal rules that govern individual behaviour and structure social interactions, the NIS approach highlights a complex set of relationships among the key players in the country-specific system of the stock and flow of knowledge to explain distinctive paths towards technology development. However, the NIS approach has many theoretical weaknesses for explaining and analysing distinctive patterns of innovation and sectoral specialisation in the contexts of latecomer countries, especially state-led capitalist economics, where non-market actors play an active role in technology catch-up and innovation. From the NIS perspective, it cannot fully explain how Korea and Japan rapidly caught up and became the world leaders in many high-tech sectors. This is because those countries have weaknesses underlying their innovation systems, such as a weak State-University-Industry relationship, while technological change is often determined outside the system. Also, the NIS approach provides static descriptions of national institutional devices and mechanisms without proper regard for the special characteristics of regional and sectoral contexts and international contexts (e.g., globalisation). These theoretical limitations for analysing latecomers' technology development and innovation are compensated for by employing the late industrialiser perspective that focuses not only on the role of national endowment of S&T, but also on the role of institutional and contextual factors in industrialisation and innovation, with particular attention to emerging economies. Therefore, this thesis extends perspectives on the NIS and late industrialisation.

Based on an institutional perspective on NIS and late industrialiser, this thesis has investigated the existing theoretical research on determinants of technology catch-up and capabilities. However, most related studies have not considered policy, institutional and contextual issues despite the significance of political and institutional reform to catch-up

economies, like Korea and Japan. Some strategy and management studies based on the resource-based view have focused on the allocation of strategic resources as a key determinant of innovativeness and performance with no thought for the process of resource development or contextual factors (Teece *et al.*, 1997; Eisenhardt and Martin, 2000). The dynamic capability view, highlighting the specific capacity for resource development and renewal in response to a changing business environment (Teece *et al.*, 1997), compensates for the weaknesses of the management theories based on the resource-based view. However, it does not explicitly consider contextual, institutional and international conditions of economic technological development, and thereby fails to analyse rapid economic and technological catch-up, since successful institutional reform and policy change directly influence the flow of valuable resources and investments in the countries. Meanwhile, Porter's diamond model emphasises the significance of national economic and institutional conditions as determinants of industrial competitiveness, but it also ignores important factors affecting growth in the contexts of Korea and Japan. This model pays no direct attention to non-market relationships (e.g., government-firm relationships) and international factors (e.g., FDI, internationalised R&D), or their impacts on technology capabilities, despite these being essential for catch-up economies.

Therefore, this thesis fills the gaps in the existing studies by covering institutional and international factors to some extent through examination of the roles of government policy in domestic market and foreign trade, IP regimes, finance systems, technology regimes and sectoral contexts in technical innovation and catch-up. These investigations will provide a more balanced perspective for understanding under-explored national, sectoral and international contexts in innovation studies, as well as overcoming the methodological limitations of existing innovation research in the contexts of East Asian latecomers, which has been mainly dominated by historical description and qualitative case analysis.

CHAPTER 4

Methodology and Research Design

4.1 Introduction

This chapter presents the research design and methodological framework used in my PhD thesis. On the basis of two methodological criteria, comparison and control, I attempted to set up a proper research design to operationalise the research questions with the rational use of measurements of variables, modelling, procedures, sample size and data sources. *“A good research design can be judged by the way it approaches the two issues of comparison and control. Designing a piece of empirical research requires the researcher to decide on the best ways of collecting data in research locales which will permit meaningful and insightful comparisons. At the same time the research design must achieve the control which gives some degree of certainty that the explanations offered are indeed superior to competing explanations”* (Bechhofer and Paterson, 2000, p.2).

Given the characterisation of research questions in my PhD thesis, quantitative and qualitative methods were jointly used to test hypotheses in large number cases (particular observations of 69 high and upper-middle income countries), and evaluate the validity of findings and arguments in small number of cases (particular observations of Korea and Japan). The selected cases, namely Korea and Japan, are homogenous vis-à-vis my theoretical framework and also meet conditions for causal inference in social science. Given that heterogeneity leads misspecification of relationships, unstable estimates of causal effects, spurious correlation for the relationships, and thereby causing serious errors (Ragin, 2000; Goertz, 2006; Mahoney, 2007), Korea and Japan exhibit sufficiently similarity to be meaningfully compared to one other meet conditions for causal inference in social science.

The statistical research that estimates average effects of independent variables on

dependent variables in 69 countries, and qualitative research on Korea and Japan that infers the causality and determines similar or different catch-up patterns and sectoral specialisation through a comparative historical analysis and Granger causality test allowed assessing the existing theory of NIS and developing a new theory in both probabilistic and deterministic approaches. After examining typical causal effects in 69 countries, I attempted to analyse whether particular cases of Korea and Japan follow a general causal patterns by using homogenous and contextual variables in a comparative historical research. The existence or absence of causality though the correlation tests inferred from the large number of sample were appraised within specified contexts through a comparative historical analysis.

As denoted by the research questions outlined in Chapter 1, the methodological approach for the analysis of institutional conditions of national technology capabilities requires deep historical knowledge and contextualised case-intensive knowledge from a comparative historical perspective, since it involves in large-scale explanatory variables (e.g., government policy), and complexities of temporal process and causal relationships. The comparative historical analysis pursuing qualitative research helped the identification of the specific values of policy and institutional factors that enabled Korea and Japan to develop national technology capabilities. In the causal explanation of explanatory variables influencing technological capabilities, individual institutional factor was identified as a necessary cause and the interrelation among the included factors (e.g. S&T policies and financial system) were sufficient for the outcome. Typological theory and temporal process analysis were used to examine descriptive and causal inference about the linkages between institutional factors (e.g., S&T policies, IP regime, financial system, NIS and SIS) and national technology capabilities over time.

This chapter is organised as follows. Section 4.2 presents the basic research strategy of this thesis to develop an appropriate research design and appraise the worth of

my methodological framework. Section 4.3 discusses the rationale for the choice of Korea and Japan as case countries and the data reliability of this study. In section 4.3, I address the key issues of methodology that have been used in the existing innovation studies to decrease the risk of method effect.

4.2 Research Design for the Thesis

Research design for this thesis was based on idea that neo-liberalism is not almost always sufficient for national technology capabilities. If it is true, are economic freedom and government inactivism not almost necessary conditions for technology catch-up in latecomer countries? Such an underlying assumption helped to frame research questions, formulate testable hypotheses and test theories. This hypothetic reasoning was addressed in a top-down manner, starting from identification of typical causal effects in large number cases through correlation test to identification of the values on variables that actually caused the particular outcomes in the examination of specific cases. A cross-national research in 69 countries was performed by estimating the partial effects of institutional variables governing business, labour and capital market and internationalisation on technology creation and investment, preferentially. Then, a case research on Korea and Japan was undertaken to indentify the causes though a comparative historical analysis in the light of specific contextual factors and temporal processes in order to elaborate and modify the findings derived from statistical research.

In a cross-national research, indicators of neo-liberalism supporting economic freedom were regarded as probability raisers stemmed from the probability theory. “*A probabilistic account — essentially the idea that a cause raises the probability of its effect— is now commonplace in science and philosophy*” (Dowe and Noordhof, 2004, p.1). Some policy and institutional factors relating to economic freedom that probabilistically increase (or decrease) the likelihood of national technology creation and investment in high and upper-middle income countries were included in this empirical study. Under the

assumption that countries may not have developed national technology capabilities without these factors (i.e., necessary causes), this empirical study aimed at generalising the typical effects of causal factors that promote a liberal (or controlled) market system in credit and labour and business, low (or high) regulatory burden on foreign trade, sound (or feeble) monetary system and a tough (or soft) IP regime on the development of national technology capabilities and innovation. These variables were estimated in multivariate statistical models to evaluate their substantive and statistical significance, given that “*independent variables that meet a specified level of statistical significance ... considered important causes*” (Mahoney, 2008, p.421).

If I found that explanatory variables are necessary (or unnecessary) for national technology capabilities in high and upper-middle income countries, what detailed evidence should I provide to draw an inference? This requires case-intensive knowledge of actual contexts to elaborate and modify findings and often reject hypotheses developed in the large number of sample (with deviant cases) (Skocpol, 1979, Savolainen, 1994; Mahoney, 2004). Hence, I undertook case studies to demonstrate the empirical validity by examining necessary institutional and political conditions that are sufficient producing the rapid technological catch-up in Korea and Japan. Government S&T policies, financial systems, IP regimes, national innovation systems and sectoral innovation systems were addressed as necessary causal factors that produce sufficient for the development of national technology capabilities in long-run analysis, while determining similar or different innovation patterns, catch-up styles and sectoral specialisation between the countries. Since these political and institutional variables characterised path-dependent process of change and long-run evolution, a comparative historical approach that allows highly contextualised comparisons, temporal process analysis and long-run analysis might be the most appropriate method for this case study. A comparative historical analysis based on historical events and social processes across times and places helped

conceptualise and clarify both internal and external factors affecting national technology capabilities.

A comparative historical analysis is the most powerful method in social science to make novel hypothesis and propositions and demonstrate their empirical validity in the light of causal relationships, historical sequences over time and contextualised comparisons of the similarities and the differences between cases (Savolainen, 1994; Ragin, 2000; Mahoney and Rueschemeyer, 2003). *“In this confrontation of theoretical claims with empirical evidence, analytical history enjoys two significant advantages compared to all but the most exceptional quantitative research: it permits a much more direct and frequent repeated interplay between theoretical development and data, and it allows for a closer matching of conceptual intent and empirical evidence”* (Rueschemeyer, 2003, p.316). This approach that draws descriptive and causal inference from historical and contextual singularities by comparing cases is distinguished from rational choice analysis and interpretive analysis in qualitative methods (Djelic, 1998; Mahoney and Rueschemeyer, 2003; Mahoney, 2004). The comparative historical analysis is particularly appropriate for a small number of cases focusing on the causal effects on large-scale outcome, such as industrial revolution, political regimes, capitalism and NIS (Skocpol, 1979; George and Bennett, 2005, Schutt, 2006; Mahoney, 2008).

The comparative historical analysis was employed here to test the validity of findings and arguments derived from the cross-national research, and generate valid conclusion, since a given variable largely depends on historical events, sequence and duration, which could cause different outcome to cross-sectional analysis. As tools for analysing necessary and sufficient conditions for technology catch-up and capabilities in Korea and Japan, typological theory was used in conjunction with process analysis, which allows the analysis of combinations of variables and multiple paths producing outcomes by using over-time data. *“Necessary causes assume that the absence of a particular value*

(or range of values) on an independent variable will always be associated with the absence of a particular value (or range of values) on a dependent variable; sufficient causes assume that the presence of a particular value (or range of values) on an independent variable will always be associated with the presence of a particular value (or range of values) on a dependent variable” (Mahoney, 2004, p.84). In short, a necessary cause implies that it does not deliver outcome without a factor (i.e., *Y* only if *X*), whereas a sufficient cause indicates that a factor lead to outcome (i.e., if *X* then *Y*) and its interaction with other factors promotes outcome (also see Mahoney, 2007; 2008).

Typological theory that evaluates necessary and sufficient causes in similar or difference cases in theoretical dimensions relies on the method of agreement or positive comparison and difference or negative comparison (George and Bennett 2005, Mahoney, 2004). *“Typological theory involves the construction of typologies whose cells represent different values on independent and dependent variables. Different theoretical types are systematically matched to determine whether cases follow patterns of correspondence consistent with necessary or sufficient causation”* (Mahoney, 2004, p.87). Although it has the same weaknesses as Mill’s methods, such as disregard for probabilistic view of causality, measurement errors, multiple causes and interaction effects (Liebersohn, 1991; 1994), the combination between typological theory and process analysis compensates these limitations in social research (Mahoney, 2004; 2007).

Taking into consideration the large role of government in state-led innovation system, in which actors within NIS and their innovative activities are coordinated and performed by state initiatives and policies (Lee and Yoo, 2007), this thesis dealt with government policies as an interacting factor that influences to change the values of all included institutional factors (e.g., financial system, IP regime, NIS and SIS). In deterministic approach, the combinations of government policies and institutions governing innovative activities were analysed as sufficient conditions for national

technology capabilities in the contexts of Korea and Japan through a comparative historical analysis. Also, Granger causality test was employed to examine specific institutional conditions for the countries' technological development over time. The causality test allowed me to econometrically identify necessary causal factors and estimate multiple causal paths for the outcome under probabilistic assumption. Hence, this thesis could overcome criticisms pertaining to application of Mill's methods of causal inference to small-N research in terms of "*the presence of only one causes*" , "*the presence of only one cause*" and "*the absence of interaction effect*" (Lieberson, 1994, p.1225).

For systematic comparisons, this thesis relied on the method of positive comparison preferentially, given that Korea and Japan share similar institutional features as the state-led innovation model (a close a political-commercial link), and then the method of negative comparison to identify their distinctive innovation patterns and sectoral catch-up performances. "*The method of agreement or positive comparison ... is to track down regularities and similarities in patterns of conditions. The method of difference makes it possible to compare cases with fairly different outcomes ... leads to the identification of those conditions or patterns of conditions which may be responsible for variation in outcomes*" (Djelic, 1998, p.4).

A number of studies used these methods have demonstrated that similar or different growth paths are caused by similar or different national conditions, such as (i.e., market-based versus bank-based), legal origins (i.e., common law versus civil law) and corporate governance systems (i.e., shareholder versus stakeholder model). To apply these methods, some institution-related theories that are categorised Korea and Japan into different groups, such as new capitalism, legal systems, business systems, were eliminated in the method of positive comparison, since the explanatory variables were considered the same in both countries. To find distinctive innovation paths, catch-up

speed and sectoral specialisation that must account for national technology capabilities in Korea and Japan, the method of negative comparison was also used by eliminating any common features shared by the two countries.

The reason why more than one case from the state-led innovation model was selected is that previous comparative studies revealed weaknesses in capturing the underlying significance of political and institutional conditions for technology input and output in comparing patterns of innovation and sectoral specialisation. The two-sided comparison has been widely used to formulate novel hypothesis, discover a new explanation and conceptualise causation in social science research designs, given that a description of a single case, without an implicit or explicit comparison with something else, makes it difficult to develop a theory and test a theory (Bechhofer and Paterson, 2000; Ragin, 2000; Mahoney, 2008).

In short, this thesis jointly used quantitative and qualitative methods to infer the existence or absence of causality through the correlation between dependent variables and independent variables across the diverse contexts, and through typological analysis, process analysis and Ganger causality test in Korea and Japan. The statistical findings were appraised within specified contexts through a comparative historical analysis. Case studies on Korea and Japan (the state-led innovation model) might be innovative works to find theoretical shortcomings in existing theories in social science, since the statistical findings that that economic freedom (e.g., LME-style institutions and triple-helix innovation model) is not always sufficient for national technology capabilities in the large number of cases (See Chapter 5) do not conform to various theories, including VoC and NIS. The use of typological theory and process analysis enabled me to elaborate on the findings for statistical correlation between liberal/regulatory institutional conditions and national technology capabilities in 69 countries by drawing on fine-grained evidence from within Korea and Japan to show that how their institutional and policy frameworks affect

technology catch-up and capabilities. In this thesis, rejections of several hypotheses developed in cross-national research, indicating that neo-liberalism is not sufficient for the development of national technology capabilities were supported in the examination of actual cases through typological theory and process analysis which provided convincing evidence and additional implications for arguments and theories. Through typological analysis, the type of innovation system of Korea and Japan (e.g., state-led innovation model) serves new explanation and conceptual development in innovation studies.

4.2.1 Rationale for Choice of Research Method

This section attempts to justify the validity of the methods used in this thesis. Most research methods used in previous innovation studies have weaknesses in application to selected case countries' contexts (i.e., Korea and Japan) because of advanced countries-biased methodology for developing theory and testing conceptual frameworks. A qualitative approach, such as the survey or interview method, has been widely used in this field to capture an in-depth understanding of human behaviour and the reasons (e.g., institutions) that govern such behaviour. The qualitative method produces invaluable information for the contextual dynamics of phenomena in a particular case, which are useful especially for studies on emerging countries (Peng *et al.*, 2001). However, high heterogeneity and complexity of institutional features in Korea and Japan make validation of the research findings and generalisability of their essential insights and concepts more difficult. Therefore, this thesis employed a comparative historical research method using descriptive methodology and a quantitative research method to seek empirical support for the analytical frameworks proposed in Chapter 3.

An appropriate methodological stance for this thesis is as follows. First, this thesis attempted to undertake an integrated and systematic analysis by extracting multiple levels of factors from various theoretical perspectives and innovation research. As explained in Chapter 3, the theoretical framework in this thesis was developed by integrating new

institutional theory, NIS approach and late industrialiser perspective, which allow filling the gaps in the existing innovation research of Korea and Japan in terms of theoretical perspective. To my best knowledge, no comprehensive studies exist that have examined the relationship of institutional, organisational and policy factors with respect to technology capabilities and innovation performance in a systematic and empirical way. Therefore, this integrated theoretical approach contributes to the existing innovation studies by addressing the specific economic, political and institutional conditions for product and process of innovation with multiple theoretical lenses.

Second, this thesis addressed research questions based on empirical investigations with a broad sample covering 37 high-income countries and 32 middle-income countries to quantitatively analyse the correlation between institutional factors and national technology capabilities. With a cross-country regression, looking at the big picture enabled me to generalise significant institutional and policy determinants of technology capabilities before analysing these linkages in the particular cases. Although a cross-sectional estimation has some weaknesses in examining these linkages due to the high heterogeneity of countries, this empirical study successfully controlled huge technology gaps, different levels of economic development and various institutions by using relevant control and dummy variables. This empirical testing constructed comprehensive datasets around government size, monetary system, IPRs and regulatory burden on business and trade. With the empirical findings, I introduced a historical comparative analysis in the case studies of Korea and Japan. Considering historical and contextual dynamics of innovation, this method helped in identifying significant determinants of technology capabilities and different or similar technology catch-up patterns and sectoral specialisations between the countries. As mentioned above, historical comparative analysis is an appropriate method for this study, since it aims not only to explore general patterns, but also to capture the historical and contextual singularities across countries

(Child, 2000; Kogut, 2001). The discussion based on comparative analysis of empirical findings highlights the importance of specific institutional-setting in national technology capabilities, drawing a profile of technological and innovation patterns and sectoral specialisation.

Third, the dynamics of triple helix indicators within NIS and the contextual factors in Korea and Japan have been statistically analysed by using time-series data to remedy methodological shortcomings in the existing studies on NIS that have used historical and descriptive research methods. By testing the causal relationship of research and development (R&D) expenditures by sectors within NIS with respect to the production of patents, this empirical analysis enabled me to compare empirically specific institutional conditions for technology input-output relationships and different innovation patterns between Korea and Japan. With regards to validity, this empirical testing introduced longitudinal data collection approaches to reduce the bias coming from rapid changes of the transition periods in Korea and Japan.

Fourth, distinctive styles and determinants of sectoral technology catch-up in Korea and Japan have been analysed by coupling historical comparative research with an empirical investigation. After identifying institutional and policy factors affecting the catch-up occurrence, speed and performance, the delay factors and the contributing factors affecting technology catch-up performances have been investigated with comparative case studies on the two path-creating catch-up models of biotechnology and wireless telecommunications technology in Korea and Japan.

Therefore, this thesis fills the methodological and theoretical gaps in prior innovation research by historical comparative research and an empirical investigation of social phenomena via statistical techniques. The findings of this study may be generalised to apply in other catching-up or emerging countries.

4.2.2 Rationale for Choice of Cases

Case study research is essential for this study because it provides a systematic way to explore historical events for institutional reform and technological change and to analyse their impacts on innovation activities in the real-life contexts of Korea and Japan. In studies of institutional change and its impacts on economic and innovation activities, a comparative research method using particular case(s) (e.g., nation, region, sector) is a major research method in social sciences and life sciences for direct comparison with other phenomena and theory-building or theory-testing (Benbasat *et al.*, 1987; Yin, 1994; Stake, 1994). “*Case studies are analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods. The case that is the subject of the inquiry will be an instance of a class of phenomena that provides an analytical frame—an object—within which the study is conducted and which the case illuminates and explicates*” (Thomas, 2011, p.513:5). In this sense, case study research helps in detailed contextual analysis of events or conditions and their relationships using a descriptive method or an explanatory method (Yin, 1994).

A rational case selection that is based on representativeness (not randomness) is important for reliability and credibility issues or generality of findings because a limited number of cases or instances can produce case-biased findings (issues of validity and generalisability) (Saunders *et al.*, 2003). To select the cases, this study adopted both a positivist approach and a phenomenological approach. Based on the positivist approach, which picks out as many cases as possible from similarity of case background, 69 high-income and upper middle-income economies are selected on the basis of gross national income (GNI) per capita in 2009, calculated by using the World Bank Atlas method. Cross-sectional research using such large numbers can avoid the controversial issues of the case-biased findings and generalisability. However, this approach shows some

weaknesses that ignore the intrinsic importance of cases as well as their contextual background conditions (Yin, 1994).

A phenomenological approach that selects small numbers of cases complements the methodological shortcomings in the positivist approach. Although a phenomenological approach has difficulty in generalising from the specific cases (Stake, 1994), it provides in-depth understanding of the phenomenon with a detailed contextual analysis and an examination of the outlier characteristics of the cases (Gerring, 2004). Therefore, this study also adopted a phenomenological approach for a detailed study of how institutional reform and policy change affect technological catch-up patterns and capabilities in the contexts of Korea and Japan.

The problem of conceptualising and generalising the findings from a few cases can be resolved in the research method with a rational choice of representativeness using a clustering process with a systematic comparison (Ragin, 1994). By drawing two-sided comparisons with the clustering method (i.e., categorisation), many studies using only a few cases have proven the application of research results to cases or situations beyond the specific contexts in which the research was conducted (Whitley, 1999; Whittington and Mayer, 2000; O'Sullivan, 2000; Guillén, 2001; Hall and Soskice, 2001; Amable, 2003). In the clustering method, representativeness is selected from several sub-groups that are somehow similar in characteristics (e.g., in market-based vs. bank-based economies, common law vs. civil law systems, stakeholder vs. shareholder corporate governance models). Therefore, this thesis selected Korea and Japan from the state-led capitalist model while introducing a two-sided comparison.

The cases selected for this thesis satisfy the criteria for case selection proposed by Van Evera (1997): (i) data richness and diverse predictions; (ii) similarity of case background; and (iii) prototypicality and importance of case background conditions. First, since the selected countries (i.e., Korea and Japan) are member countries of the

Organization for Economic Cooperation and Development (OECD), large amounts of data and previous studies analysing specific characteristics of the cases are available. Also, there are diverse arguments, explanations and theories to address the research questions of this study. The details are presented in Chapter 2.

Second, Korea and Japan have similar backgrounds in economic and technological development. The resemblance of case backgrounds makes easier the controlled comparison of several cases and the unit of analysis (Yin, 2003). The similarities in backgrounds of Korea and Japan are as follows. Both Korea and Japan have made remarkable progress in their innovation capabilities and rapid technological catch-up in East Asia. The two countries are currently the world's top scientific technology-oriented countries due to their successful transition from imitation to innovation in their technological capability, which enabled them to transform from technology users to technology generators (Kim, 1997; Chang *et al.*, 2006).

As shown in Table 4.1, Japan is the world's leader in number of patent applications and the third largest country in R&D expenditures, whereas Korea is ranked as the world's leader in terms of resident filings per R&D expenditure and the fourth largest nation in number of patent applications. Recently, Korea has joined the ranks of high-income countries in the World Bank classification. As historical background, Korean was under Japanese colonial rule during the World War II, underwent poverty after the Korean War (1950-53) and suffered economic recession after the 1997 Asian financial crisis (Chang, 2003, 2008). Despite such economic and social chaos, Korea has demonstrated rapid economic growth and technological catch-up, which could be attributable to effective industrial and innovation policies under strong government leadership.

Table 4.1 World Top 10 for Patent and R&D Activities

Rank	No. patent applications (2008)		No. patent granted by countries (2008)		Resident filings per R&D expenditure (2008)		Expenditures on R&D (billions of US\$, PPP, 2011)	
1	Japan	502,054	Japan	239,338	Korea	5.08	USA	405.3
2	USA	400,769	USA	146,871	Japan	3.37	China	153.7
3	China	203,481	Korea	79,652	New Zealand	1.82	Japan	144.1
4	Korea	172,342	Germany	53,752	Russia	1.56	Germany	69.5
5	Germany	135,748	China	48,814	Ukraine	1.09	Korea	44.8
6	France	47,597	France	25,535	Australia	1.02	France	42.2
7	UK	42,296	Russia	22,870	China	0.91	UK	38.4
8	Russia	29,176	Italy	12,789	Germany	0.91	India	36.1
9	Switzerland	26,640	UK	12,162	Poland	0.77	Canada	24.3
10	Netherlands	25,927	Switzerland	11,291	USA	0.72	Russia	23.1

Source: Compiled from the data from WIPO and UNCTAD statistics.

In some ways, Korea has followed the Japanese growth patterns for economic recovery and technological catch-up. A great success of Japan's post-war growth strategies - moving first from labour-intensive industries (e.g., textiles, food) to heavy and chemical industries (e.g., ship construction, steel, machinery) and then R&D-intensive industries (e.g., automobile, electronic goods, semiconductors, ICTs such as mobile phones) - reflected Korea's economic policy to transform its industrial structure in the same way (Stern *et al.*, 1995). This has enabled Korea to enter the same markets as Japan as a competitor. The combination of high quality, low price, cheap labour and rapid delivery that causes strong demand for Korean products from other developing countries, including China, could benefit Korean firms and make them more competitive than Japanese firms in the export markets. Also, a highly over-valued Japanese yen during the 1970s and 1990s against a managed valuation of the Korean won could have helped Korean firms gain a global competitive edge in shipbuilding, semiconductors (DRAMs), automobiles and handsets (Forge and Bohlin, 2008).

Third, the case countries were selected in light of the criteria of the typical characteristics and contextual importance. Although many case studies meet the criteria for data richness and similar case backgrounds, cases have been selected without

considering contextual similarities, which can misconstrue research findings (Locke and Thelen, 1995). For this reason, this study considered unique socio-economic contexts of the cases that share similar features of policy and institutional frameworks, industrial structures, finance and innovation systems.

The similarities in socio-economic contexts between Korea and Japan are as follows. First, both countries' finance systems are characterised by strong government intervention in the financial sectors, strict regulation regarding the allocation of financial resources and significant government subsidisation of the cost of borrowing in the product and process of innovation. The governments act as a risk-sharing partner with industry and banks to facilitate R&D expenditures in high-yield industries. Second, government and large firms play the central role in shaping the NIS as a major driving force behind the rapid catch-up success in both Korea and Japan. However, the countries have the same weaknesses; many universities still have lower levels of research capability and make smaller contributions in both countries' innovation systems compared with the frontier countries. The lack of universities' capacity is responsible for the low levels of knowledge transfer, R&D cooperation and university spin-offs, which is a problem in Korea's and Japan's innovation systems.

Third, in both countries, large established industrial firms (chaebol in Korea and keiretsu in Japan) are key contributors to their innovation systems, which are distinguished by venture companies in the network-based innovation system of the US. Korea's large chaebol-centred system and chaebols' close ties with government are much more similar to Japan's than any other business model within high-income countries and other East Asian newly industrialised countries (e.g., Taiwan, Singapore). The Korean chaebol is analogous to the Japanese zaibatsu (family-owned conglomerate), which is different from the current Japanese corporate 'families' centred on a bank, namely keiretsu (Chang, 2003). The government adopted the business model of zaibatsu and

intentionally formed chaebols, such as Hyundai, Samsung and Daewoo, after the Korean War as a national objective because zaibatsu succeeded in rebuilding a destroyed economy and played a key role in laying the foundation for economic growth in Japan in the post-war era (Forge and Bohlin, 2008). Like the Japanese, the Korean industrial structure centred on large business groups, a hierarchy controlling commercial operations and also some political parties from the early stage of economic development. The countries' industrial and innovation policies were favourably created for the groups, which allowed them to gain monopolistic profits from product markets, raise funding from credit markets and acquire expertise from labour markets in order of precedence (Kim and Nelson, 2000; S-J. Chang, 2003). Although the Korean chaebol-centred system has been the target of criticism as the root cause of the financial crisis and the subsequent economic recession from 1997 through 2001, chaebols have rendered a great service in the rapid economic growth and technological catch-up with developed countries. The financial crisis brought about economic reform and organisational restructuring that changed its growth strategy to a high-tech-based growth, particularly ICT-driven growth, moving away from scale- or cost-based competition for basic consumer goods, electronics and other lighter manufacturers with low- and middle-income countries (Kim, 2009). For example, the profiles of chaebols, such as Samsung and LG, have changed from focusing on low-tech home appliances to focusing on high-tech products with sophisticated design in the field of ICTs to compete with foreign firms in developed economies (Forge and Bohlin, 2008).

Therefore, the selected cases of Korea and Japan satisfy the three criteria of case selection and the condition for a comparative analysis. A comparative analysis of cases that have similar characteristics of historical socio-economic contexts can overcome the risk of comparing apples with oranges (Locke and Thelen, 1995). Since Korea and Japan are exemplified as successful technological catch-up countries in the state-led capitalist

model, this study sheds light on the comparative studies on NIS in which the principles and configurations are modelled on the systems of advanced countries by examining the trajectory of state-business relationships and external heterogeneity in contextual homogeneity.

4.2.3 Data, Sources and Reliability

This study was based on a comparative historical analysis and an empirical investigation via statistical techniques using different sources of secondary data to validate analytical frameworks and to examine the research questions proposed in my thesis. Broadly, there are two methodological approaches for data analysis in social sciences: qualitative methods and quantitative methods. Since these methods have pros and cons, a rational choice of method that fits the research purposes and questions is required for data analysis (Yin, 1994). A qualitative method provides in-depth understanding of real-life phenomena and contemporary issues, but is less able to be generalised (Miles and Huberman, 1994; Remenyi *et al.*, 1998). On the other hand, a quantitative method is more efficient for testing hypotheses and more reliable for generating research findings, but tends to miss contextual detail (Hart and Banbury, 1994).

I have employed a comparative historical approach using descriptive methodology to interpret detailed institutional features in the specific contexts of Korea and Japan, as well as statistical models to numerically analyse this contextual interpretation in the analytical frameworks proposed in Chapter 3. Chapters 6 and 7 take a comparative historical approach to operationalise the research questions. This approach can facilitate insightful interpretation of institutional change in a national context, considering diverse institutional aspects, including S&T policy, industrial structure, finance system, NIS, SIS and IP regime. Empirical investigations attempted to validate contextual interpretations.

Chapters 5 and 7 are based on a triangulation technique to check data validation by using more than two sources and measurements. Triangulation is defined as “*a method*

of cross-checking data from multiple sources to search for regularities in the research data” (O’Donoghue and Punch, 2003, p.78). Based on the triangulation technique, multiple data sources, periods, predictor variables and methods of data analysis were introduced to investigate whether the data examined through different methods leads to the same empirical outcomes with the data used in this thesis, which might help increase data reliability and the overall validity of this study. Reliability, which refers to the degree to which the data collection method yields consistent findings and similar conclusions (Saunders *et al.*, 2003), is an essential pre-requisite for validity. Compared with primary data, secondary data are more effective in increasing reliability because of lower risks of observer error or bias (Robson, 2002) and greater ease in other researchers verifying the reliability (Denscombe, 1998).

With such advantageous use of secondary data, the empirical studies of Chapters 5 and 7 collect S&T indicators and policy and institutional data from various sources, including the World Bank, OECD, International Monetary Fund (IMF), United Nations Educational, Scientific and Cultural Organization (UNESCO), World Economic Freedom (WEF), National Science Foundation (NSF), US Patent and Trademark Office (USPTO), Korean Intellectual Property Office (KIPO), Japan Patent Office (JPO) and government official reports and white papers from Korean and Japanese ministries. Data coding of economic, institutional and innovation variables were initially performed in Microsoft Excel 2007, and regressions were run in Eviews 4.0. Specific data descriptions are mentioned in relevant chapters, depending on the aims of the empirical investigations.

4.3 Methodology Issues of Innovation and Validity

Various indicators for innovation input and output are used as the proxy of technology capabilities and competitiveness, depending on aims, types of questions and research contexts. Since the credibility of research findings is determined by the selection of

appropriate variables and measures (Schoenfeldt, 1984), the selection of innovation measures must be carefully considered in conjunction with methodology issues, validity and the research context. Therefore, this section addresses methodology issues of innovation and discusses the strengths and weaknesses of previous empirical studies on technology capabilities and innovation performance.

4.3.1 Measurement of Technology Capabilities: A National Dimension

There are five empirical approaches to measuring national technology capabilities across countries: the World Economic Forum (WEF) Technology Index; the United Nations Development Program (UNDP) Technology Achievement Index (TAI); the ArCo Indicator of Technological Capabilities; the United Nations Industrial Development Organization (UNIDO) Industrial Development Scoreboard; and the Science and Technology Capacity Index developed by the RAND Corporation. Table 4.2 summarises a wide variety of constituents that form national technology capabilities.

National technology capabilities can be measured by three sub-indexes: (i) knowledge generation; (ii) technological infrastructure for knowledge diffusion; and (iii) human capital. First, all technology capabilities indexes employ patent statistics as one component of national technology creation. However, R&D resource is included in the only two indexes among them: the UNIDO (enterprise financed R&D) and RAND (R&D expenditure). The reason why the others do not employ the monetary value of R&D may be because of the problem of missing value with data unavailability, which restricts the data-setting for number of countries. For example, the ArCo index covers 167 nations with the exclusion of R&D sources, but the use of R&D resource reduces the sample size to 87 nations in the STCI (RAND) and 76 nations in the Industrial Development Scoreboard (UNIDIO). Although the patent covers many nations including poor countries due to the ease of the data collection, there has been controversy over the use of patent

statistics in research, including that the quality of patents substantially varies from country to country in different legal systems and institutions (e.g., commercial relations, investor protection, property rights), and all patents are not inventive, innovative and citable (Griliches, 1998; Almeida *et al.*, 2002). Also, relying on patents granted by the USPTO could overestimate the technology capacity of the US (Archbugi and Pietrobelli, 2003; James, 2006; Patel and Pavitt, 1997; Rycroft, 2002). Another important indicator of knowledge generation is the number of S&T publications, which are included on the sub-index of technology creation in the ArCo and the RAND. With the S&T articles, the RAND adds the number of internationally co-authored papers to the sub-indicator of embedded knowledge. Considering today's internationally integrated environment, the count of internationally co-authored papers might be useful to look at the globalisation process of academia. Like patents, however, the use of scientific and engineering publications has disadvantages, including that the quality of the articles fluctuates widely among countries and that the prevalence of English-speaking can be overestimated since the academic journals monitored by the Institute for Scientific Information are published in English (Archbugi and Coco, 2005; James, 2006).

Second, sufficient technological infrastructure is essential for developing technology capabilities. As a sub-indicator of technological infrastructure, the WEF, the UNDP and the ArCo include telephone and Internet penetrations and electricity consumption. In general, technological infrastructure covers the two ICT sectors supporting creating, accessing, storing, transmitting and manipulating information (Archibugi and Coco, 2004; Fagerberg and Srholec, 2008). One is telephony, including fixed and wireless telephones. This is commonly used for the delivery of ideas, information sharing and interactions among entrepreneurs (O'Donnell *et al.*, 2007). The growth of wireless telephones contributes to the development of electronic components (e.g., MP3, digital TV, voice recording, digital camera) and provides many job

opportunities in the digital content industry (Bigne *et al.*, 2007). Another development is the Internet, which has been used worldwide to share, acquire and transfer the latest information and knowledge. Communication over a network increases business efficiency and productivity by engaging in e-payment, e-commerce, e-banking and e-insurance (Davison and Cotten, 2003). However, it cannot be the universal standard to measure the country's technology infrastructure because Internet usage and penetration are still at low levels in developing countries due to the high costs of access and installation (Archibugi and Coco, 2004).

Third, human capital is an important indicator of national technology capabilities. Many theories prove the positive impact of human capital on economic development, productivity and innovation, while emphasising the role of government subsidies for education and training systems in the development (Bowles and Gintis, 1975; Becker, 1993; Mahroum, 2007). In this sense, all of the indexes of technology capabilities employ the mean years of schooling and the tertiary science enrolment ratio to measure countries' possession of human resources. Notably, the ArCo index employs the literacy rate to estimate marginal human abilities, which might help reduce the problem of biased measurement and cover many more poor countries.

Table 4.2 Components of National Technology Capabilities: A National Dimension

	WEF	UNDP(TAI)	ArCo	UNIDO	RAND(STCI)
Knowledge Generation	No. of patents; No. of Tertiary enrolments.	No. of patents; Receipts of royalty & license fees.	No. of patents; No. of scientific articles.	No. of patents; Enterprises finance R&D.	No. of patents; No. of scientific articles; No. of internationally co-authored papers.
Technological Infrastructure	The Internet penetration; PCs penetration; Telephone penetration; Non-primary exports; Public institutional & macroeconomic conditions in the growth; Competitiveness Index.	The Internet penetration; telephone penetration; Electricity consumption; Medium and high technology exports.	The Internet penetration; telephone penetration; Electricity consumptions.	FDI; Foreign royalty Payments; Capital goods; Telephone mainlines; Manufactured value added (MVA); Medium and high technology share in MVA; Manufactured exports; Medium and high technology share in manufactured exports.	R&D expenditure; No. of institutions; No. of scientists & engineers.
Human Capital	Included in the sub-index of Technology Generation.	Years of schooling; No. of tertiary science enrolments.	No. of scientific tertiary enrolments; Years of schooling; Literacy rate.	No. of technical enrolments.	GDP; No. of tertiary science enrolments

Source: Compiled by the data from Lall and Albaladejo (2001), Wagner *et al.* (2001), UNDP (2001), WEF (2001), Furman *et al.* (2002), Desai *et al.* (2002), UNIDO (2002) and Archibugi and Coco (2002; 2004).

Table 4.3 Components of National Technology Capabilities: An International Dimension

	Tech. Exploitation	Tech. Generation	Tech. Cooperation
Innovation Input		(i) FDI in acquiring control of an existing enterprise abroad; (ii) FDI in wholly owned facilities abroad; (iii) Internationalized R&D funding.	Work groups or teams that integrate codified & tacit knowledge.
Innovation Process			(i) Purposes of international innovation network (e.g., exploitation, Generation); (ii) Members of innovation networks (e.g., government agencies, firms, universities); (iii) International R&D performance & other types of learning activities (e.g., learning by interaction)
Innovation Output	(i) International trade: intra-firm trade, technology trade and wholesale trade; (ii) Patents extended to foreign countries.	Patents produced by foreign subsidiaries of MNC.	Transactional social capital

Source: Compiled by the data from Rycroft (2003).

Despite such weaknesses, the synthetic indexes of national technology capabilities not only suggest the key components, but also provide a meaningful numerical statement that helps in interpreting the level of individual country technological competitiveness versus other countries (a cross-country comparison). However, the aggregation of various components into a single number has been criticised for conflicting testimonies that distort the reality of a country's S&T capacity level (James, 2006). Furthermore, the indexes of national technology capabilities do not consider international factors, such as foreign direct investment (FDI) and internationalised R&D. In the context of increasing global production and competition, cross-border innovation activities and cooperation are essential for developing national technology capabilities and competitiveness, especially in developing countries. In fact, many developing countries rely on foreign techniques to build up technology capabilities due to a lack of intellectual capital. Therefore, the following section discusses the measurement of technology capabilities in international dimension.

4.3.2 Measurement of Technology Capabilities: An International Dimension

This section introduces the global technology index to investigate key components influencing technological capabilities, considering increases to the connectivity and interdependence of business and innovation caused by globalisation. Broadly, international activities for technology capabilities are undertaken with the three motivations: (i) new knowledge exploitation; (ii) new knowledge generation; and (iii) technological cooperation (Freeman, 1997; Raycroft, 2002; Archibugi and Pietrobelli, 2003). Table 4.3 summarises indicators of global technology input and output.

First, the cross-border activity for exploiting new technology is measured by the number of patents extended to foreign countries, foreign investment and trade (Archibugi and Iammarino, 2002; Archibugi and Pietrobelli, 2003). This is undertaken mainly by profit-seeking firms through the channels of (i) intra-firm trade in products between

affiliated units of multinational enterprises (MNEs); (ii) technology trade (i.e., royalties and license payments); and (iii) wholesale trade - importing finished goods then reselling them (Malerba and Orsenigo, 1996; Rycroft, 2002). Wholesale trade should be the key channel used for the exploitation of new knowledge in developing countries.

Second, the international activity for generating new technology is measured by FDI, internationalisation of R&D and patents yielded by foreign subsidiaries of MNCs (Rycroft, 2001). Such international activity is performed mainly by the largest MNEs in the leading industrialised countries of the triad (North America, Europe, and East Asia); it includes FDI, the reallocation of R&D facilities to, and the acquisition of existing R&D in foreign countries (Patel and Pavitt, 1997; Archbugi and Pietrobelli, 2003). FDI plays an important role in acquiring new skills and technologies by facilitating the purchase of existing facilities or firms in the host country (the technology pull effect), as well as by utilising and transferring knowledge generated by the home country through establishing new plants and facilities in the host country (the technology push effect) (Ostry, 1998; Rycroft, 2002). Cross-border R&D investment and patenting also are regarded as major components of technology capabilities. In reality, these activities are at work in old manufacturing industries such as food and paper products, but rarely undertaken in high-tech industries (Cantwell and Santangelo, 2000).

Third, national technology capabilities is measured by the level of technical and research cooperation among domestic and foreign players, which include universities, research institutes, intermediate organisations (e.g., professional and trade associations) and firms (by building up strategic alliances and joint ventures) (Freeman, 1990; Rycroft, 2002). The building of a sound science and innovation network is essential to keep domestic organisations current with changing technologies. The network enables domestic organisations to form international partnerships, strategic alliances and joint ventures so as to acquire skills and techniques needed to succeed in specific or complex

innovative projects that are difficult to complete with self-developed technology (Chen, 1997; Mowery *et al.*, 1998; Archibugi and Pietrbelli, 2003). R&D cooperation is performed through several channels: technology exchange agreements (e.g., cross-licensing, mutual second-sourcing), one-directional technology flow agreements (e.g., licensing), direct investment, management contracts, product sharing, R&D collaboration and manufacturing/marketing/services agreements, among others (Freeman, 1990; Rycroft, 2002). Technical cooperation for manufacturing is also performed through various channels, including original equipment manufacturing (OEM), second sourcing arrangements and manufacturing arrangements (i.e., assembly and testing agreements) (Marceau, 1994; Archibugi and Piretrobelli , 2003).

Research for the technology index might suggest that national technology capabilities is measured not only by indicators of domestic innovation input and output proposed in section 4.2.1, but also by innovation variables related to the cross-border activities. The internationalisation of R&D and joint R&D with foreign organisation can provide effective learning and technology accumulation in the development of national technology capabilities (Hobday, 1995; L. Kim, 1997): *“learning by doing, learning from spillovers, learning from advances in science and technology taking place in other sectors and/or other countries, and especially learning by interaction (with suppliers and users, as well as with competitors) may be just as important as R&D-based learning”* (Rycroft, 2002, p.5:30).

4.3.3 Measurement Issues of Innovation and Validity

Considering the methodological issues for various innovation indicators used in prior studies, I explored an appropriate methodological stance for my study. There is no consistent measurement of technology capabilities or innovation performance, which depends on the goals and contexts of the research. Table 4.4 presents the strengths and

weaknesses of the main explanatory variables commonly used in the innovation literature as a proxy of innovation. First, R&D data are widely used as an input measure of innovation process because the data are regularly updated and easily collected across sectors and times of research. However, all R&D expenditures are not productive in generating new products and technology (Becheikh *et al.*, 2006). Second, the counts of patents and scientific papers are considered as well-screened indicators by a third party, such as a government agency, and universally used as an output measure of innovation process. However, their main weakness is that not all innovations are patentable (Becheikh *et al.*, 2006). Third, new product counts are regarded as a direct measure of innovation performance. However, new product announcements are subjectively made based on the company plan for marketing and with no objective screening system (Hagedoorn *et al.*, 2003). Innovation indicators stemming from a firm-based survey or interview have several weak points due to biased results caused by the firm's self-interested responses and unqualified dichotomous measures of innovation (Balzat and Hanusch, 2004; Neil *et al.*, 2004; Becheikh *et al.*, 2006).

Despite the pros and cons of innovation indicators shown in Table 4.4, patent data are widely used as a proxy of innovation output in many empirical innovation studies. The limitation of patent data is that they do not cover tacit and implicit knowledge, and therefore all inventions are not patentable and all patents are not innovative (Griliches, 1998). Also, there is a structural bias in patenting across the size of firms because of patents' high registration and maintenance costs as well as different administrative laws for which to apply (Almeida *et al.*, 2002). However, the count of patents is a reliable indicator of innovation output because it represents efforts in the development of new ideas and new products, as well as outcomes of innovation input.

Table 4.4 Strengths and Weaknesses of Key Innovation Indicators

Measurement	Indicators	Strengths	Weaknesses
Indirect measure	<i>R&D expenditure</i>	<ul style="list-style-type: none"> • Regular and standardised data collection; • Internationally comparable. 	<ul style="list-style-type: none"> • Input measure of innovation process; • Monetary adjustment for international comparison.
	<i>Patents</i>	<ul style="list-style-type: none"> • Regular and structured data collection; • Regular update; • Precise Breakdown across time, industry and technology; • Direct measure of technology development. 	<ul style="list-style-type: none"> • Measure invention rather than innovation; • Not all inventions are patented and patentable; • Different registration system across countries.
	<i>Patent citations</i>	<ul style="list-style-type: none"> • Measure of specific impact of patent. 	<ul style="list-style-type: none"> • Difference of citation across time and sectors.
	<i>Scientific paper</i>	<ul style="list-style-type: none"> • Regular and structured collection; • Internationally comparable and precise breakdown across sectors. 	<ul style="list-style-type: none"> • Measure of scientific output rather than innovation.
Direct measure	<i>New products</i>	<ul style="list-style-type: none"> • Direct measure of innovation; • Direct use for research purpose. 	<ul style="list-style-type: none"> • Identifying by company itself (self interest, value-laden and fashion); • No objective screening system.
	<i>Firm based survey</i>	<ul style="list-style-type: none"> • Direct measure of innovation; • Uncovering underlying activities related to innovation; • Possibility of identifying multiple variable or indicators for innovation. 	<ul style="list-style-type: none"> • Biased result depending on sample, measure and response rate (unqualified dichotomous measurer to innovation); • Intrinsically manipulative.

Source: Compiled by the data from Patel (1988), Hagedoorn and Cloudt (2003), Archibugi and CoCo (2005) and Becheikh, *et al.* (2006).

Many economists have repeatedly examined its correlation with economic indicators, such as gross domestic product (GDP) and productivity, to validate patents as an innovation output. The leading examples of earlier investigations are Schmookler (1952, 1954) and Pakes and Griliches (1984). Schmookler (1952; 1954) was the first to use patent statistics as an indicator of innovation output and as an explanation of correlations between number of patents and aggregate total factor productivity (TFP). Pakes and Griliches (1984) developed the knowledge production function by employing productivity growth, the stock market value of a firm or industry and patent counts as the technology output. In their production function of knowledge, R&D expenditures and a number of scientists directly affect knowledge creation and patenting.

Meanwhile, the monetary value of R&D data is commonly used as an indicator of innovation input since it has a direct or indirect effect on innovation performance by providing various learning opportunities, cross-border knowledge flow, spillovers and externalities (Griliches, 1998; Rycroft, 2002). A great deal of empirical evidence has proven a strong relationship between patents and R&D activity by examining the elasticity of patents with respect to R&D expenditures, the distributed lag of R&D effects, as well as the significance and signs of a trend in the relationship between R&D expenditures and patents (Scherer, 1983; Hausman *et al.*, 1984; Hall *et al.*, 1986; Acs and Audretsch, 1989). The strong relationship implies that patents and R&D expenditures are good indicators of technology output and technology input, respectively.

However, Pakes and Griliches (1984) pointed out stronger relationships between R&D and patents in the cross-section dimension, but weaker relationships in the time-series dimension. In their study, the median R-square was on the order of 0.3 in the time-series dimension in contrast to 0.9 in the cross-sectional dimension. *“Because the bulk of R&D expenditures are spent on development, most of the time-series variance in this variable must come from the differential success in the further development of existing*

projects rather than from the initiation of new ones. The relatively low correlations in the time dimension should, therefore, not be all that surprising, but they imply that patent numbers are a much poorer indicator of short-term changes in the output of inventive activity or the 'fecundity' of R&D" (Griliches, 1998, p.302:1).

Therefore, this thesis used the data of patents and R&D expenditures as technology input and output indicators to identify key determinants of national technology capabilities across countries in the cross-sectional dimension. The data of patents and R&D were also employed to examine specific institutional conditions for technology input-output relationship and technology catch-up patterns in Korea and Japan in the time-series dimensions. Patent data and R&D data fit well with the main aim and argument of this thesis to empirically examine technology catch-up performance in Korea and Japan, which are the world's leaders in global patenting, R&D and high-tech trade.

4.4 Conclusion

This chapter has developed a methodological framework by addressing the important issues of research design, case selection, data analysis and measurement. Heterogeneity of methodological approaches has been used in the existing empirical studies on innovation due to various innovation indicators, sources and measures; hence, I have explored an appropriate research design to decrease the risk of method effect and increase confidence in the conclusions. Given the longitudinal characteristics of innovation studies, a comparative historical research method was used for a systematic and contextualised comparison between the selected cases. Based on the method of positive comparison, the case selection of Korea and Japan relied on similar socio-economic contexts and institutional characteristics, including science and technology policy, financial system, industrial structure, NIS and IPRs. With the coupling of a comparative historical research method, empirical models are intended for quantitatively testing hypotheses and theories.

To verify data validation and gain reliable research findings, I have introduced multiple data, sources and measurements. Therefore, my research framework has been constructed to balance the potential benefits and costs in selecting cases, data and methods.

CHAPTER 5

Institutional Conditions for National Technology

Capabilities: A Cross-country Study

5.1 Introduction

Globalisation leads the dynamics of innovation activities for the stock and flow of knowledge across borders. To strengthen international competitiveness and develop national technology capabilities at a global level, countries have introduced open-door policies supporting international technology exploitation, generation and cooperation through foreign direct investment (FDI), internationalised research and development (R&D) activities and international value chains and clusters (Dicken, 1998; Lall, 2001; Rycroft, 2002; Rodrik, 2004). In general, cross-border innovation activities are undertaken with three intentions and motivations: (i) technological exploitation through international trade; (ii) technological generation through the internationalisation of R&D; and (iii) technological cooperation through international strategic alliances and partnerships (Freeman, 1991; Rycroft, 2002; Archibugi and Pietrobelli, 2003). The details were presented in Chapter 4.

All cross-border innovation activities are significantly affected by government policies and institutions supporting economic freedom that allows the voluntary exchange of knowledge, cooperation and entrepreneurial activity (Strong, 2009; Fabro and Aixala, 2009; Levie and Autio, 2011). The government plays a pivotal role in establishing a favourable climate for the dynamics of cross-border innovation activities by minimising or removing obstacles that organisations encounter in pursuit of innovation (Hobday, 1995; Mathew and Cho, 2000). The government plays a facilitating role to maximise innovation input, process and output by setting up legal systems and incentives supporting

global technology exploitation, generation and cooperation (Jameson and Soule, 1991; Goh, 2005). These systems and incentives cover a wide range of macro regimes and monetary policies, including tax, tariff, intellectual property rights (IPRs) protection and subsidies for start-ups, among others (Goh, 2003, 2005).

In neoclassical economics, liberal government policies that support economic freedom in open market systems and trade liberalisation are regarded as the engine for economic development. This suggests reducing political intervention in national economies and privatisation of nationalised industries, while enhancing the role of the private sector in modern society (Crouch, 2001; Campbell and Pedersen, 2001; Friedman, 2002; Harvey, 2005; Plant, 2009). In this sense, neo-liberalism contributes to the development of national technology capabilities by promoting productive and innovative activities through cross-border information flow, technology transfer and joint R&D under globalisation.

However, does the liberalisation of trade and capital movement (labour, credit, businesses) always make a positive contribution to the stock and flow of knowledge and technology? Do government intervention and regulatory policy impede the dynamics of innovation activities? How did state-led economies, such as Korea and Japan, rapidly catch up and develop technology capabilities? To answer these questions, this study empirically investigates the effects of government policies and institutional conditions (liberalised versus regulative systems) on national technology capabilities, given that the stock and flow of knowledge, as well as R&D cooperation/competition, are directly affected by the country's policy and institutional frameworks from an national innovation system (NIS) perspective (Nelson, 1991; Freeman, 1995; Lundvall, 1998; Etzkowitz and Leydesdorff, 2000; Marques *et al.*, 2006).

Table 5.1 Recent Studies on Economic Freedom

Key Arguments	Authors	Topic
Economic freedom leads to more investment, higher per capita incomes, and growth rates.	Azman-Saini, W.N.W <i>et al.</i> (2010) Bergh, A. & M. Karlsson (2010) Djankov, S. <i>et al.</i> (2010) Fabro, G. & J. Aixala (2009) Faria, H.J. & H.M. Montesinos (2009) Gwartney, J.D. <i>et al.</i> (2006) Hall, J.C. <i>et al.</i> (2010) Heckelman, J.C. & S. Knack (2009) Lothian, J.R. (2006) N'Da, K. <i>et al.</i> (2009)	Foreign Direct Investment, Economic Freedom and Economic Growth: International Evidence Government Size and Growth: Accounting for Economic Freedom and Globalization The Effect of Corporate Taxes on Investment and Entrepreneurship. Economic Growth and Institutional Quality: Global and Income-Level Analyses Does Economic Freedom Cause Prosperity? An IV Approach Institutions and the Impact of Investment on Growth Institutions, Capital, and Growth Aid, Economic Freedom, and Growth. Institutions, Capital Flows and Financial Integration Economic Freedom and the Impact of Technology on Productivity
Economic freedom leads to less poverty and improvements in the general living conditions of a society.	Bjornskov, C. <i>et al.</i> (2010) Connors, J. & J.D. Gwartney (2010) Leeson, P. (2010) Shleifer, A. (2009) Stroup, M.D. (2007)	Formal Institutions and Subjective Well-Being: Revisiting the Cross-Evidence Economic Freedom and Global Poverty Two cheers for capitalism? The Age of Milton Friedman Economic Freedom, Democracy, and the Quality of Life
Economic freedom leads to more cooperation, tolerance, and peaceful relations.	de Soysa, I. & H. Fjelde (2010) Eriksen, S. & I. de Soysa (2009) Gartzke, E. (2007) Strong, M. (2009) Steinberg, D.A. & S.M. Saideman (2008)	Is the Hidden Hand an Iron Fist? Capitalism and Civil Peace, 1970–2005 A Fate Worse than Debt? International Financial Institutions and Human Rights, 1981–2003 The Capitalist Peace Peace through Access to Entrepreneurial Capitalism for All Laissez Fear: Assessing the Impact of Government Involvement in the Economy on Ethnic Violence
Economic freedom leads to entrepreneurial business activity; political allocation leads to crony capitalism and political corruption	Bjornskov, C. & N.J. Foss (2008) Dreher, A. <i>et al.</i> (2007) Freytag, A. & R. Thurik (2007) Heckelman, J.C. & B. Powell (2010) Levie, J & E. Autio (2011)	Economic Freedom and Entrepreneurial Activity: Some Cross-Country Evidence Corruption around the World: Evidence from a Structural Model Entrepreneurship and Its Determinants in a Cross-Country Setting Corruption and the Environment for Growth Regulatory Burden, Role of Law, and Entry of Strategic Entrepreneurs: An International Panel Study

I could not find any relevant theoretical or empirical studies to explain the relationship of liberal (or regulatory) policies and institutions with respect to national technology capabilities. Table 5.1 provides a list of selected recent studies in this area. Most examine the impact of neo-liberalism on economic growth, productivity and social performance. Economic freedom is considered to be a key contributing factor influencing investment and economic growth (Bergh and Karlsson, 2010; Hall *et al.*, 2010), human welfare (Shleifer, 2009; Lesson, 2010), cooperation and peaceful relations (de Soysa and Fjelde, 2010; Strong, 2009) and entrepreneurship (Heckleman and Powell, 2010; Levie and Autio, 2011). Despite the linkage to innovation, these studies did not address policy and institutional factors relating to economic freedom as determinants of national technology capabilities and innovation performances despite their linkages. The low level of political intervention and liberal policies for market and trade might influence the dynamics of innovation in a free and fair competitive environment, which facilitates market entry for start-ups, the mobility of capital and labour, FDI and international R&D cooperation. The positive relationship between liberalism and innovation has been confirmed; countries with highly open and free trade systems are on the lists of technologically advanced countries, including the United State and Western Europe (EFW, 2007).

Therefore, this study is a new attempt to empirically examine the effects of government regulation and policy on technology capabilities across countries. Under the argument that economic freedom provides the fuel for technology progress and innovation performance, I investigate a direct correlation between innovation variables and policy (or institutional) variables, as related to political intervention and government policy for credit, labour and product markets and foreign trade. The study extends previous studies that mainly focused on economic and social consequences.

This chapter is organised as follows. Section 5.2 presents the theoretical

background of the hypotheses. Section 5.3 outlines data-setting, modelling and procedures to test hypotheses. Section 5.4 discusses the findings and the limitations of this empirical testing. Last, section 5.5 offers conclusions and directions for future research.

5.2 Theoretical Background of Hypotheses: Determinants of National Technology Capabilities

Globalisation based on the concepts of economics, trade and financial freedom among countries spread rapidly across the border after the break-up of the Soviet Union (EFW, 2007). Globalisation reduces transaction and information costs by eliminating the national boundary and thereby facilitates cross-border economic and innovation activities. (Kleinknecht and Wengel, 1998). Although both political democracy and economic freedom seek constitutional and structural protection for economic efficiency, they have substantially different characteristics. For example, democracy guarantees personal liberty, equality and individualism, whereas economic freedom permits free trade and liberal competition, and also allows individuals to allocate and utilise resources (James, 2006). Economic freedom is consistent with low barriers to economic activities by increasing the labour mobility that would allow resources to be allocated more efficiently (Lethrer and Asakawa, 2004). In this sense, economic freedom can contribute to national technology capabilities by facilitating cross-border technology trade and R&D cooperation and international partnership.

The advantages of economic freedom induce countries to undertake institutional and policy reforms to create a cooperative (or competitive) R&D environment by opening up technology sectors, while transferring the role of government from leader to intermediary or facilitator within the NIS. Based on the world rankings of economic liberalisation from the Economic Freedom of the World (EFW) annual report, all

advanced countries belong to the top ranking; that is, countries with low levels of politics in their economy and high levels of freedom enter high-income countries with high gross national income (GNI), gross domestic product (GDP) per capita and life expectancy. Given that technological progress is the key factor in economic growth in knowledge-intensive societies, one can assume that weaker government regulations and stronger liberal regulatory systems have positive effects on technology creation and investment. Based on this, three government variables are introduced in this study to empirically examine their relationship with national technology creation and investment across countries: (i) a liberal (or controlled) market system in credit and labour and business; (ii) freedom (or restriction) on foreign trade; and (iii) a large (or small) size of government.

First, I assume that tight government regulation in the credit, labour and product markets negatively affects national technology capabilities. More specifically, restrictions on the credit market indicate that credit allocation and interest rates are controlled by the government, and the government sets a limit on foreign banks and investors that enter into domestic credit markets and compete with local banks (Allen *et al.*, 2006; EFW, 2011). Hence, credit markets might be related to innovation activity since the condition of credit markets directly affects capital flow and investment for resource allocation and utilisation, which are crucial for the product and process of innovation. Likewise, long-term technology investment (e.g., R&D) and venture capital that funds technology start-ups might be very sensitive to interest rates (determined by the market or controlled by the government). This implies that technical innovation depends on a stable monetary policy and credit (or capital) market climate. In this sense, a liberal system of credit markets can positively influence technology creation and investment.

The condition of labour markets might directly affect the extent of national technology capabilities. Freedom in the labour market is consistent with a high labour turnover rate, as well as the liberty of employees and employers that allows for

determining wages and hiring and firing (EFW, 2011). A flexible wage-setting system with the freedom of hiring and firing improves productivity of labour by arousing emulation. In corporations' effort to sustain and upgrade their position, the market has become very competitive due to the accumulation of know-how, skills and knowledge and thereby the development of national technology capabilities. Also, the mobility of human resource is indispensable in the innovation process. Mobility allows academic scientists to start up their own companies or work in private science-based ventures (Lethrer and Asakawa, 2004). As the primary source of technology progress in the United States, the mobility of scientists and the consequent close ties between industry and the academic community that promote university spin-offs have been highlighted in many studies (e.g., Blumenthal *et al.*, 1986; Mowery and Rosenberg, 1993; Lethrer and Asakawa, 2004). Therefore, I anticipate that the liberal system of labour markets has a positive impact on national technology capabilities.

Last, regulation of the product market indicates non-freedom in price-setting, barriers in the entrepreneurial process, high transaction and bureaucracy costs and other illegal payments aimed at influencing government policies (Fay *et al.*, 2007). Hence, regulation might result in the dominance of a few giant corporations and monopolies, a low quality of entrepreneurship and a low level of start-ups, which makes for an uncooperative and uncompetitive R&D environment. Consequently, I expect that strict government regulation of the credit, labour and product markets negatively affects technology creation and investment.

Hypothesis 1

(a): Strict government regulation in the credit, labour and product markets negatively affects national technology creation.

(b): Strict government regulation in the credit, labour and product markets

negatively affects national technology investment.

Second, I assume that free trade increases technology input and output by facilitating the cross-border technology trade, R&D cooperation and FDI. In today's age of globalisation, freedom of exchange across national boundaries is an essential condition for economic growth and technological progress. Many goods and services are now produced abroad while being covered by external resources in the product and process of innovation. The removal of trade barriers leads to intense competition in both domestic and international markets, with differentiated goods (or services) needed to survive and subsequently stimulate cross-border innovation activities to exploit, as well as the creation of new technology (Gu, 1997; Rycroft, 2002). Market competition is intensified by various free trade agreements (FTAs) and global organisations such as the World Trade Organisation (WTO), which expedites the free flow of capital and global interdependence in the product and process of innovation (Amable, 2003). Under liberalised foreign trade, FDI, internationalised R&D and technology trade (exporting and importing technology licensing) become prevalent as the main channels for building up and developing technology capabilities (Rycroft, 2002). Since these channels have a direct or indirect effect on technology development and innovation by providing learning opportunities, spillovers and externalities, free trade opens a gate for mastering, absorbing and transferring advanced technologies in a highly collaborative or competitive environment. Consequently, I expect that foreign trade liberalisation contributes to national technology capabilities.

Hypothesis 2

(a): More freedom in international trade positively affects national technology creation.

(b): More freedom in international trade positively affects national technology investment.

Third, I assume that excessive government involvement (i.e., a large government) in economic activities has a negative influence on national technology capabilities. A large government indicates large government expenditures as a proportion of the total expenditures and high marginal tax rates, as well as more input and output from state-owned enterprises (SOEs) versus private firms. A country with a large government suggests that the public sector plays the dominant role in economic and technological development. The larger expansion and market share of the public sector over the private sector might create unfair and uncompetitive innovation environment, which impedes productive and innovative activities of firms. Consequently, I expect that a large government (a high level of government spending as a share of total spending, a larger government enterprise sector and a high marginal tax rate) negatively affects technology creation and investment.

Hypothesis 3

(a): A large government has a negative effect on national technology creation.

(b): A large government has a negative effect on technology investment.

Finally, I assume that size of government moderates these effects such that low regulatory burdens on credit, labour and business and foreign trade have positive effects on national technology capabilities if the government is small. Why is that? A large government can be the main obstacle to the flow of capital, the entrepreneurial process and foreign trade in the process of innovation since the increase of government spending relative to spending by individuals and businesses implies that resources are allocated not

by personal choice, but by political choice and government decision-making. Similarly, the country that relies on SOEs over private firms in the production of goods and services is likely to restrict the mobility of capital and labour, new business entry and technology trade because SOEs generally engage in protected industries with government funds, concentrating more on producing commodities for domestic markets rather than exporting. In this sense, SOEs play by rules and public wants (or demands) that are different from those of private firms, which are dependent on consumers for their revenue or on investors for their capital. Also, high marginal tax rates and low income thresholds indicate heavy reliance on government that causes tight regulation of credit, labour, business and international trade, as well as the consequent exacerbation of innovative activities. Therefore, I expect that the combination of government size and liberal (or control) systems strengthens the effects on technology investment and creation.

Hypothesis 4

(a): Government size and regulatory burden on credit and labour market access, business and trade interact such that the lighter the regulatory burden and the smaller the size of government, the larger the relative prevalence of national technology creation.

(b): Government size and regulatory burden on credit and labour market access, business and trade interact such that the lighter the regulatory burden and the smaller the size of government, the larger the relative prevalence of national technology creation.

The four hypotheses are tested with the sample of high-income and upper middle-income countries. The research design and methodological framework used in this empirical study are discussed in the next section.

5.3 Models, Sample, Measurements and Procedures

This section outlines the sample, variables, modelling and procedures used in this empirical study. To test the four hypotheses, a sample of 69 countries, 37 high-income and 32 upper middle-income, was selected on the basis of the countries' grouping from the World Bank. Rational choice of sample is the key issues of reliability and credibility for conceptualising and generalising the findings (Stake, 1994; Saunders *et al.*, 2003; Gerring, 2004). Is the sample of high income and upper-middle income economies, excluding low income economies is reliable to generalise significant institutional and policy determinants of national technology capabilities across countries? The reasons why this study omitted lower-middle income and low income countries are, because the countries' institutional conditions for national technology capabilities are little important due to almost no reliance on innovation and technological change to increase income, production and export. Even in innovation input and output indicators used here as dependent variables most low-income countries showed practically no R&D investments and zero count of patents granted at the USPTO (USPTO and UNESCO statistics), thus I feel justified in ignoring them.

The criterion of classification of high income and upper-middle income countries was GNI per capital in 2009, calculated by using the World Bank Atlas method. The World Bank classifies 70 countries into high-income economies by 2009 GNI per capita of \$12,196 or more, while 54 upper middle-income economies are those in which GNI per capita was between \$3,946 and \$12,195. The reason why I ended up with only 69 countries out of the total of 124 high-income and upper middle-income countries in the World Bank classification is because some small economies (e.g., Cayman Islands, French Polynesia) and some centrally planned economies (e.g., Dominica, Libya) were excluded due to data unavailability as well as comparability issues in terms of time frame, variables and the like. Also, US data are omitted due to a big numerical difference with

other countries in terms of patent production and R&D expenditures. In the dataset, total patents in the United States numbered 89,869,327 whereas only 5 were granted at the US Patent and Trademark Office (USPTO) for Albania (the lowest country) from 2006 through 2010. Likewise, on average from 2005 through 2009, the United States spent more than US\$368 million for R&D whereas the amount of R&D spending in Bosnia and Herzegovina (the lowest countries) was only US\$6.632. Table 5.2 shows a list of samples included and excluded in this study.

Table 5.2 List of Sample

	Inclusion	Exclusion
High-income Economies	Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea (Rep.), Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, Croatia, Curacao, Hong Kong SAR (China), Kuwait, Malta, Singapore, Trinidad and Tobago	Andorra, Aruba, Bahamas, Bahrain, Barbados, Bermuda, Brunei Darussalam, Cayman Islands, Channel Islands, Cyprus, Equatorial Guinea, Faeroe Islands, French Polynesia, Gibraltar, Greenland, Guam, Isle of Man, Liechtenstein, Macao SAR (China), Monaco, New Caledonia, Northern Mariana Islands, Oman, Puerto Rico, Qatar, San Marino, Saudi Arabia, Sint Maarten (Dutch part), St. Martin (French part), Turks and Caicos Islands, United Arab Emirates, Virgin Islands (U.S.), United States
Upper Middle-income Economies	Albania, Algeria, Argentina, Azerbaijan, Bosnia and Herzegovina, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Gabon, Iran (Islamic Rep.), Jordan, Kazakhstan, Latvia, Lithuania, Malaysia, Mauritius, Mexico, Panama, Peru, Romania, Russian Federation, Serbia, South Africa, Thailand, Tunisia, Turkey, Uruguay	American Samoa, Antigua and Barbuda, Belarus, Botswana, Cuba, Dominica, Grenada, Jamaica, Lebanon, Libya, Macedonia (FYR), Maldives, Mayotte, Montenegro, Namibia, Palau, Seychelles, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Venezuela (RB)
Total	69	55

With the sample of 69 countries, the two innovation input and output indicators that are widely used in existing empirical studies on innovation were employed as dependent variables. As a proxy of national technology investment, the countries' data on gross domestic expenditure on R&D (GERD) was collected for 2005 through 2009 from

the database of UNESCO institutes. As a proxy of national technology creation, the data of patents granted at the USPTO were employed. The counts of US patents granted by country of origin based on the residence of the first-named inventor from 2006 through 2010 were collected from the database of the USPTO. The average monetary value of R&D was used for 5 years due to a large missing value, while the total count of patents was used for 5 years due to a cumulative effect. The time frame of GERD was from 2005 through 2009 and the patent was from 2006 through 2010, with a time lag of one year to four years since innovation results from the inherently complex nature of innovation activities are time consuming, risky and uncertain. Table 5.3 presents a description of variables used in this study.

All independent variables, comprising institutional and policy factors related to economic liberalisation, were taken from EFW 2011 annual report for 2006 through 2009. As many renowned economists, including Adam Smith, Milton Friedman and Friedrich Hayek, have mentioned, voluntary exchange and market coordination are the engines of economic growth. Policies and institutions supporting freedom of personal choice, exchange, competition and entrepreneurial activity coordinated through markets are important sources of long-term growth (EFW, 2011). The EFW annual report provides the degree to which the policies and institutions of various countries support economic liberalisation. It attempts to make a synthetic index of economic freedom of countries by combining five areas: size of government; regulation of credit, labour and business; freedom to trade internationally; legal structure and security of property rights; and access to sound money. According to the EFW index, Hong Kong has the highest rating for economic freedom, 9.01 out of 10 in 2010. The other open economies among the top ten are Singapore (8.68), New Zealand (8.20), Switzerland (8.03), Australia (7.98), Canada (7.81), Chile (7.77), the United Kingdom (7.71), Mauritius (7.67) and the United States (7.60). The bottom ten nations, relatively closed economies, probably linked to centrally

planned economies are Zimbabwe (4.08), Myanmar (4.16), Venezuela (4.28), Angola (4.76), Democratic Republic of Congo (4.84), Central African Republic (4.88), Guinea-Bissau (5.03), Republic of Congo (5.04), Burundi (5.12) and Chad (5.32).

The EFW data have been widely used in many academic studies to examine the causal or correlation relationship between economies' freedom and various measures of economic and social performance, such as investment, income, GDP growth, human welfare and entrepreneurship (see Table 5.1). This study employed the EFW data of government size, regulation (credit, labour and business) and regulatory burden of overseas trade as independent variables while introducing the monetary system, and legal structure and property rights, as control variables. Also, size of government used a moderator of government regulation and trade barrier effects on national technology capabilities since their interaction influences the strength of the relationship between dependent variables (patent and R&D expenditures) and independent variables (government regulation and trade barriers).

Table 5.3 Description of Variables

	Description	Year	Source
<u>Dependent Variables</u>			
Patent	Data is taken from numbers of patents granted at USPTO during the periods of 2006-2010. The total count of each country's patent data is used for 5 years.	2006 - 2010	US Patent Trademark Office http://www.uspto.gov/patft/
R&D Expenditure	Data of gross domestic intramural expenditure on R&D in current PPP\$ is taken from UNESCO institute during the period of 2005-2009. Logarithmic of average value of each country's R&D investment is used for 5 years.	2005 - 2009	United Nations Educational, scientific and Cultural Organization http://www.uis.unesco.org/
<u>Independent Variables</u>			
Regulations of Credit, Labor and Business	First, credit market controls and regulations are measured by three sub-components (i) the percentage of bank deposits held in privately owned banks; (ii) foreign bank competition estimated by foreign bank assets as a share of total banking sector assets; (iii) private sector credit calculated by the share of domestic credit allocated to the private sectors; (iv) determinants of interest rates. The ratings are from 0 to 10. The larger share of privately held deposits and domestic credit, the larger share of foreign bank, and interest rates determined by market forces with positive real rates (the large difference among the deposit and lending) are given the high rating, 10. Second, labour market regulations are estimated by (i) minimum wage calculated by the ratio of mandated minimum wage to the average value added per worker; (ii) hiring and bargaining regulation; (iii) centralised collective bargaining; (iii) mandated cost of hiring measured as a percentage of salary; (iv) mandated cost of worker dismissal measured in weeks of wages; (v) the length of conscription. These sub-components are calculated the zero-to 10 rating. The lower mandated minimum wage, the hiring by no obstructive regulation, wage-setting by no centralized bargaining process and no military conscription receive 10. Third, business regulation estimated by (i) price controls; (ii) administrative requirements; (iii) bureaucracy costs; (iv) the time and money costs to start a business; (v) undocumented extra payments and bribes; (vi) the	2005 - 2009	Economic Freedom of the World 2011 Annual Report http://www.freetheworld.com/release.html

	time and money costs for licensing; (vii) the time cost of tax compliance. The scale of six sub-components is from 0 to 10. None price control, none burdensome administrative requirements and the lower time and money costs for start-up business, licensing and tax compliance are given the highest value of 10. These different three regulations (credit markets, labour market and business) are set by zero-to 10 ratings and then averaged to construct the regulation index.		
International Free Trade	The constitutions of trade liberalisation are: i) taxes on international trade comprised by taxes on international trade as a share of exports and imports, the unweighted mean of tariff rates and standard deviation of tariff rates; (ii) regulatory trade barriers measured by non-tariff barriers and the time cost values to exports and imports a good; (iii) the actual size of the trade sector relative to expected; (iv) black-market exchange rates measured by the percentage difference between the official and the parallel market exchange rate; (v) International capital market control estimated by the restriction of foreign ownership and FDI. The lower average tax rates, the lower regulatory barriers, the larger trade sectors relative to the expected size, the lower black market exchange rates and the lower international capital market controls set a high value on the freedom of international trade. These components underlying of the free trade are averaged then calculated the zero to 10 rating for each country: $(\text{observation maximum value} - \text{the country's actual value}) / (\text{observation maximum value} - \text{observation minimum value})$ multiplied by 10. The average value of each country's index is used for 2005-2009.	2005-2009	Economic Freedom of the World 2011 Annual Report http://www.freetheworld.com/release.html
Size of Government	Government size is measured by four components: (i) the general government consumption spending as a percentage of total consumption; (ii) the general government transfers and subsidies as a percentage of GDP; (iii) State owned enterprises (SOEs) output and government investment as a share of total output and investment; (iv) top marginal income and payroll tax rate. The large government size that is high proportion of government expenditure, transfer sector, investment and taxes is obtained the lower value. The valuation of government size for each country under 0 to 10 scale calculating by the $(\text{observation maximum value} - \text{the country's actual value}) / (\text{observation maximum value} - \text{observation minimum value})$ multiplied by 10. The average value of each country's index is used for 2005-2009.	2005 - 2009	Economic Freedom of the World 2011 Annual Report http://www.freetheworld.com/release.html
<u>Control Variables</u>			
GDP per capita	GDP per capita based on purchasing power parity (PPP), which is converted to current international dollars using PPP rates. Logarithmic of average value of each country's GDP per	2005-2009	World Bank http://data.worldbank.org/

	capita is used for 5 years.		
GDP Growth	Annual percentage growth rate of GDP at market prices based on constant local currency. Average percentage of each country's annual GDP growth rate is used for 5 years.	2005-2009	World Bank http://data.worldbank.org/
Population Growth	Annual population growth rate. Average percentage of each country's annual population growth rate is used for 5 years.	2005-2009	World Bank http://data.worldbank.org/
Education Level	The counts of the tertiary or higher education enrollment counts in all programmes devoting to advanced research and professions are collected as a proxy of education level. Logarithmic of average value of each country's tertiary enrolment count is used for 5 years.	2005-2009	United Nations Educational, scientific and Cultural Organization http://www.uis.unesco.org/
Access to Sound Money	Access to sound money is measured by four components: (i) the average annual growth of the money supply in the last five years minus average annual growth of real GDP in the last ten years; (ii) the standard deviation of the inflation rate over the last five years; (iii) the rate of inflation during the most recent year; (iv) freedom to own foreign currency bank accounts. The scale of six sub-components is from 0 to 10. The country receives a rating 10 if that money growth was equal to the long-term growth of real output with no variation in the rate of inflation over the five-year period, perfect price stability and no restrictions on foreign currency bank accounts. The average value of each country's index is used for 2005-2009.	2005-2009	Economic Freedom of the World 2011 Annual Report http://www.freetheworld.com/release.html
Legal Structure and Property Rights	Legal structure and security of property rights are measured by seven components: (i) Judicial independence; (ii) impartial courts; (iii) protection of property rights; (iv) Military interference in rule of law and the political process; (v) Integrity of the legal system; (vi) Legal enforcement of contracts; (vii) Regulatory restrictions on the sale of real property. The scale of six sub-components is from 0 to 10. The country receive a 10 rating if the legal framework is efficient and follows a clear, neutral process with entirely Judicial independence, well-protection of property, no involvement of military in politics, impartiality of the legal system and no restrictions on transfer ownership of property. The average value of each country's index is used for 2005-2009.	2005-2009	Economic Freedom of the World 2011 Annual Report http://www.freetheworld.com/release.html

In detail, the first predictor of government regulation was measured by restriction on market entry to engage in voluntary exchange. The three markets of credit, labour and product were considered as sub-indexes of government regulation to examine their linkages to national technology creation and investment. The credit market regulation index was calculated with four components: share of privately owned bank deposits, foreign bank assets as a share of total banking sector assets, share of domestic credit allocated to private sectors and determinants of interest rates. The regulatory components indicated the extent to which the banking industry is dominated by private firms, whether foreign banks are allowed to enter and compete in the market, which credit is supplied to the private sector and whether interest rates interfere with the market in credit. The labour market regulation index was calculated with six components: the ratio of mandated minimum wage to the average value added per worker, hiring and bargaining regulations, centralised collective bargaining and mandated cost of hiring measured as a percentage of salary, mandated cost of worker dismissal measured in weeks of wages and the length of conscription. The regulatory components indicated the extent to whether wages and hiring (or firing) conditions are determined by economic freedom of employees and employers, and whether conscription interferes with the market in labour. The business (product market) regulation index was calculated with six components: price controls, administrative requirements, bureaucracy costs, time and money costs to start a business, undocumented extra payments and bribes, time and money costs for licensing and time cost of tax compliance. The components were designed to identify the extent to which regulations and bureaucratic procedures restrain pricing decisions, competition and new business entry.

The value of each component was established by 0 to 10 ratings and combined to form the index of credit, labour and business regulation. The three indexes were individually used as an independent variable. They were also united in a synthetic index

of regulation so as to examine the general impact of regulation on dependent variables. The regulation variables from 2006 through 2009 were averaged due to the missing value problem. The country with a tight regulatory restraint that limits the freedom of exchange in credit, labour and product markets was given the lowest value of zero.

The second predictor of the international trade barriers index was created by the combination of five components: taxes on international trade as a share of exports and imports, the mean of and standard deviation of tariff rates, non-tariff barriers and the time cost values to export and import a good, the actual size of the trade sector relative to expected black market exchange rates, the restriction of foreign ownership and FDI. Tariffs, quotas and hidden administration of customs, and controls on exchange rate and capital movement can limit international trade. With 0 to 10 ratings, the index of trade barrier was created by integrating the five components. The average value of the summary index was used with the time frame of 2005 through 2009. The country with tight trade restrictions was given the lowest value, zero.

The third predictor of government size index was formed by combining five components: government consumption spending as a percentage of total consumption, government transfers and subsidies as a percentage of GDP, SOE output and investment as a share of total output and investment, top marginal income and payroll tax rate. These components indicated the extent to which a country relies on the political process to allocate resources, whether the public sector plays the dominant role in the production of goods and services and which high marginal tax rates apply at relatively low income levels. On the scale of 0 to 10, a country with more government spending as a share of total spending, a larger government enterprise sector and higher marginal tax rates earned the lowest ratings. The average value of the government size index was used for 2005 through 2009. The index of the government size was also used as a moderator of government regulation and international trade barrier effects on national technology

capabilities.

Regarding control variables, GDP per capita, GDP change, population growth, higher education, monetary system and legal system and property rights, as well as dummy (upper middle-income countries=1) were employed to control their influences in the analyses. First, since the level of economic development parallels the extent of technology capabilities, I used GDP per capita (purchasing power parity, PPP), as well as GDP (PPP) per capita squared to capture any curvilinear effects. Second, the changes in GDP from the previous year to the current year, as well as the population growth during the previous year, were used as control variables, since economic expansion can facilitate the dynamics of innovation activities to exploit new markets. These data of GDP and population were taken from World Bank datasets for the period 2005 through 2009. Third, this model was controlled by the counts of tertiary enrolments since a knowledge-creating institution, namely a university, is one of the key players in not only cultivating highly skilled personnel, but also participating in new product and innovation processes (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2006; Marques *et al.*, 2006). The data were obtained from UNESCO datasets. The time frame was from 2005 through 2009. Fourth, the index for access to sound money was used as a control variable. Since *“high and volatile rates of inflation distort relative prices, alter the fundamental terms of long-term contracts, and make it virtually impossible for individuals and businesses to plan sensibly for the future”* (EFW, 2011, p.6), the consistency of monetary policy with long-term price stability and the ease with which other currencies can be used as alternative currencies are indispensable factors for innovation projects involved in risk, uncertainty and long-term investment. The data were taken from EFW datasets for 2005 and 2009. Finally, this model was controlled by countries’ varieties of legal systems: rule of law, security of property rights, an independent judiciary and an impartial court system. In the absence of security of property rights, protected by the rule of law, individuals are

unlikely to undertake productive and innovative activities since the fruit of their labour cannot be properly protected. Therefore, the index of legal system and property rights was employed for 2005 and 2009.

For these data analyses, a cross-sectional regression was used with a relatively short time series (five years). Given that I am interested in the effects of institutional conditions on developing national technology capabilities, possible low variability in institutional variables was a plausible concern. To verify that the use of cross-sectional regression techniques was appropriate, I computed standard deviation of predictor variables: government regulation, trade barriers and government size. Standard deviation is widely used to examine how much variation or dispersion exists from the mean. A low standard deviation suggests low variability in values whereas a high standard deviation indicates that the data points are spread over a large range of values (Gujarati, 2003). Table 5.4 shows the descriptive statistics for all variables used in this empirical model. As shown in Table 5.4, I confirmed that the variability of the index values was trivial through relatively low standard deviations in values of policy and institutional variables, even though the set of countries was highly heterogeneous. For this reason, I chose to employ cross-sectional regression instead of panel regression to analyse the dataset.

With the cross-sectional data analysis, the methods of least squares (LS) and negative binomial count (NBC) were employed in Eviews 5.0 to test the correlation between independent variables and dependent variables. After the correlation test, I also employed alternative data, periods and predictor variables to check the robustness of my data analysis. For robust statistics, first, I separately ran a regression including and excluding the US data due to a big difference in patent production between the United States and other countries. Second, high-income economies and upper middle-income countries were separately estimated due to different levels of economic development and huge technology gaps. Third, I employed the data of the World Bank's regulatory quality

index as an alternative predictor variable of government regulation. I also tested numerous alternative proxies by employing the data of the Global Entrepreneurship Monitor National Expert Survey: business freedom, trading freedom and corruption. The findings proved robust against specification changes. Fourth, the raw data of patent counts were replaced by logarithmic value of patents, and a correlation test with independent and control variables was performed using the LS method instead of the NBC method. This robustness check did not reveal major differences in estimation results. Furthermore, I undertook several diagnostic tests by employing correlation matrix and White heteroskedasticity and confirmed that there were no concerns about multicollinearity and heteroskedasticity. I briefly discuss these diagnostic test outcomes after the analysis of multivariate regression results in the next section.

5.4 Estimation Results and Discussion

This section discusses the estimation results for the correlation between liberal regulatory institutional systems and national technology across countries. Given the expectation that institutional restrictions on market entry and international trade with a large government interrupt the dynamics of innovation activities, four hypotheses were tested with the sample of high-income and upper middle-income countries. To verify the hypotheses, as a first step, I computed descriptive statistics to examine the basic features of variables used in this study (see Table 5.4). By summarising a large set of observations with a single indicator, descriptive statistics allow simply looking at the asymmetry of the probability distribution of a real-valued random variable (skewness), as well as a range of variations in the dataset within observations (standard deviation). Then, I ran multiple regressions on a number of patents and logarithmic values of R&D expenditures through the respective methods of NBC and LS to identify significant determinants of success or failure in the development of national technology capabilities.

Table 5.5 Multivariate Analysis

	Patent		Log (R&D expenditure)		Verification of Hypotheses
	Model 1	Model 2	Model 3	Model 4	
Control Variables					
Dummy	-0.841 (0.219)	-0.798 (0.236)	-0.110 (0.769)	-0.102 (0.791)	
Log(GDP per capita)	-5.374*** (0.002)	-5.496*** (0.002)	-2.426** (0.013)	-2.335** (0.023)	
Log (GDP per capita) ²	0.373*** (0.000)	0.378*** (0.000)	0.196*** (0.000)	0.191*** (0.001)	
GDP change	-0.001 (0.981)	-0.004 (0.925)	-0.000 (0.979)	-0.000 (0.985)	
Population growth	0.126 (0.536)	0.119 (0.560)	-0.042 (0.707)	-0.037 (0.747)	
Log(Tertiary Enrolment)	1.129*** (0.000)	1.232*** (0.000)	1.093*** (0.000)	1.091*** (0.000)	
Monetary System	0.017 (0.921)	0.031 (0.858)	-0.047 (0.708)	-0.050 (0.695)	
Legal System & PRs	0.316* (0.063)	0.259* (0.100)	0.456*** (0.000)	0.478*** (0.001)	
Independent Variables					
Gov. Regulation (GR)	-2.209** (0.075)		-1.332* (0.100)		<i>H1</i> Rejection
Credit		-0.763* (0.071)		-0.424* (0.100)	
Labour		-0.737* (0.100)		-0.467* (0.100)	
Business		-0.539* (0.093)		-0.502* (0.100)	
Trade Barrier (TB)	2.815** (0.019)	2.794** (0.019)	1.681** (0.038)	1.658** (0.047)	<i>H2</i> Acceptance
Gov. Size (GS)	0.312 (0.776)	0.355 (0.754)	0.493 (0.423)	0.427 (0.512)	<i>H3</i> Rejection
GS x GR	0.388** (0.041)	0.381* (0.053)	0.164* (0.100)	0.171* (0.093)	<i>H4</i> Acceptance
Gs x TB	0.417** (0.019)	0.417** (0.019)	0.237** (0.050)	0.234* (0.062)	<i>H4</i> Acceptance
Constant	-0.094 (0.549)	-0.102 (0.516)	-0.311* (0.069)	-0.298* (0.076)	
<i>R</i> ²			0.923	0.923	
<i>Adjusted R</i> ²			0.905	0.902	
<i>F</i> Statistics			52.38	43.31	
<i>P</i> value (<i>F</i> -Statistics)			0.000	0.000	
Observations	69	69	69	69	
Methods		NBC		LS	

Notes: *, **, *** indicate statistical significant at the 10%, 5% and 1% level, respectively.

Table 5.5 outlines the estimation results. Glancing over Table 5.5, no differences are found between the two models using patents and R&D expenditures as dependent variables. Government regulation and trade barriers have statistically significant effects

on patent creation and R&D spending, whereas government size has an insignificant effect on the dependent variables (patents and R&D expenditures). However, the relationship of government with patent creation is stronger ($p < 0.05$) than that with R&D spending ($p < 0.1$), while significance levels of trade barriers are identical in both regressions ($p < 0.05$).

In the estimation result, first I found that government regulation has a statistically significant effect on patent creation and R&D spending at the 5 percent and 10 percent significance levels (*Model 1* and *Model 3*), respectively. However, it has a negative direction, meaning that government restrictions in local markets positively affect national technology creation and investment since a country with a free market system is given a high value. This is a surprising result since I anticipated that tight government regulation limits the allocation and utilisation of resources, knowledge exchange and entrepreneurial processes, and consequently arrests technological development. With such an unexpected result, I divided the index of government regulation into three areas, credit, labour and product markets, so as to examine the details (*Model 2* and *Model 4*). However, I obtained identical results from this estimation; all regulation variables were statistically significant, but their minus signs remained unchanged. Therefore, I could not accept hypothesis 1 that strict government regulation in credit, labour and product markets negatively affects national technology creation and investment.

There are three possible explanations for a positive correlation between government regulation and national technology capabilities. First, the sample of high-income and upper middle-income countries used in this empirical study could produce an effect opposite to what was expected. Compared with lower middle-income countries or low-income countries, the countries have relatively free market systems to engage in voluntary exchange and allocate resources to private parties through market force. In

this context, an excessively liberal regulatory system with no government interference could produce myopic behaviours among market participants (short-term oriented) that concentrate on obtaining immediate profit and discourage long-term value creation and investment, such as R&D. Second, free market entry without any strings attached is likely to result in excessive and unfair competition that makes for low viability of new start-ups and SMEs. Blind reliance on the principle of market economy without any government intervention in market entry could cause the monopolisation of established firms since new firms (latecomers) are incapable of competing with them due to difficulties in cutting costs, attracting more clients and improving the supply chain. Start-ups and S&M businesses are key contributors to the development of technologies in frontier countries. Third, excessive deregulation could create an air of anxiety about a flight of capital, illegal leakage of knowledge and surreptitious use without licensing that discourages innovative and productive activities in technology investment and creation. Given that relatively well-off economies (e.g., the sample of high- and upper middle-income countries) are competent to generate their own technologies with advanced indigenous capabilities, stricter regulation may be needed so as to prevent the leakage of important knowledge incurred in the inordinate mobility of capital (e.g., credit, labour, techniques), as well as to protect innovators against the illegal use of their intellectual properties. For such reasons, I concluded that government regulation in domestic markets positively affects the development of national technology capabilities in the contexts of high-income and upper middle-income economies.

Second, I found that trade liberalisation is an important determinant of technology capabilities. It has a strongly significant effect ($p < 0.05$) with a positive sign, meaning that more freedom in international trade leads to an expansion of R&D expenditures and patent production. According to my expectation that an open-door policy promotes the stock and flow of knowledge by facilitating active FDI, technology

trade and R&D cooperation across the border, I accepted hypothesis 2 and confirmed that the removal of trade barriers play an important role in increasing technology input and output.

Third, I found that the size of government has a statistically insignificant effect on both patent production and R&D expenditure, in contrast to my expectation that the preponderance of the public sector's investment and output over those of the private sector negatively affects technology progress and innovation performance. Therefore, I did not accept hypothesis 3 and concluded that there is no connection between government size and technology capabilities. However, the significance of government size becomes stronger when it is used as a moderator of regulation and foreign trade effects on national technology capabilities. This result indicates that government size does not directly correlate with patent production and R&D expenditures, but its interaction with the regulatory (or liberal) institutional condition of the domestic market and foreign trade is strongly correlated with national technology capabilities. As shown in Table 5.5, the interaction of small government with weak government regulatory burden on market entry and foreign trade positively correlates with national technology investment and creation at a 5% significance level. Therefore, I accepted hypothesis 4 and concluded that small government size in combination with liberalised domestic markets and foreign trade systems facilitates more active technology investment and creation.

Regarding control variables, first, both patent production and R&D expenditures have a curvilinear association with GDP per capita. Second, GDP per capita has a negative effect on national technology capabilities, indicating larger investments in technology input and output as a percentage of GDP in less wealthy rich countries, such as newly industrialised countries (e.g., Korea, Singapore, Taiwan). Third, increasing enrolment in tertiary education facilitates the expansion of R&D expenditures and

patenting. Fourth, a strong rule of law to secure property rights used as a proxy of IPRs here has a positive influence on innovation climate, as expected. Other control variables, including population growth and monetary system, are not significant. In this multiple equation, the adjusted R^2 value shows that over 90 percent of dependent variable account for all the explanatory variables, which is a fairly high value considering its maximum value.

Several diagnostic tests proved the reliability of this regression model with nospecification errors. First, the joint hypothesis was tested by the ANOVA technique to detect the overall significance of the included independent variables in the regression model. Since the p value of the observed F is zero, as shown in Table 5.5, the null hypothesis that all slope coefficients are simultaneously equal to zero can be rejected, and I confirmed the overall significance of explanatory variables used in this model. Second, I employed a correlation matrix to detect the possible consequence of multicollinearity. Table 5.6 shows the result of the correlation matrix. Since all of the pair-wise correlation coefficient between two repressors is lower than 0.7, there is no concern about mulitcollinearity. Third, I undertook the White heteroskedasticity test. Since the p value is very low (near zero), there is no concern about heteroskedasticity. Alternatively, the *chi-square* value obtained from the White test was lower than the critical *chi-square* value at the chosen level of significance; hence, I confirmed that the errors (residuals) are both homoskedastic and independent of the regressors. Table 5.7 summarises the White heteroskedasticity test result.

Table 5.6 Diagnostic Tests: Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Patent	1.000										
(2) Log(GERD)	0.397	1.000									
(3) Gov. Regulation	0.146	0.010	1.000								
(4) Trade Barriers	-0.134	0.093	0.550	1.000							
(5) Gov. Size	-0.025	-0.292	0.058	0.045	1.000						
(6) Monetary System	0.201	0.256	0.478	0.466	-0.187	1.000					
(7) Legal Structure	0.173	0.425	0.650	0.423	-0.227	0.603	1.000				
(8) Log(Tertiary Enrolments)	0.261	0.700	-0.375	-0.192	-0.063	-0.208	-0.199	1.000			
(9) Log(GDP per capita)	0.175	0.409	0.529	0.352	-0.211	0.633	0.669	-0.272	1.000		
(10) GDP Change	-0.192	-0.347	-0.257	-0.126	0.159	-0.388	-0.393	-0.014	-0.545	1.000	
(11) Population Growth	-0.161	-0.341	0.039	-0.048	0.145	-0.073	-0.072	-0.349	-0.022	0.174	1.000

Note:

- (1) This table above shows the intercorrelations among eleven regressors; the main diagonal is the correlation of one variable itself, which is always 1 by definition, and the others are the pair wise correlations among the explanatory variables.
- (2) If the pair-wise or zero-order correlation coefficient between two regressor is exceed 0.8, then multicollinearity problems is likely to occur (See Gujarati; 2003, p.387-436).

Table 5.7 Diagnostic Tests: White Heteroskedasticity Test

Newey-West HAC Standard Errors & Covariance (lag truncation=3)			
<i>F</i> -statistic	2.7856	Probability	0.0020
(Observations) \times (R^2)	40.668	Probability	0.0181
Log Likelihood	-23.123	Durbin-Watson Statistics	1.8069
R^2	0.6256	Adjusted R^2	0.4010
Included Observations	65	Excluded Observations	4

Note:

- (1) If the p value is low, we can reject the null hypothesis that there is heteroskedasticity. As shown in this table, p value 0.002 is very low, thus there is no heteroskedasticity problem.
- (2) If the chi-square value obtained in this regression exceeds the critical chi-square value at the chosen level of significance, we can reject the null hypothesis that there is no heteroskedasticity. The chi-square value is obtained by $\text{observation} \times R^2$ with df , $NR^2 \sim \chi^2 df$. In this equation, $\text{observation} \times R^2 = 40.668$ is lower than the 5 percent critical chi-square value for 24 df is 36.415.

5.5 Conclusion and Further Studies

This empirical study has shown that technology capabilities are influenced by political and institutional conditions for market entry, voluntary exchange of capital and foreign trade. The findings are as follows. First, the regulatory system of domestic market entry and transaction facilitates the expansion of R&D expenditures and patenting in high-income and upper middle-income countries. This may suggest that reliance only on the principle of the market economy with no government interference discourages productive and innovative activities since excessive freedom can cause short-termism, capital flight, the monopolisation of established firms, the leakage of important knowledge and illegal use of intellectual properties. Second, a low regulatory burden on international trade increases technology input and output, as expected; hence, I suggest that removing trade barriers is necessary to promote the stock and flow of knowledge and the consequent development of technology capabilities. Third, I found that the size of government acts as a moderator of regulation and foreign trade effects on national technology capabilities, but does not directly correlate with it. This may imply that small government size

combined with liberalised domestic markets and foreign trade systems facilitates technology investment and creation. Therefore, I concluded that the regulatory system of domestic markets, liberalised systems of trade and their interaction with small government size positively affect national technology capabilities in industrialised countries.

However, this empirical study has several limitations that can direct future research. First, the study excluded the data of developing and transition countries (low middle-income and low-income countries) due to data unavailability. This could have produced strikingly different results. With a larger sample, it may be possible to control the different legal origins or varieties of capitalism for greater statistical significance. Second, a more reliable methodology selection should be required by using panel data with longitudinal approaches, which allows for looking at all variable changes over time and thereby estimating those linkages in more detail. Finally, while I have chosen a country-level analysis, an analysis of the effect of liberal regulatory systems on innovation at the sectoral level could also be fruitful since the institutional condition and the degree of government interference varies from industry to industry.

Despite these limitations, this study contributes to the existing literature. Most research on innovation has neglected the study of institutional context although there is widespread recognition that innovators are susceptible to institutional or contextual influences because of the unique characteristics of technological innovation - it is a risky, costly, uncertain and long-term investment. Also, most political economists have addressed institutional and policy factors as important determinants of economic growth, human welfare and entrepreneurship despite innovative activities being affected by institutional and policy frameworks that shape competitive and cooperative research climates. Therefore, this study fills gaps in the existing political economy and innovation studies by demonstrating the effect of institutions on technology capabilities.

CHAPTER 6

Institutions, Government Policies and Technology Capabilities in Korea and Japan

6.1 Introduction

In a knowledge-intensive economy, technological innovation is the most significant source of economic growth and social development (Cantwell, 1989; Kogut, 1991; Porter, 1990). The country-specific institutional setting for the stock and flow of knowledge, reflecting the creation of new sources for comparative advantages of a country or a firm, produces distinctive innovation patterns, directions and magnitudes (Nelson, 1993; Freeman, 1995; Lundvall, 1998; Etzkowitz and Leydesdorff, 2000). As the contributing factors influencing technology capabilities in Korea and Japan, this study explores the distinctive features of industrial science and technology (S&T) policy, the intellectual property (IP) regime, financial system and national innovation system (NIS).

Prior to a discussion of distinctive institutional setting and configuration, first, the evolution of S&T policies over the past four decades is explored in Section 6.2. With a brief outline of historical background and current status of economic and technological development in Korea and Japan, I evaluate effectiveness of changes in government S&T policies and the consequences of institutional reforms in sub-section 6.2.3. I analyse distinctive legal systems and innovation environments for the creation, protection and use of intellectual property in Section 6.3. In particular, effective patent-related regimes and policy measures to accelerate patent registration, commercialisation and patented technology transfer are emphasised as the key success factors influencing national technology capabilities. Section 6.4 discusses unique characteristics of the financial

system in the two countries, given that the national finances for investment and funding systems determine not only wealth creation, but also innovation success (Krugman, 1986; Taylor, 2004). Section 6.5 explores the evolution of NIS to analyse how key players within NIS and contextual factors have contributed to the rapid technology catch-up and success in innovation in the contexts of Korea and Japan. I also discuss strengths and weaknesses underlying their innovation systems. With the historical and contextual comparative analysis (S&T policy, IP regime, financial system and NIS), similarities and differences of specific institutional conditions for the technology input-technology output relationship are also discussed in econometrical models (Section 6.6). This empirical investigation enables us to identify different mechanisms and paths for national technology capabilities between the countries. Finally, Section 6.7 presents key arguments and the conclusion.

6.2 Science and Technology Policies and Institutions

This section presents the historical background of economic and technology development in Korea and Japan. The fast growth of Korea and Japan is attributable to rational industrial, international and S&T policies towards innovation-driven growth. A successful change in government policies with institutional reforms responding to the level of economic development enabled the countries to become the world's top scientific technology-oriented countries. Their effective S&T policies provide lessons for policy makers in developing countries.

6.2.1 Korea's Science and Technology Policy

Korea has shown rapid economic growth over the past four decades, so dramatic that it is often called the 'East Asia miracle'. Korean gross domestic product (GDP) per capita (current PPP\$) eased past the \$10,000 mark and had markedly increased to 29,004

(current PPP\$) in 2010 (World Bank Statistics). Such a great achievement is attributable to effective changes in S&T policy and institutional reforms responding to the level of economic development over time. Broadly, Korea's S&T policy has evolved in the three developmental stages – the imitation and importation of technologies in the 1960s and 1970s, domestic innovation steps in the 1980s, and high-technology improvements since the 1990s (Kim and Dhalman, 1992; L. Kim, 1997; Kim and Nelson, 2000; Lee, 2000). Table 6.1 summarises the government policy priority, key strategic industries, and staple items for export and investment in different stages.

In the earlier stage of economic development, covering the 1960s and 1970s, the government formed the 'Economic and Social Development 5 Year Plan', which enabled Korea to stand on tiptoe among modern industrial nations. Under the 5-year plan, Korea's gross national product (GNP) per capita jumped from US\$100 in 1963 to US\$1,000 in 1977, while exports sharply rose from US\$100 million to US\$10 billion in the same year (Bank of Korea Statistics). Imitation or copying mechanisms were used for exports of home goods, learning foreign skills and technical improvement. The 5-year plan was intended to increase export competitiveness by fostering the heavy chemical industry and changing its industrial structure from light-centred industries (e.g., textiles, food) to heavy-centred industries (e.g., ship construction, steel, machinery). It set the stage for Korea to become the world's leader in shipbuilding capacity.

Table 6.1 Evolution of Korea's Science and Technology Policies

Terms	Innovation Steps	Structure	Key S&T Polices and Framework Laws	Objectives of S&T polices & Government Role
1960s	Imitation or factor-driven	Labour intensive industries	5 Years Economic Plan (1962-1966); S&T Promotion Act (1967)	Establishing scientific institutions (e.g., MOST and KIST); promoting export for light products.
1970s	Internationalisation or investment-driven	Scale intensive industries	Technology Development Promotion Law (1972); Engineering Technology Promotion Law (1973); Government-sponsored Research Institute Law (1973); Korea Science and Engineering Foundation Law (1976).	Building scientific infrastructure, GRIs and Science Park (Daedok Science town); promoting knowledge transfer; improving the imported foreign technologies.
1980s	Domestic Innovation (manufacturing capabilities)	Technology intensive industries	Technology Development Promotion Law (1982); Industrial Research Associations Promotion Law (1986); Act on Korea Institute of Nuclear Safety (1989)	Promoting private research labs, industrial firms' innovation and indigenous R&D; developing higher education system; learning the need of skills.
1990s	High Technology Innovation (Innovation capabilities)	High-tech intensive industries (transition to knowledge-based economy)	Space and Aeronautics programme (1990); Highly Advanced National Project (1992); Cooperative R&D Promotion Law (1993); Creative Research Initiative project (1997); Special Law on Science and Technology (1997); Five Year Plan for S&T Innovation (1998); 21 st Century Frontier R&D programme (1999); the National Research Laboratory Programs (1999)	Upgrading the national S&T system, cultivating S&T independence, fostering human capital, developing the cutting-edge technology, improving the private sector's research capabilities, promoting collaborative R&D activities.
2000s			Vision 2025 (2000); Biotech 2000 (2000); National Nanotechnology Initiative (2001); Nanotechnology Development Promotion Law (2002); Daegu Gyeongbuk Institute of S&T Act (2003); The Revised National S&T Promotion and Development Program (2003); IT 839 Strategy (2004); Act on the Establishment, Operation and Nurturing of Government Research Institute in the Fields of S&T (2004); Space Development Promotion Act (2005); Nuclear Energy R&D Program (2006); Bio-Vision 2016 (2007)	Improving quality of education and research; Strengthening S&T competitiveness, upgrading the public awareness of innovation, focusing future-oriented frontier research; fostering world-class scientists; building world-class informatisation.

Source: Compiled by the data from various national policy reports and white papers: MOST (various year), MEST (2010), ISI *et al.* (2008).

As an S&T development plan, the government started to establish public research organisations, such as the Korean Institute of Science and Technology (KIST), and enacted a number of innovation laws, such as the ‘Technology Development Law’ and the ‘Engineering Service Promotion Law’ (Lee, 2000). The S&T policy focused on building up technological infrastructure, the introduction of foreign techniques and the increase of research and development (R&D) investment in basic science (Chang, 2003). With this governmental effort, the gross domestic expenditure on research and development (GERD) markedly increased from a mere US\$4 million in 1963 with a proportion of 0.25 percent to GDP to US\$33 million in 1970 with the proportion of 0.38 pe cent to GDP (KOSIS Statistics). However, R&D expenditure was undertaken by the public sector in most cases although the proportion of private R&D steadily increased, accoutring for 3 percent of GERD in 1963 and 29 percent of GERD in 1970 (KOSIS Statistics). This suggests that government was the key contributor to Korea’s innovation system as both financier and performer, while firms played a minor role in the national S&T development plan in the earlier development stage.

Entering the 1980s, the S&T policy stressed the significance of domestic innovation to rapid economic and technological catch-up with developed countries. It brought about institutional reform towards the quality of economic growth from quantitative expansion (Lee, 2000; Teubal, 2000). Starting from the ‘Technology Development Promotion Law’ enacted in 1982, the government established a number of R&D programmes to increase the stock and flow of knowledge at both firm and national levels, as well as the consequent development of indigenous skills in science and technology (Lee, 2000). To facilitate the industrial firm’s innovative activities, the government set up various financial incentives, including tax reduction or exemption for technology trade, R&D investment and subsidies for human capital, among others (MOST, 2003; Teubal, 2000). Such a political measure bolstering the private sector’s R&D

expenditures led to an increase in GERD by a factor of ten, from US\$428 million in 1980 to US\$4,428 million in 1989, while changing the ratio between the public sector and the private sector from 64:36 to 19:81 (KOSIS Statistics). In this stage, the larger share of R&D financed by the private sector suggests that the industrial firms became a major player in Korea's innovation system.

In the 1990s, Korea underwent an economic boom and bust simultaneously. Korea's GDP per capital passed the \$10,000 mark in 1995 and it joined the Organisation for Economic Cooperation and Development (OECD) in 1996, but suddenly fell into financial crisis in 1997. The introduction of financial liberalisation brought about large economic reforms, including the financial system (e.g., taxation, accounting system, banking industry), public enterprises (i.e., privatisation) and regulatory policy (i.e., open-door policy). Based on the liberalisation, the government loosened some controls on the flow of capital (e.g., credit, labour, technology) and investments abroad. However, these reforms led to a trade deficit, increasing foreign debt, excessive overseas expansion and massive capital flight due to the nature of political, structural and institutional defects (Chang, 2003). The cozy relationship between politics and business, the outdated corporate structure (i.e., nepotism) and the chaebols-dominated economic system were important causes of the financial crisis in Korea (Chang, 2003). The crisis (1997-1999) led to negative growth, with GDP shrinking 6.9 percent from 1997 to 1998 (see Table 6.2).

Table 6.2 Korea's Economic and Innovation Indicators, 1986-2010

	1986	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010
GDP (constant 2000 US\$, million)	206,381	295,602	342,368	394,387	460,681	449,061	533,384	594,230	639,102	698,799	751,360	800,206
GDP per capita (constant 2000 US\$)	5,011	6,895	7,841	8,872	10,119	9,701	11,346	12,478	13,303	14,468	15,457	16,372
GDP growth (annual %)	10.61	9.15	5.87	8.53	6.99	-6.85	8.48	7.15	4.61	5.17	2.29	6.16
High-tech exports (current US\$, million)	8,909 ⁽¹⁾	10,819	13,891	20,054	27,416	30,645	53,950	46,600	75,742	92,944	112,486	n.a.
High-tech exports (% of total exports)	15.94 ⁽¹⁾	18.03	19.76	22.65	24.06	27.05	35.06	31.52	32.91	32.14	27.59	n.a.
GERD (constant 2000 Won, million)	1,523	3,210	4,989	7,894	10,878	11,336	13,848	17,325	22,185	27,345	34,498	n.a.
Royalty & license fees												
Payments (current US\$, million)	473	1,364	1,628	1,719	2,431	2,469	3,221	3,002	4,446	4,650	5,656	8,964
Receipts (current US\$, million)	15	37	105	155	185	260	688	853	1,861	2,045	2,381	3,145
No. Patents application by KIPO												
Resident	3,640	9,082	15,951	28,554	68,405	50,596	72,831	76,570	105,250	122,188	127,114	131,805
Non-Resident	9,115	16,738	15,122	17,158	21,921	24,672	29,179	29,566	34,865	38,733	43,518	38,296
No. Patents granted at USPTO	n.a.	290	586	1,008	1,567	3,362	3,472	4,009	4,671	6,509	8,730	12,508

Note: The data of ⁽¹⁾ is 1988

Source: Compiled by the data from KOSIS, KIPO, USPTO, World Bank, WIPO and UNESCO Statistics.

However, the activity of innovation was not interrupted by the crisis. Despite a deep economic recession, the Korean national technology input and output steadily increased during the crisis. As shown in Table 6.2, R&D expenditures and the payments of royalties and license fees were unaffected by negative GDP growth, and the two indicators of technology input continued to grow from pre-crisis to during the crisis. As indicators of national technology output, high-tech exports increased by about 0.9 percent and the number of patents granted by the United States Patent and Trademark Office (USPTO) doubled between 1996 (pre-crisis) and 1998 (during the crisis).

Such vigorous activity for technology investment and creation may have resulted from the government effort to shift to an innovation-driven economy by setting up a long-term innovation strategy. In the pre-crisis period, Korea's government enforced the long-term S&T policies supporting cutting-edge innovation by establishing a series of R&D programmes. For example, the 'Space and Aeronautics Programme' launched in 1990 to develop the aerospace engineering and national defence industry by 2000 (MOST, 2007). This programme proposed to create new satellite technology in three areas: scientific satellite, multipurpose satellite and communication satellite (MOST, 2007). Another typical example is the 'Highly Advanced National Project' (the HAN project). The HAN project was a long-term (1992-2002) plan for large-scale investments (US\$3.2 billion) to develop the national technology capabilities (MOST, 2007). The HAN project embraced two schemes for product and process of innovation. First, it planned to build up internationally competitive high-tech industries so as to strengthen Korea's competitive edge in exporting. These high-tech products included HDTV (high-definition television), ISDN (Integrated Services Digital Network), ASIC (Application Specific Integrated Circuit), biomedical, micromachining and next-generation automobiles (MOST, 2007). Second, the HAN project proposed to develop fundamental technology to realise sustainable economic growth. As the improvement plan for the living environment, it

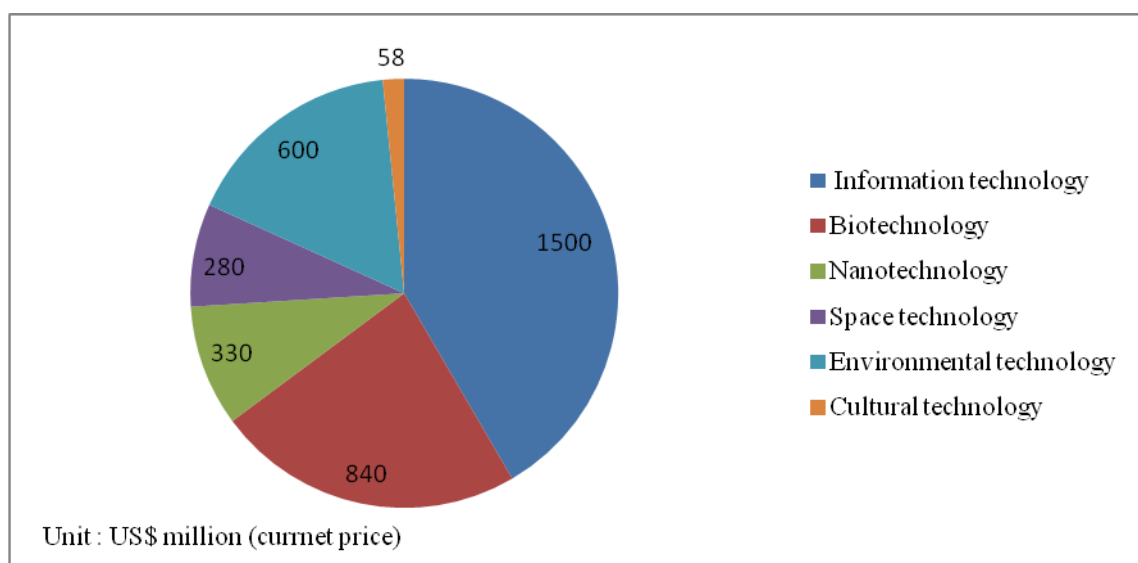
focused on the progress of environmental technology, manufacturing systems, new energy, human sensibility ergonomics and new-generation semiconductors with the objective of sustainable economic growth (MOST, 2007). To achieve these goals, the government formulated special laws for promoting high-tech start-ups and joint R&D with private organisations, such as the ‘Cooperative R&D Promotion Law’ (1993) and the ‘Special Law on Science and Technology’ (1997) (MOST, 2007). Such long-term S&T policies in the pre-crisis era might have contributed to the expansion of R&D activities in the creation of Korea’s own technologies during the crisis, regardless of economic recession, as shown in Table 6.2.

During the crisis period, Korea more strongly stressed the importance of technical innovation through autonomous R&D. The building of world-class technology capabilities might have been the only way to cope with the financial crisis in the absence of national resources. It led to far-reaching economic reform as a whole, including political and social structure, financial system, trade policy, IP regime and NIS (Jang, 2000; H.J. Chang, 2002). To efficiently carry out industrial S&T policies, the public sector was restructured by removing superfluous parts (i.e., officials, departments), while faltering firms and local banks were liquidated through merger and acquisition (M&A) (H.J. Chang, 2002). Also, Korea’s government changed its funding system and corporate policy to promote venture capital and small and medium enterprises (SMEs) in contrast to the previous policy that offered preferential treatment for chaebols’ expansion and innovation processes (S. Kim, 1998; Jang, 2000; S. Kim, 2002).

With these reforms, Ministry of Science and Technology (MOST) established the ‘21st Century Frontier R&D Programme’ and the ‘National Research Laboratory Programme’ in 1999 to develop cutting-edge science and technology. The 21st Century Frontier R&D Programme targeted advanced technological capabilities by the year 2010 in newly emerging areas: information and communication technology (ICT),

biotechnology, nanotechnology and culture technology. For the duration of this program (1999-2010), US\$3.4 billion was assigned for sub-R&D projects to develop the four strategic technologies (MEXT, 2010). To meet the goal, the National Research Laboratory (NRL) programme was launched in the same year to promote research centres of excellence (ISI *et al.*, 2008). More than 440 public and private research laboratories (278 higher education institutions, 114 national research institutes and 50 corporate research centres) were sponsored by the government, which had created about 12,300 S&T papers and 3,600 patents through 2006 (Tsipouri and Patsatzis, 2006, p.131; Bartzokas, 2007, p.19). Such a government effort to rebuild its economy by transforming to a high-tech economy might have increased public awareness of the importance of innovation, facilitating R&D expenditure, patenting and technology trade in high-tech fields. Table 6.2 illustrates a constant increase in innovation activities, despite negative GDP growth during the crisis. Hence, it enabled Korea to recover its economy and redeem the full amount of its International Monetary Fund (IMF) relief loans, US\$1.96 billion in 2001 (MOST, 2003).

Figure 6.1 Korea's Government Expenditures in Key High Technology areas, 2004



Source: Compiled by the data from ATIP (2006) and ISI *et al.* (2008).

In the post-crisis, the National Science and Technology Council (NSTC) drew up the 'National S&T Promotion and Development Plan' in 2002. With a five-year plan, it aimed to increase GDP per capita to US\$15,000 and enhance the overall living standard by 2006, fostering six promising technologies – IT, biotechnology, nanotechnology, environmental technology, space technology and cultural technologies (BMBF website; Bark, 2003, p.5). In 2004, the government spent more than US\$3.6 billion to establish research centres at universities, cultivate a creative workforce and support innovation activities in these areas (ATIP, 2006, p. 9). Figure 6.1 shows Korea's expenditures in the six areas under the S&T plan.

However, the National S&T Promotion and Development Plan was revised in 2003 when Mr. Noh Moo-Hyun was inaugurated as the president of Korea. The revised National S&T Promotion and Development Plan changed its time frame to 2003-2007 and emphasised networking among R&D players to attain balanced national development (Bark, 2004; Yim, 2005). This plan was designed with five goals for shifting from a catch-up to a frontier country (Baek and Jones, 2005, p.14). First, it aimed at improving technological capabilities of government research institutes (GRIs), academia and firms by setting up various policy measures, including tax incentives to firms' R&D spending, technical and financial assistance for SMEs and start-ups and subsidies for the employment of R&D personnel (Baek and Jones, 2005). A special programme for SMEs, such as the 'Techno Park Programme' designed by the Institute of Industrial Technology Evaluation and Planning (ITEP), supports SMEs and start-ups through the formation of innovation complexes that promote joint R&D with universities, research institutions and large regional firms (ISI *et al.*, 2008). The government also relaxed regulations on labour mobility and capital control in GRIs and universities to promote spin-offs and the dynamics of innovation while expanding their autonomy (ISI *et al.*, 2008). Second, it proposed an increase in the efficiency of R&D investment by minimizing the overlapping

of public and private spending, while putting new emphasis on elevating S&T personnel by reforming science education systems and expanding the job market for highly qualified workers (ISI *et al.*, 2008). Third, it focused on enhancing international competitiveness in ICT, biotechnology, environmental and energy technology, space and marine technologies, as well as system and materials and processing technologies as core technologies for future growth. To develop indigenous technology in these areas, several medium-term and long-term projects have been set up with annual funding from the government budget of more than US\$200,000, for example, Biotech 2000 (2000-2007), Bio-Vision 2016 (2007-2016), National Nanotechnology Initiative (2001-2009), Nuclear Energy R&D Programme (1992-2005) and the IT 839 Strategy (2004-2007) (Suh, 2002; Lim, 2004; MIC, 2004; Wieczorek, 2007; Bartzokas, 2007). Also, this plan suggested that the improvement of the diffusion mechanism was stipulated by strengthening IPR protection system and developing intermediaries, such as regional and sectoral innovation clusters (Tsipouri and Patsatzis, 2006). Fourth, it aimed to develop effective NIS for a cooperative relationship among government, universities and industry, as well as joint R&D with foreign organisations. The government set up the 'Technology Innovation Centre Programme' to facilitate active R&D cooperation among universities and firms and the 'Technology Business Incubator Program' to promote entrepreneurs and start-ups through an injection of funds, information and technologies (Kotilainen 2005, p.39). New performance-oriented evaluation and management systems were also suggested for the progress (Kotilainen, 2005; ISI *et al.*, 2008). Fifth, it planned to create an S&T-friendly culture and favourable climate for high-calibre talent by reducing the burden of military service obligation and expanding the reward system for scientists and engineers (ISI *et al.*, 2008). A more detailed description of the 'National S&T Promotion and Development Plan' is presented in Table 6.3.

Table 6.3 The Revised National S&T Promotion and Development Programme (2003-2007)

Main Goals	Measures (Instruments)
Development of technology capabilities of government research institutes, universities and firms.	<ul style="list-style-type: none"> • Increasing R&D spending to 3% of GDP by 2007 by setting up tax incentives. • Fostering 10,000 SMEs by offering technical and financial assistance. • Providing subsidies for the employment of R&D personnel. • Relaxing regulations (e.g., on land use, environment) for and entrepreneurs and start-up companies. • Expanding the government R&D budget for basic research to 25%. • Raising the share of universities' R&D to 15% by 2007. • Promoting organizational flexibility and labour mobility in the GRIs and expanding their autonomy. • Deregulating ceilings on Chaebol shareholding and on capital control.
Increase in the allocative efficiency of R&D investment and securing the supply of a high-quality human resource.	<ul style="list-style-type: none"> • Minimizing the overlapping of public and private spending. • Cultivating high skilled and trained manpower in the field of S&T to be responsive to industry's needs. • Securing the supply of highly qualified engineering and scientists by reforming engineering and vocational education.
Development of high technologies and improvement of diffusion mechanism.	<ul style="list-style-type: none"> • Intensively fostering future core technologies (ICT, biotechnology and nanotechnology), mega-science (e.g., space and marine technologies), energy, and public welfare (e.g., health, transportation). • Promoting ten technology areas by US\$ 3 million by 2008 – intelligent robots, future automobiles, non-memory semiconductors, digital televisions and broadcasting, next-generation mobile telecommunications, display devices, intelligent home networks, digital content and software, next-generation rechargeable batteries and biomedical products. • Building up internationally competitive the material and component-related industries. • Upgrading the diffusion mechanism by creating intermediaries between technology invention and diffusion, improving technology evaluation schemes, and strengthening the intellectual property rights system (e.g., providing patent information and streamlining patenting procedures). • Creating regional and sectoral innovation clusters.
Development of institutional framework and NIS	<ul style="list-style-type: none"> • Facilitating the dynamics of R&D cooperation among government, universities and firms. • Promoting the cross-border R&D collaboration. • Making an East Asia regional R&D hub in Korea. • Establishing a national information system for S&T by 2008. • Building up a performance-oriented evaluation and management system. • Expanding the roles the NSTC and MOST for the coordination of S&T policies and R&D programmes.
Development of technology infrastructure	<ul style="list-style-type: none"> • Offering the social compensation for highly qualified workers by reducing the burden of military service obligation, raising the share of scientists and engineers' career tracks in the government, and developing the reward system for scientists and engineer. • Establishing an S&T-friendly culture and social environment.

Source: Compiled by the data from Bark (2003), Yim (2005), Tsipouri and Patsatzis (2006) and ISI *et al.* (2008)

Furthermore, the government reformed its education system by setting up the reform programme called 'Brain Korea 21' so as to upgrade research capabilities of universities, train top-level human resources, strengthen industry-university ties, promote international cooperation and facilitate university spin-offs (MOEHRD, 2001). More than US\$1.2 billion were invested from 1999 to 2005 to accomplish these objectives by forming 570 research teams from 74 universities (ISI *et al.*, 2008). In 2006, the second reform programme of Brain Korea 21 was designed by the Ministry of Education & Human Resource Development (MOEHRD). With an investment plan of US\$2.2 billion from 2006 to 2012, a wide range of academic disciplines, including humanities, social and natural sciences as well as engineering and applied sciences, has been supported for training human resources and facilitating R&D activities (The Korea Herald, 27.4.06).

In a nutshell, government policies that focused on the development of home-grown S&T capabilities by supporting indigenous R&D enabled Korea to rapidly catch up and join the ranks of technologically developed countries. Korea had become the third largest country in terms of number of patents granted by the USPTO (12,568) in 2010, followed by Japan and Germany (USPTO Statistics); it ranked fifth in R&D spending (US\$44.8 billion) in 2011, while taking first place in terms of R&D spending as percentage of GDP (UNESCO Statistics). Also, S&T policy supporting sectoral innovation allowed Korea to attain global leadership status in many high-tech fields, including electronics, automobiles, ships, machinery, petrochemicals, robotics and wireless telecommunications (MEXT, 2010). The remarkable economic growth in the post-crisis might have been driven by exporting products manufactured in these high-tech sectors. Hence, the rapid technology catch-up of Korea is attributable to successful changes in policy and institutional frameworks towards high-tech innovation-oriented growth under strong government leadership. The redirection of S&T policy towards an advanced S&T-oriented society, and the consequent institutional reforms during the crisis,

allowed Korea to recover its economy and reach world leader in many high-tech fields, which has been an inspiration to the world economy.

6.2.2 Japan's Science and Technology Policy

Japan has long focused on technology capabilities and innovation as the main engines of economic growth, starting with the Meiji-restoration in 1868 when the ruling elite set up a number of industrialisation programmes to modernise the physical infrastructure and education system with the aim of reinforcing national military and economic growth (through catching up) after the model of Western imperialism (Beasley, 1990; Fagerberg and Godinho, 2005). The technology-based growth policy of Japan is up to 50 years older than that of Korea. Research centres, universities and family-owned business groups, the zaibatsus (similar to Korean chaebols) were also founded to develop engineering and applied science. In this stage, the public sector and the zaibatsus played a pivotal role in growth and in interaction with the bureaucracy and the military (Fagerberg and Godinho, 2005). The industrial structure was concentrated on food processing and textiles, but moved to machinery and heavy chemical industries after the First World War (Odagiri and Goto, 1996). The defeat of Japan in the Second World War brought about large structural reform by dissolving the military-based system and the zaibatsus-centred structure to catch up economically and technologically with the West. With a growing role for private initiatives, new business groups, the keiretsus, emerged. The keiretsus are distinguished from the zaibatsus by a greater role of banks and less family control. Banks and businesses became more autonomous, getting out the state control and the power of the bureaucracy.

Since before World War II, public research institutes have existed in Japan to build up modern industrial society through technological revolution. Typical examples of public institutes include the Electric Experimental Laboratory (1891), the Tokyo

Industrial Experimental Laboratory (1900) and the Institute of Physical and Chemical Research (1917) (METI, 2008). The General Headquarters of the Supreme Commander for the Allied Powers (GHQ/SCAP) controlled military and naval research organisations, while setting a limit on basic science research, particularly in the areas of atomic physics and aeronautical science, by other research organisations. Private firms (i.e., Zaibatsus) were forced to undertake military-related R&D for electronic technology (RIETI, 2009). Gijutsuin (the Cabinet's board of technology) was responsible for the wartime mobilization of science and technology; it was abolished in 1945 (RIETI, 2009).

After the war, the Ministry of Commerce and Industry (MCI) was founded in 1948 to draw up and implement industrial and technology policy. The MCI initiated a programme of institutional reform to improve public awareness of technical innovation, facilitate industrial firms' R&D and cultivate engineers and technicians (Harayama, 2001). The government also promoted the introduction of foreign techniques and production by technical transfer by enacting the 'Foreign Capital Law' and the 'Foreign Exchange Law' as a measure of post-war reconstruction; *"Based on these laws, the Japanese government allocated its scarce foreign currency selectively to those firms capable of adapting and improving import technology in order to encourage the importation of advanced technology and to promote a domestic technology base"* (Sakakibara and Cho, 2002, p.678). Due to a lack of resource in the creation of Japan's own technologies, Japanese industries heavily relied on foreign techniques, and hence imitation was a key method for industrialisation and internationalisation in that period (AIST, 2007). The public sector was a dominant player within NIS, since the modest incentives (e.g., tax and financial incentives) set by the government, combined with weak institutions (e.g., capital support system, HR support system, corporate R&D support system, NIS), did not encourage the private sector to undertake innovation activities (Sakakibara and Cho; Harayama, 2001).

Table 6.4 Evolution of Japan's Science and Technology Policies

Terms	Key Events	Key S&T Polices & Framework Laws	Major Objectives of S&T polices & Government Role
1940s 1950s	Foundation of the MCI (Ministry of Commerce and Industry) and the AIST (Agency of Industrial S&T) in 1948.	Policy Concerning Industrial Rationalisation (1950); Foreign Capital Law (1952); Foreign Exchange Law (1952).	Promoting research activities for post-war reconstruction; Introducing foreign techniques and technology transfer; Supporting testing laboratories & research institutes.
1960s	Relocation of its affiliated testing laboratories outside Tokyo in 1961; Plan to construct research & academic city in Tsukuba in 1963; Emergence of the first central research laboratory boom.	Act on the Mining & Manufacturing Technology Research Associations (1961); Big Project (1966).	Reducing the dependence on imported techniques; Assisting private-sector R&D activities; Building private-sector research laboratories; Encouraging joint mining & manufacturing technology research between SMEs.
1970s	The two oil shocks (1973; 1979); A change in S&T policy to the focus of private-sector research activities, from the government-led research activities.	Sunshine Programme (1974); VLSI Programme (1976); National R&D Programme for Medical & Welfare Apparatus (1976); Moonlight Programme (1978).	Promoting private-sector R&D and its collaboration with the national research organisation; Developing new energy and energy-conservation technologies, very large-scale integrated (VLSI) circuits for next-generation computers, and medical & welfare devices.
1980s	Friction with USA against Japan's free ride in basic research; Relocation of national research institutes focusing on basic research in Tsukuba to the new science city; Foundation of Japan Key Technology Centre (1985); Foundation of the New Energy and Industrial Technology Development Organization (NEDO) (1988); Emergence of the second central research laboratory boom.	Next Generation R&D Programme (1981); System for Promotion of Coordinated & Creative Science and Technology (1981); Human Frontier Science Program (1987); Act for Strengthening Infrastructure for R&D of Industrial Technologies (1988).	Developing key next generation industrial technologies; Facilitating private-sector basic research activities; Promoting industry-academia-government R&D collaboration; Promoting international research cooperation.
1990s	The collapse of the bubble economy; Reform of R&D programmes & national research organisations in 1993; Foundation of the National Institute for Advanced Interdisciplinary Research in 1993; Foundation of Technology License Organisations in 1998	Industrial S&T Frontier Program (1993); New Sunshine Program (1993); Basic Act on S&T (1995); S&T Basic Plan I (1996). Law for Promoting Research Cooperation (1998); Law for Promoting University-Industry Technology Transfer (1998).	Creating an internationally appealing centre of excellence (COE) for basic research as a response to the R&D free-ride criticism; Upgrading NIS for strengthening State-University-Industry relationship; Promoting domestic knowledge stock and flow; Developing technology for practical research application.
2000s	The recovery of economic recession; Build of high-tech parks and specialised innovation cluster; Promotion of inter-ministerial policies. Development of and support of non-profit organisations and social entrepreneurs.	S&T Basic Plan II (2001); S&T Basic Plan (2006); Biomass Nippon Strategy (2006); New Health Frontier Strategy (2007); Innovation 25 (2007). Asian Gateway Initiative (2007); Intellectual Property Strategic Programme (2007); Priority Policy Programme (2007)	Establishing a fair R&D evaluation system; Securing experts and providing specialised training; Supporting researcher's mobility and autonomy; Strategically promoting international R&D activities; Creating socially valuable technologies; Developing high-quality basic applied research, Making a competitive R&D for academia and researchers; Accelerating research commercialisation through a triple cooperation;

Source: Compiled by the data from various national policy reports and white papers: CSTP (Various years), METI (Various years), RIETI (various years) and ISI *et al.* (2008).

Table 6.4 summarises the evolution of Japanese S&T policies over time. In the 1960s, the government began to support corporate R&D by providing tax reductions or exemptions that encouraged industrial firms to establish their research laboratories and join in national R&D programmes, such as the ‘Big Project’ (Harayama, 2001). In 1966, the Big Project was planned and designed by the Agency of Industrial Science and Technology (AIST), which is the advisory body of the MITI, the predecessor of the current METI (Ministry of Economy, Trade and Industry) (RIETI, 2009). It was an ambitious R&D plan to reduce dependence on imported techniques and promote the private sector’s R&D activity as well as strengthen state-industry cooperation (Yamaguchi, 2008; RIETI, 2009). All participants in this project received various subsidies from the government to assist with R&D, which led to a boom in private-sector research laboratories in the 1960s (RIETI, 2009). Under such circumstances, the government planned to construct an internationally competitive research and academic city, in Tsukuba, Ibaraki Prefecture, in 1963 to resolve the problems of poor communication between individual research institutes and inactive R&D cooperation among various actors (RIETI, 2009). A total of 43 testing laboratories and research institutes affiliated with 10 government ministries and agencies related to S&T were located in the Tsukuba until 1979 (RIETI, 2009). The government also founded the Japanese Industrial Technology Association in 1969, which was charged with developing the Tsukuba science city by facilitating joint research activities among government laboratories, private research organisations and universities (Harayama, 2001; METI, 2008).

Various medium-term or long-term S&T policies, series of R&D programmes and financial incentives were formed from the 1970s to the 1990s to shift to a knowledge economy based on science and technology. In the 1970s, the Japanese government designed energy R&D programmes against the backdrop of the oil shocks. Since Japan

heavily relied on imported oil and overseas natural resources, the two oil shocks of the 1970s triggered the promotion of R&D for new energy technologies (Sunshine Program, 1974) and R&D for energy-saving technologies (Moonlight Program, 1978) (RIETI, 2009). Also, a number of subsidy programmes supported private sector R&D to develop state-of-the-art technologies so as to catch up with frontier countries, such as the United States, Germany and the UK. The VLSI Program (1976) aimed at promoting very large-scale integrated (VLSI) circuits for next-generation computers, and the National Research and Development Program (1976) for developing health, medical and welfare devices are prime examples (RIETI, 2009). The national S&T policy involved a shift of emphasis from government-led research activities to those under private-sector initiative, whereupon the private-sector firms became key contributors to the Japanese innovation system in technology investment and creation from the 1970s (Freeman, 1995; Branstetter and Ug, 2004).

In the 1980s, Japan entered the post catch-up stage. There was a great government effort to promote basic research activities by setting up various R&D programmes and policy measures, such as (i) formation of the ‘Next Generation Industry Basic Technology R&D Program’ and ‘System for Promotion of Coordinated and Creative Science and Technology’ in 1981; (ii) the introduction of policy measures supporting private-sector basic research activities and corporate R&D in form of tax exemptions in 1985; (iii) the foundation of the ‘Japan Key Technology Center’ in 1985; and (iv) the ‘Act for Strengthening Infrastructure for Research and Development of Industrial Technologies’ in 1988 (Kuwahara, 1999; Watanabe, 1999; METI, 2008; RIETI, 2009). Also, Japan-initiated international research collaboration program, the so called ‘the Human Frontier Science Program’, was launched in 1987 to undertake joint R&D with foreign research organisations, mainly in the research of living organisms and the development of research findings for the benefit of all humankind (RIETI, 2009). Such effective government

policies might lead to an upsurge in technology input and output, such as patenting, R&D investment, high-tech exporting and royalty/licensing fee payments (or receipts). As shown in Table 6.5, the number of patent applications doubled from 1980 to 1990, while receipts for royalty/licensing fee increased more than eight-fold during from 1980 to 1991. However, despite government support for the industry-academia-government relationship, the problem of inactive R&D collaboration between public and private R&D organisations still existed in this period (Harayama, 2000).

In the 1990s, following the burst of its asset-price bubble, government carried out large reforms of industrial structure and NIS, since Japan faced a slowdown of economic growth and international competitiveness (Branstetter and Ug, 2004). The government revised previous R&D programmes to formulate a new integrated S&T policy, while restructuring national research organisations to minimise duplication of work done by different organisations as well as their overlapping investments. In 1993, the ‘Industrial Science and Technology Frontier Program’ and the ‘New Sunshine Program’ were born by integrating the three national programmes (the ‘Big Project program’, the ‘Next-Generation R&D program’ and the ‘National Research and Development Program for Medical and Welfare Apparatus’) and the two national programmes (the ‘Sunshine Program’ and the ‘Moonlight Program’), respectively (RIETI, 2009). In the same year, the two R&D institutes, the National Institute of Materials and Chemical Research and the National Institute of Bioscience and Human-Technology, merged with four national research institutes, the National Chemical Laboratory for Industry, the Fermentation Research Institute, the Research Institute for Polymers and Textiles and the Industrial Products Research Institute (RIETI, 2009).

Table 6.5 Japan's Economic and Innovation Indicators, 1980-2010

	1980	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010
GDP (constant 2000 US\$, million)	2,819,571	4,150,255	4,323,346	4,368,141	4,567,702	4,544,072	4,667,448	4,688,317	4,885,067	5,081,105	5,140,555	5,010,032
GDP per capita (US\$)	28,196	33,595	34,801	34,956	36,320	35,947	36,789	36,786	38,235	39,771	40,253	39,309
GDP growth (annual %)	2.81	5.20	0.82	0.86	2.64	2.05	2.86	0.26	2.74	2.04	1.17	4.00
High-tech exports (current US\$, million)	60,158 ⁽²⁾	65,586	77,209	95,072	100,165	94,011	127,375	94,729	124,045	126,618	123,732	n.a.
High-tech exports (% of total exports)	23.93 ⁽²⁾	24.24	24.07	25.55	26.15	26.15	28.69	24.78	24.10	22.06	17.31	17.06
GERD (constant 2000 Yen, million)	8,414 ⁽¹⁾	13,078	13,596	15,079	14,155	15,169	15,304	15,551	15,782	17,273	17,377	n.a.
Royalty & license fees												
Payments (current US\$, million)	1,330	6,050 ⁽³⁾	7,199	8,306	9,828	8,947	11,006	11,020	13,644	15,500	18,311	18,768
Receipts (current US\$, million)	350	2,365 ⁽³⁾	3,060	5,184	6,680	7,388	10,227	10,421	15,701	20,095	25,700	26,680
No. Patents application by JPO												
Resident	165,730	332,952	337,498	319,261	339,045	357,379	384,201	365,204	368,416	347,060	330,110	290,081
Non-Resident	25,290	27,752	24,699	21,940	37,629	44,716	35,342	56,601	54,665	61,614	60,892	54,517
No. Patents granted at USPTO	n.a.	20,743	23,164	23,517	24,059	32,118	32,992	36,339	37,032	39,411	36,679	46,978

Note: The data of (1) is 1986, (2) is 1988, and (3) is 1991.

Source: Compiled by the data from KOSIS, KIPO, USPTO, World Bank, WIPO and UNESCO statistics.

However, an economic slump with massive unemployment lasted throughout the year, while the neighbouring nation, Korea, was catching up with Japan's manufacturing techniques at a blinding speed, giving rise to a sense of crisis in Japan. This brought about a change in national S&T policy away from international R&D cooperation to a focus on domestic technology transfer and state-university-industry cooperation, as well as the development of new manufacturing industries that would increase domestic employment (METI, 2008). Also, the Japanese S&T policy promoted R&D activity for market-induced applied research, in contrast to the previous S&T policy that strongly focused on the research of basic sciences. Against this backdrop, the 'Science and Technology Basic Plan I' was born in 1996 after enactment of the Basic Act on Science and Technology in 1995 (Watanabe, 2000; Yamaguchi, 2008).

With the goal of creating an advanced S&T-oriented society, the first Basic Plan (1996-2000) mainly focused on fostering high-quality human resources and a cooperative R&D environment, suggesting financial support to 10,000 post-doctoral researchers, joint research and technical cooperation among ministries related to S&T and NIS based on tripartite cooperation (JFEO, 1998; Watanabe, 2000; Harayama, 2001; Nolan, 2007). Also, the first Basic Plan proposed to increase R&D investment of government since its share of GERD had the lowest percentage compared to Western industrialised countries (Sakakibara and Cho, 2005). In this sense, the government formed investment schemes to increase public R&D investment and to double research funding until 2000 (also see Hiroo, 2002; Yamaguchi, 2008).

Meanwhile, the Law for Promoting Research Cooperation and the Law for Promoting University-Industry Technology Transfer were enacted in 1998 to promote technology transfer and joint R&D between universities and industrial firms (Yamaguchi, 2008; Motohasi, 2005). These laws led the Japanese education system and NIS reforms to compensate for weaknesses in universities' R&D capacity and collaboration with industry.

With cooperation between the Ministry of Education (ME) and other ministries related to S&T, university personnel were allowed to work as consultants in private companies, private firms could establish research facilities on university campuses and excellent students were trained in internship programmes (Schacht, 1998; Fujisue, 1998; Yamaguchi, 2008; Motohasi, 2005). Under the leadership of the Technology Licence Organisations (TLOs), universities started to transfer their research findings to private firms mainly through tacit agreements and licensing contracts (Takenaka, 2005; Motohasi, 2005). As the fruits of that labour for creation and utilisation of scientific knowledge by developing R&D capabilities of universities, Japan ranked first in the listings of US patents granted to foreign investors with 32,992, as shown in Table 6.5.

Table 6.6 International Comparisons of Science and Engineering Articles, 1995 and 2007

Rank	Country	1995	2007	Average Annual Change (%)	% of World Total, 2007
1	US	193,337	209,695	0.7	27.7
2	China	9,061	56,806	16.5	7.5
3	Japan	47,068	52,896	1.0	7.0
4	UK	45,498	47,121	0.3	6.2
5	Germany	37,645	44,408	1.4	5.9
6	France	28,847	30,740	0.5	4.1
7	Canada	23,740	27,799	1.3	3.7
8	Italy	17,880	26,544	3.3	3.5
9	Spain	11,316	20,981	5.3	2.8
10	Korea	3,803	18,467	14.1	2.4
Total (World)		564,645	758,142	2.5	n.a

Source: Compiled by the data from NSF statistics.

Also, Japan was ranked the world's third highest nation in terms of number of S&T articles, behind two English-speaking nations, the United States and the UK in 2000 (see Table 6.6). Considering most academic journals and books in English monitored by the Institute for Scientific Information (James, 2006), Japan's R&D expenditures in

education and academic research capabilities are at the highest level in the world. Therefore, the first Basic Plan (1996-2000) secured innovation success in improving human capital, universities' R&D capabilities and infrastructure of R&D system. Nevertheless, the government announced the second Basic Plan by revising the first Basic Plan in 2001 with recognition of the urgent need for institutional reform related to S&T, including R&D evaluation, supporting and management systems to strengthen international competitiveness further and to acquire the ability for sustainable development (Harayama, 2001; Noland, 2007).

Following the first plan, which ended in 2000, this second plan ran from 2006 through 2011. The second Basic Plan aimed at (i) the construction of a competitive environment; (ii) the establishment of R&D evaluation systems based on fairness and transparency; (iii) the improvement of supporting systems for autonomy and mobility of researchers; (iv) the elevation of R&D management; (v) the building of properly operational university-industry-state relationships; (vi) the promotion of technology transfer to the private sector; (v) the creation of small and medium-sized innovative firms; and (vi) international technical tie-up (MEXT, 2003; Noland, 2002; Harayama, 2001; Hiroo, 2002). The Japan Society for the Promotion of Science (JSPS) was in charge of promoting international S&T collaboration (Sikka, 1998). Table 6.7 outlines the key objectives of the Japanese S&T Basic Plan II and Basic Plan III.

In comparison with the Basic Plan I, first, the Basic Plan II more strongly focused on fostering high-tech businesses and entrepreneurs. This might follow the American innovation model, since small industrial entrepreneurial firms contributed to the 1990s economic recovery and the development of S&T in the United States. These firms were more productive and innovative, generating more patents and new products per employee, than the large and diversified firms (Hane, 2002; Eto, 2005). Second, the Basic Plan II stressed the increase of government R&D expenditures and the need for competitive

funding in newly emerging fields, including life science, ICTs, environmental science and nanotechnology and materials (ISI *et al.*, 2008). These areas were maintained as priorities in the Basic Plan III, as shown Table 6.7 (ISI *et al.*, 2008). This plan also emphasised the role of regional government in building up technology parks or specialised innovation clusters to increase the stock and flow of knowledge as a measure of regional economic and technological development (Kondo, 2005). Third, the Basic Plan II addressed a fair and transparent R&D evaluation system and a researcher support system with mobility, autonomy and flexibility as decisive factors for generating excellent innovation performance (Harayama, 2001). This plan also pursued educational reform to secure experts and provide specialised training (Harayama, 2001). Fourth, the Basic Plan II stressed the acceleration of commercialisation of research findings through active industry-academia-government collaboration to create socially valuable technologies, such as health, welfare and security technologies (MEXT, 2003; AIST, 2007; Yamaguchi, 2008). Some could be regarded as highly successful, contributing to the recent recovery of the economy and S&T development.

However, a serious coordination problem arose among ministries and government agencies in formulating their innovation policies due to overlapping functions and areas in some cases (Harayama, 2001, Hiroo, 2002). To solve this problem, the ‘General Science and Technology Council’ was created in 2001 through structural reform of the ‘Science and Technology Council’. The government assigned the role of consultant and coordinator to this newly built S&T Council so as to implement national S&T policy in an efficient and comprehensive way (MEXT, 2003). In the same year, the STA the ME were integrated into the MEXT to coordinate education, industrial and innovation policies. The MEXT was in charge of cultivating human resources and promoting R&D and innovation in various fields, including natural science, social science and humanities (Harayama, 2000; MEXT, 2003).

Table 6.7 Japan's Science and Technology Basic Plan in the 2000s

Categories	Basic Plan II (2001-2005): Key objectives and measures	Basic Plan III (2006-2011): Key objectives and measures
S&T System Reform	Improving S&T activities and creation of world-class excellent achievements by (i) constructing competitive R&D environment by increasing competitive funds; (ii) enhancing the mobility of human resources using fixed-term appointment; (iii) developing self-reliance of young researchers; (iv) establishing flexible, effective, and efficient management of R&D systems; (v) utilising qualified persons and development of a variety of career paths; (vi) promotion of basic researches by setting fair and transparent evaluation system.	Improving the foundation for promoting S&T and intellectual infrastructure to maintain the global S&T competitiveness by (i) increasing competitive funds/indirect cost in a fair and highly transparent screening system; (ii) revitalizing research activities of organisations through competition; (iii) developing laboratory/research facilities in basic research; (iv) implementing selective development of key elemental technologies and system integration for equipment; (v) building up a framework for creating, protecting and utilising IP; (vi) establishing a cross-ministerial R&D management system
NSI Reform	Upgrading industrial technology capabilities and cooperative industry-academia-government by (i) building up joint-research centres and TLOs for free exchange of information; (ii) promoting technology transfer from academia to industry; (iii) developing systematic measures in academia to facilitate inter-faculty personnel change; (iv) developing patent management by research organisations to efficiently commercialise useful R&D results using transfer contracts; (v) improving a system for venture firms by fostering entrepreneur spirit and increasing funds for start-ups.	Increasing the role of universities in NIS and creating persistent innovation from its own unique research results by (i) improving the mobility of human resources in universities; (ii) providing preferential indirect costs to private universities to strengthen the research functions; (iii) operating various R&D system according to the development stage and the characteristics of the R&D; (iii) building a sustainable/progressive industry-university-government collaboration system; (iv) revitalising the collaboration of university IP centres and TLOs; (v) promoting the utilization of new technologies through public procurement; (vi) promoting high-tech start-ups and university spin-offs.
Education Reform	Building up internationally competitive universities and upgrading the quality of education/research by (i) increasing practical and vocational training; (ii) enlarging financial supports and scholarships; (iii) establishing a social system to certify engineer's qualification in the international community.	Developing and securing human resources that meet the needs of society and future S&T by (i) fostering young researchers, female researchers and offering researchers; (ii) enlarging financial aids for doctorate course students; (iii) establishing a long-term internship system; (iv) promoting the activities of academic societies.
Regional Innovation	Vitalizing Japan's economy through regional technical innovation and new industrial creation by (i) establishing and supporting intellectual clusters to facilitate the triple collaboration in region; (ii) promoting inter-regional technology transfer.	Enhancing safe and quality lives for local residents, and producing creative/innovative regions by (i) forming regional clusters; (ii) promoting inter-ministerial coordination by eliminating vertical divisions between ministries.
Strategic International Innovation	Assembling world-class researchers and information into Japan and solving global problems (e.g., food security, energy shortage and infectious diseases prevention) by (i) strengthening partnership with all countries; (ii) supporting publication of research results in English and systematic disseminating world-class papers in cooperation with academic societies; (iii) internationalising domestic R&D environment.	Fostering world-class researchers and upgrading S&T capabilities by improving the diversity of research and standards of research through accepting outstanding foreign researchers by (i) forming of a multilayered network (government, research institutions, academic societies, researchers); (ii) strengthening the S&T community with Asian nations through network formation.
Strategic Priority Areas	(i) life sciences; (ii) ICT; (iii) environmental sciences; (iv) nanotechnology & materials; (v) energy; (vi) manufacturing technology; (vii) Infrastructure; (viii) frontier- outer space and the oceans	(i) life sciences; (ii) ICT; (iii) environmental sciences; (iv) nanotechnology & materials; (v) energy; (vi) manufacturing technology; (vii) basic for society –security, safety, infrastructure, administration; (viii) frontier- outer space, satellite, oceans and the earth.

Source: Compiled by the data from various national policy reports and white papers: CSTP (various years), METI (various years), RIETI (various years) and ISI *et al.* (2008).

In light of these circumstances, the third S&T Basic Plan (an upgraded version of Basic Plan II) was launched in 2006 and ended in 2011; it still has an impact on on-going R&D projects (White Paper of S&T Basic Plan, 2006). The third Basic Plan aims at creating new intellectual, cultural, social and economic values by improving public understanding and backing of S&T and applying the results of S&T activities to the benefit of society (MEXT, 2010). To make sure this scheme succeeds, the third plan emphasises developing human resources to be capable of producing a wide variety of high-quality research and creating a highly competitive research environment, while promoting persistence and spawning innovation (JSPS, 2006). In other words, the third plan has been executed based on the following two stances, '*S&T to be supported by public and to benefit society*' and '*Emphasis on fostering human resources and competitive research environments*' (MEXT: White Paper of S&T Basic Plan, 2006, p.8), which might lead a change in Japanese S&T growth strategy, moving from infrastructure investment to education/research investment. More than US\$208 billion in total R&D investment was financed by the Japanese government between 2006 and 2011 to successfully complete the third plan (MEXT, 2010).

The focus of long-term S&T progress through the development of world-class human resources in the third Basic Plan resulted in systemic reforms, including R&D evaluation systems in every ministry, regional R&D systems, an NIS (emphasis on the role of universities), R&D management systems and supporting systems (ISI *et al.*, 2008). A fair evaluation system (non-sectionalism) that offers an equal opportunity for individuals to compete with each other is stressed in this plan to exert its ability to the maximum from the viewpoint of creating a more competitive R&D environment (JSPS, 2006; White Paper of S&T Basic Plan, 2006). With these reforms, the government established a range of measures supporting young, female and foreign students/researchers to take on new challenges and to work independently based on their

own freely held ideas, thereby providing autonomy to researchers (JSPS, 2006). Specialised training is provided for talented people to improve learning ability, originality and creativity, for the purpose of fostering, securing and proactively using human resources (MEXT, 2010; ISI *et al.*, 2008).

In sum, Japan's government successfully reformed its economy by setting up a series of laws and policies supporting dynamic R&D and innovation activities. The long economic recession in the 1990s led the government to start the re-examination of the past policies and establishment of new S&T development plans every five years by revising the running projects. As a measure of long economic recession, the government has formulated the five-year projects of Science and Technology Basic Plan I, II and III by reflecting current issues and compensating the defect from 1996. The first Basic Plan emphasised training top-level human resources by setting up specific programmes to finance and foster 10,000 post-doctoral researchers as a key measure of technological breakthrough. The second plan focused on a strategic distribution of capital investment and R&D funding as important means to raise the quality of research in eight priority areas - life sciences, ICTs, environmental sciences, nanotechnology and materials, energy, manufacturing technology, social infrastructure, outer space and oceans, and other emerging fields. The third plan set up more specific actions to systematically advance S&T over its 5-year implementation period (AIST, 2007, MEXT, 2010). However, the coordination problem among of ministries and agencies related to S&T still exists, which might be the main obstacle to a sustainable technological development in Japan.

6.2.3 Summary and Discussion

Government policies for industrial and S&T growth have successfully evolved over time corresponding to the level of domestic economic development and global economic trends (e.g., liberalism) in both Korea and Japan. Effective institutional reforms and S&T

policies have enabled Korea and Japan to change from imitation-driven to innovation-driven activities, from labour-intensive to R&D-intensive industrial structures and from a favourable climate for government enterprise (public sector) to an individual enterprise-centred R&D environment (private sector). The private sector's R&D has been actively supported by direct subsidies and low-interest bank loans for the purpose of developing core technologies and strengthening international competitiveness (Yim and Kim, 2005; Cuhls, 1998). Considering weaknesses in the current Korean and Japanese innovation systems, such as the weak tripartite cooperative relationship, low levels of universities' R&D capabilities, and low availability of venture capital, progress might be made by effective government S&T policies and institutional reforms.

Korea's S&T policy reflected an ambitious goal to become a leading nation, catching up with G7 countries in terms of newly emerging and high-tech fields, which produced long-term specific sectoral programmes. For instance, after 1990 when the 'Space and Aeronautics Program' was launched, Korea launched 10 satellites into space by 2007 (Korea Herald, 2009.06.13). Furthermore, the government set an ambitious goal of making Korea one of the seven largest aerospace powerhouses in the world during the next decade, while planning to land robots and human beings on the moon by 2020 and 2030, respectively (Korea Herald, 2009.06.13). Rapid catch-up with the frontier countries in high-tech fields was the motto of the 1990s and the 2000s S&T policies - the 'HAN Project', 'the 21st Century Frontier Programme' and the 'Revised National S&T Promotion and Development Programme'. Details were stated in section 6.2.1. To achieve this goal, the government established various policy measures supporting corporate R&D. Compared with tax on R&D in other OECD member countries, Korea's tax incentive system might be more systematically created and organised. It covers a wide range of areas, including customs tax support, capital investment tax support, human resources (HR) tax support and tax support for R&D centres (ISI *et al.*, 2008). The tax

exemption for the development of human resources has been effectively managed to overcome the shortage of skilled workers in the context of Korea.

Meanwhile, Japan's S&T policy, especially the second and third Basic Plan, offered an effective plan for dealing with existing problems and a new direction for development of S&T. It set clear objectives, instruments and policy prioritisations that were codified in strategy papers or white papers to inform the public and relevant stakeholders about current and future policies regarding S&T (MEXT, 2010). In this context, the Japanese foresight studies are active in filtering out future directions (Cuhls, 1998). Compared with the Chinese fixed, 5-year S&T plan, it had more dynamic and guiding functions and did not operate strictly by orders. The guiding function might be much more effective in a hierarchically oriented society like Japan than in a decentralised democracy like Germany. The Japanese S&T Basic Plan III has brought about a reform of NIS towards a network-based system to promote closer state-university-industry relationships and internationalisation of S&T activities. The internationalisation of S&T is aimed at creating new knowledge and disseminating it widely across countries to resolve social problems confronting human beings throughout the world (MEXT, 2010). Despite this reform, inward orientation and inter-firm linkage are still quite strong in Japan, which is similar features in Korea (ISI *et al.*, 2008).

Is the S&T policy of Japan a model for that of Korea? First, overall, the top-down and government-directed industrial S&T policies were one of the most conspicuous characteristics of Korea, which resembles Japan. Although Japan is a highly centralised country like Korea, meaning that the central government directs S&T policy to local authorities for regional innovation, S&T parks and cluster policies have made many regions stronger by improving regional autonomy in Japan (Toshiyuki, 2007; Shigeru, 2007). Some specialised clusters, especially the Sapporo venturing cluster, have produced good results for technology transfer from academia to firms and joint R&D between them,

as well as an increased number of venture businesses based on seeds from universities (Kondo, 2006). The reform of the overall decentralisation of policy and measures supporting more freedom and self-responsibility of regional authorities and institutions are on-going, with a high ranking on the agenda in Japan (ISI *et al.*, 2008).

Second, R&D in both Korea and Japan is internationalised but not globalised. The firms invest in and send their employees all over the world to exploit new markets and learn new knowledge and techniques. However, most R&D is performed within the country, and firms are not willing to export knowledge and undertake international cooperation in the field in which they are recognised as the world's leader (Cuhls and Kuwahara 1994). Perhaps, this is the key reason why the countries have a relatively low level of international cooperation compared with advanced countries.

Third, government funds for research and product development are distributed in a highly competitive manner, while picking out priority areas through various means to allocate resources in Korea and Japan. Nevertheless, the priority areas listed as promising industries have until now held a different status. For instance, nanotechnology and materials research and ICT have produced better innovation performance in Japan and Korea, respectively, but life science and biotechnology have progressed less than expected despite a longer period of investment in both countries (ISI *et al.*, 2008). Regarding this issue, a policy for supporting bio-clusters to attract MNEs and make a good international partnership might be needed to achieve the goal in the absence of a science base.

Finally, the evolution and reform of Korea's innovation system might be influenced by the Japanese S&T policy. This is reflected in Korea's technology foresight activities conducted by the Science and Technology Policy Institute (STEPI) and later by the MOST with its affiliated agency, the Korean Institute for Science and Technology Evaluation and Planning (KISTEP) (Holtmanspötter *et al.*, 2006, p.111; Shin and Cuhls,

2007). As an important policy tool in S&T policy, Korea's foresight studies, which began in the early 1990s, were strongly inspired by the Japanese Delphi studies (Shin *et al.*, 1999; Shin and Cuhls, 2007; Schlosstein, 2007). With the adoption of Japanese methodology, three Delphi foresight studies have been undertaken so far to provide vision and direction to the eight emerging S&T areas that have high potential for the growth of national wealth and the betterment of quality of human life: space and earth, material and manufacturing, information and knowledge, food and bio-resource, life and health, energy and environment, safety and security and social infrastructure. The third Korean technology foresight study influenced the second Basic Plan (2008-2011) (Park and Schlosstein, 2005; KISTEP, 2011).

6.3 Patent Policies and Intellectual Property Regimes

The security of proprietary rights to intellectual assets that allows local innovators to reward ingenuity and creativity stimulates technology acquisition, diffusion and creation, and thereby contributes to growth of the economy (Song, 2006). There are two different angles on the role of intellectual property rights (IPRs). IPRs act as a facilitator for foreign technology transfer and foreign direct investment (FDI), while playing a defensive role in the leakage of important technologies (Kim, 2003).

Numerous previous studies have focused on the role of intellectual property (IP) regime in economic development and innovation performance as an important policy measure to facilitate creative and innovative activities. From the Schumpeterian perspective on innovation, Romer (1991) stressed the role of patent protection in economic development and its impact on R&D and innovation activities. Park and Ginarte (1997) examined an indirect effect of IPR instruments on economic growth and concluded that new business development and R&D intensity are affected by IP regimes. More recently, many empirical studies have addressed IPRs as the key driving force of

economic and technology developments. Maskus (2000) examined the causal relationship between IPRs and the growth of national income and found that an increase in income leads to stronger IPRs to protect highly sophisticated products. Schneider (2005) analysed the role of high-tech trade, IP regime and FDI in determining the rate of innovation and economic growth in 47 developed and developing countries and concluded that strong IPRs have more significant effects on technological and economic growth in developed economies than in developing economies. Meanwhile, Chen and Puttitanun (2005) estimated the linkages of IPRs and innovation performance in 64 developing economies and proved the positive impact of IPRs on innovation and the inverted U-shaped relationship between strong IPRs and GDP per capita.

However, there has been a heated controversy on the effect of a tough IP regime on economic development and technical innovation in developing countries. The main question under debate is whether a tough IP regime to protect IPRs draws the interest of both technology suppliers (i.e., advanced countries) and recipients (i.e., developing countries) or whether the protection of IPRs always encourages technology transfer, diffusion and creation in the context of developing economies (Maskus, 2000; Lall, 2003). Regarding this issue, Lall (2003) argued that the strong protection of IPRs by itself does not facilitate active FDI, technology transfer or local innovation in developing countries. He suggested that a soft IP regime is suitable for countries in the early stage of technological development, whereas a tough IP regime is pertinent to technologically advanced countries. Therefore, a study of the evolution of IPR regimes is needed to analyse how Korea and Japan have reformed their government policies and legal systems to create, protect and utilise IP.

This section discusses the specific institutions and policies related to IPRs to analyse the means by which the countries realise rapid catch-up and become a world leader in IP creation and utilisation. The dramatic increase of Korean and Japanese

patenting is attributable to the effective change of IP regimes according to level of industrialisation, which is in line with previous studies on the effects of IPRs with respect to the level of industrial, technological and economic development (Lall, 2003; Lesser, 2001; Branstetter *et al.*, 2007). Hence, this study supports previous research suggesting that the countries could not have reached their current levels of innovation capabilities if strong IPRs had been enforced in the early stage of industrialisation (Lall, 2003).

6.3.1 Korea's Patent Policy and Intellectual Property Regime

The Korean government has reformed a number of policy measures to create, utilise and protect IPRs over time. The first patent law was formulated in 1946 to stimulate domestic patenting with the foundation of the Patent Bureau in Korea. The Patent Bureau was in charge of controlling and managing all types of IP, including patents, utility models, industrial designs and trademarks, to increase intellectual assets as a national objective (H.K. Chang, 2003). After the promulgation of the 'Trade Law' in 1949, the 'Design Law' in 1961, and the 'Copyright Act' in 1986, the Patent Bureau was renamed the Korean Industrial Property Office (KIPO) in 1988. The KIPO has played an important role in upgrading its IP scheme in Korea and harmonising patent procedural laws with changing international standards (H.K. Chang, 2003).

The Korean government began to revise its patent law in the early 1980s, starting with the amendment of patent law adapting to the Paris Convention for the Protection of Industrial Property in 1980, the amendment of patent law adapting to the Patent Cooperation Treaty in 1982 and the amendment of patent law that covers the patenting of substances or compositions in the areas of the chemical, pharmaceutical and biotech industries in 1986 (Song, 2006). With the successful reform of patent policy, the number of Korean patent applications and registrations dramatically increased by the end of the 1980s after Korea introduced substance patents. However, the share of Korean patent

registrations and applications by local residents was still a very low percentage compared with those of foreigners. This may imply that foreign organisations played a larger role in knowledge creation and commercialisation and, by extension, copying or imitating foreign technologies and products were main channels for building national technology capabilities in the 1980s at the pre-catch-up stage. Table 6.8 shows the proportion of local residents to foreigners in terms of Korean patent registration and applications

In the stages of the post-catch-up period, Korea underwent a serious economic recession starting in the mid-1990s, but Korean patent registrations and applications were unaffected by the crisis, as shown in Table 6.8. The constant increase in patent production might be attributable to the effective reform of IP regimes, especially patent-related policies. Korean patent law and its court of appeals/trials system were revised and reformed to promote the dynamics of innovation: the amendment of patent law adapting to Uruguay Round/Trade Related Aspects of Intellectual Property Rights (UR/TRIPs) in 1995; the amendment of patent law that covers the opposition to grants after patent registration in 1997; and the establishment of the Examination Guideline for E-Commerce Related Inventions in 2000 (Song, 2006). Above the rest, the establishment of the guideline for e-commerce-related inventions in 2000 triggered the multiplication of related start-ups and patent applications in business method (BM), which multiplied almost 10 times, from 978 in 1999 to 9,655 in 2000 (KIPO Statistics).

Table 6.8 Korean Patent Registrations and Applications by Local and Foreign Residents, 1980-2007

Year	Koreans		Foreigners		Total	Korean		Foreign		Total
	Registrations	Proportion%	Registrations	Proportion%		Applications	Proportion%	Applications	Proportion%	
1980	186	11.4	1,446	88.6	1,632	1,241	24.5	3,829	75.5	5,070
1982	274	10.5	2,335	89.5	2,609	1,556	26.3	4,368	37.7	5,924
1984	297	12.6	2,068	87.4	2,365	2,014	23.3	6,619	76.7	8,633
1986	458	24.2	1,436	75.8	1,894	3,641	28.5	9,118	71.5	12,759
1988	575	26.4	1,599	73.6	2,174	5,696	28.4	14,355	71.6	20,051
1990	2,554	32.9	5,208	67.1	7,762	9,082	35.2	16,738	64.8	25,820
1992	3,570	34.0	6,932	66.0	10,502	15,952	51.3	15,121	48.7	31,073
1994	5,774	49.4	5,909	50.6	11,683	28,564	62.5	17,148	37.5	45,712
1996	8,321	50.4	8,195	49.6	16,516	68,413	75.7	21,913	24.3	90,326
1998	35,900	67.9	17,000	32.1	53,900	50,596	67.3	24,592	32.7	75,188
2000	22,943	65.6	12,013	34.4	34,956	72,831	72.4	29,179	28.6	102,010
2001	32,833	63.0	12,842	37.0	34,675	73,714	70.5	30,898	29.5	104,612
2002	30,175	66.6	15,123	33.4	45,298	76,570	72.1	29,566	27.9	106,136
2003	30,525	69.1	13,640	30.9	44,165	90,313	76.1	28,339	23.9	118,652
2004	35,284	71.9	13,784	28.2	49,068	105,250	75.1	34,865	24.9	140,115
2005	53,419	72.7	20,093	27.3	73,512	122,188	75.9	38,733	24.1	160,921
2006	89,303	73.9	31,487	26.1	120,790	125,476	75.5	40,713	24.5	166,189
2007	91,645	74.2	32,060	25.9	123,705	128,701	74.6	43,768	25.4	172,469
Total	511,260	65.9	203,170	31.9	636,206	1,005,742	70.0	430,181	30.0	1,435,923

Source: Compiled by data from KIPO statistics
<http://www.kipo.go.kr/kpo/index.html>

The jump in BM patents after launching the guideline suggests the important role of IP regimes in industrial development as well as the need for IP regime changes in response to the change of techniques. Such an effective change of IP regimes enabled Korea to steadily increase patents, despite the economic recession, by facilitating residents in creating patents and using the commercialised knowledge. In this sense, the share of Korean patents by local residents has grown larger than those by foreigners since the mid-1990s, as shown in Table 6.8. Among foreigners, Japanese, Americans and Germans have played the leading role in both patent registrations and applications in Korea (KIPO Statistics, 2007).

The Korean government has focused on a pro-creation role with a strong IP regime to protect new knowledge and techniques by developing autonomous R&D capabilities, after its industrial structure moved to knowledge-intensive products. Likewise, the government has strengthened its IPRs with the aim of active FDI and technology transfer from technologically advanced foreign firms through the construction of a protective IP environment, preventing illegal knowledge leaks and surreptitious use without licensing (Song, 2006). Hence, it suggests that Korean IP regime embraces both a pro-creation role and a pro-diffusion role of IPRs: encouraging local firms to conduct innovative R&D in the creation of new knowledge while inducing foreign firms to pursue technology licensing and direct investments in Korea.

6.3.2 Japan's Patent Policy and Intellectual Property Regime

Japan has a long history of protecting its IPRs. The first full-fledged patent law was formulated in 1885 in the Meiji Era when agriculture was the major industry in a resource-based economy (Flamm and Nagaoka, 2007). After industrialisation, moving to a knowledge-based economy, intellectual assets became a significant source of national growth in Japan. The revolution of information technology (IT) accelerated the reform of

IP regimes to make software and intangible assets patentable in a highly IP-protected environment, which facilitated innovative and creative activities in Japan (Wade, 2005; Arai, 2006).

The Japanese government has changed its IP regime to strongly protect IPRs by focusing on the pro-creation role since the middle of the 1990s when Japanese underwent a long economic recession (Branstetter and Ug, 2004). Through the revision of existing patent law, the legal environment has changed from a soft IP regime to a tough IP regime, while extending the scope of patentability and enforced the restriction on compulsory licensing (Arai, 2006). The prevention of infringement also has been strengthened by the reform of the private damage system and criminal sanctions. The underestimated private damage system has been changed by the inclusion of opportunity costs in estimating the lost profits to infringements (Nagaoka, 2005).

In detail, Japan's political and legal reforms for IPRs were motivated by the Structural Impediments Initiative (1994), which is a mutual agreement for structural reform between Japan and the United States. Under this agreement, the Japanese government changed its patent system from a pre-grant opposition system to a post-grant opposition system (the post-grant re-examination), and then it was integrated into the patent invalidation trails in 2004. The pre-grant opposition system involves the delay of patent examination because it allows competitors to oppose a proposed patent before it is formally granted (Jaffe and Lerner, 2004; Nagaoka, 2005). Also, the US-Japan agreement reflected the restriction of the possibility of compulsory licensing unless for the purpose of public interests, satisfying domestic demand and correcting anti-competitive conduct and for medicine export. Many of these applications have been made by the medical, biotechnology and cable/satellite industries (Merges, 1996; Nagaoka, 2005).

In the same year, the World Trade Organization (WTO) agreement on trade-related aspects of IPRs (TRIPS) brought about a reform of IP regime; the protection covers all

inventions and discoveries, except for a specified technology field, and for no less than a period of 20 years counted from the filing date guaranteed for the protection (Flamm and Nagaoka, 2007). The Japanese government also extended the scope of patentability to computer programmes through amendment of the patent law. Software was not patentable without the combination of hardware before 1993; however, a computer-readable storage medium in 1997 and then software itself obtained product patents in 2000 (Merges, 1996; Nagaoka, 2005). Later, drugs and even DNA sequences became patentable (Arai, 2006). The change to strengthen copyright and patent protection of software contributed to the increasing proportion of contracts with patents in software licenses, from less than 1 percent of the contracts in 1990 to 22.6 percent in 1998 (Nagaoka, 2005).

Table 6.9 Top Five Countries: U.S. Patents Granted to Foreign Inventors (1990-2006)

	Japan	Germany	Taiwan	U.K.	Korea
1990	19,525	7,614	732	2,789	225
1991	21,026	7,680	906	2,800	405
1992	21,925	7,309	1,001	2,425	538
1993	22,293	6,893	1,189	2,295	779
1994	22,384	6,731	1,443	2,234	943
1995	21,764	6,600	1,620	2,478	1,161
1996	23,053	6,818	1,897	2,453	1,493
1997	23,179	7,008	2,057	2,678	1,891
1998	30,840	9,095	3,100	3,464	3,259
1999	31,104	9,337	3,693	3,572	3,562
2000	31,296	10,234	4,667	3,667	3,314
2001	33,223	11,259	5,371	3,965	3,538
2002	34,858	11,280	5,431	3,843	3,786
2003	35,515	11,444	5,298	3,631	3,944
2004	35,348	10,779	5,938	3,450	4,428
2005	30,341	9,011	5,118	3,148	4,352
2006	36,807	10,005	6,360	3,585	5,908

Source: Compiled by the data from USPTO statistics.

With successful reform, Japan ranked at the top with 36,807 patents in the listings of US patents granted to foreign investors in 2006 (see Table 6.9). The recent change of IP environment with the aim of lifting the IP level to the top, first the Japanese

government has emphasised the importance of creativity and inventiveness. For these, knowledge-creating institutions, especially universities, have been restructured to actively promote IP resource exploitation, knowledge diffusion and technology transfer to industry in Japan (Wade, 2005). Second, the development of specialist human resources has been focused on the promotion of IP. To cultivate the talents equipped to deal with IP, the Japanese government encouraged universities to set up law courses related to IP in 2004 and built up two IP graduate schools in 2005 (Arai, 2006). Third, the government formulated the 'Basic Law on IP' (2003) to improve the creation, protection and use of intellectual assets, while establishing intellectual property headquarters to effectively set up new IP policy and coordinate among government departments and other interested parties (Arai, 2006). Finally, the Intellectual Property Plan 2005 was launched to increase international patenting, as well as protect trade secrets and diffusion of pirated copies by introducing the Patent Examination Acceleration Law and establishing the Intellectual Property High Court (Flamm and Nagaoka, 2007), which might be modeled on the U.S. Court of Appeals of the Federal Circuit. The IP High Court plays an important role in the speedy resolution of disputes through predictable decision timing and controlling the inward flow of counterfeit products to Japan (Arai, 2006). The strong IPRs of Japan are proved by reports from the Business Software Alliance of the level of business software piracy. In 2006, Japan was the third lowest country, at 25 percent, in terms of business software piracy, after New Zealand (22 percent) and the United States (21 percent) (Arai, 2006).

6.3.3 Summary and Discussion

There are successful reforms of legal and political institutions for IPRs protection responding to the level of economic development in Korea and Japan. The countries benefit from strong protection of IPRs because they have attained a certain threshold in

the process of industrialisation, which supports Lall's (2003) argument of a positive effect of a soft IR regime (a negative effect of a tough IP regime) on national technology capabilities in the early stage of industrialisation.

Table 6.10 International Property Right Index, by Ranking, 2008

Rank	Country	IPRI	LP	PPR	IPR	Rank	Country	IPRI	LP	PPR	IPR
1	Finland	8.7	8.9	8.5	8.6	27	Estonia	6.6	6.8	7.4	5.5
2	Netherlands	8.5	8.4	8.6	8.6		Malta	6.6	7.5	6.3	6.0
	Denmark	8.5	8.6	8.3	8.6	29	Chile	6.5	6.6	7.0	6.0
4	New Zealand	8.3	8.8	8.3	7.9		Israel	6.5	6.0	6.6	7.0
	Sweden	8.3	8.6	8.5	7.8		Qatar	6.5	7.0	6.8	5.6
	Germany	8.3	8.3	7.9	8.7		Taiwan	6.5	5.9	7.3	6.3
	Norway	8.3	8.5	8.7	7.7	33	Hungary	6.4	6.1	6.6	6.5
8	Switzerland	8.2	8.8	8.0	8.0	34	Slovakia	6.3	5.6	7.1	6.2
	Australia	8.2	8.3	8.1	8.2		Cyprus	6.3	6.6	6.4	5.9
10	Austria	8.1	8.4	7.8	8.1	36	Malaysia	6.2	5.9	6.8	5.9
	Iceland	8.1	8.9	8.5	6.8	37	Italy	6.1	5.6	5.9	6.8
	Singapore	8.1	8.2	8.2	7.8		Rep. Czech	6.1	6.0	5.7	6.5
13	Ireland	8.0	8.1	7.9	7.8	39	Greece	6.0	5.8	6.1	6.0
14	Canada	7.9	8.3	7.5	8.0	40	Tunisia	5.9	5.7	7.1	5.0
15	United Kingdom	7.8	7.9	7.1	8.5		Jordan	5.9	5.6	6.6	5.5
	United States	7.8	7.1	7.8	8.6		Lithuania	5.9	5.5	6.9	5.2
17	Japan	7.6	7.4	7.2	8.2	43	Botswana	5.8	6.7	6.4	4.1
18	Belgium	7.5	7.4	6.7	8.2	44	Bahrain	5.7	5.5	6.5	5.2
19	Hong Kong	7.3	7.8	7.8	6.2		Mauritius	5.7	6.3	6.0	4.9
20	France	7.2	7.1	6.4	8.1	46	Costa Rica	5.6	6.3	5.9	4.7
	Luxembourg	7.2	8.4	5.1	7.9		Kuwait	5.6	6.3	6.9	3.7
22	Portugal	7.1	7.1	7.2	7.0		Slovenia	5.6	6.6	4.7	5.5
23	United Arab Emirates	6.9	6.6	7.7	6.4		India	5.6	4.9	6.7	5.1
24	Spain	6.8	6.1	7.1	7.3	50	Uruguay	5.5	6.5	5.2	4.9
	Rep. Korea	6.8	6.3	7.3	6.8						
	South Africa	6.8	5.9	7.1	7.4						

Note: The IPRI comprises three macroeconomic indicators: (i) legal and political environment (LP) measured by judicial independence, rule of law, political stability and control of corruption; (ii) physical property rights (PPRs) measured by protection of physical property rights, registering property and access to loans; and (iii) IPRs measured by protection of IPRs, patent protection and copyright piracy.

Source: Compiled by the data from the 2009 International Property Right Index (IPRI).

<http://www.internationalpropertyrightsindex.org/>

Under a tough IP regime, patent laws and the court of appeals/trials systems have been also substantially changed for the expansion of patentable scopes, restrictions on compulsory licensing and stronger protection against infringement and piracy by reinforcing penalties against infringers and increasing criminal sanctions and patentees' power to collect evidence of infringement in the countries (Flamm and Nagaoka, 2007). Several policy measures to strengthen IPRs contribute to the upsurge of domestic

patenting by inducing both local and foreign residents to conduct the dynamics of innovation, which enables Korea and Japan to make IP rich countries. A tough IP regime could attract foreign organisations to make technology licensing, joint-R&D and strategic alliances with local firms and research institutes with less fear about illegal knowledge leakage, thereby facilitating the transfer and diffusion of new technologies more actively.

Table 6.10 provides country rankings for degrees of IPRs. Although both Korean and Japanese IPR scores are far higher than the mean value for the world (5.4), IP regimes for IPRs protection in the countries are relatively weak compared with those of other technologically advanced countries. However, progressive institutional reforms toward a tough regime have enabled the countries to accelerate patent registration, patented technology transfer and faster commercialisation, which might provide important implications for other countries, especially those in the transition stage, to upgrade their IP regimes.

6.4 National Financial System

This section analyses similarities and differences in financial systems supporting innovative activities and key financial factors contributing to national technology capabilities in Korea and Japan, given that innovation success depends upon national finance system, including funding system and taxation system. The importance of national financial system as determinants of economic and innovation performances have been highlighted by recent works on endogenous growth theory (e.g., Aghion and Howitt, 2009; Ang, 2010) on varieties of capitalism perspective (e.g., Taylor, 2004; Tylecote and Vertova, 2007), and NIS (Lundvall, 2002; Leydesdorff and Fritsch, 2006). The details are presented in Chapter 3. Along with NIS, national finance system might directly affect coordination mechanisms, roles of players, innovation paths and sectoral specialisation, hence distinctive features of the countries' financial system and policy frameworks were

explored as important factors affecting rapid technology catch-up.

6.4.1 Korea's financial system

Korea's financial system has been constantly reformed over the past four decades to increase domestic savings and foreign investments, while creating a favourable environment for technology trade and R&D expenditures. With the scarcity of foreign exchange, foreign loans and external finance play an important role in raising funds for R&D and innovation in Korea.

The Korean financial system has been reformed corresponding to the changing needs and structure of the economy over time. The 1970s financial policy offered financial aid to local firms, especially GRIs and chaebols, to intensively foster strategic industries (i.e., heavy and chemical industries) and increase competitiveness in exports. Export-oriented firms enjoyed credit and lower borrowing costs than domestic-oriented firms to encourage export growth and internationalised R&D. The government provided export-oriented firms with preferential access to credit at substantially subsidised rates (Cho and Kim, 1995). Entering the 1980s, Korea's government started to restructure the national financial system to produce more balanced industrial sectors due to the chaebol-dominated structure. With reform of the taxation system, the government was forced to redirect financial policy towards redistribution. Tax credits to business activities of the chaebols began to decline while improving tax favours and lending conditions for SMEs (Cho and Kim, 1995).

The 1990s was a chaotic period of boom and bust in Korea. With financial liberalisation came large economic reform, including the taxation systems, financial institutions and banking industry structures, alleviation of money market regulations, stabilisation of currency credit, execution of real-time accounting systems, liberalisation of interest rates and privatisation of public sectors (MOST, 2007). Deregulation of

financial policy towards liberalisation of banking caused short-term foreign debts, massive capital flights and drop in monetary value, which yielded US\$40 million of trade gap every year until the mid-1990s (S-J. Chang, 2003). These problems hindered economic growth and ultimately the economy fell into financial crisis in 1997. The financial crisis led to extensive reform of the financial system as a whole. Based on free competition and market principles (the motto of the new liberalism of the financial policy), the government did not directly participate in economic activities and firms' profit creation, as contrasted with the former characterised by heavy intervention and control of financial sectors (Jang, 2000; Kim, 1998).

The government set up a package of tax and financial incentives to encourage firms with minimum equity to enter priority industries, and it used its control of the banking system to exert strong leverage on the behaviour of firms (World Bank, 1987; Cho, 1989; Vittas and Wang, 1991; Cho and Kim, 1995). With better market access, SMEs had more incentives and opportunities for direct investment and functional activities, such as R&D and investment in equipment, in the 1990s (Cho and Kim, 1995). Such a successful reform of the financial system helped fuel the economic recovery and contributed to the current economic and technological developments in Korea.

6.4.2 Japan's Financial System

Japan is the second largest economy in the world with substantial foreign exchange reserves and healthy corporate/banking sectors. Japanese banks have strong capital positions with massive deposit bases and serve as a source of liquid global capital in the national financial system (Sharma, 2010). The fast growth of Japan as a global economic power, rapidly moving away from a defeated nation, might be partly driven by its sound monetary policy and financial system, which could create a stable environment with low taxes, inflation and interest rates.

Japan's financial system was reformed in three different phases, linking to important economic reform events. The first phase was the post-war period, when direct government allocation of funds was the key source for the reconstruction of Japan's economy and the development of industrial capabilities (Vittas and Wang, 1991; Vittas and Kawaura, 1995). The second phase covered from the 1960s to the mid-1970s, when Japan's financial system was rigidly segmented and subject to wide-ranging controls. Until the mid-1970s, the Japanese financial system was characterised by heavy government control of financial resources, the dependence of city banks on credit from the Bank of Japan to fund their loans to industrial firms and over-borrowing of industrial firms with a low level of artificial interest rates (Kuroda and Oritani, 1980; Horiuchi, 1984; Ikeo, 1987).

The third phase started from the mid-1970s when the financial market was liberalised. The introduction of financial liberalisation removed credit constraints while allowing innovators to obtain external finance (Vittas and Cho, 1996). The Japan Development Bank was the first bank guaranteed its managerial autonomy, meaning that it does not suffer political pressure to fund projects without prospects and can allocate project funds and investments based on the professional judgment of bank staff. This is attributable to the low level of loan losses despite the Development Bank focusing on long-term industrial finance and risky projects (e.g., R&D). Commercial and trust banks concentrated more on short-term loans and diversified loan portfolios (Vittas and Cho, 1996).

Overall, Japan's financial system (bank-based structure) is quite unique and distinct from Anglo-American financial systems (liberal-market structure). The idiosyncratic features of the Japanese financial system include the large role of banks as lenders, shareholders and providers of other finance services, a close relationship between banks and firms and the intermediary role of large industrial firms in channelling funds to

small firms at the periphery of different industrial groups (Vittas and Cho, 1996; Sharma, 2010). Regarding sources of funds used for policy loans to promote R&D investments in the target fields, Japan relies on funds mobilised through the government, such as postal savings, which differs from Korean (Vittas and Cho, 1996). Korea has relied heavily on central bank credit and deposits mobilised by commercial banks. Domestic savings and investments are major sources of finance for the implementation of industrial S&T projects, while funds raised through foreign loans are scarce. Large domestic savings are attributable to the stability of prices that encourages the growth in savings in Japan (Vittas and Kawaura 1995).

6.4.3 Summary and Discussion

Recent research on endogenous growth theory has addressed R&D efforts and financial factors as key sources of long-term economic growth, since credit market imperfection (e.g., credit constraints) is thwarted in innovators' attempts to obtain sufficient external financing (Blackburn and Hung, 1998; Aghion *et al.*, 2005; Ang, 2008; Aghion and Howitt, 2009). The national finance policy has evolved with industrial S&T policy and influenced each other, implying that the direction of finance policy and measures change in response to a changing national S&T development plan in different economic growth stages. In general, the government acts as a financier and an investor in industrial and technological development in the early stage of economic development, since most financial sectors' activities are controlled by the central government, including their ownership and deposit/lending rates (Vittas and Cho, 1996). Meanwhile, there is relative openness in the banking and financial system in the mature stage, providing the bank has autonomy to manage monetary policy and allowing for external finance, to increase venture capital and attract private lenders to undertake innovative and R&D activities (Vittas and Wang, 1991; Vittas and Cho, 1996). The national finance system plays a

pivotal role in not only wealth creation, but also in technical innovation by facilitating R&D activities (Krugman, 1986; Taylor, 2004), which are the driving force behind the rapid economic and technology catch-up of Japan and Korea.

The idiosyncratic features of financial systems in Korea and Japan can be summarised as follows. First, Korea's finance system is characterised by strong government intervention in the financial sectors and significant government subsidisation of the cost of borrowing in the product and process of innovation. To strengthen state control over finance, the Korean government owns both development and commercial banks, which allows for expansion of the scope of government control over the allocation of financial resources and directly implements industrialisation and innovation. The scope of directed credit programmes is also much broader than in Japan.

Second, there are different sources of funds for policy loans between Korea and Japan. In Korea, the greater part of policy loans and expenses are financed through central bank credit at a discounted rate, with less reliance on fiscal funds, unlike in Japan. The heavy dependence on the central bank in Korea could explain why its prices and inflationary pressures have been less stable and higher than in Japan because the central bank creates money to raise funds when necessary for implementing public policy. With less stable prices, the Korean financial sectors are relatively less mature than those of Japan.

Third, foreign capital rather than domestic savings or investments is a more significant source of policy-based finance in Korea, compared with Japan. In the absence of capital accumulation, foreign capital has been the key source of funding to achieve industrial and S&T policy goals even if foreign capital influx was controlled by the government with a repressive policy that enabled Korea to accelerate economic growth in an immature stage, but negatively affected the mobilisation of financial resources.

Finally, governments in both Korea and Japan have implemented a selective

financial policy that offered great access to credit and low borrowing costs to the priority sectors as a national objective. A number of scholars have criticised the selective policy because of the potential for misallocation of resources and an imbalance in the industrial structure incurred by high borrowing costs of non-priority sectors (Koo, 1984; Kwack, 1984). However, the countries' financial policy succeeded in rapidly expanding production and developing technology capabilities through the selection of industries with futures, the smooth adjustment of declining industries, the restructuring of companies facing difficulties and the rationalisation of entire sectors of industry suffering from overcapacity (Vittas and Cho, 1996). Furthermore, the government in both countries act as a risk-sharing partner with banks and industry by controlling finance to support and encourage R&D.

6.5 National Innovation System

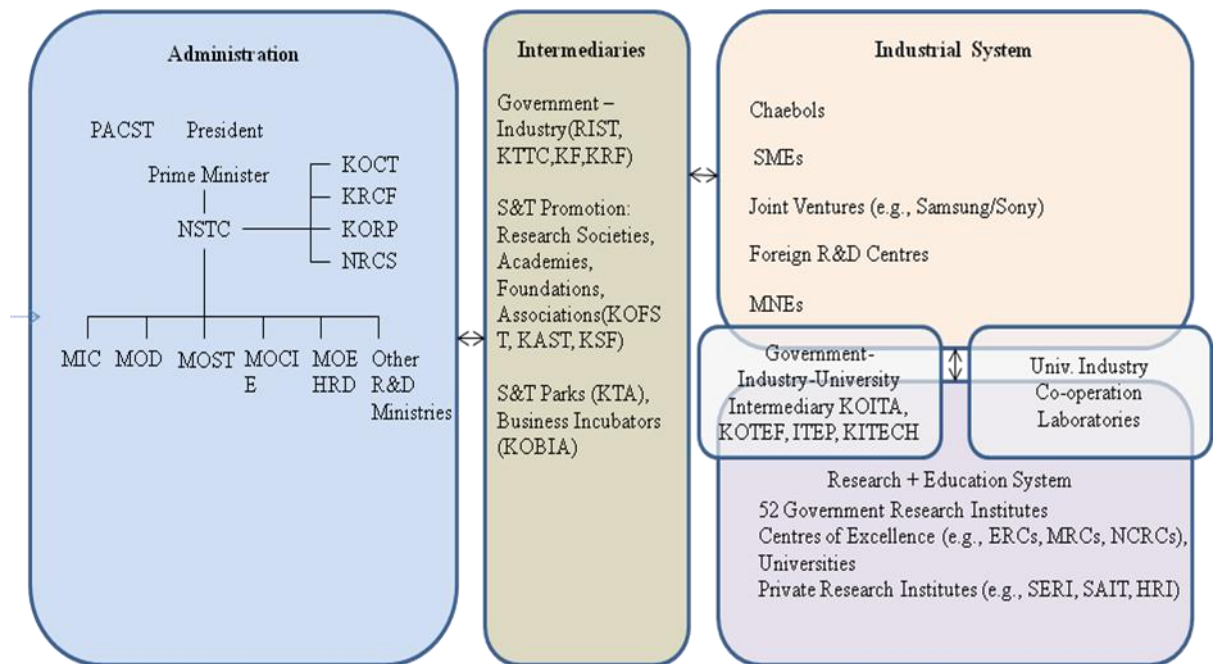
Innovative activities are governed by networking and cooperative relationships among the five major agents within NIS: administrative organisations, public/private research institutes, higher education institutes, industrial firms and intermediaries (Senker, 1996; Chang and Shin, 2004; ISI *et al.*, 2008). Government, large firms and universities play the central role in shaping NIS as major driving forces behind rapid catch-up success in both Korea and Japan. Various ministries and governmental agencies are in charge of innovation programs and policy design and coordination. Through government research institutes, a strong linkage exists among the political system, the research system and the education system. Intermediaries help enhance the link of research and education systems with the industrial system to support R&D collaboration among government, university and firm. Since a science park builds a bridge to facilitate R&D cooperation among players within the NIS (Castells and Hall, 1994), this thesis considered not only government agencies, but also industrial S&T clusters as intermediaries.

With the success story of Silicon Valley that contributed to regional or urban renewal, reindustrialisation and synergism (Castells and Hall, 1994), there were many comparative studies on industrial S&T parks in different local contexts; for example, Cambridge science park in the UK (Keeble *et al.*, 1999), Sophia-Antipolis in France (Longhi 1999), Swedish science parks (Löfsten and Lindelöf, 2002), Australian technology park (Phillimore, 1999), Tsukuba research park in Japan (Bass, 1998), Singaporean science parks (Koh *et al.*, 2005), the St. Petersburg Technology Park in Russia (Kihlgren, 2003) and Zhangjiang high-tech park in China (Lai and Shyu, 2005).

The large body of innovation studies highlighted the advantages of clustering in the development of technology capabilities at sectoral, regional and national levels (Castells and Hall, 1994; Hsu *et al.*, 2003; Koh *et al.*, 2005; Roberts, 1998; Storey and Tether, 1998; Vedovello, 1997). From the institutional perspective, a science-based industrial park is considered as a specialised physical infrastructure that provides a competitive environment for creating new institutional forms, such as venture capital (Koh *et al.*, 2005; Dodgson, 2008). It is designed to promote R&D activities in organisations located in the vicinity of the park by facilitating technology transfer and joint-R&D among research institutes and firms (Löfsten and Lindelöf, 2002; Lai and Shyu, 2005). In this sense, S&T parks fit well for addressing intermediaries within NIS. The following sections provide a detailed discussion of strengths and weaknesses underlying the Korean and Japanese innovation systems.

6.5.1 Korea's Innovation System

The analysis of Korea's NIS investigates distinctive coordination mechanisms, learning processes and the roles of various players as well as contextual factors within the system. Figure 6.2 presents the specific institutional configurations for national technology capabilities in Korea.

Figure 6.2 Korea' Innovation System

Source: Compiled by the data from various national policy reports and white papers (various years).

Government

Korea's government has played a large role as a planner of S&T policy, as well as a performer, sponsor and facilitator of R&D in NIS (Kim, 1997; Kim and Nelson, 2000). The 1997 Asian financial crisis resulted in the redirection of S&T policy to develop indigenous and autonomous R&D capabilities as measures of economic recovery, while restructuring administrative institutions to efficiently coordinate ministries and government agencies related to science and technology by establishing the National S&T Council in Korea (NSTC) (Suh, 2000; Yim and Kim, 2005). The NSTC acted as the overall coordinator for S&T-related policies pursued by various ministries: the Ministry of Science and Technology (MOST) - S&T policies; the Ministry of Commerce, Industry and Energy (MOCIE) - industrial policies; the Ministry of Information and Communication (MIC) - ICT policies; the Ministry of Education and Human Resource Development (MOEHRD) - HR policies and the Ministry of National Defence (MND) (ISI *et al.*, 2008).

Likewise, the NSTC controls four research councils: Korea Research Council of Fundamental S&T (KRCF), Korea Research Council of Industrial S&T (KOI), Korea Research Council of Public S&T (KORP) and Korea Research Council for Economics, Humanities and Social Sciences (NRCS)¹ (MEST, 2010). These four research councils are in charge of determining GRIs' research areas and funding, as well as supervising and evaluating GRIs' performance, as well as submitting the budget for the GRIs (Yim and Kim, 2005). Among 18 ministries involved in S&T, MOST was the key contributor to Korea's innovation system as a planner and forecaster in developing core and future-oriented technologies (ISI *et al.*, 2008). Regarding the recent change of the government structure, MOST with its newly established S&T+1-Office (OSTI) has been subordinated to NSTC (MOST, 2010). This office is responsible for S&T planning, coordination, evaluation and R&D budget allocation (MEST, 2010).

Research Performers: Government Research Institutes, Chaebols and Universities

GRIs and large private firms (chaebols) play the leading role of research performer, whereas SMEs and education institutes (universities) contribute less to Korea's innovation system than in other technologically developed countries, implying a low level of knowledge transfer and R&D cooperation between universities and firms. First, GRIs are key research performers in the innovation system of Korea. "*GRIs often acted as agencies in the execution of ministerial R&D programs, lacking autonomy in operation, management and decision-making*" (Yim, 2005, p.14).

52 GRIs were under the auspices of the country's four research councils and the MOST as shown in Table 6.11. One of the public research institutes with a strong research performance is the Korean Advanced Institute of Science and Technology

¹ The NRCS was established in 2005 after the dissolution of its predecessors, the Korea Research Council for Humanities and Social Sciences (KCHSRI) and the Korean Council for Economic & Social Research Institutes (KCERI) (MOST, 2006).

(KAIST). The KAIST was founded in 1971 with the aim to generate top-quality scientists and engineers by setting up world-class training and education systems (Lim, 2000; Yim and Kim, 2005). Another leading public research institute is the Korea Science and Engineering Foundation (KOSEF). The KOSEF provides financial support for several academic organisations to promote academic and publication activities (Guettler, 2007). The number of researchers in public research institutes amounted to 14,395 in 2003, a share of 7.3 percent of the total number of researchers in public, private sector and university research institutions. In terms of R&D expenditure, the public research institutes' share declined between 1996 and 2005 from 17.4 percent to 13.2 percent. Table 6.12 shows Korea's R&D expenditures and researchers by sector.

Second, large private firms are the major players in the process of catch-up and innovation in the NIS of Korea. In the early stage of economic development, GRIs played the leading role in national technology creation and investment in Korea. In 2005, corporate R&D expenditures contributed 76.9 percent to total R&D (see Table 6.12). However, R&D was heavily concentrated in a small number of chaebols, while SMEs and foreign companies were much less involved in corporate R&D (Hemmert, 2007). The 30 largest companies accounted for 91 percent of the corporate sector's R&D in 2005; Samsung Electronics' share of total corporate R&D amounted to 37.3 percent, while other chaebols such as Hyundai Motors and LG Electronics spent more than 1 trillion won each on R&D (ISI *et al.*, 2008). Chaebols' R&D expenditures were concentrated in the electronic, automobile and ICT sectors, accounting for more than 75 percent of the total in 2005, indicating a strong bias in the Korean economy. Many chaebols focus on economic and technology research, policy and business consultancy by setting up their own research institutes. Examples include the Samsung Economic Research Institute (SERI), the Samsung Advanced Institute of Technology (SAIT), the Hyundai Research Institute (HRI) and the LG Economic Research Institute (LGERI) (Hemmert, 2007; ISI *et al.*, 2008).

Table 6.11 Korea's Government-Funded Research Institutes

Administration	GRI s
The National Research Council for Economics, Humanities and Social Sciences (NRCS)	Korea Development Institute (KDI), Korea Energy Economics Institute (KEEI), Korea Environment Institute (KEI), Korea Information Strategy Development Institute (KISDI), Korea Institute for Health and Social Affairs (KIHASA), Korea Institute for Industrial Economics and Trade (KIET), Korea Institute for International Economic Policy (KIEP), Korea Institute for National Unification (KINU), Korea Institute of Curriculum and Evaluation (KICE), Korea Institute of Public Finance (KIPF), Korea Labour Institute (KLI), Korea Legislation Research Institute (KLRI), Korea Maritime Institute (KMI), Korea Research Institute for Human Settlements (KRIHS), Korea Research Institute for Vocational Education and Training (KRIVET), Korea Rural Economic Institute (KREI), Korean Educational Development Institute (KEDI), Korean Institute of Criminal Justice Policy (KICJP), Korean Women's Development Institute (KWDI), National Youth Policy Institute (NYPI), Science and Technology Policy Institute (STEPI), Korea Institute of Public Administration (KIPA), Korea Transport Institute (KOTI).
The Korean Research Council of Fundamental Science and Technology (KRCF)	Korea Basic Science Institute (KBSI), Korea Astronomy and Space Science Institute (KASI), Korea Institute of Science and Technology (KIST), Korea Research Institute of Bioscience and Biotechnology (KRIBB)
The Korea Research Council for Industrial Science and Technology (KOCI)	Korea Institute of Oriental Medicine (KIOM), Korea Institute of Industrial Technology (KITECH), Electronics and Telecommunications Research Institute (ETRI), National Security Research Institute (NSRI), Korea Food Research Institute (KFRI), Korea Research Institute of Machinery and Materials (KIMM), Korea Research Institute of Chemical Technology (KRICT), Korea Institute of Toxicology (KITOX), Korea Electro-Technology Research Institute (KERI)
The Korea Research Council for Public Science and Technology (KORP)	Korea Institute of Science and Technology Information (KISTI), Korea Institute of Construction Technology (KICT), Korean Railroad Research Institute (KRRRI), Korea Ocean Research & Development Institute (KORDI), Korean Research Institute of Standards and Science (KRRIS), Korea Institute of Energy Research (KIER), Korea Institute of Geoscience and Mineral Resources (KIGAM), Korea Aerospace Research Institute (KARI), Korea Polar Research Institute (KOPRI)
Ministry of Science and Technology (MOST)	Korea Advanced Institute of Science and Technology (KAIST), Korea Atomic Energy Research Institute (KAERI), Korea Institute of Nuclear Safety (KINS), Korea Science and Engineering Foundation (KOSEF), Kwangju Institute of Science and Technology (KJIST), Korea Institute of Advanced Study (KIAS), Korea Institute of Radiological and Medical Sciences (KIRAMS), Korea Institute of S&T Evaluation and Planning (KISTEP)

Source: Compiled by the data from national policy reports and white papers: ISI *et al.* (2008), MOST (2007) and MEST (2010).

Table 6.12 Korea's R&D expenditures by Sectors, Researchers, Research Types, S&T Publications, and Patents

	1990	1992	1994	1996	1998	2000	2001	2002	2003	2004	2005	2006
R&D Expenditure (Million won)												
Government	591,662	1,060,356	1,540,615	1,895,618	2,099,470	2,031,981	2,160,166	2,552,632	2,626,356	2,964,646	3,192,887	3,497,050
University	244,322	302,874	608,851	1,018,822	1,265,074	1,561,865	1,676,777	1,797,096	1,932,663	2,200,886	2,398,284	2,721,874
Firm	2,374,502	3,625,801	5,745,280	7,963,611	7,972,073	10,254,655	12,273,579	12,975,354	14,509,663	17,019,811	18,564,243	21,126,780
Total	3,210,486	4,989,031	7,894,746	10,878,051	11,336,617	13,848,501	16,110,522	17,325,082	19,068,682	22,185,343	24,155,414	27,345,704
No. of Researchers												
Government	18,407	24,233	26,137	24,203	19,431	21,563	20,984	21,702	22,025	24,057	22,604	23,874
University	43,582	43,392	74,877	77,220	92,591	100,643	102,501	111,083	121,039	121,968	125,039	132,042
Firm	63,523	81,322	89,284	100,924	87,169	115,026	138,317	147,021	153,996	166,289	187,785	209,878
Total	125,512	148,947	190,298	202,347	199,191	237,232	261,802	279,806	297,060	312,314	335,428	365,794
Research Types (Million won)												
Basic Research	514,843	628,637	1,131,935	1,439,020	1,585,367	1,746,138	2,025,019	2,373,234	2,758,620	3,399,400	3,706,840	4,143,273
Applied Research	771,062	1,313,326	1,880,824	2,927,270	2,848,458	3,370,088	4,075,940	3,763,601	3,973,994	4,712,161	5,034,149	5,430,098
Experimental Development	1,924,581	3,047,068	4,881,987	6,511,761	6,902,792	8,732,274	10,009,561	11,188,245	12,336,067	14,073,782	15,414,425	17,772,333
Total	3,210,486	4,989,031	7,894,746	10,878,051	11,336,617	13,848,501	16,110,521	17,325,081	19,068,681	22,185,343	24,155,414	27,345,704
No. S&T Publications	N.A.	N.A.	N.A.	N.A.	33,190	47,143	55,414	63,588	73,333	N.A.	N.A.	N.A.
No. Patents(1,000)												
Applications	25.8	31.1	45.7	96.6	130.0	75.2	172.2	190.0	190.0	203.7	203.7	160.9
Registrations	7.8	10.5	11.7	12.5	24.6	52.9	35.0	34.7	34.7	45.3	45.3	73.5

Sources: Compiled by the data from KOSIS, NTIS, OECD and WIPO statistics.

Third, universities are emergent players in Korea's innovation system. Universities published 83.5 percent of the total number of scientific publications, while GRIs published 11.6 percent and private sector research institutes only 4.9 percent from 1995 to 2000 (ISI *et al.*, 2008). The reform of education system has made remarkable progress in terms of student enrolment, quality of students (PISA standards) and science and engineering articles publications over the last decades. Between 1970 and 2004, the number of institutions of higher education grew from 142 to 411, the number of students exploded from 201,436 to 3.555 million. The higher education enrolment rate increased between 1990 and 2002 from 33.2% to 81.3% and surpassed 95% in 2006, which was the highest share of all OECD countries (MEST, 2010). As a result, Korea ranked as the 10th highest country for science and engineering articles publications (18,467), while being the fastest with China among top ten countries in terms of average annual growth rate between 1995 and 2007 as shown in Table 6.6.

To build the research capabilities of universities, the Korean government provides support to establish research centres, specifically, centres of excellence (COE), in universities. Under the auspices of the government (MOST, KOSEF), more than 150 COEs have been funded specialising in several disciplines to build specific research capabilities, foster talents, facilitate technology transfer and promote cooperation with firms in related fields (Yim, 2005; Guettler, 2007). According to the Korean Statistical Information Service (KOSIS) Statistics, universities transferred 591 patents and technologies to private companies in 2005; Seoul National University earned 1.5 billion won for transferring 54 technologies, followed by the Korea University with 743 million won and 140 technology transfers. KAIST showed an outstanding performance in university-industry cooperation, accounting for 1,285 patent registrations and trademarks in 2005. Despite increases in academic R&D efforts for patenting, technology transfer, few university spin-offs and a low level of R&D cooperation with firms are still serious

problems for Korean.

Intermediaries (State-University-Industry Cooperation)

First, S&T parks play the pivotal role in promoting the dynamics of industry-university cooperation in Korea's innovation system. As a prime example, Daedok Innopolis, the largest research complex in Korea, has created a highly competitive research environment by building a network for knowledge flow that facilitates R&D cooperation, university spin-offs and entrepreneurial processes (Kim and Ko, 1998; Shin, 2001); *“the objective of a science park is to be a seedbed and an enclave for technology, and to play an incubator role, nurturing the development and growth of new, small, high-tech firms, facilitating the transfer of university know-how to tenant companies, encouraging the development of faculty-based spin-offs and stimulating the development of innovative products and processes”* (Koh *et al.*, 2005, p.219).

Daedok Innopolis was established by the central government initiative with the aim of developing future industries and regional development through resolving the overpopulation and industrial overconcentration in Seoul (Park, 2004). Table 6.13 shows size, the number of tenant organisations, key players and major research areas and industries in the typical state-driven high-tech clusters in East Asia. Before 1993 when the project of Taejon EXPO launched, GRIs and government-funded universities had the dominant role in R&D and innovation in the Daedok Innopolis, but Taejon EXPO launched in 1993 sparked off the establishment of private firms and R&D centres to locate in the Daedok Innopolis (Oh, 2002). By the end of 2007, the Daedok Innopolis has 977 organisations (73 government-sponsored research institutes, 6 universities and 898 firms), which was eight times larger than Tsukuba since city.

Table 6.13 East Asian State-driven High Technology Clusters

	Tsukuba (Japan)	Daedok (Korea)	Hsinchu (Taiwan)
Plan Announced	1963	1973	Early the 1970s
Size	6669 acres	6860 acres	1811 acres
Residing institutions	172 (14% of the public sector, 86% of the private sector) (2008)	977 (7% & Gov.-sponsored research institutes, 0.6 % Universities, 91% firms) (2007)	384 (1.9% of the public sector, 9.5 % foreigners, 88.6% of private sector) (2004)
Employments	13,000 (2008)	40,338 (2007)	10,918 (2003)
Venture Firms	146 (2008)	322 (2007)	n.a.
Key Players	Education and Research Institutes (IAIs), and Large established firms (e.g., Mitsubishi, NEC, Hitachi)	GRIIs (government-sponsored research institutes), universities and Chaebls (e.g., Samsung, LG, Sunkyung)	Research institutes, universities and SMEs
Major Research Areas	Basic and experimental research	Basic and applied research	Production-oriented technology
Major Industries	Environment and Energy (23 %), Life Science and Biotechnology (18%), IT and Electronics (17%), Nanotechnology, material and manufacturing (16%), Metrology and Measurement Science (16%) and Geological Survey and Applied Geosciences (10%) (2008)	ICT (40%), Biotech (14%), Material Science (9%), Chemical Engineering (8%), energy resource (8%) (2007)	ICT (87%) Biotech (7%), Precision machinery (5%) (2004)

Source: Compiled by data from Tsukuba Science City, Daedok Technopolis and Hsinchu Science Park websites.

Universities residing in Daedok Innopolis played the crucial role in transferring knowledge to firms through supplying highly skilled manpower, as well as establishing several industrial liaisons and small business assistance programmes that support

entrepreneurships, spin-offs and R&D collaboration with venture firms (Park, 2004). As a result, the number of venture firms derived from the residing research laboratories and universities organisations sharply increased from only 7 firms in 1991 to 322 firms in 2007 with 20 incubating institutions in Daedok Innopolis (Daedeok Technopolis Statistics). In particular, Technology Transfer of Business Incubator established in KIST facilitates the staff and graduates to start new firms in high-tech field (Kim and Ko, 1998). However, most spin-offs were created by public research institutes, especially the KIST and Chungnam National University (Daedeok Technopolis statistics). The lower proportion of new start-ups spun off from the private sector should be the facing problem of Daedok Innopolis as well as NIS in Korea.

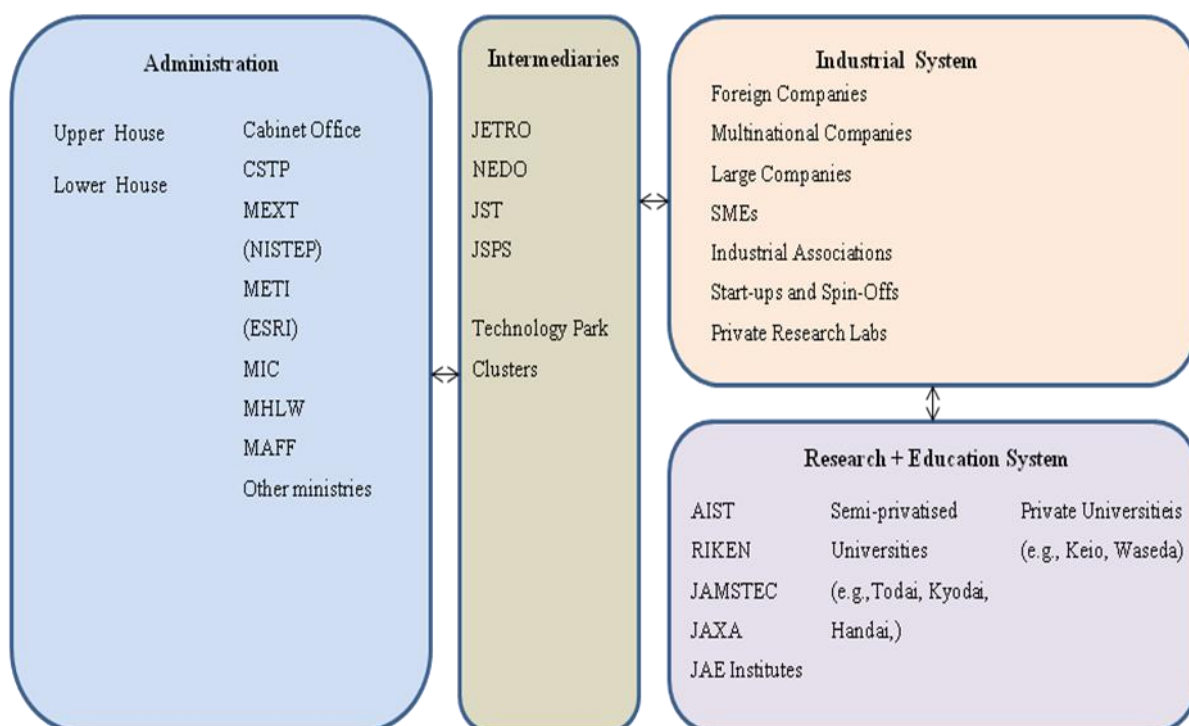
Regarding government agencies as intermediaries, Small and Medium Business Administration (SMBA) supports SMEs' R&D activities and innovation. The SMBA encourage to engage in partnership with academia and research institutes, while assuring that governmental institutions purchase their technological products for a certain period of time under the programmes of the 'Industry-University-Research Consortium Project for Technological Development' and the 'New Technology Purchasing Assurance Program' (Kim, 2006). Also, there are a number of intermediaries facilitating joint R&D across industries and countries; the Korean Industrial Technology Association (KOITA), the Research Institute of Industrial Science and Technology (RIST), the Korea Technology Transfer Institute (KTTC), the Science and Technology Policy Institute (STEPI), the Korea Foundation (KF) and the Korean Research Foundation (KRF), among others. (Guettler, 2007; ISI *et al.*, 2008).

6.5.2 Japan's Innovation System

Like Korea's innovation system, the main actors in Japan's innovation system are the government and large companies, while universities play a minor role in the process and

product of innovation. Figure 6.3 presents the structure of the innovation system in Japan.

Figure 6.3 Japan's Innovation System



Source: Compiled by the data from various national policy reports and white papers (various years).

Government

Japan's government has the mediating role, bringing different stakeholders in the innovation system to create, utilise and transfer knowledge. In the Japanese innovation system, five ministries are in charge of national policies design and implementation (see Figure 6.3): the Ministry of Education, Culture, Sport, Science and Technology (MEXT), the Ministry of Economy, Trade and Industry (METI), the Ministry of Health, Labour and Welfare (MHLW), the Ministry for Agriculture, Forestry and Fisheries (MAFF) and the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MIC). By integrating the former Science and Technology Agency (STA) and the National Institute of Science and Technology Policy (NISTEP), MEXT plays a larger role in

formulating S&T policy and R&D programmes among these ministries (Nakamura *et al.*, 2008). The Council for Science and Technology Policy (CSTP) within the cabinet office participates in NIS to effectively coordinate and implement policies related to science and technology (Nakamura *et al.*, 2008). The Science Council of Japan (SCJ) is responsible for deliberating important matters, promoting liaisons for research concerning S&T and international exchanges concerning S&T (ISI *et al.*, 2008).

Research Performers: Independent Research Institutes, Multinational Enterprises and Universities

Independent research institutes (IRIs), MNEs and universities are key contributors to Japan's innovation system. First, there are several IRIs acted as R&D performers, especially in basic research. National Institute of Advanced Industrial science and Technology (AIST) and Institute of Physical and Chemical Research (RIKEN) are typical examples. The AIST is the largest research performer with 2,288 researchers including 82 foreign researchers (AIST Statistics). In 2012, the AIST spends 79,734 million yen to develop basic research and further industries. Composition of research fields are environment and energy (24%), life science and biotechnology (17%), ICT (17%), nanotechnology, metrology and measurement science (16%), material and manufacturing (15%), and applied geosciences (11%) (AIST Statistics). AIST has over 40 autonomous research laboratories located at six research bases, which are spread all over Japan².

Another larger performer in Japan's innovation system is the RIKEN with over 4000 domestic researchers and 500 foreign researchers. The RIKEN undertakes R&D activities in a wide range of fields, including physics, chemistry, medical science, biology,

² For example, AIST Hokkaido (genome-based biofactory), AIST Tohoku (chemical processes with low environmental loads), AIST Chubu (advanced material processes), AIST Kansai (R&D in medical engineering and ubiquitous energy devices), AIST Chugoku (biomass energy), AIST Shikoku (health technology) AIST Kyushu (on-site sensing and diagnostic system), AIST Tokyo Waterfront (bio-IT fusion technology) and Akihabara Site (collaboration among industry, academia, and government for IT) (AIST webaiste).

and engineering technology (excluding only the humanities and social sciences). RIKEN plans to invest 90,036 million yen in the creation of cutting-edge technology until 2012 (RIKEN website). RIKEN has been located in nine regions (Wako, Sendai, Sayo-gun, Kobe, Tsukuba-shi, Yokohama City, Nagoya and Tokyo), while establishing collaboration centres in five foreign countries, the United States, the United Kingdom, Singapore, China and Korea (RIKEN website). Unlike Korea's GRIs, neither RIKEN nor AIST is a government institution, although both receive funding from the Japanese government and financial support from industry (ISI *et al.*, 2008). Despite such great efforts of the AIST and the RIKEN, in the gross, R&D expenditures of IRIs have continued to decrease as national technology output increase (e.g., patent production) since 2002 (see Table 6.14), which equates to less innovative and lower contribution to NIS compared with Korean GRIs.

Second, the large industrial firms (keiretus) are also major players in the Japanese innovations system, indicating more than 70 percent share of GERD (See Table 6.14). Nearly half of the R&D expenses in the private sector are spent by the top 10 large companies: : Toyota Motors, Honda Motors, Nippon Telegraph & Telephone, Nissan Motors, Hitachi, Matsushita Electric Industrial, Sony, Toshiba, Nippon Life Insurance and Mitsubishi UFJ Financial Group (Fortune, 2007). However, their R&D cooperation with domestic universities and public institutions is very low levels because most of them (e.g., Toyota, Sony, Canon) are global actors (MNEs) and have R&D centres all over the world. This implies that Japanese private companies tend to outsource more R&D to overseas universities than to home-based Japanese knowledge institutes.

Table 6.14 Japan R&D Expenditures by Sectors, Researchers, Research Types and S&T Publications and Patents

	1990	1992	1994	1996	1998	2000	2001	2002	2003	2004	2005	2006
R&D Expenditure (Million ¥)												
Government	1,416,443	1,707,775	1,816,054	1,977,817	2,091,760	2,320,197	2,602,478	2,633,758	2,598,310	2,696,296	2,454,625	N.A.
University	2,296,992	2,576,281	2,752,551	3,013,120	3,222,879	3,208,418	3,233,392	3,282,338	3,263,109	3,273,966	3,407,410	N.A.
Firm	9,267,166	9,560,685	8,980,253	10,058,409	10,800,063	10,860,215	11,451,011	11,576,840	11,758,939	11,867,276	12,745,840	N.A.
Total	13,078,315	13,909,493	13,596,030	15,079,315	16,139,925	16,289,336	16,527,998	16,675,053	16,804,155	16,937,584	17,845,224	N.A.
No. of Researchers (1,000)												
	505.0	518.9	N.A.	617.4	625.8	647.6	675.9	646.5	675.3	677.2	N.A.	704.9
Research Types (Million ¥)												
Basic Research	1,577,700	1,783,077	1,858,568	2,016,004	2,139,520	2,205,448	2,203,655	2,298,896	2,316,931	2,239,012	2,355,047	N.A.
Applied Research	2,923,559	3,115,674	3,052,779	3,366,285	3,648,374	3,585,494	3,525,765	3,503,195	3,567,933	3,589,801	3,754,619	N.A.
Experimental Development	7,590,307	7,895,840	7,514,304	8,463,489	9,062,521	9,197,692	9,359,615	9,541,535	9,607,933	9,771,088	10,362,433	N.A.
Total	12,091,565	12,794,589	12,425,651	13,845,776	14,850,414	14,988,634	15,089,034	15,343,626	15,492,798	15,599,901	16,472,099	N.A.
No. S&T Publications												
	N.A.	N.A.	N.A.	N.A.	305,604	327,465	336,634	344,200	354,832	N.A.	N.A.	N.A.
No. Patent												
Applications (1,000)	376.8	384.5	N.A.	401.3	437.4	486.2	496.6	496.6	486.9	486.9		427.1
Registrations (1,000)	59.4	92.1	N.A.	215.1	141.1	125.9	121.7	121.7	120.0	120.0		122.9

Source: Compiled by the data from KOSIS, NTIS, OECD and WIPO statistics

Third, universities are emergent players in Japan's innovation system. To promote the research capabilities of universities, the education system was reformed in 2004³. The reform led to the semi-privatisation of a number of public universities and the expansion of government budgets for private universities. Among semi-private universities, the University of Tokyo, University of Kyoto and University of Osaka have made significant contributions to research advances in a variety of fields by promoting joint-use inter-university research institutes (Christensen, 2011). However, most universities still concentrate on education, not research (Kondo, 2006). Universities' R&D expenditure amounted to 3,407,410 million yen, accounting for 19 percent of the total in 2005 (see Table 6.14).

Intermediaries (State-University-Industry Cooperation)

Like the Korean Science Town Daedok Innopolis, the well-known Japanese Tsukuba Science City as an intermediary between the public and private sectors by bringing together people from universities, national laboratories and domestic firms, as well as attracting multi-national enterprises (MNEs) to promote active R&D cooperation.

Tsukuba Science City was the first high technology industry complex in East Asia. It aimed at dispersing population concentrated around Tokyo and creating the largest and world-class research and education centres to maximise clustering effects (Yuta, 2010). This city concentrates on advanced basic and experimental research: environment and energy (23%), life science and biotechnology (18%), IT and electronics (17%), nanotechnology (16%), metrology and measurement science (16%) and geological survey and applied geosciences (10%) (Yuta, 2010; Tsukuba Science City website). As shown in Table 6.13, Tsukuba Science City has over 13,000 researchers (40% of the total for the

³ The MEXT was required to distribute research funding through open competition (rather than on a historical basis) and develop a rigorous assessment system for evaluating institutions' teaching and research (Christensen, 2011).

whole country) and 5,500 of who hold doctorate degrees and 3,500 foreign researchers in 148 corporate R&D institutes, 20 government laboratories and IRIs, 5 educational institutes and 146 venture firms. Some corporate R&D institutes have the world top level experimental facilities with advanced research and technical skills, such as Electron-Positron Supercollider TRISTAN's and Photon Factory at KEN, High Magnetic Field and High Voltage Electron Microscopy Facility at NIMS (Yuta, 2010). Among universities, the national University of Tsukuba (NUT) plays the leading role in fostering specialised manpower, transferring scientific knowledge and increasing spin-offs and joint R&D, indicating 5 new spin-offs (76 accumulated totals), 295 cooperation research with industry (746 million yen), 118 patent applications and 14 licenses in 2008 (Yuta, 2010). Along with Tsukuba Science City, several specific industrial clusters, such as Sapporo Valley specialised in ICT, promoted R&D cooperation in the product and process of innovation (MEXT, 2010).

Regarding government agencies acting as intermediaries, Japan society for the Promotion of Science (JSPS), Japan Science and Technology Agency (JST) and the Japanese External Trade Organisation (JETRO) were key contributors to NIS. They encouraged the private sector to undertake innovative activities and joint R&D through offering information (or advice) regarding for trading partners and investment contexts, as well as financial supports for entrepreneurial processes and R&D cooperation (ISI *et al.*, 2008).

6.5.3 Summary and Discussion

Large structural reforms of governmental, industrial and educational sectors have streamlined NIS in Korea and Japan. Distinctive features of Korea's and Japan's innovation systems are summarised as follows. First, the countries undertook an administrative restructuring to effectively design S&T policy and solve serious

coordination problems caused by overlapped functions and duplicated research among ministries and research institutions (MOST2007; MEXT, 2010). The Korean government plays a strong leadership role in the process of technology catch-up as a financier/performer of R&D than the Japanese government, which acts more as a mediator or facilitator than a leader in NIS. GRIs played and still play a pivotal role in Korea's innovation system (Sohn and Kenny, 2007).

Second, large industrial firms (rather than SMEs and venture firms) were and still are the dominant players in both Korea's and Japan's innovation systems despite industrial reform and S&T policy redirection supporting venture capital and start-ups. The Korean conglomerates, namely chaebols, and the Japanese MNEs still account for more than two-thirds of total R&D expenditures (ISI *et al.*, 2008). Their share of R&D expenditures accounted for 77.3 percent of firms, 12.8 percent of government research institutions and 10 percent of universities in 2006 in Korea (KOSIS Statistics). The largest share in Japan also came from business sectors, at 71.4 percent, and the percentage of the government and education sectors was 9.4 percent and 19.1 percent, respectively, in 2005 (KOSIS Statistics).

Third, universities are emergent players in the innovation systems of Korea and Japan. Due to universities' lack of research capabilities, the Korean and Japanese government reformed the education sectors and redesigned S&T policies to train high-calibre talent and internationalise the university research system (Park, 2004; Lehrer and Asakawa, 2004). Also, the government established various intermediaries, including S&T parks, incubators and S&M business administrations, to facilitate R&D cooperation between the academic community and industry, university spin-offs and international scientific collaboration and to produce better knowledge transfer and closer ties between public and private research (Park, 2004; ISI *et al.*, 2008). However, many universities still have lower levels of research capabilities and make smaller contributions to both

countries' innovation systems, compared with the frontier countries such as the United States and Europe, which is the rising issue in Korea's and Japan's innovation systems (Haryana, 2001; Rhee, 2004).

Finally, Japan's Tsukuba Science City and Korea's Daedok Innopolis could supplement a weak state-university-industry relationship by facilitating entrepreneurial processes, university spin-offs as well as joint R&D with venture firms. However, both clusters are less internationalised compared with the Taiwanese Hsinchu Science Park, which has a close connection with the Silicon Valley and foreign MNEs in manufacturing electronics and other ICT-related products. Since the sustained growth obviously depends on interactions between foreign organisations and local organisations in globalisation, close linkages with foreign research institutes, MNEs and other countries' technopoles are essential for national technology capabilities in Korea and Japan.

6.6 Specific Institutional Conditions for Technology Input and Output

The previous sections emphasised that public research institutes and local firms are key actors in innovation systems, while universities and start-ups make smaller contributions to NIS (MEXI, 2008; MEST; 2010). To further investigate specific institutional conditions for technology input-output relationships and patterns of technological development in Korea and Japan, this section empirically examines which sectors within NIS strongly contribute to national technology creation in Korea and Japan, and how much time lags are required for creating and communalising knowledge by using the Granger causality test. Before the causality test, the unit root and cointegration estimations were undertaken as pre-tests to avoid spurious regression situations.

6.6.1 Models, Sample, Measurements and Procedures

A two-way causation test was performed with the sample of Korea and Japan. The

number of patents registered at the Korean Intellectual Property Office and the Japan Patent Office were used as the variable for national technology output (technology creation) in Korea and Japan, respectively. In general, national technology creation is measured using three elements: patents, S&T articles and innovation counts (Archibugi and Coco, 2004; Fagerberg and Srholec, 2008; WEF, 2001). In this study, however, S&T articles were not appropriate for testing the causal relationship with R&D and technology trade, and longitudinal data on the innovation count were unavailable; therefore, commercialised knowledge, the patent, was used as the proxy for national technology creation. As enabling sources influencing national technology creation, five monetary values were used—public R&D, private R&D, FDI inflow, export of technology licensing and import of technology licensing—because they have a direct or indirect effect on the creation of technologies by providing various learning opportunities, cross-border knowledge flow, spillovers and externalities (Griliches, 1998; Rycroft, 2002). The time lags of $t-1$, $t-2$, $t-3$, $t-4$, $t-5$ and $t-6$ were also used since technology creation is innovation-time-consuming process. The time frame was 1986-2006 because of the issue of data availability – the “zero value” of the time period was omitted (see Table 6.15: Data Description and Table 6.16: Descriptive Statistics).

Prior to the Granger causality test, the augmented Dickey-Fuller (ADF) unit root test is performed to check whether the variables are individually stationary or nonstationary using the integrated order 0, 1 and 2, denoted as $I(0)$, $I(1)$ and $I(2)$. If the variables obtained from the ADF test equal $I(1)$, in the next step the cointegration test is undertaken to see whether the two variables are cointegrated. Econometrically, the cointegration between the two variables implies that their linear combination becomes stationary, and the residuals obtained from the cointegrating regression become stationary although the individuals are nonstationary (Engle and Granger, 1987; Gujarati, 2003). If this is not the case, the causality test is questionable and meaningless, which violates the

Granger representation theorem. Eview 5.0 was used for the tests in this research.

Augmented Dickey-Fuller Test

The ADF test is employed to check a unit root, meaning the variable in the time series data is nonstationary. The ADF test includes the lagged values of the difference terms and considers the possibility of serial correlation in the error term (Gujarati, 2003). The ADF test is performed in the three different forms: (i) Y_t is a random walk, (ii) Y_t is a random walk with drift and (iii) Y_t is a random walk with drift around a stochastic trend. Here Y_t indicates patent, public R&D and private R&D, FDI inflow, technology export and technology import. In each case, the time series is nonstationary if the computed τ value of (ΔY_{t-1}) in absolute term is less than 10 percent of the Mackinnon critical τ value. If there is a unit root $I(0)$, the variables are differenced once $I(1)$ or twice $I(2)$ until they becomes stationary. In this study, the time series was individually tested by using from $t - 1$ through $t - 5$ in the above three random walk models.

Cointegration Test

The VAR-based Johansen' method is employed to test for cointegration if each variable obtained from the ADF test is nonstationary. The cointegrating relationship suggests a stationary linear combination of two series given a group of nonstationary series, meaning there is a long-run equilibrium relationship between the variables (Johansen, 1991). In this study, Likelihood Ratio (LR) in the Johansen' method was used to test the cointegration among the two variables: (i) patent and R&D expenditures (public and private sectors), (ii) patent and FDI inflow and (iii) patent and technology trade (technology export and technology import). For a robust estimation, the cointegration test was run with lag intervals of $1-1$, $1-2$, $1-3$ and $1-4$ under the two models, the intercept-included model and the model with an intercept plus trend. If the value LR was larger

than 5 percent critical value, then there were cointegrating relationships between the two variables. Also, the mechanism of vector error correction was used as the diagnostic test to confirm the cointegration relationships, as well as to determine the number of cointegrating equations (CEs). To estimate the amount of cointegration, the null hypothesis is that there is one cointegrating equation at most; that is, two cointegration relationships exist.

Causality Test

As mentioned above, the cointegrating relationship between two variables is the precondition to the Granger causality test. If the variables (e.g., patent and R&D expenditure) are cointegrated, although each is individually nonstationary, then we can test whether R&D expenditure causes patent or patent causes R&D expenditure.

The Granger Causality test can be written as follows:

$$Y_t = \alpha_0 + a_1 Y_{t-1} + \dots + \alpha_\ell Y_{t-\ell} + \beta_1 X_{t-1} + \dots + \beta_\ell X_{t-\ell}$$

$$X_t = \alpha_0 + a_1 X_{t-1} + \dots + \alpha_\ell X_{t-\ell} + \beta_1 Y_{t-1} + \dots + \beta_\ell Y_{t-\ell}$$

where Y is patent, X is R&D expenditure (public and private), FDI inflow and technology trade (export and import), t is time, and ℓ is the lag length.

Bivariate regression was used to test the two-way causation: X Granger causes Y and Y Granger causes X . The null hypothesis is that X does not Granger cause Y in the first regression and Y does not Granger cause X in the second regression. For the two-way causation test, the null hypothesis is built as below. The null hypothesis can be rejected if the p value of the observed F is lower than the 10 percent significance level. All variables are transformed into their logarithmic values.

Table 6.15 Description of Data

	Description	Year	Source
Patent	Data are a number of patents registered at the KIPO and the JPO. It includes utility patents, design, plant, and reissue patents, defensive publications, and statutory invention registrations.	1986-2006	Korea : Korean Intellectual Property Office Japan : Japan Patent Office
Public R&D	Gross Domestic R&D expenditure in the public sector, converted to U.S dollars at official exchange rates. R&D covers basic research, applied research and experimental development.	1986-2006	Korea : Korean Statistical Information Service Japan: Korean Statistical Information Service
Private R&D	Gross Domestic R&D expenditure in the Private Sector, converted to U.S dollars at official exchange rates.	1986-2006	Korea : Korean Statistical Information Service Japan : Korean Statistical Information Service
FDI Inflow	Foreign direct investment is the sum of equity capital, reinvestment of earnings, and other short-long and long-term capital. Data of FDI inflow are in current U.S dollars.	1986-2006	Korea : OECD, World Bank Japan: Bank of Japan
Technology Export	Technology export includes high R&D intensive products, such as aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. Data are in current U.S. dollars.	1986-2006	Korea : World Bank Japan: World Bank
Technology Import	Data are in current U.S. dollars.	1986-2006	Korea : World Bank Japan: World Bank

Table 6.16 Descriptive Statistics

Korea (1986-2006)	Patents	GERD	Public R&D	Private R&D	FDI Inflows	Tech. Exports	Tech. Imports
Mean	22271.43	109.26	26.84	83.37	31.83	2.71	19.95
Median	11700.00	100.00	29.28	74.89	23.25	1.12	19.47
Maximum	73500.00	286.30	68.71	217.59	93.33	16.25	45.20
Minimum	1900.00	19.30	3.67	15.63	4.59	0.11	4.11
Std. Deviation	20983.81	69.27	18.21	51.07	30.12	3.93	11.47
Skewness	0.94	0.89	0.50	0.99	1.11	2.30	0.34
Kurtosis	2.74	3.40	2.53	3.72	2.92	7.81	2.09
Jarque-Bera	3.18	2.94	1.07	3.91	4.37	3.84	1.13
Probability	0.20	0.22	0.58	0.14	0.11	0.00	0.56
Observations	21	21	21	21	21	21	21
Japan (1986-2006)	Patents	GERD	Public R&D	Private R&D	FDI Inflows	Tech. Exports	Tech. Imports
Mean	579347.70	1615.71	505.25	1111.41	106.02	68.68	51.35
Median	621400.00	1659.92	577.45	1122.46	43.67	58.27	49.40
Maximum	704900.00	2055.89	625.47	1468.41	521.24	184.02	82.97
Minimum	381000.00	935.06	250.74	684.32	-200.88	7.23	23.61
Std. Deviation	102683.80	336.86	119.67	225.07	162.93	53.47	16.91
Skewness	-0.60	-0.79	-1.03	-0.51	0.83	0.88	0.26
Kurtosis	1.98	2.51	2.75	2.33	3.43	2.71	1.91
Jarque-Bera	2.30	2.41	3.77	1.30	2.72	2.92	1.33
Probability	0.31	0.29	0.15	0.52	0.25	0.23	0.51
Observations	21	21	21	21	21	21	21

Note: Patents are the numerical numbers. R&D, FDI, Technology exports, and Technology imports are the monetary values, US\$ 100 million.

6.6.2 Estimation Results and Discussion

To test the causal relationships between the production of patents and the enabling sources influencing national technology capabilities, the Granger causality test was performed in this study because it allows for the identification of important determinants of national technology creation in Korea and Japan. Before the causality test, as the first step, the ADF test was employed to check a unit root in the time series. All variables $I(0)$ of the Korean and Japanese times series in the above three random walk models were nonstationary. After consideration of possible autocorrelation in the error term, they became stationary $I(1)$ or $I(2)$. Therefore, the cointegration test was performed to check whether their linear combination was $I(0)$, although each variable is individually $I(1)$.

Table 6.17 shows cointegration test results for the pairs of nonstationary series in Korea and Japan. The LR values of the five pairs exceed a 5 percent significance level, in which case the null hypothesis is rejected, implying that a cointegration relationship exists between them. In detail, first, all the models are statistically significant in the equation of patent and public R&D, except for the Korean model using the lag interval 1-1. Second, there are cointegrating relationships between patent and private R&D, except for the Korean model using the lag intervals 1-2 and 1-3. Third, the null hypothesis is rejected in the Korean model using the lag interval 1-4 while the Japanese model using 1-2, 1-3 and 1-4 is statistically significant in the equation of patent and FDI inflow. Fourth, the Korean model using the lag intervals 1-2 and 1-4 is statistically significant in the equation of patent and technology export. In the case of Japan, there are cointegration relationships in the model using the lag intervals 1-2, 1-3 and 1-4. Regarding the test for patent and technology import, the null hypothesis is rejected in the Korean model using the lag intervals 1-1 and 1-4 and in the Japanese model using the lag intervals 1-2, 1-3 and 1-4. Therefore, it is confirmed that the combination of patent and others (GERD, public R&D, private R&D, FDI inflow, technology export and technology import) become stationary;

that is, they have a long-term equilibrium relationship, although each variable obtained from the ADF test is individually nonstationary. This meets the condition of the Granger causality test. All variables are transformed to their logarithmic values. Table 6.18 presents the results of the Granger causality test. This test was run in the four models to investigate the direct influence of R&D, FDI and technology trade (export and import) on national technology creation in Korea and Japan. For the test, the time lags of $t-1$, $t-2$, $t-3$, $t-4$, $t-5$ and $t-6$ were used in this study because technology output is time-consuming, and it carries an uncertain return.

First, I found that GERD causes the creation of patents (Model 1), but there is no causal relationship between patent and FDI inflow (Model 4) in the case of Korea or Japan. The p value of the observed F is higher than the 10 percent significance level, and consequently the null hypothesis cannot be rejected in Model 4. This suggests that domestic R&D expenditures greatly contribute to national technology capabilities while MNEs of foreign investors lack influence in the development of technologies and innovation in the contexts of Korea and Japan. In detail, Korean Model 1 using $t-1$, $t-2$, $t-3$, $t-4$ and $t-5$ rejected the null hypothesis, meaning GERD causes the creation of patents from one year to five years later, while the Japanese causal relationships exists from three years to four years later. This has the implication of a shorter life cycle of products, as well as more costly and time-consuming processes to develop technologies in Japan than in Korea. This may be attributable to a more high-tech intensive system in Japan. Compared with a strong GERD and patent relationship, the weak causal relationship between FDI inflow and patent creation supports Hobday's (2003) argument. He classified emerging or developing economies into four models: the R&D-based growth model (e.g., Korea, Taiwan), the import-substitution industry restructuring (e.g., Latin America, India), the passive FDI strategies (e.g., Malaysia, Philippines) and the MNEs or FDI-dependent growth model (e.g., Singapore) (also see UNCTAD, 2003a).

Table 6.17 Cointegration Test (Deterministic Trend)

(1) Korea

LR	Intercept	No. of CE(s)	Intercept & Trend	No. of CE(s)	Intercept	No. of CE(s)	Intercept & Trend	No. of CE(s)	Intercept	No. of CE(s)	Intercept & Trend	No. of CE(s)
Lag interval	Log Patent and Log GERD				Log Patent and Log Public R&D				Log Patent and Log Private R&D			
1-1	17.89	None*	22.51	None	15.20	None	17.93	None	32.91	None**	37.71	None**
	1.49	At most 1	5.86	At most 1	1.70	At most 1	4.05	At most 1	0.99	At most 1	5.43	At most 1
1-2	31.74	None**	37.76	None	21.26	None**	23.42	None	12.80	None	18.70	None
	1.07	At most 1	4.36	At most 1**	2.13	At most 1	3.97	At most 1	0.21	At most 1	3.90	At most 1
1-3	13.10	None	19.93	None	22.34	None**	26.83	None*	13.35	None	20.26	None
	0.25	At most 1	6.68	At most 1	1.20	At most 1	5.39	At most 1	0.11	At most 1	5.43	At most 1
1-4	18.91	None*	30.94	None**	21.86	None**	26.42	None*	27.15	None**	48.73	None**
	4.01	At most 1*	7.63	At most 1	2.99	At most 1	7.46	At most 1	2.68	At most 1	7.51	At most 1
Lag Interval	Log Patent and Log FDI Inflow				Log Patent and Log Technology Export				Log Patent and Log Technology Import			
1-1	8.73	None	17.75	None	9.39	None	21.65	None	16.20	None*	21.81	None
	2.60	At most 1	6.12	At most 1	0.01	At most 1	9.35	At most 1	2.95	At most 1	8.37	At most 1
1-2	5.58	None	13.19	None	22.28	None**	38.93	None**	11.28	None	17.48	None
	1.17	At most 1	2.85	At most 1	0.23	At most 1	9.15	At most 1	2.85	At most 1	7.30	At most 1
1-3	11.07	None	16.03	None	10.02	None	16.08	None	8.77	None	19.68	None
	2.86	At most 1	4.59	At most 1	0.00	At most 1	5.31	At most 1	0.95	At most 1	7.77	At most 1
1-4	29.34	None**	38.83	None**	9.14	None	41.92	None**	19.19	None*	30.54	None**
	4.22	At most 1*	13.65	At most 1*	0.00	At most 1	8.82	At most 1	0.93	At most 1	6.85	At most 1
Hypothesized no. of CEs	5 % Critical value:		1 % Critical value:		5 % Critical value:		1 % Critical value:					
	Intercept		Intercept		Intercept & Trend		Intercept & Trend					
non	15.41		20.04		25.32		30.45					
At most 1	3.76		6.65		12.25		16.26					

Note: * (**) denotes rejection of the hypothesis at 5% (1%) significance level. None*(**) suggest 1 cointegrating equation. At most 1*(**) suggest 2 cointegrating equations. Lag intervals 1-1 indicate the test VAR regresses DY_t on DY_{t-1} . Otherwise, the lag intervals 1-2 indicate DY_t on DY_{t-1}, DY_{t-2} etc.

(2) Japan

LR	Intercept	No. of CE(s)	Intercept & Trend	No. of CE(s)	Intercept	No. of CE(s)	Intercept & Trend	No. of CE(s)	Intercept	No. of CE(s)	Intercept & Trend	No. of CE(s)
Lag interval	Log Patent and Log GERD				Log Patent and Log Public R&D				Log Patent and Log Private R&D			
1-1	22.34	None**	27.11	None*	16.51	None*	30.59	None**	22.55	Non**	25.03	None
	6.60	At most 1*	8.49	At most 1	5.73	At most 1*	7.65	At most 1	6.93	At most 1**	9.39	At most 1
1-2	19.75	None*	27.11	None*	13.37	None	49.69	None**	18.20	None*	23.81	None
	5.95	At most 1*	9.22	At most 1	3.77	At most 1*	7.39	At most 1	6.26	At most 1*	10.89	At most 1
1-3	24.96	None**	29.72	None*	14.17	None	34.55	None**	21.32	None**	31.34	None**
	8.00	At most 1**	10.09	At most 1	2.80	At most 1	7.01	At most 1	4.23	At most 1*	13.40	At most 1*
1-4	15.41	None**	42.84	None**	13.67	None	39.74	None**	22.72	None**	44.45	None**
	3.76	At most 1**	20.03	At most 1**	4.03	At most 1*	9.22	At most 1	3.55	At most 1	19.17	At most 1**
Lag Interval	Log Patent and Log FDI Inflow				Log Patent and Log Technology Export				Log Patent and Log Technology Import			
1-1	13.19	None	13.95	None	11.04	None	21.79	None	12.91	None	20.50	None
	3.73	At most 1	3.74	At most 1	1.46	At most 1	7.43	At most 1	4.75	At most 1*	7.60	At most 1
1-2	15.65	None*	15.93	None	13.28	None**	23.43	None	12.66	None	18.52	None
	5.58	At most 1*	5.72	At most 1	0.66	At most 1	9.65	At most 1	5.87	At most 1*	6.75	At most 1
1-3	35.59	None**	38.95	None**	14.68	None	37.67	None**	25.75	None**	26.88	None*
	6.93	At most 1**	10.19	At most 1	0.00	At most 1	14.47	At most 1*	6.22	At most 1*	7.33	At most 1
1-4	29.81	None**	31.89	None**	14.82	None	36.93	None**	26.61	None**	32.26	None**
	4.17	At most 1*	5.96	At most 1	0.01	At most 1	8.10	At most 1	11.70	At most 1**	12.30	At most 1*
Hypothesized no. of CEs	5 % Critical value:		1 % Critical value:		5 % Critical value:		1 % Critical value:					
	non	Intercept	Intercept	Intercept	Intercept & Trend	Intercept & Trend	Intercept & Trend	Intercept & Trend				
		15.41	20.04	20.04	25.32	30.45						
	At most 1	3.76	20.04		12.25	16.26						

Note: * (**) denotes rejection of the hypothesis at 5% (1%) significance level.

Second, GERD is divided into two domestic performers, the public sector and the private sector, to identify the major players in the progress of technologies in the context of Korea and Japan. In both countries, the causal relationship between patent and private R&D (Model 1-1) is more strongly significant than the interrelation between patent and public R&D (Model 1-2). In detail, the number of patents is affected by public R&D and private R&D after one year, and then their relationships are continued for three years in Korea. However, Japan's R&D expenditure in the public sector causes patents for only one year ($t-1$), and then the causal relationship disappears after that. This may imply that the Japanese public sector is less effective and innovative than the Korean public sector in national technology creation. Furthermore, in Japan, patent activity is not immediately influenced by R&D expenditure in the private sector, unlike in Korea, but private R&D facilitates patenting from four years to six years later. The high-tech-based industrial structure in Japan is also confirmed because it is required for long-term R&D investment in the creation of cutting-edge technology.

Third, I found that patents create technology export in Korea. The causal effect is held from the first to the third years after patenting. This suggests that patent activity contributes to an increase in technology export and international competitiveness in Korea. With this test result, Korea's export-oriented policy is confirmed. The export of technologies could stimulate the competitive spirit of local firms to rapidly catch up to narrow the technology gap. However, the causality between patent and technology export exists in the reverse order in Japan. That is, the export of technology causes patents, but it is not affected by patenting. This may suggest that export is the channel for the stock and flow of knowledge to produce patents in Japan. The causality test is statistically significant in the model using $t-1$, meaning after one year the number of patents is increased by the increase in technology export.

Finally, there is the stronger causal relationship between patent and technology

import in Korea. In the model using the time lag 1, the null hypothesis that technology import does not cause patent is rejected at a 1 percent significance level. This implies that Korea depends more on foreign techniques as the means of technology development and innovation than Japan. The causation is strengthened after one year and disappears after three years. In the case of Japan, the causal relationship is weak and only significant in the model using the time lag 6, meaning that patent creation is influenced six years after foreign technologies are introduced. This may be attributable to the introduction of sophisticated technologies because it takes time to master, absorb, transfer and improve imported technologies in national technology creation. The weak causal relationship between patent and technology trade (both export and import) might suggest an innovation pattern of 'learning by research' (not 'learning by doing').

This empirical investigation contributes to the existing literature. It suggests an alternative method for estimating institutional conditions for technology input-output relationships by using the Granger causality test. Previous studies have addressed technology input variables as determinants of technology output variables through correlation tests. This study is a new attempt to empirically examine country-specific institutional conditions and innovation patterns employing innovation variables for key actors within NIS and contextual factors, in contrast to existing research that has used historical and descriptive approaches. However, this empirical study has two limitations. Due to the lack of university R&D data availability, I have used data from the public and private sectors. Also, I have not considered the dynamics of NIS, such as R&D cooperation, which directs future study.

Table 6.18 Granger Causality Test

(1) Korea

Null Hypothesis			<i>Lag1</i>	<i>Lag2</i>	<i>Lag3</i>	<i>Lag4</i>	<i>Lag5</i>	<i>Lag6</i>
Model 1	(1) GERD does not cause Patent.	<i>F</i>	7.912**	5.097**	8.007***	6.999***	5.616**	2.993
		<i>Prob.</i>	(0.011)	(0.021)	(0.004)	(1.010)	(0.040)	(0.271)
	(2) Patent does not cause GERD.	<i>F</i>	0.436	0.867	0.380	1.808	1.289	2.300
		<i>Prob.</i>	(0.517)	(0.441)	(0.768)	(0.220)	(0.393)	(0.336)
Model 1-1	(1) Public R&D does not cause Patent.	<i>F</i>	8.088**	3.800**	3.850**	1.835	1.258	0.915
		<i>Prob.</i>	(0.011)	(0.048)	(0.041)	(0.215)	(0.403)	(0.605)
	(2) Patent does not cause Public R&D.	<i>F</i>	0.502	0.946	0.592	1.810	0.494	2.819
		<i>Prob.</i>	(0.488)	(0.411)	(0.632)	(0.220)	(0.770)	(0.284)
Model 1-2	(1) Private R&D does not cause Patent.	<i>F</i>	9.784***	9.206***	3.634**	1.871	1.367	5.482
		<i>Prob.</i>	(0.006)	(0.002)	(0.048)	(0.208)	(0.369)	(0.162)
	(2) Patent does not cause Private R&D.	<i>F</i>	0.118	1.176	0.404	0.818	0.855	4.010
		<i>Prob.</i>	(0.734)	(0.336)	(0.752)	(0.547)	(0.565)	(0.213)
Model 2	(1) FDI inflow does not cause Patent.	<i>F</i>	1.172	0.323	0.218	0.453	0.302	0.099
		<i>Prob.</i>	(0.208)	(0.728)	(0.881)	(0.767)	(0.892)	(0.987)
	(2) Patent does not cause FDI inflow.	<i>F</i>	1.278	0.538	0.205	1.623	2.140	2.579
		<i>Prob.</i>	(0.273)	(0.595)	(0.890)	(0.259)	(0.211)	(0.305)
Model 3	(1) Technology export does not cause Patent.	<i>F</i>	2.150	0.819	0.740	1.185	0.748	0.215
		<i>Prob.</i>	(0.160)	(0.460)	(0.549)	(0.386)	(0.621)	(0.939)
	(2) Patent does not cause Technology Exports.	<i>F</i>	4.810**	2.454*	3.597**	1.629	0.939	9.230
		<i>Prob.</i>	(0.042)	(0.100)	(0.049)	(0.257)	(0.526)	(0.121)
Model 4	(1) Technology Imports does not cause Patent.	<i>F</i>	8.915***	3.613*	1.309	0.493	1.867	1.141
		<i>Prob.</i>	(0.008)	(0.054)	(0.320)	(0.741)	(0.254)	(0.220)
	(2) Patent does not cause Technology Imports.	<i>F</i>	1.021	0.598	0.195	0.276	0.243	0.456
		<i>Prob.</i>	(0.326)	(0.563)	(0.897)	(0.885)	(0.926)	(0.806)
Obs.			20	19	18	17	16	15

Note: *, **, and *** indicate the rejection of null hypothesis at 10%, 5% and 1% level, respectively.

(2) Japan

Null Hypothesis			<i>Lag1</i>	<i>Lag2</i>	<i>Lag3</i>	<i>Lag4</i>	<i>Lag5</i>	<i>Lag6</i>	
Model 1	(1)	GERD does not cause Patent.	<i>F</i>	1.861	1.232	1.734	5.757**	3.953*	3.399
			<i>Prob.</i>	(0.190)	(0.321)	(0.217)	(0.017)	(0.078)	(0.052)
	(2)	Patent does not cause GERD.	<i>F</i>	0.873	2.450	2.940	1.463	1.147	7.177
			<i>Prob.</i>	(0.363)	(0.160)	(0.139)	(0.299)	(0.441)	(0.127)
Model 1-1	(1)	R&D expenditure in the Public Sector does not cause Patent.	<i>F</i>	5.254**	1.974	0.671	0.331	1.284	1.394
			<i>Prob.</i>	(0.034)	(0.175)	(0.586)	(0.849)	(0.395)	(0.474)
	(2)	Patent does not cause R&D Expenditure in the Public Sector.	<i>F</i>	0.000	0.029	0.136	0.219	0.313	1.548
			<i>Prob.</i>	(0.990)	(0.971)	(0.936)	(0.919)	(0.885)	(0.442)
Model 1-2	(1)	R&D Expenditure in the Private Sector does not cause Patent.	<i>F</i>	0.426	2.202	2.442	3.974**	4.080*	4.881*
			<i>Prob.</i>	(0.522)	(0.147)	(0.119)	(0.045)	(0.074)	(0.064)
	(2)	Patent does not cause R&D Expenditure in the Private Sector.	<i>F</i>	1.341	3.524*	0.607	1.665	0.609	4.952
			<i>Prob.</i>	(0.262)	(0.057)	(0.623)	(0.249)	(0.699)	(0.177)
Model 2	(1)	FDI inflow does not cause Patent.	<i>F</i>	0.869	2.878	1.197	1.896	2.459	2.598
			<i>Prob.</i>	(0.369)	(0.122)	(0.485)	(0.394)	(0.143)	(1.753)
	(2)	Patent does not cause FDI inflow	<i>F</i>	6.861	0.451	6.110	4.991	2.774	3.441
			<i>Prob.</i>	(0.122)	(0.654)	(0.143)	(0.287)	(0.194)	(0.228)
Model 3	(1)	Technology Exports does not cause Patent.	<i>F</i>	2.245*	0.848	1.400	0.313	0.973	1.032
			<i>Prob.</i>	(0.100)	(0.447)	(0.290)	(0.862)	(0.501)	(0.533)
	(2)	Patent does not cause Technology Exports.	<i>F</i>	0.000	0.162	0.121	0.122	0.472	0.324
			<i>Prob.</i>	(0.984)	(0.851)	(0.945)	(0.970)	(0.785)	(0.888)
Model 4	(1)	Technology Imports does not cause Patent.	<i>F</i>	0.317	0.403	0.140	1.004	1.185	6.224*
			<i>Prob.</i>	(0.580)	(0.675)	(0.933)	(0.453)	(0.414)	(0.081)
	(2)	Patent does not cause Technology Imports.	<i>F</i>	2.310	1.131	0.989	1.703	2.109	1.824
			<i>Prob.</i>	(0.185)	(0.348)	(0.430)	(0.232)	(0.195)	(0.332)
Obs.				20	19	18	17	16	15

Note: *, **, and *** indicate the rejection of null hypothesis at 10%, 5% and 1% level, respectively.

6.7 Conclusion

This chapter analyses distinctive features of S&T policies, IPR regimes, financial systems and NIS for national technology capabilities in the contexts of Korea and Japan, given that the technological catch-up process and innovation performance depend on a country-specific institutional setting and policy framework. Government regulations and priorities, as well as legal institutions, are perhaps the only factors that explain countries' variations in trade and production patterns and sectoral specialisations, as well as their different trajectories in innovation. The empirical investigations for causal relationships among key actors within Korea's and Japan's innovation systems and contextual factors have proved the critical role of local firms (rather than MNEs) in both countries, more internationalised R&D system in Korea, as well as more innovative and effective of Korean public sectors than Japan's public sector in the creation and investment of technologies.

Korea's government has more heavily intervened in the process and product of innovation as a financier and performer of R&D than Japan's government, which has acted more as a mediator or facilitator than leader in NIS (ISI *et al.*, 2008). As R&D performers, large industrial firms were and still are the dominant players in both Korea's and Japan's innovation systems despite significant institutional reform for venture capital and start-ups. Korean chaebols and Japanese MNEs still account for more than two-thirds of total R&D expenditure (MEXT, 2008; MEST, 2010). Also, many universities still have lower levels of research capability and make smaller contributions in both countries' innovation systems, compared with frontier countries such as the United States and Europe. This is a major problem in Korea's and Japan's innovation systems.

Despite the problem of universities' R&D capabilities producing low degrees of joint R&D, spin-offs and knowledge transfer, both countries have achieved rapid technology catch-up with the United States and Western Europe in many high-tech fields,

such as ICTs. Rational S&T and financial systems make it possible to upgrade national technology capabilities. First, the countries' financial policies are well-coordinated with industrial, export and innovation policies. Export-oriented and R&D-based firms receive tax favour and other financial aid through various government programmes to develop world-class products and technology capabilities in both Korea and Japan. Second, strong government leadership and an effective mechanism for collective risk-sharing by industry, government and lenders in both countries contribute to national technology capabilities. Such a partnership is essential to encourage industrial firms to undertake long-term innovation investment (e.g., R&D), especially in an immature stage. Third, the government S&T policy and funding systems focus on the fast-growing and high-yielding industries in which income elasticity of demand has been high, technological progress has been rapid and labour productivity has risen quickly. Their strategies focus on dynamic comparative advantage rather than static cost considerations (Johnson, 1982; Yotopoulos, 1991). Fourth, the countries' financial systems have been reformed to meet their S&T goals. The focus on financing priority industries in Japan and Korea has been flexibly adjusted by phasing out declining industries in an orderly and timely fashion.

CHAPTER 7

Technology Catch-up and Sectoral Innovation Systems: Case Studies on Biotechnology and Wireless Telecommunication Industry in Korea and Japan

7.1 Introduction

This chapter discusses the specific policy and institutional frameworks for sectoral catch-up performance and technology capabilities, with particular emphasis on biotechnology and wireless telecommunication industries. Prior to an analysis of these industries, Section 7.2 looks at which industrial sectors of Korea rapidly caught up with those of Japan by examining productivity and technology gaps between the two countries' manufacturing industries. Given different levels of sectoral catch-up performance of Korean firms versus Japanese firms (as a comparative benchmark), I investigate key external factors around the firms, including industrial structure, market system, knowledge regime and sectoral innovation system, as determinants of catch-up occurrence, speed and performance in the context of Korea. Also, distinctive styles, paths and determinants of Korean sectoral catch-up performance are briefly compared to those of other catch-up countries, particularly Taiwan.

Sections 7.3 and 7.4 analyse specific policies and sectoral innovation systems to identify the main cause of the delay in biotechnology catch-up and the success of wireless telecommunication catch-up in the contexts of Korea and Japan. Compared to the wireless telecommunication industry, both countries have experienced a pathetic return on large-scale government funding and corporate research and development (R&D) in biotechnology, given the top policy priority on attaining rapid catch-up in that field.

Korean innovation capability even lags behind the Japanese in many biotechnology sectors, such as clinical medicine and medical technology and brain science (OECD, 2006). Hence, Section 7.3 discusses weaknesses in the underlying biotechnology policies and innovation systems of Korea and Japan so as to determine the root cause of the countries' delay in leapfrogging advanced countries' biotechnology capabilities. Section 7.4 analyses strengths of specific policies and innovation systems for wireless telecommunications to find the key contributing institutional and contextual factors that have affected the rapid technology catch-up in Korea and Japan. Despite larger investments and government funding in Japan's information and communication technology (ICT)-related industries, the ICT capabilities of Korea far surpass those of Japan in the creation of new technologies, especially wireless telecommunication technology. Korea's mobile telecommunication has recently overtaken Japan in terms of production, sales, export and innovation. As key actors in the innovation system of ICT, government, education institutes and firms are examined to investigate their roles in and contribution to the diffusion of 3G mobile phones and the creation of new wireless technologies.

7.2 Sectoral Technology Catch-up

There is no doubt that Japan is a role model for the East Asian newly industrialised countries (NICs) in the process of technology catch-up. Among the NICs, institutional conditions for technology catch-up and innovation in Korea resemble those in Japan, as mentioned in Chapter 6. The established large industrial firms are in the vanguard of catch-up and scientific progress in Japan and Korea, whereas small and medium-sized enterprises (SMEs) and foreign multinationals play the leading role in industrialisation and innovation in Taiwan and Singapore, respectively (Hobday, 1995; Rodrik, 1999). Also, extensive government intervention, political-commercial links, large firm-centred

industrial structures and export-oriented policies, as well as in-house R&D and home-grown talent-based innovation are unique and distinct from other high-income countries (Stern *et al.*, 1995; Kim and Nelson, 2000; Chang, 2003). Because of similar institutional frameworks and climates surrounding the technology catch-up process, dealing with Japan as a comparative benchmark might be appropriate for the detailed analysis of Korea's catch-up. Considering Japanese firms as forerunners and Korean firms as latecomers, I investigate how far behind Korean firms lag Japanese firms within the same industry and in which industrial sectors Korea rapidly caught up with Japan, in addition to what determined the catch-up occurrence, speed and performance of Korea.

7.2.1 Levels and Determinants of Catch-up Performance

Countries are categorised as technology catch-up economies on the criteria of higher growth and better innovation performance in new products/services compared with advanced countries (Park and Lee, 2006). Table 7.1 shows that the East Asian NICs (Korea, Taiwan, Singapore and Hong Kong) had two-digit average annual growth rates in US patents from 1975 through 1995. Among them, Korea increased its share of total US patents rapidly and surpassed the level of technology capability in advanced countries, including Germany, France and the UK. Over the past three years, Korea has become the largest patent producer and R&D performer in the world. Among advanced countries, Japan had the highest growth rate in patent production, except for the United States.

Table 7.1 Ranking of Technology Catch-up Status and Level of Technology Capabilities in Korea

Average growth rate of the USA patents registered by countries (1975-1995)*		No. patent applications (2008)		No. patent granted by countries (2008)		Resident filings per R&D expenditure (2008)		Expenditures on R&D (billions of US\$, PPP, 2011)						
Rank	Country	Rank	Country	Rank	Country	Rank	Country	Rank	Country					
1	Korea	31.75	1	Japan	502,054	1	Japan	239,338	1	Korea	5.08	1	USA	405.3
2	Taiwan	23.09	2	USA	400,769	2	USA	146,871	2	Japan	3.37	2	China	153.7
3	Singapore	20.22	3	China	203,481	3	Korea	79,652	3	New Zealand	1.82	3	Japan	144.1
4	Hong Kong	10.80	4	Korea	172,342	4	Germany	53,752	4	Russia	1.56	4	Germany	69.5
5	Israel	9.46	5	Germany	135,748	5	China	48,814	5	Ukraine	1.09	5	Korea	44.8
6	Finland	8.59	6	France	47,597	6	France	25,535	6	Australia	1.02	6	France	42.2
7	Ireland	8.49	7	UK	42,296	7	Russia	22,870	7	China	0.91	7	UK	38.4
8	Japan	7.54	8	Russia	29,176	8	Italy	12,789	8	Germany	0.91	8	India	36.1
9	Brazil	6.85	9	Switzerland	26,640	9	UK	12,162	9	Poland	0.77	9	Canada	24.3
10	Chile	6.83	10	Netherlands	25,927	10	Switzerland	11,291	10	USA	0.72	10	Russia	23.1

Note: the USA data was excluded.

Source: compiled by data from Park and Lee (2006), WIPO statistics and UNCTAD statistics.

To investigate the level of catch-up in Korean manufacturing industries, the productivity catch-up index was introduced. The productivity catch-up index has been widely used for comparisons to determine the degree of competitiveness and technology progress across firms, industries and countries (Schreyer, 2005; Motohasi, 2006; Lee and Jung, 2010). The catch-up index is measured by firm productivity distance from industry average productivity in the country or distance between the industry average levels of total factor productivity (TFP) or labour productivity within countries (also see Jung *et al.*, 2008). That is, $\{(\text{each firms' TFP in country A} - \text{industry average TFP in country A}) + (1 + \text{industry TFP in country A} - \text{industry TFP in country B})\} * 100$. An index value higher than 100 indicates higher TFP of country of A (e.g., Korea) compared to that of firms in country B (e.g., Japan), meaning that a firm in county A leapfrogs a firm in county B.

Lee and Lim (2001) analysed the three catch-up models of Korean firms in six manufacturing sectors by estimating the productivity and technology gaps with their competitors in Taiwan and Japan. The first model is the path-following catch-up model, indicating that latecomer firms (e.g., Korean firms) follow the growth path undertaken by forerunners (e.g., Japanese firms). Electronics, personal computers and machine tools are included in this model. The second model of skipping catch-up suggests that latecomer firms follow the path to an extent but leapfrog some stages. D-RAM and automobiles belong to this model in the case of Korea. The third model of path-creating catch-up indicates that latecomer firms explore and create their own path of technological development and innovation. A typical example is Korean wireless telecommunication. More recently, Lee and Jung (2010) classified Korean firms into four catch-up models, as a competitive benchmark of Japanese firms, through the TFP index: overtaking, convergence, slow catch-up and increasing gap.

Table 7.2 Technology Catch-up Patterns in the Selected Manufacturing Industries, Korea

ICPA code	Industry name	1990 TFP gap	1995 TFP gap	2000 TFP gap	2004 TFP gap	Patterns
6	Food & related products	110.3	116.7	111.2	110.9	Overtaking
9	Lumber & wood	141.1	131.8	137.9	150.9	Overtaking
10	Furniture & fixtures	99.6	119.2	125	129.1	Overtaking
16	Stone clay glass	92.2	108.9	108.6	112.6	Overtaking
14	Petroleum & coal products	163.7	195.3	114	102.7	Convergence
18	Fabricated metal	100	128.5	110	96.3	Convergence
19	Machinery non-elect	92.5	122	110.2	108.5	Convergence
20	Electrical machinery	30.8	75	73.1	96.6	Convergence
22	Transportation equipment	84	103.8	92.5	97	Convergence
7	Textile mill products	57.1	81.3	87.8	82.4	Slow Catch-up
8	Apparel	19.4	53.2	57.5	59.6	Slow Catch-up
11	Paper & related products	75.6	92.2	74	86.6	Slow Catch-up
12	Printing publishing	98.4	106.4	111.1	88.3	Slow Catch-up
13	Chemicals	78.7	91	90	80.9	Slow Catch-up
21	Motor Vehicles	54.5	75.1	78.8	88	Slow Catch-up
23	Instruments	40.7	73.1	60.2	61	Slow Catch-up
24	Rubber & misc plastics	61.6	80.5	81.7	76	Slow Catch-up
15	Leather	104.3	128	121.1	104.2	Increasing gap
17	Primary metal	70	89.2	78.8	61.3	Increasing gap
total		69.5	92.1	86.5	91.2	

Source: Compiled by the data from Jung and Lee (2010).

Table 7.2 presents the degrees and patterns of technology catch-up in 19 manufacturing industries in Korea versus Japan through the TFP index. From 1990 through 2004, the first level of overtaking included the industries related to food, lumber and wood, furniture and fixtures, in addition to son-clay-glass products in Korea. These industries are involved in relatively low technology. One Korean manufacturing firm that surpassed Japanese firms in the sector of food and kindred products is the CJ Corporation. The second pattern of convergence embraces the industries related to petroleum, coal products, fabricated metal, electrical machinery, ship-building and transportation equipment in Korea. Samsung Electronics, LG Electronics and the Hyundai Heavy Industries Corporation are representative firms belonging to this pattern in terms of TFP. The third pattern of slow catch-up includes textile mill products, apparel, paper, chemicals, motor vehicles, instruments and the rubber and plastics industries in Korea. Of note, the

automobile-related industry of Korea rapidly caught up with that of Japan before the Asian financial crisis of 1997, but the gap between the two countries has widened in terms of sales, productivity and innovation performance (Jung and Lee, 2010). The last pattern of increasing gap indicates a negative catch-up performance of Korean firms versus Japanese firms. It includes the leather and primary metal industries. As shown in Table 7.2, the sectoral differences in catch-up patterns reveal a concentration on high-value knowledge and R&D-intensive products over labour-intensive products in Korea.

To further investigate key institutional factors affecting technology catch-up performance in the industries characterised by ‘overtaking’ and ‘convergence’, I employ a number of empirical studies to examine determinants of catch-up occurrence, speed and performance. Most of these studies highlight the role of knowledge regime, industrial structure, foreign trade policy and sectoral innovation system in technology catch-up. For example, Lee and Lim (2001) argued that the technological leapfrogging of the latecomers is conditioned on degrees of innovation frequency, uncertainty of the technological trajectory and access to foreign knowledge bases. In Catellacci’s (2007) catch-up model, appropriability conditions, levels of technological opportunities, education and skill levels, degree of openness to foreign competition and size of the market are emphasised as determinants of productivity and technology catch-up (also see Park and Lee, 2006; Lee and Jung, 2010).

First, in the knowledge regime, explicit knowledge rather than tacit knowledge might be more important in the process of technology catch-up. Knowledge explicitness is related to the ease of the translation into information using formulas, diagrams, numbers and words, while knowledge tacitness cannot be easily codified and described, implying that the transfer of tacit knowledge is costly and uncertain (Grant, 1996; Gonzalez-Alvarez and Nieto-Antolin, 2007). In this regard, firms that depend on tacit knowledge are more likely to seek industrial secrecy than to file patents (Gonzalez-

Alvarez and Nieto-Antolin, 2007; Jung and Lee, 2010). Thus, in the context of latecomers, a knowledge regime based on explicit knowledge (rather than tacit knowledge) might serve rapid technology catch-up, with the advantages of ease of codification and transferability among people, as well as low complexity for learning. Table 7.3 demonstrates the contribution of the knowledge regime based on explicitness to the Korean manufacturing industries. The industries are classified by four catch-up patterns. Korean firms in the industrial sectors with the catch-up pattern of convergence have a higher degree of knowledge explicitness than those with slow catch-up and increasing gaps. The convergence pattern embraces the electronics and ICT sectors as shown in Table 7.2. Explicitness of knowledge is measured by the number of patents per unit R&D expenditure in each sector.

Table 7.3 Degrees of knowledge explicitness by Four Catch-up Patterns, Korea

Catch-up pattern	1990	1995	2000	2004	Total
Overtaking	0.063	0.029	0.018	0.010	0.028
Convergence	0.041	0.172	0.034	0.022	0.052
Slow Catch-up	0.061	0.054	0.020	0.019	0.039
Increasing Gap	0.058	0.097	0.029	0.020	0.045

Note: Explicitness of knowledge and technology is calculated by (number of patents registered in each sector in each year) / (R&D expenditure in each sector in each year).

Source: Compiled by the data from Jung *et al.* (2008), Jung and Lee (2010) and Park and Lee (2006).

Second, the acquisition of imported technology embodied in capital goods, such as machinery, might play an important role in technology catch-up performance in the context of latecomers. A number of studies have demonstrated a positive correlation between embodied technology transfer and labour productivity of latecomer firms (Lee, 1995; Lee and Lim, 2001; Mazumdar, 2001). This relationship is evident in the Korean case, as shown in Table 7.4. Industrial sectors with the catch-up pattern of convergence

are related to a higher degree of embodied technology transfer in Korea. The degree of embodied technology transfer is measured by the level of embodied technical change as a share of the sector's total imported machinery and equipment by using industry-level machinery import data from input output (IO) tables (Jung and Lee, 2010).

Table 7.4 Degrees of Embodied Technology Transfer by Four Catch-up Patterns, Korea

Catch-up pattern	1990	1995	2000	2003	Total
Overtaking	0.116	0.119	0.123	0.17	0.139
Convergence	0.436	0.417	0.483	0.478	0.464
Slow Catch-up	0.232	0.258	0.238	0.239	0.253
Increasing Gap	0.401	0.315	0.228	0.266	0.316

Note: Embodied Technology Transfer is calculated by (imported machinery input in each sector in each year) / (total machinery input of the sector in each year).

Source: Compiled by the data from Jung *et al.* (2008), Jung and Lee (2010) and Park and Lee (2006).

Table 7.5 Degrees of large firm dominance by Four Catch-up Patterns, Korea

Catch-up pattern	1990	1995	2000	2004	Total
Overtaking	0.177	0.213	0.139	0.166	0.178
Convergence	0.347	0.419	0.382	0.448	0.406
Slow Catch-up	0.235	0.251	0.264	0.249	0.245
Increasing Gap	0.36	0.333	0.375	0.392	0.362

Note: Large firm dominance is calculated by (largest firms' sales in each sector in each year) / (total sales in each sector in each year).

Source: Compiled by the data from Jung *et al.* (2008), Jung and Lee (2010) and Park and Lee (2006).

With such different characteristics of organisations between the two catching-up countries, “...the Korean firms find themselves more fitted in environments featuring low appropriability and high cumulativeness (persistence), whereas the Taiwanese firms are more fitted to those featuring high appropriability...” (Park and Lee, 2006, p.746:4).

Chaebols prefer the technology regime involving low appropriability and high cumulativity. On the other hand, Taiwanese SMEs are more sensitive to cumulativity than Korea's chaebols, and they enjoy relatively high appropriability because of worries about their knowledge linkage to large firms and multinational enterprises (MNEs) (Park and Lee, 2006). This has implications for other catching-up economies. Table 7.5 presents the degree of top-firm dominance measured by the largest firm's sales as a share of total sales in each sector. The sectors with convergence patterns are led by the largest firms.

7.2.2 Findings and Discussion

I have introduced previous empirical works on latecomers' technology and productivity catch-up to analyse the levels of catch-up performance and the catch-up patterns of Korean firms compared to those of Japanese firms. As important determinants of catch-up, knowledge explicitness, monopolistic market structure and acquisition of advanced technology embodied in capital goods (e.g., machinery, equipment) are identified in the context of Korea. The four determinants are drawn from existing studies on the sectoral innovation system (Malerba, 2002; 2004) and technology regime (Nelson and Winter, 1977; 1982), as well as a number of case studies on latecomers' technology catch-up and innovation (Park and Lee, 2006; Lee and Jung, 2010). Therefore, this study extends the literature on technology regime, market structure and trade policy to the catching-up context to examine in which sectors catch-up tends to occur or not, and what affects the speed of catch-up and innovation.

The main findings of our analysis are as follows. Technology and productivity of Korean firms have rapidly caught up with Japanese firms in industrial sectors characterised by more explicit knowledge, a higher degree of embodied technology transfer, a shorter product cycle, easier access to external knowledge and higher

appropriability, given the limited sources for R&D. On the other hand, advanced countries, including Japan, hold higher technology capabilities in industrial sectors related to relatively more tacit knowledge, longer cycle time and lower appropriability. This suggests that explicitness of knowledge and embodied technology transfer enable latecomer firms and countries to close the productivity and technology gaps, since such knowledge and technology are related to the ease of codification, transfer and commercialisation of R&D outcomes. Furthermore, the industries with a more monopolistic market structure and a higher degree of external discipline from pursuit of world market competition led better innovation performance in the context of Korea.

This study has provided a comprehensive evaluation of technology catch-up models that enables us to compare significant determinants and levels of technology capabilities with other catching-up countries and advanced countries. Based on this study for the identification of important determinants of sectoral catch-up performance, the next section analyses sectoral specific institutional conditions and policy mechanisms for the progress in detail by employing the two industries, biotechnology (a slow catching-up model) and wireless telecommunication industries (a rapid catching-up model) in Korea and Japan. Considering the interplay between national innovation system (NIS) and sectoral innovation system (SIS), key factors delaying and accelerating rapid technology catch-up in the industries are determined to find policy measures for improvement.

7.3 Policies and Innovation Systems of Biotechnology in Korea and Japan

A country-specific institutional setting and top priority policy cause idiosyncratic styles and patterns in national and sectoral development. For example, Korea's innovation system characterised by a good partnership between government-sponsored research institutes (GRIs) and firms with the government priority policy for intensively fostering

ICTs enabled Korea to become the most powerful ICT country in the world (Lee and Yoo, 2007). Meanwhile, the rapid growth of biotechnology in France is attributable to a strong research capacity of universities and their close links to public/corporate research institutions in NIS, as well as a priority policy for biotechnology sectors (Lee and Yoo, 2007).

The progress of newly emerging and knowledge-intensive industries, such as biotechnology and ICT, is significantly influenced by institutional and policy factors because of their unique characteristics. Biotechnology can be distinguished by heavy dependence on basic scientific research compared with other industrial technologies (e.g., electronics, automobile) and its close ties with market-induced applied research. It is widely used to create commercial products in various industries, including the agricultural, chemical, pharmaceutical and environmental fields (Kenney, 1986; Shan and Hamilton, 1991). Such basic scientific research-based technology is needed to build up the capacity of universities and their close ties with research institutes and industry (Mowery and Rosenberg, 1993; Lehrer and Asakawa, 2004; Casper and Kettler, 2001). Compared with other newly emerging high-tech fields, a domestic or international partnership based on a cooperative relationship, rather than a competing relationship (e.g., the case of ICTs), is an important channel for catching up and developing biotechnology. In this sense, the uniqueness of biotechnology brings about the reform of NIS and the revision of existing science and technology (S&T) policy to establish a cooperative innovation environment so as to promote active R&D cooperation among key players within NIS and strengthen the international partnership in the development of the commercial applicability of basic scientific research.

Japan is one of the world's largest countries, with the United States, Germany and the UK, in terms of R&D investment in biotechnology innovation. In Japan, the long economic recession and slowdown of international competitiveness since the late 1980s

brought about R&D reforms and institutional change to create new frontiers and build up internationally competitive high-tech industries. Life science has been treated as a priority in the national development plan through enactment of special laws boosting biotechnology R&D since that time (Watanabe, 2000; Noland, 2007). In the absence of a scientific base, the government has pursued strategic alliances with the world's top foreign R&D organisations while establishing bio-clusters to promote start-ups, university spin-offs and R&D cooperation (Whitley, 2003; Lehrer and Asakawa, 2004). Regarding the biotechnology sector, traditional biotechnology products have a large share of the total domestic production of biotechnology firms in Japan. It embraces traditional fermentation, cultivation, mutagenesis and pollution treatment technology. In Japan, food and drink manufacturing industries ranked first in terms of number of firms, employees, R&D expenditure and performance, followed by pharmaceutical industries (OECD, 2006).

On the other hand, Korea has emerged as the key player in the global biotechnology market. In the early 1980s when chemical and genetic engineering emerged as the national economic growth sector in developed economies, Korea started to recognise biotechnology as an important discipline to strengthen industrial competitiveness and level up national technology capabilities (L. Kim, 1997; Kim and Nelson, 1999). Entering the 1990s, the national S&T policy included biotechnology as a key strategic technology by setting up several incentives supporting biotechnology R&D activities. In this period, under the special law to promote biotechnology, biotechnology-related research institutes and firms were established (Rhee, 2003). Although almost ten years later than Japan, Korea has attained world-class capabilities in the areas of fermentation technology, antibiotics, diagnostics and hepatitis B vaccines (Rhee, 2003). In the field of biotechnology, bio-foods and biopharmaceuticals have the largest share of the total in terms of domestic production and employees (OECD, 2006).

Compared to other priorities (e.g., ICTs, nanotechnology, environmental

technology), however, both countries have experienced a pathetic return on large-scale government funding and corporate R&D, which led to a slowdown in catching up with the frontier countries, such as the United States, Germany, France and the UK. Korean innovation capability even lags behind the Japanese in many biotechnology sectors, such as clinical medicine and medical technology and brain science (OECD, 2006). What is the root cause of countries' delay in leapfrogging advanced countries' biotechnology capabilities despite a huge investment and a top-priority policy on achieving rapid catch-up? To find the answer, I critically analyse weaknesses underlying the biotechnology policy and innovation system in Korea and Japan by employing Bartholomew's model of innovation system of biotechnology after a brief discussion of the nature of biotechnology and review of previous innovation research on biotechnology innovation system. Bartholomew (1997) highlighted important institutional and policy factors influencing the stock and flow of scientific knowledge: tradition of scientific education, patterns of basic research funding, links to foreign research organisations, degree of commercial orientation of academia, labour mobility, venture capital system, national technology policy and technological accumulation in related industrial sectors (Bartholomew, 1997, p.246).

7.3.1 Literature on Biotechnology Innovation

Biotechnology refers to the application of microorganisms, such as a bacterium, virus or parasite, to the production of goods and services (Bartholomew, 1997). Broadly, biotechnology can be divided into four fields of engineering: genetic engineering, cellular engineering, embryonic cell engineering and enzyme engineering. By employing useful properties of living organisms, the general aim is to make human life more abundant and comfortable (e.g., for longevity, dietary life improvement, prevention or cure of disease, including incurable and hereditary diseases) (Shan *et al.*, 1994). Biotechnology is widely

applied in various fields of industry, including agricultural, chemical, pharmaceutical and environmental protection, for industrial and commercial value creation (Kenney, 1986; Shan and Hamilton, 1991). However, biotechnology involves a high level of technological uncertainty and continuous controversy over bio-ethics in the commercialisation process (George *et al.*, 2001; Bartholomew, 1997).

Compared with other industrial technologies (e.g., automobiles, textiles, shipbuilding), biotechnology relies more heavily on basic scientific research, hence academic scientists and researchers play a pivotal role in the development of this area (McMillan *et al.*, 2000). A close link between basic research and market-induced applied research is essential, which blurs the traditional classifications of basic research and applied research (Mowery and Rosenberg, 1993). With the nature of biotechnology, the catch-up process and performance are directly influenced by the country-specific institutional setting and policy measures that cover the scientific education system, venture capital system and research funding system, as well as government regulation and policy in resource mobility (e.g., labour, capital, technique) and international partnership with R&D institutions (see Kenney, 1986; Shan and Hamilton 1991; Mowery and Rosenberg 1993; Bartholomew, 1997).

The importance of institutional and policy factors influencing biotechnology innovation are as follows. First, the national education system has a pivotal role in accumulating, disseminating and creating scientific knowledge through cultivation of scientists and engineers and promotion of research collaboration with R&D organisations (Kenney, 1986). Second, the national funding of basic research that sponsors academic scientists and research laboratories provides the opportunity to learn and generate new scientific knowledge. This supports machinery, equipment and materials relating to research and development in the process and product of biotechnology innovation (Mowery and Rosenberg, 1993; Shan and Hamilton, 1991). Third, the availability of

venture capital that funds start-up firms is crucial for scientific advancement and the subsequent technological progress. Venture capital encourages scientists and academic researchers to establish their own firms related to biotechnology; hence, it promotes scientific knowledge diffusion and spillover from research institutions to industry (Pisano, 1996; Bartholomew, 1997). Fourth, the mobility of human resources and the cooperative relationship between research institutions and industry are essential to develop biotechnology. Mobility allows academic scientists to start up their own companies or work in private science-based ventures (Lethrer and Asakawa, 2004).

As a primary source of the United States' biotechnology advantage, close ties between industry and the academic community, and the mobility of scientists, have been highlighted in much of the literature (e.g., Blumenthal *et al.*, 1986; Mowery and Rosenberg, 1993; Lethrer and Asakawa, 2004). For example, Blumenthal *et al.* (1986) emphasised the importance of cooperative relationships between academia and biotechnology firms. By using US patent data, they found that patent applications in biotechnology firms linked to universities number almost four times as many as independent firms that do not collaborate with research institutions. Likewise, Lethrer and Asakawa (2004) demonstrated that a negative effect of labour immobility on biotechnology innovation performance by illustrating the Japanese case that restricts the top scientists' movement to protect important knowledge related to national security secrets. Fifth, strategic alliances and cooperative relationships with foreign R&D organisations are important channels for the progress of biotechnology, especially in catching-up countries characterised by a shortage of skilled workers in the absence of a science base. Cross-border R&D cooperation enables innovators to acquire, master and transfer resources in the improvement of existing knowledge and generation of new discoveries (Shan and Hamilton, 1991). In this sense, a liberal regulatory environment is essential to increase the stock and flow of scientific knowledge (Porter, 1990; Shan and

Hamilton, 1991).

7.3.2 Weaknesses of Policies and Innovation Systems of Biotechnology in Korea and Japan.

This section critically analyses weaknesses underlying the biotechnology innovation systems in Korea and Japan to identify the main obstacles in the catch-up process by comparing them with the innovation system in the United States, which is the world's most powerful nation in biotechnology.

Several overlapping factors behind a slow rate of catching up in biotechnology in the countries are as follows. First, I found the weak point in the national education system. Knowledge-creating institutions, namely universities, are contributors to the innovation system of biotechnology with a role in not only cultivating highly skilled manpower, but also participating in new product and innovation processes. The triple helix theory highlights the important role of universities in newly emerging technology fields such as biotechnology (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2006; Marques *et al.*, 2006). This is analytically different from the traditional NIS models (e.g., statist and laissez-faire models) focusing on the central role of firms in technological innovation (Ludnvall, 1992) and the triangle model focusing on the decisive role of government in tradition (Inzelt, 2004). The success of biotechnology catch-up and innovation depends heavily on the R&D capabilities of universities. The main task of universities is to establish a close relationship between its faculty members and industry for active knowledge transfer and R&D cooperation, while establishing business assistance programmes supporting venture business and spin-offs for the dynamics of innovation (Castells and Hall, 1994; Etzkowitz and Leydesdorff, 2000; Oh, 2002). However, higher education in both Korea and Japan is inactive for spin-offs and joint R&D compared with the United States; it also still concentrates on learning and mastering extant knowledge

rather than research based on creativity and originality despite a long-term investment in cultivating expertise in the fields of science and engineering (Bartholomew, 1989; Westney 1993; Oh, 2002).

Second, basic research funding systems in Korea and Japan are comparatively inefficient. Although the governments have encouraged the study of scientific engineering by providing many jobs for graduates, public funding of basic research is relatively low and inefficiently allocated compared with the United States. The allocation of research funding in both countries was directed by a myopic approach based on seniority rather than merit, which obstructed the building of autonomous research capabilities (Harayama, 2001; Odagiri and Goto 1993). Likewise, scientific research funding is overly weighted toward the publicly funded national universities and laboratories. This results in most university R&D and patenting activities being undertaken by the publicly funded national universities in Korea (e.g., the KAIST, Seoul University) and Japan (e.g., Tokyo University, Kyoto University), which also differs from the United States (Kneller, 2003; Rhee, 2003). In the United State, private top universities are key contributors to the innovation system of biotechnology (Kneller, 2003).

Third, there is relatively inactive R&D collaboration among research institutes and biotechnology firms in Korea and Japan. This weak cooperative relationship may be due to the traditional tendency to belittle the commercialisation of academic research, which led to low availability of venture capital. The positive effects of R&D networking among R&D institutes and partnerships with biotechnology-related organisations, including venture firms and hospitals, on the growth of biotechnology are highlighted in many previous empirical studies on innovation (Zucker and Darby, 1995; Powell *et al.*, 1996; DeCarolis and Deeds, 1999; Nilson, 2001). The state-university-industry cooperative relationship in Korea and Japan is comparatively weaker than in the United State, linking to a low level of technology transfer (Branstetter and Ug, 2004; Motohasi,

2005). The tripartite relationship in Korea is even lower than in Japan due to relatively feeble scientific and information networks, which caused the delay in Korea's biotechnology catch-up (Castells and Hall, 1994).

Fourth, I found low availability of venture capital, low quality of entrepreneurship and low turnover rates of labour, including scientists, in Korea and Japan (Ergas, 1987; Bartholomew, 1997; Rhee, 2003). These are largely responsible for the government's policy restricting top scientists and academia at national universities from engaging in their own businesses or working with private firms as partners so as to prevent knowledge leakage (Lehrer and Asakawa, 2004). Since most scientists and researchers in Korea and Japan are given the title of public officer with the role of producing public goods, their business activities are strictly controlled by the government, which negatively affects life science venture capital investment, spin-offs and entrepreneurial processes related to biotechnology in the countries (also see Whitley, 2003; Kneller, 2003). Regarding venture capital investments in life science, Japan was at a lower level with US\$73 million than even Korea (US\$77.5 million) in 2007 (OECE, 2009).

The lower availability of venture capital in Japan may be due to its socio-cultural system, including its collectivist culture and the risk-averse nature of its society. In contrast to individualism characterised by the Anglo-American countries, the collectivist culture in Japan values trust and long-term relationships, and thereby attaches great importance to groups' interests in relation to individual interests (Lee and O'Neill, 2003). In this sense, inter-firm cooperation plays an important role in the catch-up process of biotechnology in Japan, while venture capital and entrepreneurship are the engines of biotechnology progress in the United States (Bartholomew, 1997). The first high-tech entrepreneurial process, or new biotech firms (NBFs) through spin-offs, emerged in the United States in the 1970s (Jung *et al.*, 2007). The established firms (rather than the

NBFs) acted as key financiers and performers of R&D in the Japanese innovation system of biotechnology, while inter-firm linkage was a key channel for increasing the stock and flow of scientific knowledge biotechnology catch-up, which is similar to Korea's innovation system of biotechnology (Henderson *et al.*, 1999; Shin, 2001; Jung *et al.*, 2007).

7.3.3 Reforms of Policies and Innovation System of Biotechnology in Korea and Japan

Against a slow rate of catch-up in biotechnology, there was large institutional reform in Korea and Japan to compensate for the weaknesses (as mentioned above in Section 7.3.2) that impeded the stock and flow of scientific knowledge. While evaluating the competitiveness of the Korean biotechnology industry, effective policy change and institutional reform toward the rapid catch-up are outlined below.

Korea

Korea started to promote biotechnology innovation mainly to resolve the food shortage of the early 1980s (Jung *et al.*, 2007). With the promulgation of the Genetic Engineering Development Act (1983), the Biotechnology Promotion Law (1983) and the Basic Science Research Law (1989), the government established the Research Institute of Bioscience and Biotechnology in 1985 by spinning off from the Korea Institute of Science and Technology (KIST) and from the Bio-industry Association in 1991 (Rhee, 2003). Entering the 1990s, biotechnology was selected as one of the national strategic industries (together with ICTs and nanotechnologies) under the Highly Advanced National (HAN) Project (MOST, 2007). The HAN Project (1992-2001) proposed the development of bioengineering, especially in the fields of biomaterials, pharmaceuticals and agrochemicals, as a national objective (MOST, 2007). This brought about large institutional reform, including the education system. Korean universities started to

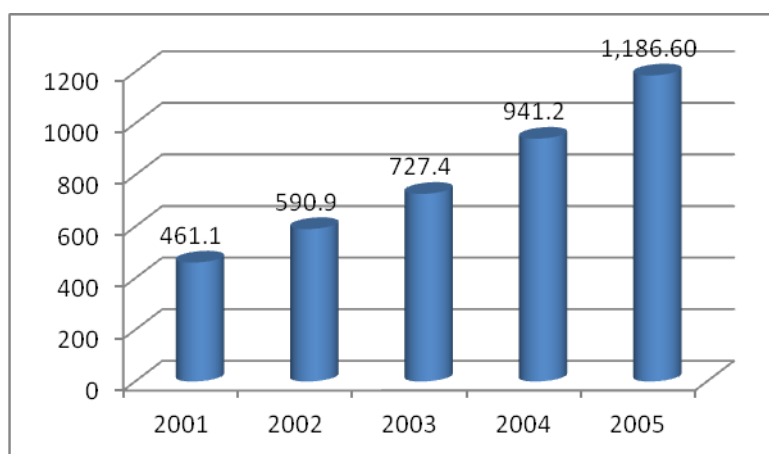
establish biotechnology-related departments, industrial liaisons and research centres under special missions to foster talents and prompt spin-offs and R&D cooperation with other research institutes and industry (Rhee, 2003). However, the allocation of government funding for the biotechnology sectors was smaller than for other high technologies, such as ICTs. Under the HAN Project, about 19 percent of government budget was allocated to the biotechnology industry sectors while ICT-related industries received about 34 percent (Lee and Yoo, 2007). This might be the fundamental reason why biotechnology has not progressed as fast as ICTs in Korea.

As a derivative of the HAN Project, the long-term plan of the Biotech 2000 Programme was established in 1994, with an ambitious goal of Korea joining the world's top seven competitive countries in biotechnology by 2010; “... *forecasts the market for biotechnology goods to reach \$12 billion by 2010, and it expects biotechnology exports to increase ten times over the next decade, particularly as South Korean innovations gain patent recognition in overseas markets*” (Wong *et al.*, 2004, p.42). The major areas were biosensors, BIOMEMS, DNA microarrays, bioinformatics, nanobiotechnology, antibody engineering, anti-aging drug development, neurobiology, drug delivery system, gene therapy, carbohydrate engineering and genomics and breeding technology for transgenic animals and plants (Rhee, 2003).

To compensate the defect that obstructs biotechnology catch-up process, Korea's government planned to invest US\$15 billion for 14 years through a step-by-step process under the Biotech 2000 Programme: (i) establishing a sound scientific foundation to reduce the high level of dependence on foreign technologies (1994-1997); (ii) creating a cooperative R&D environment and strengthening the university-industry-state relationship (1998-2002); and (iii) reaching world-class capability in basic scientific research and its commercialisation (2003-2007) (Rhee, 2003). To achieve these goals, the government sharply increased its R&D investment, as shown in Figure 7.1. It grew by

more than 50 percent from 2001 (US\$461 million) to 2005 (US\$1,187 million). Despite this effort, the Biotech 2000 Programme did not progress as much as initially forecast due to inherent institutional and structural problems that produced inactive R&D cooperation and low availability of venture capital and home-grown talent. It led to the birth of the 21st Frontier Research Programme with wide-ranging reforms.

Figure 7.1 Korean Government R&D Investments in Biotechnology, Million PPP\$, 2001-2005



Source: compiled by the data from MEST statistics.

In the 21st Frontier Research Programme, twenty R&D projects were formed with an investment of US\$3.5 billion (MOST, 2007). The main research areas in the biotechnology sector were: (i) functional analysis of human, microbial and crop genomes; (ii) biodiversity of indigenous plants; (iii) stem cell biology and therapeutic applications; (iv) proteomics research; and (iv) high throughput screening of novel compounds for bioregulators using structural biology and pharmacogenomics (Rhee, 2003; Wong *et al.*, 2004). This programme more strongly focused on the development of human capital, internationalisation of R&D and strategic alliances with foreign organisations in the absence of a science base of facilities and capabilities (Lee, 2000). The government established the High Quality Human Resources Development Project by the reform of

national education and training systems to cultivate scientists and engineers in the fields of biotechnology (MOST, 2007). Likewise, the government promoted cross-border R&D cooperation to acquire, master and transfer scientific knowledge by establishing Korean biotech cooperation centres in foreign countries, for example, the Korea-UK Bioscience and Biotechnology Cooperation Centre in the Institute of Biotechnology of Cambridge University and the Korea-China Bioscience and Biotechnology Cooperation Centre on the campus of Shanghai Research Centre for Life Sciences (Rhee, 2003). Despite such government effort to promote cooperative innovation activities, however, Korean cooperative applications for patents still indicated low numbers, accounting for just 3 percent (407) of the total patent applications to the KIPO (13,387) between 2000 and 2004 in the field of biotechnology (KIPO Statistics).

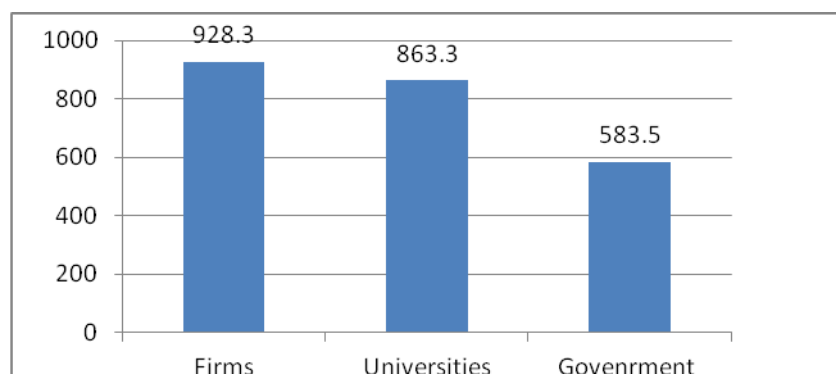
The Korean government also established a number of legal institutions to bolster venture capital investments and new start-ups related to biotechnology, for example, the Act on Special Measures for the Promotion of Venture Businesses (1997) and the Brain Research Enhancement Act (1998) (Jung *et al.*, 2007). The institutional reform led the success of an upsurge in venture capital investment and entrepreneurial processes in Korea. Table 7.6 shows that Korea is the 13th highest country in total venture capital investment in life sciences with US\$77.5 million, which overtook Japan's venture capital investment (US\$73 million) in 2007. Regarding venture businesses, the number of biotech start-ups markedly increased from only 70 in 2000 to 605 in 2003. In parallel, only one Korean biotechnology firm was publicly listed in 2000 and the number rose to 23 by 2003. Over one-third of biotech venture firms are engaged in the biomedical field (Cho *et al.*, 2007).

Table 7.6 Biotechnology Venture Capital Investments, OECD Countries, 2007

	Life Sciences		All Venture Capital	
	Total (million US\$)	Average size per investment (thousand US\$)	Total (million US\$)	Average size per investment (thousand US\$)
United States	5,507.0	10,255.1	30,885.9	8,110.8
Canada	523.3	6,460.9	1,702.3	3,724.9
France	483.1	2,268.2	1,802.1	2,130.1
United Kingdom	447.6	2,062.6	4,388.6	3,971.6
Germany	351.9	1,312.9	1,302.8	924.0
Sweden	299.5	1,081.4	811.2	1,139.3
Switzerland	167.4	4,184.6	622.2	6,549.4
Australia	140.8		1,104.0	
Belgium	121.9	3,584.4	431.2	2,613.4
Denmark	122.0	1,848.7	627.0	4,045.0
Spain	101.9	2,830.2	1399.4	5,280.7
Netherland	91.2	1,682.2	953.4	2,755.4
Korea	77.5	1,937.0	1,322.5	2,150.4
Japan	73.0	405.8	710.0	522.8
OECD	8,631.3	2,059.3	50,117.2	3,535.9

Note: The data of Japan is 2006.

Source: compiled by the data from OECD biotechnology statistics (2009).

Figure 7.2 Korean Biotechnology R&D by Sector of Performance, Million PPP\$, 2006

Source: compiled by the data from OECD biotechnology statistics (2009).

Regarding R&D activities of key actors within Korea's biotechnology innovation system, firms had the largest share of total biotechnology R&D expenditure, at 39.1 percent, followed by universities (36.5 percent) and public research institutes (25.4 percent) in 2006, as shown in Figure 7.2. Six hundred and forty firms were engaged in eight sectors of biotechnology in 2004: biopharmaceutical, biochemical, biofood,

bioenvironmental, bioelectronics, bioprocess and equipment, bioenergy and bioresource, and bioassay, bioinformatics and R&D services (OECD, 2009). In the eight sectors of biotechnology, the largest market is the biopharmaceutical sector with 189 firms and 4,356 employees, followed by the biofood industry with 157 firms and 3,471 employees. Meanwhile, the largest share of bio-production is in biofood (i.e., amino acids) with 43 percent, followed by biopharmaceuticals (40 percent) and biomedical (6 percent), as shown in Table 7.7. Over half of R&D investments and production is undertaken by large established firms (e.g., LG Chemical Ltd., SK Chemical Ltd.), which contrasts to the United States (Rhee, 2003). The advanced biotechnology in the United States is attributable to new start-ups that were founded by venture capitalists, large incumbent chemical/medical firms and researchers in biotechnology (Jung *et al.*, 2007).

Table 7.7 Korean Biotechnology Firms by Biotechnology Sectors, 2004

	Biotechnology firms and employment by application field		Production by field of activities
	No. firms	No. employees	Percentage
Biopharmaceutical	189	4,356	40%
Biofood	157	3,471	43%
Bioenvironmental	87	1,583	5%
biochemical	86	983	6%
Bioprocess & equipment	55	657	2%
Bioassay, Bioinformatics & R&D services	33	531	3%
Bioenergy and Bioresource	21	407	1%
Bioelectronics	12	150	
Total	640	12,138	

Source: Compiled by the data from OECD biotechnology statistics (2006).

Japan

The slow catch-up in biotechnology with the United State brought about the revision of existing S&T policies and the reform of NIS and other institutions (e.g., education system, research funding system, IPRs) in Japan since the highly regulated institutional system retarded the stock and flow of scientific knowledge as well as the commercialisation of

basic research. On the whole, the existing scientific technology policy was reviewed to complement the vulnerabilities underlying the national innovation system. The function of government was extended to reduce or remove legal and culture barriers so as to promote dynamic innovation, which was proposed by the Second S&T Basic Plan launched in 2001. The Basic Plan II (2001-2005) strongly focused on creating a cooperative R&D environment, building properly operational university-industry-state relationships, increasing university spin-offs and NBFs and strengthening international technical tie-up (MEXT, 2003; Noland, 2007).

The laws supporting merit-based salary, rather than seniority, and the administrative autonomy of public research institutions were established to stimulate competitive and cooperative R&D, which allows national universities and public laboratories convert into self-governing Independent Administrative Institutions (IAIs) (Lehrer and Asakawa, 2004). By allowing academic freedom, universities could work as consultants in private companies, private companies could establish research facilities on university campuses and both could jointly conduct research (Yamaguchi, 2008; Motohasi, 2005). Also, they acted as a training partner through internships to foster high-quality human resources (Lehrer and Asakawa, 2004), which is beneficial to the industry as well as society as a whole.

Japan's innovation system based on industry-university-state tripartite cooperation was consolidated by revising the 'Law for Promoting Research Cooperation' (1998) and enacting the 'Law for Promoting University-Industry Technology Transfer' (1998), the 'Law on Special Measures for Industrial Revitalization' (1999) and the 'Law to Strengthen Industrial Technical Ability' (2000) (Harayama, 2001; Lynskey, 2006). These laws contributed to the birth of technology licensing organisations (TLOs) at universities. TLOs stimulate technology transfer to commercialise research results by allowing academia and public research to obtain the ownership of patents and faculty

members to work in private firms (Lynskey, 2006); “By October 2003, 36 authorised TLOs had been established in Japan, a sharp increase from four in 1998, and they took various forms, including joint stock companies and limited liability companies. These TLOs had filed 3378 domestic patent applications and 602 foreign patent applications by March 2003, resulting in 705 technology transfer contracts and royalty income of ¥850 million. Moreover, as of January 2002, there were 70 university professors or researchers working as company executives, 31 working as TLO executives and 13 as company auditors” (Lynskey, 2006, p.1395).

Despite the government effort to create socially valuable technologies in biotechnology industry, the Japanese competitive power in biotechnology still far lagged behind the American. As a catch-up strategy, the ‘Basic Policy towards Creation of Biotechnology Industry’ was established in 1999 to intensively industrialise biotechnology. Quantitatively, the Basic Policy proposed (i) an increase of government budget for biotechnology; (ii) an increase of public funding for biologists, bioinformaticians and other scientists related to life science; and (iii) an increase of venture capital and biotechnology start-ups through enlarging financial support of government agencies (Harayama, 2001; Kneller, 2003; Lehrer and Asakawa, 2004; Lynskey, 2006). Qualitatively, the network of relationships among academia, scientists and entrepreneurs was underlined to coordinate basic scientific research and applied research to swiftly commercialise research results (Lehrer and Asakawa, 2004). The freedom of university scientists was guaranteed by the establishment of a number of legal institutions which allow academics at national universities to hold patent rights, work in the private sector and found their own venture companies to develop and commercialise their discoveries (also see Kneller, 2003).

In the absence of a basic science foundation, the government promoted cross-border R&D and strategic alliances with firms and research institutes related to

biotechnology in technological advanced countries. The government sent a number of domestic scientists to the advanced countries, rather than local doctoral programmes (Saxonhouse, 1986), as well as encouraged Japanese firms to invest in foreign universities to develop basic research and its commercial application in the area of bioengineering (Westney, 1993; Lehrer and Asakawa, 2004). The United States was targeted for strategic alliances and partnerships to acquire and transfer advanced scientific knowledge and techniques, especially adaptability and applicable capabilities that allow scientific knowledge to translate into commercial products (Shan and Hamilton, 1991; Saxonhouse, 1986; Bartholomew, 1997). This is strikingly different from US biotechnology firms that enter into cooperative agreements with foreign firms to raise funds for projects that involve a large investment, are time-consuming and contain high risk.

Table 7.8 Number of biotechnology alliances, the Triad, 1990 to 2006

	1990	1992	1994	1996	1998	2000	2001	2002	2003	2004	2005	2006
USA	28	77	125	141	120	165	274	219	274	277	358	360
Europe	26	61	95	101	81	91	171	177	178	197	217	280
Japan	6	8	11	20	11	9	17	41	28	32	54	53
Other	11	11	12	20	6	22	48	56	52	50	75	96
Total	45	98	161	177	147	200	355	332	368	389	481	526

Source: compiled by the data from OECD biotechnology statistics (2009).

Partnership with US research institutes and firms led to an upsurge in the accumulation of scientific knowledge by stimulating the flow of scientific knowledge from the United States to Japan, and thereby improving biotechnology progress, especially in molecular biology research, in Japan (Bartholomew, 1997). Table 7.8 presents the increase in numbers of strategic alliances by domestic and multinational firms for the stock and flow of biotechnology in Japan. Although the number of biotechnology alliances steadily increased from 6 in 1990 to 53 in 2006, this was an extremely low number compared with the United States and Europe.

Traditional biotechnology products (i.e., traditional fermentation, cultivation, mutagenesis and pollution treatment technology) have accounted for a great portion of total domestic production of biotechnology firms, while modern biotechnology products (i.e., recombinant DNA, cell fusion, tissue culture, biomimetic technology) has had the smallest share of the total (OECD). Table 7.9 shows that traditional biotechnology and modern biotechnology products constituted 82 percent (PPP\$45,623 million) and 18 percent (PPP\$9,886), respectively. Food products accounted for 62 percent of total domestic production of biotechnology firms, followed by pharmaceuticals, diagnostic reagents and medical instruments (20 percent) and chemical products (6 percent) in 2003. In the Japanese bio-industry, the majority of biotechnology firms worked in the food or drink manufacturing sector in 2003, at 20 percent (242 firms). The chemical industry was second, at 11 percent (127 firms), followed by pharmaceutical manufacturing (20 percent). In 2003 1,162 firms were active in the biotechnology industry of Japan (OECD, 2006).

Table 7.9
Japanese Biotechnology Production of Firms, by Biotechnology Sector, 2003

	Total	Traditional %	Modern %	Share of total Production %
Foods	36,132.2	98	2	62
Pharmaceuticals, Diagnostic Reagents & Medical Instruments	11,296.2	49	51	20
Chemical Products	3,165.2	51	49	6
Environment-related Equipment & Facilities	1,497.9	90	10	3
Tech. Support and Services	1,057.7	34	66	2
Equipment and Facilities for Research & Production	460.5	24	76	1
Agriculture-related	449.5	87	13	1
Bioelectronics	252.0	100		
Livestock & Fisheries related	232.7	70	30	
Research Samples & Reagents	206.5	37	63	
Data Processing	127.5	28	72	
Fiber & Fiber Processing	19.0	56	44	
Other Products	606.9	89	11	6
Total	55,512.6	82	18	

Source: Compiled by the data from the Japan Bioindustry Association (JBA) and OECD.

7.3.4 Summary and Discussion

I have discussed weaknesses underlying the biotechnology innovation system in Korea and Japan to search for the cause of the slow catch-up with biotechnology in advanced countries, despite top priority policy for biotechnology progress. The main findings are as follows. First, both countries' innovation systems of biotechnology are characterised by in-house R&D and innovation, which are distinct from the network-based innovation system found in the United State and other newly industrialised Asian countries, such as Singapore. In such an in-house-based innovation system, inter-firm cooperation (rather than international cooperation) is the main channel for the stock and flow of scientific knowledge and techniques. In the absence of a science base of facilities and capabilities, like Korea and Japan, a cooperative relationship with foreign institutes and firms is essential for progress in biotechnology. Second, the highly regulated institutional system results in a lack of commercial orientation in academia, a lack of mobility among scientists, as well as low-quality entrepreneurship and university spin-offs that impede the catch-up process. Third, the low availability of venture capital and the weak tripartite relationship are hindrances to rapid catch-up in biotechnology in both Korea and Japan. Japan lags behind even Korea in terms of the number of NBFs and venture capital investments in life sciences, while the weak university-industry relationship is a more serious problem in Korea due to the lower level of R&D capability of universities that are still focusing on learning and mastering extant knowledge.

In Japan, biotechnology R&D is performed mainly by established firms (biopharmaceuticals), which is similar to the Korean innovation system but different from the NBFs-based innovation system of the United States. Although several biotechnology start-ups have grown through financial support from several ministries, Japan still lags behind the United States, the UK and even Korea in terms of the number of biotech firms and venture capital investments in life sciences. This is attributable to Japan's socio-

cultural system, such as its collectivist culture that causes lower mobility of labour and less availability of venture capital compared with the Anglo-American system characterised by individualism. Although Japan has removed the regulatory system by carrying out radical reforms to foster an increase in biotechnology start-ups, the mobility of human resources and cooperation between academia and business, the problems are still incompletely resolved. Regarding university-industry cooperation, universities are unwilling to conduct R&D collaboration with biotech start-ups, and inversely biotech start-ups seek cooperative relationships with other firms over education institutes (Lynskey, 2006). Also, there are still limits and restrictions on star scientists' businesses and interaction with the private sector in Japan despite the law permitting administrative autonomy of public research institutions being enforced, which allows national universities and government labs to become IAs (Lehrer and Asakawa, 2004).

On the other hand, Korea has achieved rapid technological progress in various areas of biotechnology, including antibiotics, diagnostics and hepatitis B vaccines, at internationally competitive levels (Rhee, 2003; Cho *et al.*, 2007). The Korean government established a number of biotechnology development programmes to promote technology transfer, joint R&D, spin-offs and entrepreneurial processes for the commercialisation of basic scientific results. The participants are privileged from a monetary perspective with a number of incentives, such as research funding, tax protection for intellectual resource trade, low interest loans for the construction of the R&D facilities and subsidies for human capital, among others (Chun, 2002; Lee, 2000). However, small numbers of biotech venture businesses have originated from private research institutes, and the chances of their survival are low due to the monopolistic strength of large firms, which is a problem facing Korea's biotechnology innovation system (Kim and Ko, 1998). Compared with the Japanese innovation system of biotechnology, there are more serious problems awaiting solution in the Korean innovation system of biotechnology, which

hamper the generation of competitive Korean bio-products, and thereby delay the catch-up with advanced countries. Those include: (i) the shortage of industrial manpower compared with researchers in the basic science, creating an imbalance of human resources; (ii) the immature financial market for long-term R&D investment and venture capital, (iii) the lack of university spin-offs; and (iv) the feeble scientific and information networks that cause inactive cooperation among state-university-industry and international partnership. The lower proportion of new start-ups spun off from universities and research institutions may be a result of the restriction and disallowance of individual researchers to use their research outcomes. Also, Korean universities are still focused on learning scientific knowledge, rather than fostering creative individuals, and thereby weaken the motivation to pursue biotechnology innovation.

7.4 Innovation Systems of Information and Communication Technology and Wireless Telecommunication Industry in Korea and Japan

Together with biotechnology, Information and Communication Technology (ICT) continues to grow as a future-oriented technology in nearly every country. The growth of ICT creates a new techno-economic paradigm that provides new opportunities for latecomers to rapidly catch up with or leapfrog forerunners (Perez and Soete, 1988; Lee *et al.*, 2005). The evolution of ICT is referred to as the new economy revolution, which resulted in large institutional and policy reforms in all countries because the growth of ICT makes access to knowledge and information easier, with no bounds on time or place and multiple channels; in addition, the cycle of products and techniques became shorter (Fagerberg and Verspagen, 2002). ICT also allows an increase in the stock and flow of information and knowledge by stimulating cross-border cooperation and knowledge spillover through more and better information and communication (Lipse *et al.*, 1998; Fagerberg and Verspagen, 2002; Maurer and Scotchmer, 2006). It provides electronic

communication, broadcasting, computing (e.g., data processing, software, multimedia) and communications network, which are important elements in improving the S&T infrastructure (Pilat and Lee, 2001; Corrocher *et al.*, 2007).

In the digital era, ICT is widely applied and used for the development of all technologies and industries since it is employed in every process for circulating information and transferring knowledge. ICT is utilised for socioeconomic and human development to improve income, education, health, security and other social sectors, while also being applied to various S&T fields to develop the latest technology and emerging industries (e.g., bioinformatics, environmental informatics, engineering informatics) (UNCATD, 2005). Recently, mobile telephony and the Internet have become core channels through which to promptly exchange information, acquire knowledge and facilitate cooperation by allowing efficient communication among stakeholders in the process of innovation. These channels also support business activities by reducing transaction costs and by increasing the speed of trade and the ease of market access (UNCTAD, 2007). These advantages induce changes in the institutional framework and policy for ICT adoption and diffusion (Colecchia, 2002). A liberal regulatory regime and a sense of rivalry are important sources for catch-up success in the areas of ICT, while strategic alliances and international partnerships (cooperative relationships) make a big contribution to the progress of biotechnology in many catch-up countries.

Japan is one of the frontier countries, with Korea, in terms of mobile communications and wireless technologies. Japan has long focused on the development of ICT-related industries, *inter alia*, mobile communications and wireless technologies as a national objective. Because it is a top policy priority, the government has actively intervened in the telecommunications industry in all kinds of ways needed for catching up with technologies from the United States.

The wireless network of FOMA (Freedom of Mobile Multimedia Access) was

first developed by the Japanese NTT DOCOMO and its 3G FOMA services was commercialized in 2001. A year later au (KDDI) and Softbank (the former J-Phone and Vodafone) launched 3G services commercially. Both NTT DOCOMO and Softbank provide 3G services using W-CDMA (Wideband Code Division Multiple Access) technology, while au (KDDI) introduced CDMA 2000 1x technology for 3G networks (MIC, 2010). The different strategies of the three mobile phone operators - NTT DOCOMO, au (KDDI) and Softbank - make the Japanese telecommunications market highly competitive in the creation of new knowledge and technologies. By setting up a number of aid packages and funding programmes, the government also encourages R&D cooperation among various players engaged in ICT-related industries, including service operators and equipment and handset manufactures to meet changing market demands and harmonise IT systems according to the needs of subscribers (MIC, 2010). Such a government effort enabled Japan to strengthen its international competitiveness through differentiated products and services produced by a highly competitive domestic wireless telecommunications market.

Meanwhile, Korea has overtaken Japan's capabilities in wireless technologies and become a world leader in access to information via mobile and broadband networks, with the fastest speed of wireless/wired Internet in recent years, by successfully commercialising WiBro (Wireless Broadband) and 3G mobile (Fortune, 2011; Forge and Bohlin, 2008; Nam *et al.*, 2008). By adopting the Qualcomm CDMA (Code Division Multiple Access) standard service., Korea became the first country to commercialise 3G mobile over a CDMA20001xEV-DO network with the highest speed of voice or data transmissions and various application services, including satellite services (Forge and Bohlin, 2008). With improvements in the quality of handsets, there has been an upsurge in mobile Internet users in Korea, with 46 million mobile wireless broadband subscribers and 95 percent penetration, compared to a wired line take-up of 34.4 lines per 100

inhabitants in 2010 (OECD database). With a close political-commercial link, the government supported chaebols in quickly undertaking businesses in the fields of new technologies, such as mobile communications and wireless technologies. The leading operators driving the world-class wireless technologies are KT (Korea telecom), SK (Sung Kyung) telecom and LG (Lucky-Goldstar) telecom, while Samsung Electronics and LG Electronics are major handset manufacturing firms for production of related equipment and handsets (Kushida, 2008).

How have Korea and Japan managed to rapidly catch up with the ICT of advanced countries faster than in biotechnology, even though top policy priority has been placed on attaining both ICT and biotechnology development? Why do the ICT capabilities of Korea far surpass those of Japan in the creation of new technologies, especially wireless technologies, despite smaller investments and funding in Korea? To find these answers, this section discusses effective government policies and advantages of ICT innovation systems in Korea and Japan, with particular attention to mobile communications and wireless technologies. Since Korea's competitiveness in mobile telecommunication industry has recently overtaken Japan's in terms of production, sale, and export, I also critically analyse the contributions of key actors within the innovation system to the creation and diffusion of new wireless technologies in Korea after a review of literature on determinants of ICT innovation.

7.4.1 Literature on Information and Communication Technology Innovation

ICT is an emerging factor driving economic growth and social development in the recent knowledge-based society. The growth of ICT leads the emergence of a new economic business model that influences the speed of production, sales and foreign trade, as well as transforms innovation patterns from concentrated R&D to diversified R&D and network-based innovation (Fagerberg and Verspagen, 2002; Hobday *et al.*, 2004). As ICT evolves,

the access to knowledge and the cycle of change become easier and shorter, respectively, and hence stimulate the dynamics of knowledge flow, R&D cooperation and knowledge spillover across countries, industries and firms (Lipsey *et al.*, 1998; UNCATD, 2005; Maurer and Scotchmer, 2006).

A great deal of empirical evidence demonstrates the positive impact that ICT has on national income, firm performance, labour productivity or TFP and job creation (Bresnahan *et al.*, 2001; Pilat and Lee, 2001; Colecchia, 2002; Parham, 2002; Basu and Fernald, 2007; Guerrier and Padoan, 2007). Meanwhile, several studies on innovation have addressed ICT-related goods/services (e.g., computer, phone, Internet) as crucial components of S&T infrastructure that influences national technology capabilities and innovation (Archibugi and Coco, 2005; Fagerberg and Srholec, 2008). ICT-related goods/services allow access to the latest information and business transactions using electronic methods (e.g., e-finance, m-banking) and communication among different players, including suppliers, buyers and customers, in a way that is easier, faster and more convenient (also see UNCTD, 2007). Therefore, ICT contributes to the increase of labour efficiency, firm productivity and innovation performance, as well as the creation of more jobs.

ICT-related products/services encompass diversified mediums and tools for information and communication, such as radios, televisions, cameras, computers, telephones and the Internet. Recent mobile handsets cover all functions of the ICT by offering MP3 player, web browser, e-mail access, broadcasting service, digital camera, voice dialing and the synchronisation of information with computers (West and Mace, 2010). The Internet-enabled mobile phone is an invaluable tool to share, acquire, master, diffuse and transfer the latest information and knowledge and to interact with various people by communicating over a network in a digital era (UNCTD, 2007).

The Internet-enabled mobile phone, namely the smart phone, enables people to

communicate with one another from anywhere and to access various resources anytime; consequently, it enhances people's lives and methods of work. With these advantages, there have been a number of attempts to identify important determinants of diffusion and penetration of mobile phones and wireless technologies (Minges, 1999; Banerjee and Ros, 2004; Kim, 2005). As important factors influencing their penetration, the level of income (Baliamoune-Lutz, 2003), the degree of competitive broadband and mobile markets (Crandall *et al.*, 2002; Rouvinen, 2006), socio-cultural attributes (Kamssu, 2005) and telecommunications industry structure, pricing schemes and network externalities (Minges, 1999; Iimi, 2005) are highlighted in much of the literature. Also, the adoption and development of advanced wireless technologies by providing high-speed Internet and various services, including video calling, global roaming and upgrade services, lead the increase in subscribers and the demand for mobile phone services (Kim, 2005). The next section critically analyses success factors of ICT progress in Korea and Japan.

7.4.2 Rational Policies and Innovation Systems of Wireless Telecommunication Industry in Korea and Japan

Telecommunications is an important component of national infrastructure, as well as an essential element for new growth to replace the main export items (e.g., steel and automobiles) in Korea and Japan due to a fall in value and competitiveness incurred through a rapid change of techniques. To analyse in what way the two countries achieved rapid catch-up in ICT and a world-class wireless telecommunication industry, the rational policies and successful institutional reforms are the focus of this section.

Korea

The Korean ICT catch-up strategy was properly managed after the privatisation of state-owned telecommunications service carrier, namely Korea Telecom (KT). Starting from

the public announcement of the privatisation plan in 1987, KT became fully privatised by 2002, which was protracted for 15 years (Choi, 1997; Yoon, 1999). KT had the crucial role in building up national infrastructure for the information society as a major performer of ICT policies (Yoon, 1999). Until the mid-1990s, the Korean government directly determined the sale price of its shares in KT as well as controlled foreign investors and their investments in the domestic telecommunications industry for fear that local firms related to ICT would go bankrupt by competing with foreign firms with advanced technologies (Choi, 1997). The government had sold only 20 percent of its shares of KT by 1994 and still had its ownership and managerial power despite outside pressure, especially from the U.S. government and the World Trade Organisation (WTO) (Singh, 2000, Jin 2006).

Korea started to speed up KT privatisation after 1994 when the government formulated its policy towards 'Segyehwa' (globalisation in Korean) consistent with the global movement for privatisation, liberalisation and competition as an important political agenda. Under the Segyehwa policy, the government pushed privatisation of state-owned public firms including KT, as well as liberalisation of international trade and foreign ownership (McClelland *et al.*, 1997; Jin, 2006). At the time, the telecommunications sector was liberalised by an increase in economic demand for Korean telecommunications market entry from national and transnational corporations because both foreign and domestic firms were interested in communication service as a lucrative business to increase their value. Also, regulations for foreign ownership in Korea's telecommunications market were relaxed under outside pressure (Choi, 1997).

The main motive for privatising the state-owned telecommunications enterprise is distinct from other countries. Many countries suffered from bad debt caused by the government's monopoly, and consequently they formed the privatisation plan to improve managerial inefficiency and firm performance (Hills, 1998). However, KT had no

financial difficulties and enjoyed constant increases in revenues and net profits until it was fully privatised in 2002. The net profits of KT increased eight times from 1996 to 2001 while annually raising revenue by more than 10 percent during the same period (KT, 2001). The main driving forces for privatising KT and opening the Korean telecommunications market were the US government, the WTO the International Monetary Fund (IMF) (Singh, 2000).

The Segyehwa policy resulted in large reform of Korea's telecommunications industry, changing from a monopoly-controlled industry with a national-based business to a competition-based industry with international-based business (Hills, 1998; Jin, 2006). To prevent a monopoly of KT in the telecommunications service market, the government transferred its ownership to the private sector; it facilitated chaebols (i.e., SK and LG) to expand their share of the telecommunications market to compete with a privatised KT by setting up a three-competition policy (Jin, 2006). KT had been the dominant telecommunications service operator, accounting for 97 percent of market share for local phones, 86 percent for long-distance phones and 64 percent for international phones before the privatisation was completed in 2002 (Jin, 2006). Also, the government set up a series of R&D programmes to build competitive telecommunications industry. The Ministry of Information and Communications (MIC) was in charge of policy implementation and regulations for expansion of corporations in the telecommunications market in Korea.

Table 7.10 presents Korea's government initiatives and the specific targets for ICT growth over twenty years. Starting with 'Cyber Korea 21 strategy' (1999-2002), broadband networks and wireless technologies were largely funded by the government to help transform Korea into an ICT powerhouse with the highest Internet access rate in the world. In this regard, the government formulated the 'Act on Closing the Digital Divide' in 2001 so that broadband Internet service could become a universal service.

Table 7.10 Korea's ICT Policies

	Key ICT Strategy	Focus
1987-1985	Measures to Nurture IT Industry	Developing manufacturing techniques.
1987-1996	National Basic Information System	Improving administration, defence, public security, finance and education.
1995-2005	Korea Information Infrastructure Initiative	National information superhighway.
1996-2000	National framework Plan for Informatisation Promotion	Ten priority areas annual action plans.
1999-2002	Cyber Korea 21	A creative knowledge-based society.
2002-2006	E-Korea Vision 2006	Maximising the ability of all citizens to use ICTs.
2004-2007	IT 839 Strategy	Preparing for ubiquitous network society and improving competitiveness.

Source: compiled by the data from Lee (2005) and Forge and Bohlin (2008).

With the success of broadband penetration, the Korean government established 'IT 839 Plan' in 2004 with the ambitious goal of a ubiquitous network society. This was a comprehensive and systematic programme covering all ICT areas, including broadband services, infrastructure networks and digital devices (see Table 7.11). It was designed by the MIC for developing eight service sectors, three infrastructure sectors and nine technology sectors to attain the national goal of development of the domestic ICT industry with universal availability of broadband and the reinforcement of international competitiveness with next-generation wireless communications technology in the world telecommunications market (ETRI, 2008). Under the IT 839 Plan, wireless technologies were considered essential elements for a ubiquitous network society, while focusing on the progress of RFID (Radio-frequency identification) chips, embedded software and 4G mobile to increase global telecommunications market shares (Lee, 2005). The current ICT policy are intended to create advanced wireless technologies and fourth-generation ICTs at the global level, as well as to provide high-speed wired/wireless broadband Internet

services to all households by 2015 so that Korea stands as the worldwide ICT leader.

Table 7.11 Key areas of IT 839, Korea

8 Services	3 Infrastructures	9 Technologies
WiBro Service; DMB Service; Home Networking; Telematics Service; RFID based; W-CDMA Service; Terrestrial Digital TV; VoIP.	Broadband Convergence Network; Ubiquitous Sensor Network; Next Generation Internet Protocol (IPv6).	Next Generation Mobile Communications; Digital TV; Home Networking; IT System on Chip; Next Generation PC; Embedded Software; Digital Contents; Telematics; Intelligent Service Robots.

Source: compiled by the data from ETRI (2008).

The widespread availability of broadband (the Internet) access has been the engine of Korean economic growth and technological catch-up in the present decade (OECD, 2004). By 2008, more than 94 percent of Korean households had broadband connections via computers and mobile phones, an increase of about 65 percent from 2000, while almost 100 percent of all Korean businesses used broadband to access the Internet through various modalities, including ADSL, VDSL, cable and fibre/LAN modes (OECD Database). The speed of Korean broadband - VDSL (Very high bit rate Digital Subscriber Line) – is the world’s fastest at 14 Mbps, seven times faster than the global average (1.9 Mbps) (Fortune, 2011).

With the fixed broadband, Korea developed WiBro, which is its own wireless broadband Internet technology, enabling mobile subscribers to download/upload data and browse the Internet at broadband data rates (Nam *et al.*, 2008). As a result, Korea became the largest OECD country in terms of mobile wireless broadband penetration; 95 percent of subscribers used mobile Internet services in 2010 (OECD Database). The high percentage of Korean Internet access via mobile phone was attributable to the introduction of the advanced 3G technology network, namely CDMA1xEV-DO

(Evolution-Data Optimized), which offered voice and data transmissions at high speeds (up to 2.4M bit/sec) and supported a wide range of application services, including traffic information, m-banking, broadcasting, location services and stock prices in real time (Forge and Bohlin, 2008). CDMA1xEV-DO is the latest 3G wireless telecommunications technology to rapidly transmit large packet-sizes, with speed that is 16 times faster than the previous version of CDMA2000 (Qualcomm, 2009). Although Japan invented a 3G mobile network with NTT DOCOMO's FOMA, 3G mobile service over the CDMA1xEV-DO network was first commercialised by Korean telecommunication operators (e.g., SKT), which enabled Korea to move ahead of its competitors, including Japan, in share of the global 3G mobile market (Forge and Bohlin, 2008).

Korea also developed radio technologies to increase 3G network coverage. In Korea, 18,000 commercial WiFi hotspots had been installed by 2004, making up nearly one-third of the world's total (49,577) (Kushida, 2008). The types of technologies used and produced in Korea include WiFi (IEEE 802.11x), WiMax (IEEE 802.16x), Mobile-Fi (IEEE 802.20), ZigBee (IEEE 802.15.4), Bluetooth, (IEEE 802.15.1), Flash OFDM (IEEE 802.20) and UMTS3GPP W-CDMA, which are the frontier radio technologies that Korea holds (Kushida, 2008). These radio technologies have contributed to the improvement of 3G mobile broadband accesses and formed a foundation of the development of next-generation wireless technologies for 4G LTE.

The operators driving the above wireless technologies are KT and two chaebols' subsidiaries, SK Telecom and LG Telecom. Also, chaebols including Samsung, LG and Hyundai, are the leading manufacturing firms to produce the related chips and equipments (Kim *et al.*, 2004). Wireless technologies have been regarded as invaluable export items, and hence Korea has attempted to elevate them to world-class status by forging alliances with foreign organisations. For example, Korean mobile operator SK telecom and American Internet service provider (ISP) EarthLink established the 3G/WiFi combo joint

venture in the United States to leverage their innovation in new wireless voice and data services (EarthLink, 2005). More Recently, SK telecom has made partnerships with Qualcomm and Nokia Siemens Networks to develop the core technology of 'Enhanced Inter-Cell Interference Coordination' for LTE-advanced (SKT, 2012).

Japan

Japan has a relatively long history focusing on the development of telecommunications industry as a national growth, starting with the establishment of Nippon Telegraph and Telephone (NTT) and Kokusai Denshin Denwa (KDD) in 1952 (MIC, 2001). However, Japanese ICT diffusion lagged behind Korea and the United States in Internet penetration and the number of broadband subscribers as a proportion of the population in 2000 (MIC, 2006). This brought about the revision of existing ICT policies and the formulation of sequential development plans in Japan with the aim of fostering an advanced ICT network society by rapidly deploying high-speed networks at low prices to all part of the country (MIC, 2006). Table 7.12 summarises the evolution of ICT policies in Japan.

The e-Japan strategy proposed the construction of a high-speed backbone network to expand broadband connections and penetrations. It resulted in the upsurge of broadband users, indicating that 35 million households had a constant connection to a digital subscriber line (DSL); 23 million households had cable TV and 17.7 million households had fiber-to-the-home (FTTH) connections by 2003 (Naito and Hasuman, 2005). With such a successful outcome, attention turned towards the issue of ICT usage by developing the e-Japan Strategy II in 2003. Seven areas were selected for intensive usage promotion - health care, diet, lifestyle, financing for small businesses, knowledge, labour and administrative services (MIC, 2010). At the end of the year, the government drew up the *u-Japan* plan, focused on facilitating the development of 'ubiquitous networks' by integrating applications, hardware and wired/wireless networks. The *u-*

Japan plan had a similar goal as the *e-Japan II* strategy that focused on balances ICT infrastructure with ICT usage, but it placed more emphasis on cooperation with other Asian countries for the next-generation technologies. Under the *u-Japan* plan, Japan worked on R&D projects with China and Korea to implement the next-generation IP standard IPv6 (MIC, 2010). Despite these efforts, Japan is still a laggard in fixed and mobile broadband penetrations compared with Korea (ITU Statistics).

Table 7.12 Japan's ICT Policies

Ministry of Internal Affairs and Communication's IT Policies (2001-2004)		Development of broadband infrastructure and other advanced communication services.
2001	e-Japan strategy	Establishment of high-speed backbone network, promotion of education and learning system, e-commerce and e-government, and ensuring the security and reliability on advanced information and communication network.
2003	e-Japan strategy II	Promotion of IT usage in 7 leading areas: health care, diet, lifestyle, financing for small business.
2004	e-Japan strategy II accelerated package	Acceleration of the e-Japan strategy II implementation, aiming at the most advanced IT nation in the world by 2005.
Ministry of Internal Affairs and Communication's u-Japan Policies (2005-2010)		Realisation of autonomous and ubiquitous networked ICT society
2005	IT policy package	Development of ubiquitous network (both wired and wireless networks), advanced usage of ICT to assist in resolving social issues and improvement of the environment for ICT usage in a safe and secure manner.
2006	IT new reform strategy	Making all areas of Japan accessible to broadband by 2010 and dissemination to the world.

Source: Compiled by the data from MIC white papers (various years).

However, Japan has entered to the world top country in terms of 3G (mobile broadband) penetrations (95%) in 2012, after leapfrogging Korea (85%) and the United States (64%), which is attributable to effective government policies and reforms for wireless telecommunication industry. NTT has played the pivotal role in upgrading ICT infrastructure and creating new wireless technologies. NTT was the first inventor to develop analogue wireless cellular service using the PDC format, which was a proprietary

format used only in Japan until global standards were adopted (Lallana, 2004). Also, the development of 4G LTE (the latest wireless data communication technology was first proposed by NTT DOCOMO under the name of Super 3G in 2004, which enable operators to upgrade the standard with faster transmission speed and higher capacity on the GSM/EDGE and UMTS/HSPA network technologies (NTT DOCOMO, 2012).

Japan's government started to privatise NTT and liberalise its telecommunications market for a fair competition in the early 1980s, which was almost twenty years earlier than in Korea, by formulating the 'Telecommunications Business Law', the 'NTT Law', and the 'Background Law for the Telecommunications Law' (MIC, 2005; Kushida, 2005). After the completion of NTT privatisation in 1986, the government introduced a decentralisation policy to prevent monopolies, arranging cellular carriers' business areas by dividing into nine districts and placing strict restriction on the entry of new in other zone; IDO provided service to the Tokyo and Tokai region under the name Tokyo Digital Phone (later to become part of Softbank), while DDI concentrated on the Western district, such as Osaka, under the name Tsuka Cellular (later consolidated into KDDI) (Kushida, 2002, p.61).

Entering the 1990s, the government undertook a deregulation process with a relaxation of foreign ownership restrictions. Under the deregulation policy, the manufacture of handsets was liberalised, allowing service providers to purchase handsets from external sources. All handsets were manufactured by NTT before then (Kushida, 2002). Also, there was widespread consolidation among cellular carriers. J-phone was established after merging Digital Phone and Digital Tsuka in 1999. IDO and KDD consolidated into KDDI in 2000, standardising its brand nationally as 'au' for CDMA service, and retaining Tsuka for PDC service (Abu, 2010; Kushida, 2005; Lallana, 2004). The cellular division of NTT was also spun out and created NTT DOCOMO, which was the largest market-capitalised corporation, accounting for more than 50 percent of the

market share in Japan (Abu, 2010). The main three cellular carriers, NTT DOCOMO, au (KDDI) and Softbank, have close ties with large consumer electronics companies producing cellular handsets; NEC provides equipments to all three services, but Sony offers handsets only for NTT DOCOMO and KDDI and Sanyo produces handsets solely for KDDI's service (Kushida, 2002). In addition, the leading global handset manufacturers, Ericsson, Nokia and Motorola, could enter the Japanese handset market to work together with Japanese handset manufacturers, which enables them to rapidly catch up and upgrade innovation capabilities with sophisticated cellular equipment (Tee and Gawer, 2009; Abu, 2010). In 2008, total mobile cellular subscribers numbered 112.05 million with 88 percent penetration, indicating the mobile phone market had reached realistic near-saturation stage, of which DOCOMO accounted for 51.2 percent market share. Two other carriers, au and Softbank, held 28.9 percent and 18.9 percent of market share, respectively (TCA and ITU databases).

In the 2000s, there has been a large fluctuation in carriers of market share after when 3G services were launched in Japan. At the beginning (not actually 3G but 2.5G), au was the largest 3G service provider with 85.5 percent market share, but its market share had significantly diminished to 27.5 percent in 2010. Although DOCOMO held only 13.7 percent market share, their market share sharply increased to 48.4 percent in 2010, the result of offering a number of innovative services to subscribers with handsets and pricing strategies (TCA database). Also, there was another 3G mobile services provider, namely EMOBILE. In 2007, EMOBILE entered into 3G mobile phone markets with only 60,200 subscribers, but expanded its subscribers to 3.2 million as of April 2011 with attractive pricing, marketing and service offering (TCA database). DOCOMO, Softbank and EMOBILE used W-CDMA technology which was widely used in Europe, while only au (KDDI) introduced CDMA2000 standards invented by Qualcomm. The maximum download speeds of CDMA2000 and W-CDMA are 2.4 Mbps and 14.4 Mbps,

respectively (MIC, 2010). With SK telecom, which is also the major CDMA operator in Korea, au KDDI announced to change its standard to LTE and fully commerce LTE services by 2013 (SKT, 2012).

Regarding wireless Internet on mobile phones, the four carriers introduced Internet protocol (IP) functions to mobile phone networks and competed with provide content such as web browsing and email services (Abu, 2010). DOCOMO provides Internet services through i-mode, au through EZweb, Softbank through Yahoo!Keitai and EMBILE through EMnet (Chen *et al.*, 2007; MIC, 2010). With the invention of i-mode, DOCOMO holds the largest share in 3G networks and handsets. DOCOMO is superior in its competitive services in quality; it provides more sophisticated and user-oriented services, including video mail, high-speed web access, downloads (e.g., games) and multimedia facilities by allowing video, audio and graphic applications. Such innovative handset functions led subscribers to sign up for DOCOMO's 3G FOMA services and thereby strengthen its market power (MIC, 2010).

7.4.3 Strengths of Policies and Innovation Systems of Wireless Telecommunication Industry in Korea and Japan.

Korea and Japan have maintained the leadership position in the penetration of mobile phone broadband and Smartphone users, with continued innovations in the improvement of mobile coverage and take-up and the creation of next-generation wireless communications technology for a new standard, such as 4G LTE (OECD, 2006; ITU Statistics). Several overlapping factors behind the rapid catch-up in wireless technology in Korea and Japan are discussed below. There are three major contributors to Korea's and Japan's innovation system for the development of ICTs and wireless telecommunication industry. The first is government. As an ICT catch-up strategy, both governments formed regulatory and competitive policies for orchestrating the telecommunications sectors and

ensuring fair competition by controlling monopolies.

To equip the ground for the information society, the government in Korea and Japan established NTT in 1952 and KT in 1981. NTT and KT were state-owned organisations and had exclusive rights as local service providers until they were privatised. With the market allowing pressure from the US government, Japan started to undertake NTT privatisation in 1982, when American Telephone and Telegraph (AT&T) was entirely dissolved, and completed its privatisation in 1982 (MIC, 2005). NTT played the leading role in drawing up ICT growth policy and setting up technical standards, while controlling the market entry of equipment manufacturing firms. Large equipment manufacturers, such as Fujitsu, NEC, Hitachi and Oki Electric, joined the NTT R&D programmes as contractors and partners (Kushida, 2002; 2005). Meanwhile, KT was gradually privatised over ten years under state control. KT started for privatisation in 1993 by selling the shares owned by the government, and then was fully privatised by selling off all equity and ownership in 2002 under the World Trade Organization (WTO) Agreement on Basic Telecommunication Services. KT played a key role in universal broadband service provision and advanced wireless technologies generation, such as WiBro, to increase high-speed Internet market penetration and boost the global competitiveness of the Korean information technology (IT) market (Singh, 2000; MITI, 2008). Despite almost twenty years later than Japan, Korea's rapid catch-up with Japan in the field of ICT might be partly attributable to the gradual reform toward KT privatisation.

After privatisation, the Japanese and Korean governments placed strict restrictions on the entry of NTT and KT into new ICT markets, such as the cellular mobile market, for fear of market monopolisation by them. Such a regulatory policy promoted the rapid growth of private service operators (e.g., Japan: au by KDDI and Softbank; Korea: SK telecom and LG telecom) and led keen competition among them to create new technologies and differentiated products. For a fair competition, the countries introduced

a standard price model with a low cell phone rate that stimulates telecom operators to set up attractive service packages with a competitive marketing campaign to survive in local wireless telecommunications markets (Lallana, 2004; Jin, 2006). This could produce a surge in mobile demand, mobile subscribers and mobile Internet users.

Likewise, both the Korean and Japanese governments actively intervened in the telecommunications industry to expand ICT usage by making Internet access with high transmission speeds universally available, while facilitating active cooperation among service operators, cell phone makers and electronics companies (e.g., flat screens, certain chips) to create advanced wireless technologies (MIC, 2005; MITI, 2008). To upgrade their telecommunications industries, the government promotion followed a three step-process. The governments promote new telecommunications projects, seed new network provision and then encourage the private sector to participate in the projects by setting up various incentives (Jin, 2006). The main public R&D institutes in Japan are the National Institute of ICT, the New Generation Network Research Centre, the Information Security Research Centre and the Applied Electromagnetic Research Centre. The Electronics Telecommunications Research Institute, National Communication Association and National IT Industry Promotion Agency are major official R&D organisations related to ICTs in Korea. They have played the pivotal role in formulating and implementing new ICT programmes supporting the private sector's R&D and cooperation between service operators and handset manufactures to develop next-generation core technologies needed for the latest wireless communication standard, such as LTE (MITI; 2008; MEXT, 2008).

Remarkably, the rapid catch-up of the Korean fibre optics industry is also the result of government efforts. As the catch-up strategy, the Korean government energetically pushed to build a fibre asynchronous transfer mode (ATM) backbone from the middle of 1990s onwards. The pilot project to test and connect the ATM network with a fibre optic backbone was first executed in all government offices, and then telecom

operators, including KT and Dacom (the former LG Dacom), were commissioned by the government in a ten-year plan to develop backbone fibre networks and operate them all over the country (MITI, 2008). It implies that the government initially undertook a risky projects that is costly and uncertainty and then encouraged private sector telecom operators to invest in the project after taking out the start-up risk. To attract investment from the private sector, the government offered funding for fibre optic research and low-interest loans for building broadband infrastructure.

Second, large consumer electronics firms, Japan's MNEs and Korea's chaebols, have played the leading role in the development of wireless telecommunication industry as ICT users and equipment manufacturers. Korea's chaebols, SK and LG act as handset manufacturers as well as service providers. They have long participated in the Korean and Japanese telecommunications service markets as equipment manufacturers, starting from Time Division Exchange (TDX) Project, which is the electronic telephone exchanger entirely developed with their own domestic technologies. They joined the project for TDX invention under a government initiative because it required significant R&D and highly sophisticated techniques in the fields of electronics, semiconductors and computer software (Larson, 1994; 1995). The TDX became the foundation for upgrading their scientific technology capability to a higher level, and subsequently becoming world-class telecommunications equipment producers with strong competitiveness in exports. Recently, the Korean chaebols, especially Samsung and LG, have leapfrogged and outperformed Japanese large manufacturers (e.g., Matsushita, Mitsubishi and Sony) and become the world leader as 4G handset manufacturers and inventors of core technologies for upgrading 4G LTE.

Regarding cooperation between handset manufacturers and service operators, Korea has more effective collaborative relationships between them, whereas a superior to subordinate relationship exist in Japan. Since NTT DOCOMO has its own network

standard (the PDC standard invented by NTT), manufacturers (e.g., Sony) are required to obtain permission from the DOCOMO to sell the same handsets ordered by DOCOMO to other providers (Kushida, 2002), which might make Sony to be a laggard in the creation of new technologies in response to technical change as well as consumers' need. Although Sony had the leadership in the creation of 2G and 2.5G mobile phones, this company has been crowded out of the world mobile phone market by Korean Samsung and LG in the recent of Smartphone area (ITU Statistics).

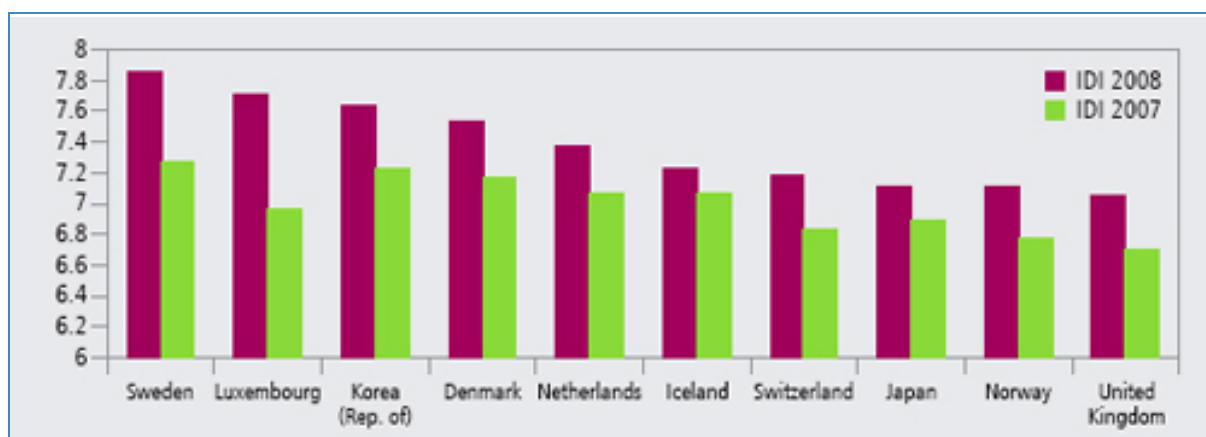
Third, an educational institution is the key contributor to the improvement of ICT-related products and services, especially Korea. Korea's information technology education system has focused on the spread of knowledge throughout the whole nation to produce well-qualified people so as to make Korea rich in human resources. This differs from Japan's elite-based system (the Oxbridge model), which selects a small number of outstanding people by setting up strict valuation criteria and then intensively trains these individuals. In this sense, there have been many IT facilities across the whole extent of Korea and the widespread training of all the people in the country in IT skills, which is a feature distinct from other advanced countries, including Japan (Forge and Bohlin, 2008). There is no doubt that the financial crisis (1997-1999) was a turning point for Korea's information society. The government established information technology training programmes for the jobless to resolve massive unemployment caused by a large-scale restructuring of chaebols and many companies' bankruptcy during the crisis. The unemployed who completed an entire training programme could receive a certificate issued by the government in addition to chances for employment in the field of ICT (Forge and Bohlin, 2008). Also, the programme educates adults in IT skills by offering free IT classes so that they feel a sense of closeness with ICT goods, such as a computer, can access the Internet and can communicate with people over a network. It leads to an upsurge in users of broadband and mobile Internet, and by extension development of the

telecommunications industry due to increased demand for high-quality ICT goods and services in Korea (also see MITI, 2008). Hence, Korea's education institutions have made a great contribution to the rapid catch-up with ICT in Japan.

7.4.4 Summary and Discussion

Korea and Japan have achieved rapid ICT catch-up with the frontier countries in the penetrations of fixed/mobile broadband and mobile phone users, which are attributable to effective government ICT policies and institutional reforms supporting continued innovation in the creation of new wireless technologies and rapidly deploying the technologies on a commercial scale. Figure 7.3 shows the world's top ten countries in the ICT Development Index (IDI). The IDI is a comprehensive indicator that is useful in comparing the level of ICT capabilities among countries. It covers ICT infrastructure, use and skills, fixed telephone penetration, mobile cellular telephone penetration, international Internet bandwidth (bit/s) per Internet user, proportion of households with a computer, proportion of households with Internet access at home, Internet penetration, fixed broadband penetration, mobile broadband penetration, adult literacy rates and gross secondary and tertiary enrolment ratios (ITU Statistics). According to the IDI, Korea has the third highest level of informatisation while Japan has the eighth highest ranking in the world, implying higher ICT capabilities, competitiveness and performance in Korea than in Japan. Among ICT infrastructure indicators, Korea is the world's top in terms of both wired and wireless broadband penetrations (ITU Statistics). Korea's success in the development of ICT infrastructure can be attributed to effective ICT policy and robust government initiatives toward an ICT-friendly environment. Remarkably,

Figure 7.3 Top 10 countries in the ICT Development Index (2007-2008)

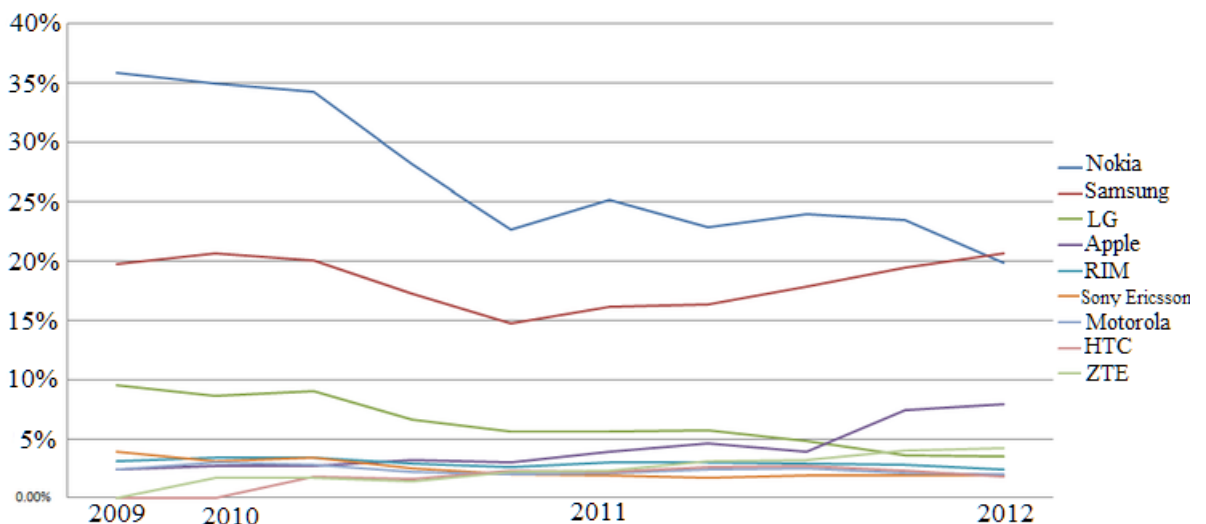


Source: Compiled by the data from ITU statistics

Both Korea and Japan have successfully transformed its telecommunications industry into a highly competitive market by privatising the state-owned operators (NTT and KT) and stimulating the market entry of private service providers (au by KDDI, Softbank, SK telecom and LG telecom), while ensuring fair competition among service operators and ICT-related equipment suppliers (Kushida, 2002; Jin, 2006). The interventionist policy restricting incumbent operator dominance (Korea's KT and Japan's NTT DOCOMO) and a legal prohibition on its mobile license (e.g., an exclusive sales contract) have improved the supply side including cellular carriers, handset manufacturers and content providers in the creation of innovative technologies, which lead to upsurge in mobile network users and handset demand (Kim, 2009). The cellular carriers quickly migrated to new standard for wireless data communications technology, such as LTE (fourth-generation long-term evolution), while creating the next-generation of core wireless technologies to upgrade the network to win over users in the heavily saturated mobile phone market in Korea and Japan (NTT DOCOMO, 2012). Korea is the first county to commercialise LTE service that covers the entire county, and has become the world leader in terms of the penetration of LTE network users with 15 percent (Korean Times, 07-22-2012).

Korea's handset manufacturers (e.g., Samsung and LG) have also overtaken Japan's Sony (Sony Ericsson) in the world handset market share. Figure 7.4 shows Samsung has been ranked as the world top and Sony as 9th in the world mobile phone market share in 2012. Until the early 2000s, Sony had the world leadership with Nokia and Motorola as a handset vendor and it was forecast to grow continuously and conquer the world 3G mobile phone market (KIEP, 2012). At that time, Japan's cellular phones were innovative in miniaturisation of size and sophistication (e.g., camera phone), while commencing the world first a mobile Internet service (i.e., i-mode) and picture messaging service. However, Sony has been suffered from Galápagos Syndrome, implying the phenomenon of a rapid decrease in international competitiveness by entering a new phases due to a product evolving in isolation from globalisation (KIEP, 2012). The insufficient strategy to improve brand value and the quality adapting to the changing in the environment could cause the huge drop in 3G/4G mobile phone market share of Sony.

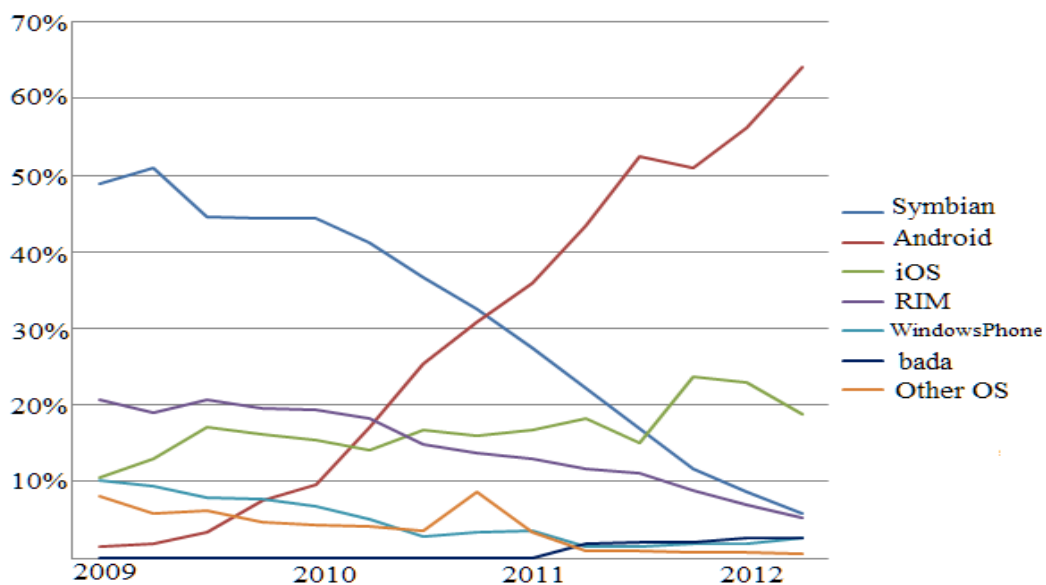
Figure 7.4 Global Market Shares of Handset Manufacturers (%), 2009-2012



Source: Compiled by data from Gartner report (2012).
<http://www.gartner.com/it/page.jsp?id=2120015>

Despite the market share of Symbian-based devices continued to decline against rival platforms led by Google's Android and Apple's iOS, Sony remains as the largest support for Symbian with Nokia (see Figure 7.5). Sony has used it as the key operating system (OS) over the past decade (Gartner, 2012). The failure of Symbian's evolution caused by passive response to the rapid change of mobile Internet trends could not attract both software and hardware developers, including content providers, which also might be the main reason for the collapse of BlackBerry's RIM. Nevertheless, Sony did not quickly abandon the support and belatedly dealt with this problem. Realising the magnitudes of the problem, recently Sony has started to transfer to Google's Android OS for its Smart phone, together with another platform led by Microsoft (Financial Times, 10-15-2012).

Figure 7.5 Global Market Shares of Smartphone Operating Systems (%), 2009-2012



Source: Compiled by data from Gartner report (2012).
<http://www.gartner.com/it/page.jsp?id=2120015>

Meanwhile, Samsung produced a variety of Smartphone operated by its own OS of Bada and other platforms, including Android, Symbian, Bada and Windows mobile enabled Samsung in a transition period to quickly adapt to digital evolution (KIEP, 2012).

After many trials and errors, the focus on Android (OS for a high-priced Smartphone) and Bada (OS for a mid-priced Smartphone) has allowed Samsung to strengthen international competitiveness in 3G and 4G mobile phone market (Financial Times, 10-15-2012). Although the concentration on the production of new mobile phone to increase profits, while offering limited services, such as upgrade service (the previous version of OS), have been criticised by mobile phone users who purchased Samsung's handset in the transition period (KIEP, 2012), Samsung has gained increasing recognition for technological sophistication and design, and become the world top in the global handset market share in 2012 (See Figure 7.4). *“Samsung and Apple continued to dominate the smartphone market, together taking about half the market share, and widening the gap to other manufacturers. No other smartphone vendors had share close to 10 percent. In the race to be top smartphone manufacturer in 2012, Samsung has consistently increased its lead over Apple, and its open OS market share increased to one-and-a-half times that of Apple in the second quarter of 2012”* (Garter, 08-14-2012).

7.5 Conclusion

I have undertaken case studies on innovation systems and policies of the biotechnology and wireless telecommunication industries in Korea and Japan. These two industries are the path-creating catch-up models, implying that latecomer firms explore their own path of technological development and innovation, but their catch-up speeds and performance differ: slow catching up of biotechnology and rapid catching up of wireless telecommunications.

Many parallels exist between Japan's and Korea's innovation systems in biotechnology versus those of the frontier countries, such as the United States. First, the public sector, including nationally funded universities and government-sponsored laboratories, is the dominant player (over private universities and corporate research

institutes) in the generation and diffusion of scientific knowledge because the majority of star scientists work in public institutes under a restrictive system that limits their working with the private sector in both Korea and Japan (Park, 2004; Lehrer and Asakawa, 2004). Second, the immobility of resources related to biotechnology creates weak state-academia-industry cooperation in these countries. The matter of a weak relationship among innovators in biotechnology innovation systems is more pertinent to Korea, with lower numbers of cooperative patenting and lower levels of joint R&D than Japan (Castells and Hall, 1994; Rhee, 2003). Third, private universities and biotechnology ventures make relatively lower contributions to the biotechnology innovation systems of Korea and Japan than public research institutes and large industrial firms. Regarding biotechnology R&D, the established firms receive the largest share of the total R&D spending over biotech ventures in both countries because of the low availability of venture capital, whereas biotech entrepreneurs or new biotech firms originated from university spin-offs have greatly contributed to development of the bio-industry in the United States (Bartholomew, 1997).

However, the rapid technology catch-up of wireless telecommunication industries in Korea and Japan suggests that the wireless telecommunication industries are largely unaffected by the low capabilities of university R&D and spin-offs and weak state-academia-industry cooperation, which are the delay factors affecting biotechnology catch-up performance in these countries. Instead, the pursuit of a competitive R&D environment, in-house R&D and inter-firm linkages (rather than international partnership) and home-grown talents made a big contribution to the progress of wireless telecommunication and ICTs in Korea and Japan. Hence, this study suggests that the triple helix paradigm that emphasises the role of universities for balanced growth based on university-industry-government relationships might be an appropriate model for biotechnology industry environment, but inappropriate for wireless telecommunication

industry environment. Both countries have achieved huge catch-up success in wireless telecommunication industry despite the lack of university R&D capabilities, inactive cooperation between academia and industry, as well as a low level of international partnership.

Korea's ICT capabilities in the creation of new products and services have even overtaken Japan's capabilities. This provides some lessons. First, the government has created a medium-term strategy for ICTs so that it can adjust its plan against the constant evolution of digital techniques, including broadband networks and digital devices. This differs from other OECD countries' long-term ICT programmes. Also, Korean ICT programmes are pragmatic and systematic with clear policy targets. For example, the IT 839 strategy targeted the collaborative development of three areas - ICT services, ICT goods and infrastructure networks. Concretely, eight service sectors, nine product sectors and three infrastructure sectors were intensively fostered as new strategic businesses with the aim of a ubiquitously networked Korea. Therefore, government intervention has enabled Korea to remain the worldwide leader in terms of wired/wireless broadband penetration with a super-highway information network. Second, the Korean government efficiently uses revenues gained from spectrum licenses and taxes on operators to reinvest in the field of ICTs by introducing spectrum auctions. Such a strategic government reinvestment from spectrum fees and taxes has contributed to the improvement of national telecommunications infrastructure and the creation of next-generation core technologies while boosting exports. Third, interventionist policy for fair and free competition without dominance by incumbents has spurred the rapid catch-up with mobile and wireless technologies of the United States and Japan. To create a highly competitive mobile market, the Korean government has annually reformed its telecommunications regulation policy and regularly inspected chaebols to restrict their excessive expansion and market share. This has increased IT venture firms (equipment

suppliers) and facilitated their cooperation with service operators in the creation of cutting-edge products and consequently led a surge in Smartphone demand and users in Korea.

CHAPTER 8

Discussion and Conclusion

The main aim of this thesis is to examine the dynamics of national technology capabilities and sectoral catch-up in Korea and Japan in relation to policy and institutional changes by focusing on regulation, finance system, national innovation system (NIS), sectoral innovation system (SIS) and intellectual property (IP) regime. On the basis of a review of relevant literatures, I developed a theoretical framework and a methodological framework to address four research questions, namely: (1) *In what way do government regulation and policy affect technology catch-up and national technology capabilities?* (2) *In what way do key actors within NIS and contextual factors affect technology catch-up and national technology capabilities of Korea and Japan?* (3) *What determines the occurrence and speed of catch-up and the level of technology capabilities in Korea and Japan?* (4) *What are key contributing and delay factors affecting the catch-up success in biotechnology and wireless telecommunications industries in Korea and Japan?* These questions leading to specific hypotheses and propositions are analysed by both a historical comparative analysis and a quantitative analysis. The findings relating to the four questions are discussed in terms of theoretical and empirical contributions, and policy implications. The limitations of this thesis and directions for further research are also discussed in the last section.

8.1 Key Arguments and Findings

This section summaries the main findings and arguments derived from theoretical and empirical analyses for the research questions of this thesis. The first sub-section discusses the estimation results for policy and institutional effects on national technology capabilities across countries. The findings are the negative effect of liberal economic

system for domestic market entry and capital flow, but the positive effect of a low regulatory burden on international trade on national technology capabilities. In addition, I found that the size of government acts as a moderator of regulation and foreign trade effects on national technology capabilities. This indicates that small government size in conjunction with the liberalised domestic market and foreign trade facilities technology investment and creation. The second sub-section discusses specific institutional conditions for causal relationships between technology input and output in the context of Korea and Japan. The findings are more effective public R&D and more dependence on foreign technology transfer in the development of national technology capabilities in the Korean innovation system. The third sub-section discusses key determinants of technology catch-up occurrence, speed and performance. With a sectoral analysis of biotechnology and wireless telecommunications technology key delaying and contributing factors affecting technology catch-up performance have been identified. Using a comparative benchmark of Japanese firms, Korean firms show better performance in catch-up speed in industries that require more explicit knowledge, higher degree of embodied technology transfer, shorter product cycle, easier access to external knowledge and higher appropriability. More detailed discussions on these findings are provided in Chapters 5, 6 and 7.

8.1.1 Government Policy and Regulation and Technology Capabilities

The first research question leading to specific hypotheses on the impacts of government policy and regulation on national technology capabilities across countries was empirically tested. On the assumption that restrictions on market entry, transactions and foreign trade with larger size of government over the private sectors interrupt the dynamics of innovation activities, I examined three institutional and policy factors as determinants of national technology capabilities: (i) liberal (or controlled) systems of credit and labour

markets, and business; (ii) freedom (or restriction) on international trade; (iii) large (or small) size of government.

First, I found that government regulation in credit, labour and product markets positively affects national technology capabilities. This was a surprising result, since I anticipated that government intervention in the marketplace could hinder the dynamics of innovative activities. A strict government regulation implies that prices and wages are determined by the government (not by competition), and that resource allocation, knowledge transfer and entrepreneurial process are controlled by the government (Allen et al., 2006; Fay et al., 2007). The possible reasons for a positive correlation between government regulation and national technology capabilities are as follows. Firstly, the sample of high-income and upper middle-income countries used in this empirical study could produce such an effect opposite to what was expected, since they have relatively free market systems, engaging in voluntary exchange and allocate resource to private parties by the market force, compared with low-income countries. In the contexts, excessive liberal systems with no government interference could yield myopic behaviours of market participants, seeking immediate profit and focusing on short-term creation and investment, since innovation inherently involves in high uncertainty. Secondly, free market entry without any strings attached could produce make excessive and unfair competitive environment, making a low chance of survival of new start-ups and S&M businesses. The blindly reliance on the principle of the market economy without any government interventions in market access could cause the monopolisation of established firms since the entry of new firms are incapable of competing with them due to difficulties for cutting in cost, attracting more clients and improving supply chain. Start-ups and S&M businesses are key contributors to the development of technologies in the frontier countries. Thirdly, an excessive deregulation could create an air of anxiety about the flight of capital, illegal leakage of knowledge and surreptitious use without licensing

that discourage innovative and productive activities in technology investment and creation. Since the relatively well-off economies (high and upper middle income countries) have competent to generate own technologies with advanced indigenous capabilities, stricter regulation action may be needed so as to prevent the leakage of important knowledge incurred in an inordinate mobility of capital, as well as protect innovators against the illegal use of their intellectual properties. Particularly, the negative effect of deregulation in credit market on the growth was proved by Korean experiences. Korea's highly liberalised credit market system made a sudden increase in foreign capital flights and bad loan, which are the fundamental cause of the 1997 of financial crisis. For such possible reasons, I argue that government regulations in domestic market positively affect the development of national technology capabilities in the contexts of high-income and upper middle-income economies.

Second, I found that low regulatory barriers in international trade positively affect national technology capabilities, implying that the open-door policy leads to the expansion of R&D expenditures and patent productions. Growing global interdependence in the product and process of innovation under globalisation (Amable, 2003), a foreign trade policy plays an important role in the dynamics of innovation activities by facilitating FDI, technology trade, internationalisation of R&D and joint R&D (Gu, 1997; Rycroft, 2002). Such the cross-border innovation activities directly affect the stock and flow of knowledge, while providing learning opportunities, spillovers and externalities in a highly cooperative R&D environment (Rycroft, 2002). Therefore, it suggests that free trade system opens a gate for acquiring, transferring and generating new knowledge, and hence contributes to the development of national technology capabilities.

Third, I found that there is no correlation between a size of government and national technology capabilities in contrast to my anticipation that a large size of government (the preponderance of the public sector's investment and output over those of

the private sector) negatively affects technological development. However, a size of government moderates these effects such that low regulatory burdens on market entry and foreign trade have positive effects on the national technology capabilities when government size is small. It suggests that SOE-oriented industrial structure (not private industrial firm-centred structure) impedes the flow of capital (credit, labour, and technique), entrepreneurial process and foreign trade, and the consequent inconducive to the development of national technology capabilities. Therefore, I argue that a small government size in the combination with the liberalised domestic market and foreign trade systems facilitates more active technology investment and creation.

These empirical findings confirm that national technology capabilities are influenced by government intervention in domestic markets and free trade policy, and their interactions with a small size of government. The empirical contributions and limitations are presented in section 8.2 and 8.3.

8.1.2 Institutional Conditions for Technology Input and Output Relationships

The second research question was addressed by examining causal relationships between technology investments and technology creations. This empirical investigation aimed at evaluating the contributiveness and the effectiveness of actors within the NIS and the contextual factors to the development of national technology capabilities in Korea and Japan. Also, I estimated how much of the current technology output (or technology input) can be explained by past values of technology input (or technology output), and whether adding lagged values of technology output (or technology input) can improve the explanation, and the other way around in the contexts of Korea and Japan.

First, I found that R&D investments cause the production of patents, whereas there is no the causal relationship between FDI and patent creation. It suggests that domestic R&D performers and financiers are key contributors in the development of

national technology capabilities, but MNEs or foreign institutions play a minor role in technology development in Korea and Japan. In comparison, Korea's R&D activities causes patent activities from one year to five years later (for a period of 5 years), while the causal relationship appears three years to four years later (for a period of 2 years) in Japan. This implies more time-consuming for generating and commercialising new knowledge, as well as shorter life cycle of products, and thereby more high technology-centred system in Japan than Korea.

Second, I found that the causal relationship between private R&D and patent production is stronger than the causality between public R&D and patents in Korea and Japan. In detail, Korea's patents are created from one year to three years (for a period of 3 years) after undertaking R&D in both public and private sectors. Meanwhile, Japan's public R&D causes patenting a year later and the casual relation disappears after that, while private R&D facilitates patenting activity four years and six years later. It suggests that the Japanese public sector is less effective and innovative in the creation of new knowledge and technology, compared with the Korean public sector. Also, patents produced over a longer time span (from four years to six years after private R&D) in Japan are attributable to a more high-tech industrial structure, compared with the case of Korea (from one year to three years after private R&D), since it demands longer-term R&D investment.

Third, I found that patenting activity causes an increase in technology export in Korea, but there is no casual relationship between them in Japan. It confirms that Korea's export-oriented policy focuses on R&D activities for market-induced applied research. Further, there is a stronger casual relationship between patent production and technology imports in Korea than Japan. It suggests that Korea has a higher level of dependence on technology import in the creation of knowledge. Korea's patents are created one to three years after introducing foreign technologies while it takes six years to produce patents

with imported technologies in Japan. It suggests that Japan's innovation relies on intangible knowledge and sophisticated techniques since it takes more time to master, absorb, transfer and codify.

Overall, this empirical study revealed (i) a critical role of R&D (lack of FDI influence) in national technology creation in Korea and Japan; (ii) stronger influence of private sector than public sector in Korea and Japan; (iii) less effective and innovative public sector in Japan compared to Korea; (iv) a high-tech oriented industrial structure of Japan and more time-consuming nature of Japanese patenting compared to Korea; (v) a higher level of dependence on foreign technologies in Korea compared to Japan.

8.1.3 Determinants and Patterns of Technology Catch-up

The third research question led to investigate in which industrial sectors Korea caught up rapidly with productivity and technology of Japan. In the observation of the rapid catch-up of Korean industries against the Japanese industries, important determinants of catch-up in terms of occurrence, speed and performance are analysed to compare catch-up distinctive mechanisms between the countries and to identify significant factors that influence latecomer countries' technology capabilities and innovation.

First, I found that Korean firms rapidly caught up with technology and productivity of Japanese firms engaged in the industries characterised by shorter product cycle, easier access to external knowledge and higher appropriability. The industries relied on more explicit knowledge and embodied technology transfer over tacit knowledge also tended to rapidly catch up. It suggests that technology catch-up performances of latecomers are determined by knowledge and technology relating to the ease of codification, transfer and commercialisation of R&D outcomes, as well as the low complexity for learning.

Second, I found that the speed and performance of catch-up in Chaebol-centred

(monopolistic market structure) and export-oriented industries (high degree of external discipline) were much faster and better than small and medium enterprises (SMEs) or venture businesses-centred and domestic demand-oriented industries in Korea. In sum, Korea's industrial structure is characterised by the dominance of large established firms, namely chaebols, and the monopolistic nature of the market. Different industrial structures induce different models of technology catch-up, different growth strategies and sectoral specialisation in the latecomer countries. Compared with Taiwan's innovation cluster model (SMEs-centred) that focus on cooperative R&D, international partnerships and sectoral specialisation in narrow areas, Korea's Chaebols-centred catch-up model seeks independent R&D, inter-firm linkages and specialises in more board areas, like ICTs (Hobday, 2003; Kim and Lee, 2003). Regarding technology regime, the Korean model is correlated with high cumulateness and low appropriability, while the Taiwanese SMEs enjoy low cumulateness and high appropriability due to a high risk for knowledge leakage to large firms (MNEs) (Lee and Park, 2006). These findings suggest that knowledge regime, financial system and trade policy are important factors in facilitating technology catch-up process in the context of Korea. It provides the important implications for other catching-up economies.

8.1.4 Sectoral Innovation Systems of Biotechnology and Wireless Telecommunication

Industry

The fourth research question was addressed by investigating specific policy and institutional changes in innovation systems of biotechnology and wireless telecommunication industries through a comparative historical analysis. The two industries in Korea and Japan are the path-creating catch-up models, indicating the latecomer firms explore their own paths of technological development and innovation. However, there were relatively pathetic returns on large scale government funding and

corporate R&D in biotechnology industry, compared to wireless telecommunication industry in Korea and Japan. In this sense, strengths of innovation system of wireless telecommunication industry and weaknesses of biotechnology innovation system were analysed to find key institutional and contextual factors contributing to and delaying the sectoral catch-up performances.

The root of the problem that makes the countries to delay the leapfrogging for advanced countries' biotechnology capabilities are as follows. First, biotechnology innovation in Korea and Japan was based on independent and in-house R&D, which is distinct from the network-based innovation system in the United State and other the Asian newly industrialised countries, such as Taiwan and Singapore. Compared with other newly-emerging high-tech fields, a cooperative relationship rather than a competing relation (e.g., ICTs case) is an important channel for catching up and developing biotechnology (Blumenthal *et al.*, 1986; Mowery and Rosenberg, 1993; Lethrer and Asakawa, 2004).

Despite absences of science base facilities and capabilities, the countries relied on inter-firm linkages rather than cooperative relationships with foreign organisations, which might delay the rapid catch-up with biotechnology of advanced countries. Second, the lack of commercial orientation of the academia, the lack of mobility of scientists, the low quality of entrepreneurships and university spin-offs impeded the catch-up process of biotechnology in the countries. The recent thesis of triple helix highlights the important role of university in biotechnology (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2006; Marques *et al.*, 2006). It is analytically different from the traditional NIS model (e.g., Statist and Laissez-Faire models) focusing on the central role of firms in technical innovation (Ludnvall, 1992) and the Triangle model focusing the decisive role of government in tradition (Inzelt, 2004). The success of biotechnology catch-up and innovation much depend upon R&D capabilities of universities. However, the countries'

universities were inactive for spin-offs and joint-R&D, while concentrating on learning and mastering the extant knowledge over research (Westney 1993; Bartholomew, 1997; Oh, 2002). Further, low availability of venture capital and weak state-university-industry relationship were the hindrances of rapid catch-up of biotechnology in both Korea and Japan. Japan lagged behind even Korea in terms of the number of NBFs and venture capital investments in life sciences, while the weak university-industry relation was a more serious problem in Korea due to the lower level of R&D capability of universities. Some policy measures for improvement are suggested in section 8.2.

Meanwhile, Korea and Japan have become the frontier countries with the United States in terms of mobile telecommunications and wireless technologies. How have they managed to rapidly catch up of the technologies at higher speed than biotechnology despite lack of university R&D capabilities and inactive government-academia-business cooperation? There are three major contributors to Korea's and Japan's innovation system of wireless telecommunication industry. The first is government. As information and communications technology (ICT) catch-up strategy, both governments formed both the regulatory and competitive policies for orchestrating telecommunications sectors and a fair competition by controlling monopolies. With close ties with private sectors, governments have made its telecommunications industry to be highly competitive by privatising the state-owned operators and stimulating private sectors to compete with the incumbent for next generation wireless technologies by offering several incentives. Also, the governments actively intervened in telecommunications industry to expand usage of ICTs by making an universal available of Internet access with high transmission speeds, create advanced wireless technologies, and facilitate active cooperation among service operators, cell phone makers and electronics companies. The second is the large industrial firms. Japan's MNEs and Korea's Chaebols have greatly contributed to the rapid catch-up of ICT-related goods and services as a service supplier, and an equipment manufacturer.

The large consumer electronics companies have long participated in the Korean and Japanese telecommunications service markets as equipment manufacturers, starting from the TDX project. They joined the project for the TDX invention under the government initiative, because it was required a large R&D and highly sophisticated technique in the fields of electronics, semiconductors and computer software (Larson, 1994; 1995). The TDX became the foundation for upgrading their scientific technology capability to a higher level, and subsequent being the world-class telecommunications equipment producers with a strong competitiveness in exports. Recently, the Korean Chaebols, especially Samsung and LG, have leapfrogged and outperform their Japanese manufactures - Matsushita, Mitsubishi and Sony, and become the world leader as a handset manufacturer and inventor of wireless technologies. The third is education institutions. Remarkably, the rational reform of education institutions has enabled Korea to overtake Japan's innovation capabilities of ICTs, especially broadband and mobile technologies. Korea's information technology (IT) education system has focused on the spread of knowledge among the whole nation to produce well-qualified people so as to make Korea to be rich in human resources, which is distinctive from Japan's elite-based system. In this sense, there have been many IT facilities across the whole extent of Korea and the widespread training of all the people in the country in IT skills (Forge and Bohlin, 2008).

Therefore, the findings suggest that the rapid catch-up of wireless telecommunications industries in Korea and Japan cannot be explained in the triple helix paradigm that highlights the role of university, since the countries have low levels of university R&D capabilities and University-Industry collaborations. Despite such weaknesses make the slowing catch-up of biotechnology, the close ties between government and large industrial firms in their innovation systems help rapidly catch up and develop technology capabilities in wireless telecommunication industry, since

university plays relatively minor role.

8.2 Main Contributions and Implications

This thesis integrated NIS and late industrialiser perspectives to analyse the country-level and sector-level dynamics of innovation and their consequences on technology progress and competitiveness. It contributes to the existing innovation literatures by providing a context-sensitive analysis of national technology capabilities and sectoral catch-up performances in Korea and Japan. The main theoretical and empirical contributions and policy implications are discussed in this section.

8.2.1 Theoretical Contributions

This thesis has developed a synthesised model by making up for theoretical shortcomings in institutional economics, the NIS and the late industrialisation. It provides a useful theoretical lens through which the primary rationale for the success of Korea and Japan in terms of national technology capabilities and sectoral catch-up performance could be analysed. The main theoretical contributions to the existing innovation studies are as follows.

First, this thesis has compensated the weak points in new institutional economics that focuses on the role of social norms and legal rules that govern individual behaviour and structure social interactions in economic growth and competitiveness (North, 1997; Aoki and Masahiko, 2001; Easterly, 2001). The theory does not look at the role of institutions in an angle of technical innovation, despite distinctive policy and institutional frameworks are key parts in producing various patterns of innovation and levels of technology capabilities across countries and industries within countries. I overcame such a blind spot the underlying of the new institutional theory by employing the theory of NIS. From the NIS perspective, NIS configurations and national institutional networks that

shape the country specific system of the stock and flow of knowledge as key sources of the variety in patterns of the product and process of innovation at various levels (Kogut, 1991; Nelson, 1993; Lundvall, 1998).

Second, this thesis has filled the gaps in NIS approach by introducing the late industrialiser perspective due to the limitation in applying into the contexts of Korea and Japan, where government and non-market actors play an active role in the development of technology capabilities. The principles and configurations of NIS were modelled on the systems of advanced countries, suggesting the build of strong professional networks and institutional links as the logical premises for the diffusion and the creation of new knowledge. Despite a weak State-University-Industry relationship, however, the countries have achieved the rapid technology catch-up and become world leaders in many high-tech fields. Also, NIS approach provides static descriptions of national institutional devices and mechanisms without proper regard to the special characteristics of sectoral, regional and international contexts, although technological change is often determined outside the system in the countries (Viotti, 2002). Therefore, this thesis extended the NIS perspective by employing the late industrialiser perspective, considering the country-specific structural, institutional and contextual environments.

Third, this thesis has developed an integrated theoretical framework by expanding the scope of analysis in the NIS due to the difficulty in capturing the idiosyncratic nature of institutional and technological changes in Korea and Japan. It makes up for the insufficient part of the conventional business theory derived by the Western multinationals' industrialisation, internationalisation and innovation processes, since the governmental implications and institutional embeddedness in Korea and Japan directly related to succeed industrial development, overseas expansions and innovation.

Fourth, this thesis has contributed to the existing theoretical research on determinants of technology capabilities and innovation by addressing political,

institutional and contextual factors that produce different patterns of innovation and sectoral specialisation across countries. The existing management studies based on the resource-based view (RBV) have underlined the significance of the bundle of the firm's unique resource and capabilities as key determinants of innovativeness and financial performance (Wernerfelt, 1984; Barney, 1991; Mahoney and Pandian, 1992; Eisenhardt and Martin, 2000). The RBV has provided the understanding of the cross-country and inter-firm differences by focusing on the choice of appropriate resources, but ignored the process of resource development and the contextual factors surrounding resource. The theoretical shortcomings in the RBV have been redeemed in the dynamic capability view (DCV), highlighting the specific capacity for resource development and renewal responding to the changing business environment (Teece and Pisano, 1994; Teece et al., 1997; Winter, 2003). However, the DCV is not suitable to my theoretical framework as the main theoretical base, since it has no consideration for the specific institutional and sectoral conditions for the stock and flow of valuable resources despite the great influence on the development of technology capabilities and catch-up performances. Although the importance of national economic and institutional conditions has been emphasized by Michael E. Porter's diamond model, this model has also failed to capture the idiosyncratic features and determinants of technology capabilities of Korea and Japan. Porter's diamond model has paid no direct attention to non-market relations and international factors (e.g., FDI, internationalised R&D), and their impacts on technology capabilities, which are key contributing factors influencing technology catch-up performances due to the lack of R&D resources in Korea and Japan.

Therefore, the integrated theoretical framework based on the NIS and late industrialiser perspectives have filled the gaps in the existing studies by focusing on institutional and contextual factors to some extent through the examination of the roles of government policy for domestic market and foreign trade, IPRs, finance system,

technology regime and sectoral contexts in technical innovation and catch-up. These investigations have been provided more balanced perspective for understanding under-explored national, sectoral and international contexts in innovation studies, as well as overcoming the methodological limitations of existing innovation research in the contexts of East Asian latecomers, which have been mainly dominated by historical description and qualitative case analysis. Further, the case study of Korea and Japan has lay out a logical basis for the State-coordination against the neo-liberalism arguments by analysing the country-specific institutional and policy frameworks and their influences on national technology capabilities and sectoral technology catch-up performance in the context of Korea and Japan.

8.2.2 Empirical Contributions

My methodological framework contributes to empirical innovation studies. First, the institutional comparative analysis of this thesis, combined with a historical approach, has provided a contextual understanding of institutional change in industrial structure, finance system, NIS and SIS, and its influences on technology catch-up patterns and sectoral specialisations. Considering historical singularities and contextual dynamics of innovation, this approach, relying on a two-sided comparison, has enabled us to capture distinctive determinants and mechanisms for technology capabilities with a systematic and a contextualised comparison between the selected cases, namely Korea and Japan. It has provided an insightful interpretation between evidence and theory, as well as a fair degree of generalisability, since it is impossible for testing the validity of the existing theory and generating an adequate theory with a single case (Bechhofer and Paterson, 2000). The two-sided comparison has been based on firstly a positive comparison method because of similar institutional and contextual features of the countries, and then a negative comparison method to find their similarities and differences in patterns and determinants

of innovation. It has enabled us to conceptualise internal and external factors affecting national technology capabilities and sectoral catch-up performances by considering historical and institutional sequences over time.

Second, this study contributes to the existing comparative studies. A number of macro studies have testified the same growth paths among countries which are grouped by institutional characteristics, such as finance systems (market-based vs. bank-based), legal origins (common law vs. civil law) and corporate governance systems (shareholder vs. stakeholder) etc. However, they have rarely examined distinctive mechanisms for technology capabilities and catch-up from an angle of innovation. Also, there have been no comparative studies focusing on the growth patterns by grouping the heterogeneity of countries into the state-led capitalist countries, such as Korea and Japan. Despite huge differences in cultural tradition and economic development level, the two different economies have shared many institutional features, including a close political-commercial link, the large firms-oriented industrial structure, the state-organised NIS and in-house R&D system. The comparative study between Korea and Japan which have the most similar characteristics in the world can overcome the risk of comparing apples with oranges. Due to the particularities of institutional settings in Korea and Japan, the widely-used research method also have the limit in applying into the contexts of countries, which encounter the problems of validation of the findings of the research and generalisability. Therefore, this thesis sheds light on the comparative studies on NIS in which the principles and configurations are modelled on the systems of advanced countries, by examining the trajectory of state-business relationships and external heterogeneity in contextual homogeneity.

Third, the empirical investigation using a wide range of sample (69 countries) has enabled us to generalise significant institutional and policy determinants of technology capabilities. The cross sectional research using such large numbers could alleviate the

problems of the case-biased findings and generalisability (Yin, 1994). The methodological issues in a cross-sectional estimation have been addressed by successfully controlling huge technology gaps, different levels of economic development, and various institutions by using relevant control and dummy variables. Also I have made up for the vulnerable point of the cross-sectional method that ignores an intrinsic importance of case and its contextual background conditions (Yin, 1994; Stake, 1994) by analysing these linkages in the particular cases. This macro-level analysis is a new attempt to empirically examine the effects government regulation and policy on technology capabilities across countries. Despite innovators are susceptible to regulatory burdens on credit, labour and business and foreign trade, government policy and regulation have been overlooked as determinants of national technology capabilities in the existing empirical innovation researches. Also, the empirical studies on political and institutional economics have addressed institutional and policy factors as important sources of economic growth, human welfare and entrepreneurship, although they directly affect innovation patterns and performances. Therefore, this empirical study has filled the gaps to the existing political economy and innovation studies.

Fourth, the time-series data analysis using triple helix indicators within NIS and the contextual factors could remedy methodological shortcomings in the existing studies on NIS that have been dominated by a combination of descriptive and historical analyses. By testing the causal relationship of R&D expenditures by sectors within NIS with respect to the production of patents, this empirical analysis has enabled to capture singularities in specific institutional conditions for technology input-output relationship, drawing a profile of innovation patterns and sectoral specialisation in Korea and Japan. The validity issue has been addressed through longitudinal data collection approaches that could reduce the bias coming from a rapid change of the transition period in Korea and Japan. This empirical study has provided a new way of explaining the dynamics of

innovation in Korea and Japan by separately examining the causal relationship of each sector contributing to the NIS between technology investment and technology creation. Most innovation studies have looked the relationship through a correlation test under consideration of technology investment as a determinant of technology creation. Also, there have no existing empirical studies on the causality to examine the causal relations between technology input variables (i.e., R&D expenditure) and technology output variables (i.e., patents). The greater part of this area have focused on the causality of economic and financial variables, for instance, between financial development (e.g., stock market volatility and catpitalisation) and economic growth (e.g., GDP) (Arestis and Demetriades, 1997; Calderón and Liu, 2003), between FDI and economic growth (Hansen and Rand, 2006; Hsiao and Hsiao, 2006), between capital investment and economic growth (Vanhoudt, 1998; Elena and Gaetano, 2001) and between international trade (e.g., export and import) and productivity (Awokuse, 2008; Harrison, 2007). Therefore, this empirical study contributes to the existing empirical studies by developing an alternative method that allows quantitatively analysing specific institutional conditions for the technology input–output relationships and the patterns of technological development.

Finally, the comparative study on technology catch-up in latecomers has provided a comprehensive evaluation of technology catch-up models, which enables us to compare different mechanisms for sectroal technology catch-up of Korean firms with those of Japanese firms. This study has also extended the recent catch-up studies by suggesting that the occurrence and speed of catch-up and innovation largely depend on technology regime, market structure, and financial system and trade policy in the contexts of latecomer countries. The findings have significant relevance to innovation strategy and policy in other countries, particularly catching-up countries with indigenous technology capabilities.

Therefore, this thesis have filled the methodological and theoretical gaps in prior

innovation researches, by using a theoretical integration of multiple innovation factors, a historical comparative research and an empirical investigation of social phenomena via statistical techniques. The findings of this thesis may be generalised to apply in other catching-up or emerging countries.

8.2.3 Policy Implications

I have concluded that the regulatory market system, liberalised system of trade and their interactions with small government size positively affect the national technology capabilities in high-income and upper middle-income countries in chapter 5. The first empirical findings for the negative impact of free market system on national technology capabilities implies that blind reliance on the principle of the market economy, meaning that prices, wages, business transactions and market entry are unconditionally determined by only competition without any government interferences, does not promote long-term value creation and innovative activities. It suggests that a free market system can produce short-termism with concerns about a flight of capital and surreptitious use without licensing, while reducing the viability of new start-ups due to being incapable for competing with the established firms without government supports. Therefore, the government should set up stricter regulatory policy to promote productive and innovative activities in the contexts of high-income and upper middle-income countries, which have relatively free market systems to engage in voluntary exchange and allocate resource to private parties by the market force. Since the countries have competency to generate own technologies with advanced indigenous capabilities, the government intervention is required for preventing the monopolisation of large firms, the illegal use of their intellectual properties and the leakage of important knowledge. The second findings that a low regulatory burden on international trade influences national technology investment and creation imply that the open-door policy promotes the stock and flow of knowledge

by opening a gate for mastering, absorbing and transferring advanced technologies. Since liberalised system of trade facilitates active FDI, technology trade and R&D cooperation across the border, it suggests that the removal trade barrier is an essential condition for developing national technology capabilities. The third findings is that a size of government moderates these effects such that low regulatory burdens on credit, labour and business and foreign trade have positive effects on the national technology capabilities when government size is small. The large government size is indicative of heavier spending of public sectors (SOEs) over individuals and industrial firms, implying that resources are allocated by political choice and government decision-making, not by personal choice. Since the SOEs generally engage in protected industries with government funds, more concentrating on producing commodities for domestic market and supplying public wants over exporting, the combination of a small government size and liberal policy strengthens their effects on technology investment and creation. Therefore, it suggests that a low degree of government involvement is necessary for developing technology capabilities of countries with highly liberalised systems of domestic market and foreign trade.

The case study of Korea and Japan supports the cross-country empirical findings, highlighting the positive effects of government interventionist policy and regulation on national technology capabilities in the contexts of relatively less globalised countries. Both Korea's and Japan's innovation environments are well-internationalised, but not less-globalised, indicating relatively low level of cross-border cooperation compared with other technologically advanced countries. Despite they invest and send their employers aboard to exploit new market and learn new knowledge (i.e., internationalisation), most R&D is performed within the countries. Also, key actors within NIS of Korea and Japan are not willing to export knowledge and engage in international collaboration in the fields where they are recognised as the world top. In this sense, effective government policies

and institutional reforms that are regarded as one of the key success factors of Korea's and Japan's rapid technology catch-up have provided new implications on policy issues.

S&T policies in Korea and Japan have been repeatedly revised to address facing problems and suggest new direction of S&T development with clear objectives, instruments and policy prioritisation, which have been codified in strategy papers or white papers to inform the public and relevant stakeholders about current and future policies. With policy change, the government has carried out institutional reform to meet their S&T policy goals by establishing effective mechanism for collective risk-sharing by industry, government and their lenders. Such a risk-sharing partnership should be essential for the long-term R&D, especially in the take-off stage toward innovation-driven growth. The government funds for R&D and product development have been distributed in a highly competitive way, picking out priority areas through various means to allocate resources. The top priority policy has been placed on financing fast-growing industries in which income elasticity of demand and labour productivity have risen quickly as well as technological progress has been rapid, while flexibly adjusting priority industries by phasing out declining industries in an orderly and timely fashion. Nevertheless, the priority areas are until now of different status. For instance, ICT and materials research have produced better innovation performance and can be regarded as the world top in both countries, whereas life science and biotechnology have been less progressed than expected despite longer period of investments.

In what ways have the Korean and Japanese governments managed their weak innovation systems to leapfrog wireless telecommunications technologies? The research on wireless telecommunications in Korea and Japan has provided mainly two important lessons to other latecomer countries. First, the intervention of government and its close ties with the private sector are key success factors for upgrading telecommunications infrastructure and developing new wireless technologies in the countries. The Korean

government has made the medium term strategic plan for S&T development to flexibly adjust its plan against constantly evolving technology fields, which is different from other OECD countries' long-term ICT programmes. The ICT-promotion policy is pragmatic and systematic with clear policy targets. For instance, the IT 839 strategy targeted the collaborative development of three areas - ICT services, ICT goods and infrastructure networks. The participants are privileged from the monetary burden with a number of incentives, such as research funding, tax deduction for intellectual resource trade, low interest loans for the construction of the R&D facilities, subsidies for human capital and so on (Chun, 2002; Lee, 2000). Second, the interventionist policy for a fair and free competition without dominance by the incumbent has helped the rapid catch-up with high technologies of the United States and Europe. To make highly competitive domestic market, the Korean and Japanese governments have actively reformed their regulation policies and regularly inspected for Korean Chaebols and Japanese large firms (MNEs) to restrict their excessive expansions and market shares. Such great efforts allow the increased of venture firms (equipment suppliers) and facilitated R&D cooperation with among various players service operators in the creation of cutting edge products, and the consequent lead a surge of mobile-Internet demand and users in Korea and Japan.

However, biotechnology in both Korea and Japan is the slowest catching-up industry in promising industries. The study of biotechnology in Chapter 7 has suggested important policy directions and implications. How should the government deal with the problems? First, both countries' innovation systems of biotechnology are characterised by the in-house R&D and inter-firm cooperation make it especially hard to rapid catch up with biotechnology of advanced countries. Compared with wireless telecommunications, the cross-border cooperation is more important than competition, thereby more globalised network-based innovation systems of biotechnology should be required for the stock and flow of scientific knowledge in absence of science base facilities and capabilities. Second,

the lack of university's R&D capacity, the large established firm-centered industrial structure and weak cooperation between academia and industry communities are the key delaying factors the slowing catch-up of biotechnology in Korea and Japan. The low availability of venture capital and the lack of commercial orientation of the academia are also the hindrances of biotechnology progress in both Korea and Japan. Japan has lagged behind even Korea in terms of the number of NBFs (new biotech firms) and venture capital investments in life sciences due to a heavy government regulation in mobility of scientists. The weak university-industry relation has been a more serious problem in Korea due to the feeble scientific and information networks and the lower level of R&D capability of universities that are still focusing on learning and mastering the extant knowledge. Therefore, the policymaker should devise effective policy measure to promote NBFs and university spin-offs, and cooperation between academia and industry communities.

8.3 Limitations and Further Research

The study has some limitations that direct future research. First, the present thesis has provided a strong relationship of institutional and policy factors with respect to technology capabilities, but could not include all possible institutional variables affecting innovative activities due to the lack of available data. The data of transition countries (low middle-income and low-income countries) has been excluded due to huge missing values in the cross-country empirical study. With a larger sample, it should be controlled the different legal origins or varieties of capitalism for greater statistical significance in future study. Also, the use of the panel data with more longitudinal approaches should be required for looking all variables changes over time and generating detail information due to cross sectional nature of the study. Second, R&D and patent data have been divided by two sectors, public and private sectors due to data unavailability of university's R&D in

the empirical study on the casual technology input-output relationships. Also, I have not considered of the cooperation among key actors within NIS, which directs future research. Third, this study has not considered organisational factors as determinants of technology capabilities. The cross-country differences in innovation patterns and performances can be caused by a complex interplay of the country-specific institutional factors and corporate governance factors: for instance market or equity-based ownership (i.e., dispersed shareholders: See Berle and Means, 1932; Chandler, 1962; Porter, 1992) and relationship or bank-based ownership (i.e., corporate cross-holdings, bank-centered ownership: See Prowse, 1990; Sheard, 1994). There have been a number of studies on corporate ownership structure as determinants of innovation. Francis and Smith (1995) examine the relationship between firms' ownership structure and innovation performance, and concluded that the firm with a highly concentrated management ownership or a significant equity block holder is more actively undertake innovation activities than the diffusely-held firm. However, the excessive firms' ownership concentration and dominated insiders over outsiders have a harmful effect on firms' performance due to arbitrary owner's decisions, less liquidity in markets and fewer opportunities to negotiate the firm's values (La Porta *et al.*, 1999; Shleifer and Wolfenzon; 2002). However, there are a strong possibility to exist information asymmetry between owners and managers in diffusely held firm (Francis and Smith; 1995), implying that the separated management structure is likely to cause the conflict of opinion among them for performing innovation projects and allocating R&D resources. However, there have been no existing studies to examine the effect of any type of corporate ownership and finance systems on technological capabilities across countries. The majority of existing empirical studies on innovation examine its correlation with the growth, such as firm performance, national income, productivity and competitiveness. Often, firms' internal variables (i.e., concentrated ownership right) and finance market systems (i.e., market capitalisation) are

used for controlling the heterogeneity of samples, while linking them to innovation performance. Further, the existing empirical studies on corporate governance and finance system have not considered their relations with innovation performance at a macro level. It may be, because an empirical testing to verify these relationships at a macro-level may encounter difficulties in moderating huge technology gaps, the different level of economic development and various institutions across countries, because their distinct characteristics cause different statistical outcomes. Therefore, future research should be conducted to examine the relationship between corporate governance factors and technology capabilities with multi-levels of analysis (firm and national levels) and in an interdisciplinary research framework (strategy, management and political economic perspective).

Despite these limitations, this study has made the contribution to the existing literature. Most research on innovation has neglected the study of an institutional context in spite of the widespread recognition that innovators are susceptible to contextual influences because of the unique characteristics of technical innovation - risky, costly, uncertainty and long-term investment. Also, the majority of political economists have addressed institutional and policy factors as important determinants of economic growth, human welfare and entrepreneurship in spite of the fact that innovative activities are affected by institutional framework that shapes competitive or cooperative research climates. Therefore, this study has filled the gaps to the existing political economy and innovation studies by demonstrating the effect of institutions on technology capabilities.

8.4 Concluding Remarks

This thesis has attempted to provide new insights in explaining the underlying dynamics of rapid technological catch-up and innovation in Korea and Japan. It has undertaken a comprehensive treatment of determinants of technology capabilities innovation in terms

of the effects of institutional, policy and contextual factors drawn from the NIS and late industrialiser perspectives. This thesis contributes to innovation literatures by considering institutional and international factors through the examination of the roles of government policy for domestic market and foreign trade, IPRs, finance system, and of technology regime and sectoral contexts in technical innovation and catch-up. These investigations have provided a more comprehensive and balanced perspective for understanding national, sectoral and international contexts of innovation, as well as overcoming some of methodological limitations of existing innovation research in the contexts of East Asian latecomers. Scholars and policy makers may gain useful lens and insights on national technology capabilities from this study and extend them in their pursuit of specific academic or policy interests particularly in the context of latecomer countries.

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