Technological Innovation and Economic Growth in Korea and Japan: A Causality Test

To investigate specific institutional conditions for the innovation-growth relationship, this paper examines the patterns of technological development in Korea and Japan. 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. Granger Causality Test is performed to analyse the causal relationships between economic development and technological innovation and economic growth in Korea and Japan. This test shows how much of the current economic growth (or innovation activity) can be explained by past values of innovation activities (or economic growth) and whether adding lagged values of innovation activities (or economic growth) can improve the explanation. Innovation activities are measured by the monetary values of R&D in public sector, private sector, technology import and technology export. In order to estimate which types of innovation activities significantly cause economic growth, and the other way around, the four variables are separately tested in two periods of pre-innovation stage innovation stage. Our test result provides important implications for institutional conditions for innovation that lead to technological catch-up and economic growth in different stages of economic development.

1. Introduction

Technological innovation is regarded as the engine for industrial development and economic growth. A number of existing studies has underlined the importance of technological capabilities and national innovation system (NIS) as the importance sources of economic development (e.g., Freeman, 1995; Kobrin, 1995) and competitiveness (e.g., Cantwell, 1989; Kogut, 1991; Porter, 1990). Also, there have been interesting studies focusing on the specific technology advantage of a country or a firm in the different national institutional context (e.g., Bartholomew, 1997; Dosi et al., 1990; Shan and Hamilton, 1991; Lundvall, 1992). From the institutional perspective, the national variations in innovation patterns, directions and magnitudes are caused by different conditions under the different legal institution and NIS, which reflect the creation of new technical sources influencing the comparative advantages of a country (also see Etzkowitz and Leydesdorff, 2000; Ziegler, 1997). The institutional perspective provides an understanding of why cooperative relationships and strategic actions for specialising in different technological sectors vary across countries.

In the knowledge-intensive economy, technological innovation has become the most significant source of economic growth and social development. The current state of economic development of East Asian countries has been accomplished through innovation-based economic & industrial policy with the extensive public intervention (UNCATD, 2003). East Asian countries have been often citied in various fields of academic literatures as the successful State-led growth model of technological and economical catch-up. Recognising the importance of scientific and technological capabilities as a measure of economic growth after WWII, the countries started to plan and implement S&T policies to build up a knowledge-intensive environment by setting up legislative measures, subsidized loans and tax incentives supporting technology and research activities (Yamaguchi, 2008; Watanabe, 2000; UNCTAD, 2003). With the aim of rapid economic catch-up with developed economies, the law for liberalising the import of foreign technologies was also enacted to facilitate international cooperation and technology transfer into local firms (Motohashi, 2005; UNCTAD, 2003). However, the inter-linkage of research institutions and inter-firm cooperation are the important factors influencing on scientific knowledge accumulation and technology transfer in process of innovation in East Asian countries, rather than venture capital and new start-ups that have greatly contributed to the development of S&T in the United States (Bartholomew, 1997; Whitley, 2003; Lehrer and Asakawa, 2004).

In order to investigate in what way East Asian countries have achieved the rapid economic and technological catch-up in the absence of natural resources, this paper selects two technologically developed countries, Korea and Japan. The reason why Korea and Japan are chosen is because the case studies of Korea and Japan allow finding answers in relation to the questions of how the country realize the rapid economic growth and technological innovation, how Korea deals successfully with the 1997 of financial crisis and how Japan climb from the 1990s of economic recession and drop in competitiveness, and what mechanisms and factors contribute to indigenous technology progress. Also, Korea and Japan are good models to analyse the role of government in the development of economy and innovation in the context of East Asia. Therefore, this study allows filling up the gaps in the existing case studies and provides the important implications for catch-up or developing countries.

Korea has showed the rapid technological and economic catch-up over the past four decades, starting from the establishment of "Economic and Social Development 5 Years Plan" in 1962 and "Korean Institute of Science and Technology" in 1966. Korea's GNP per capita sharply increased from US$87 in 1962 to US$ 19,730 in 2006 (Data from the World Bank; Bank of Korea), and the total numbers of Korean patents applied to the European Patent Office (EPO) jumped from only 2 in 1980 up to 5,029 in 2007 (Data from OECD). In terms of international patent applications through the Patent Cooperation Treaty (PCT), Korea entered into the world 7th largest nation by filling 3,565 international patents in 2004 (Song, 2006). The sudden increase of Korean patents astonishes the whole world. The fast-growing of Korean economy is attributable to the effective innovation-driven economic and industrial policies.

On the other hand, Japan has long focused on the technical innovation as the national objectives over the past ten decades, starting from the establishment of Tokyo Industrial

Experimental Laboratory in 1900, and Institute of Physical and Chemical Research in 1917 (Harayama, 2001; METI, 2008). Japanese real GDP multiplied by 65.3, from US$65.8 in 1900 to US$4,295.9 in 2007 while its population multiplied by 2.9, rising from 43.8 million people in 1900 to 127.7 million in 2007 (Data from Carmen et al., 2000 and OECD database). Regarding technical innovation indicators, Japan ranked as the second largest country in terms of R&D expenditure, after following Switzerland, and as the world top in terms of patent granted by country of origin and share of countries in total patent grants (World Economic Forum, 2008; 2009 and WIPO, 2008). According to World Intellectual Property Organisation (WIPO), the number of patents granted to applications from Japan received approximately 217,000 patents and the share of world patent grants was 29.9 per cent in 2006 (WIPO, 2008). The current state of Japanese economy is also attributable to the rational science and technology (S&T) policy and the effective national innovation system (NIS).

In both countries, the central governments have the pivotal role in technological and economic growth, which embraces the build of programme inducing organisations to undertake active R&D in the private sectors and minimising or removing obstacles which foreign and local research organisations clash under the pursuit of innovation. In order to investigate their specific institutional setting and innovation patterns, the historical and contextual background of economic and technology growth are discussed. Granger Causality Test is performed to analyse the interrelationship between economic growth and technological innovation in Korea and Japan. This test shows how much of the current economic growth (or innovation activity) can be explained by past values of innovation activities (or economic growth) and whether adding lagged values of innovation activities (or economic growth) can improve the explanation. Innovation activities are measured by the monetary values of R&D in public sector and private sector, technology import and technology export. In order to estimate which types of innovation activities significantly cause economic growth, and the other way around, the four variables are separately tested in two periods of pre-innovation stage and innovation stage. Our test result provides important implications for institutional conditions for innovation that lead to technological catch-up and economic growth in different stages of economic development.

2. Evolution of Economic & Technology Policies: Korea

Korea has showed the rapid economic growth over the past four decades, which is called as “East Asia miracle.” Korean GDP per capita could pass the 10,000 dollar mark in 1995 with the high growth rate (Bank of Korea). The fast-growing is attributable to the successful industrial reforms, organisational restructuring and the innovation-driven growth strategy. Broadly three growth strategies have been changed over the past four decades; (i) from quantitative to qualitative growth strategies; (ii) from the leadership of the state to market economy-based strategies; (iii) from macro-based to micro-based strategies.

In the earlier developmental stage of Korea, covering the 1960s and 1970s, the government formed the “Economic and Social Development 5 Years Plan” aimed at fostering basic industries, efficiently utilizing idle resources, revitalizing heavy chemical industry, increasing scientific technology investments and introduction of foreign techniques (B. Kim, 2006; Suh, 1986). Imitation or copying was used for export of home goods by learning foreign skills and technologies, which could gain a foothold in overseas expansion and technical improvement. Also, the central government started to establish public research and technology institutes including KIST (Korean institute of science and technology) and enacted the “Technology Development Law” and the “Engineering Service Promotion Law” to (W. Lee, 2000 and MOST, 2007). With the materialization of “Economic and Social Development 5 Years Plan”, Korea’s GNP per capita jumped US$100 in 1963 up US$1,000 in 1977 (Bank of Korea) and its industrial structure was converted from labour-intensive or light-centred industries (i.e., textiles and food etc.) to heavy-centred industries (i.e., ship construction, steel, machinery etc.) (Stern et al., 1995).

Regarding innovation activities, the Gross Domestic Expenditure on Research and Development (GERD) was dramatically increased from US$ 4 million in 1963 to US$ 33 million in 1970. However, R&D expenditure was undertaken by the public sector in most cases. The ratio between the government and the private sector was 97 to 3 in 1963 and 71 to 29 in 1970 as shown in Table 1. The overwhelming superiority of public sectors may imply that the national innovation policy did not directly promote firms' innovative activities in the early developmental stage, and simultaneously firms seek the short-term profit maximisation rather than the long-term earning investments, like R&D.

Table 1
Korea's R&D Expenditures (1963–2001)

	Gross R&D Investment (million US $)	Government to Private Sector (%)	Ratio to GDP (%)	R&D Personnel
1963	4	97: 3	0.25	
1970	33	71:29	0.38	5,628
1980	428	64:36	0.77	18,434
1990	4,628	19:81	1.87	70,503
2001	12,481	26:74	2.96	178.937

Source: H. W. Chang (2003). "Innovation Policy and Challenges the Korean Case" In Korea Institute of Industrial Technology and Planning (ITEP).
http://english.itep.re.kr/download/content/rc/235_1.0_attach_1.pdf

The next is domestic innovation stage in the 1980s. The main agendas of economic policies are the reinforcement of the competitiveness of heavy industry, the expansion of social development, the adjustment of industrial structure and the improvement of market economic structure by introducing economic liberalization (B. Kim, 2006; Stern et al., 1995). In this stage, three goals of economic policies - growth, price of commodities and the international balance of payment were attained at the targeted levels. Regarding the national S&T policies, the Ministry of Science and Technology (MOST) established a number of R&D programmes to bolster up the private sector's R&D activities and innovation by setting up financial incentives including tax reduction and exemption for intellectual resource trade, funding for R&D investment, and subsidies for human capital (W. Lee, 2000; Teubal, 2000; Chun, 2002). As a result, the GERD in 1980 was centuple with 428 million$ as large as the 1970's amount (33 million$), and then the national R&D expenditure jumped over 4,000 million US dollar in 1990 (See Table 1). Also, the private sector was increased by 13 per cent and public sector was decreased by 7 per cent between 1970 and 1980. However, the public sector (64 per cent) was still higher in proportion to the private sector (36 per cent) until 1980. In 1990, however, the share of R&D financed by the private sector was 81 per cent, surpassing the public sector (See Table 1). It implies that the S&T policy supporting the private sector's innovation activities greatly helps to accumulate a store of knowledge at both firm and country levels since the 1980s, and thereby developing the indigenous technology capabilities and constructing the knowledge-based society.

In the 1990s, Korean underwent economic boom and bust simultaneously. Korea's GDP per capital passed 10,000 dollar mark in 1995 and joined the OECD in 1996, but the economy fell into the financial crisis in 1997 due to several structural and institutional defects. (Bank of Korea; K. Kim; 2006). The cozy relations between politics and business, irregularities and corruption, excessive international expansion, massive capital flights, outdated corporate structures (i.e., nepotisms), and chaebols-centered business system were the important causes of the financial crisis and economic recession in Korea (Chang, 2003; B. Kim, 2006). The economic crisis led to the far-reaching reforms for state-run industries, public organizations, banking institutions and private enterprises and so on. Public sectors were reorganized with the removal of superfluous parts (i.e., officials and departments etc.) as well as faltering firms and local banks were liquidated through M&A (H. J. Chang, 2002; Jang, 2000). The government discontinued the assistance of chaebols' expansion and promoted venture business and S&M enterprises (Chang, 2002; S. Kim, 1998). Also, the government did not directly participate in economic activities contrasted with the former characterized by heavy intervention and control in markets (E. Kim, 1997). With the extensive reform, Korea's economy could be quickly recovered and redeemed the full amount of IMF relief loans (US$ 1.95 billion) in 2001 (IMF, 2003).

Regarding technological development, there was the momentous change of national research environment, from the government enterprise-oriented to individual enterprise-based environment. For dynamic innovation activities of private sectors and inter-collaboration among State, University and Industry, the national innovation system was reformed by formulating the boosting laws, such as the Cooperative R&D Promotion Law in 1993, and the Special Law on Science and Technology in 1997 (MOST, 2007). ICT, Biotechnology, nanotechnology and culture were fostered as the strategic industries (also see MIC, 2004).

Table 2

Stages of Science and Technology Policies (1960s-1990s)

	Stage	Key S&T Objective	Strategic Industry	Key S&T Policy
1960s, 1970s	Imitation & Import of Technologies	Building national technology infrastructure, knowledge transfer, importing foreign techniques	Labour intensive (1960s) Scale intensive (1970s)	Ministry of S&T (1967), Korean Institute of Science and Technology (1966), Technology Development Law and Engineering Service Promotion Law (1972)
1980s	Domestic Innovation	Increasing technology competences, promoting the private sector's innovation, learning the need of skills	Technology intensive	Technology Development Promotion Law (1982), tax and financial incentives for firms' R&D activities, Legal framework for venture capital
1990s	High Technology Improvement	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	High-tech intensive	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), 21st Century Frontier R&D programme (1999)

Source: Compiled by Author based on various national policy reports (MOST, various year).

Table 2 summarise the evolution of national S&T polices and key industries during the period of 1960s and 1990s. Notably, the "Highly Advanced National Project" (the HAN project) launched in 1992 enabled Korea to rapidly catch up with technologically developed countries. The HAN project is the long-term based (1992-2001) and the large scale R&D plan with US$ 3.2 billion investment (MOST, 2007). This project aims at improving high-tech products capable to compete with advanced countries. The high-tech products include HDTV (High Definition Television), ISDN (Integrated Services Digital Network), ASIC (Application Specific Integrated Circuit), biomedical, micromachining and next-generation automobiles and so on. Under the HAN project, Korea entered into the world highest nation with 31 per cent in terms of high-tech products as the share of total manufacturing output as shown Table 3. Before the HAN Project was properly operated, the proportion of Korea's high-tech industry as the share of total manufacturing industries was turned over the U.S.A, Germany and Japan. ICT (Information and Communication Technology) is one of the most developed high technologies in Korea. Korea is the first inventor to embark on WiBro (Wireless Broadband) services commercially and its fixed broadband speed is the fastest in the world (UNCTAD, 2007).

Table 3
High-Tech Products as the Share of Total Manufacturing Output (1980–2001)

	1980	1985	1990	1995	2001
United States	9.9	13.2	14.4	15.5	22.9
Japan	7.3	10.8	12.4	13.8	15.5
Germany	8.4	8.8	7.9	7.9	10.7
Korea	**6.1**	**7.0**	**10.5**	**14.1**	**31.0**

Source: Global Insight Inc., World Industry Service Database, 2003.

After the HAN project, Korea's government set up the 21st Century Frontier R&D programme to exploit new fields of S&T and create cutting-edge technology by make up for the weak points in the current NIS. Compared with the HAN project, This R&D programme more significantly addressed human capital, venture capital, entrepreneurship and R&D cooperation among State, University and Industry as the important sources of regional and national development (MOST, 2007). Under the 21st Century Frontier R&D programme, all enabling sources influencing on technological capabilities, including R&D expenditures, researchers, trade of technical licensing, patents and corporate R&D centres were sharply increased (see Table 4). In this period, Korea had become the world top in terms of R&D-intensive products, including LCD TV, MP3, digital camera, digital contents and computer & information services (MIC, 2004).

Table 4

Korea's Technological Innovation Indicators (1971-2003)

	1971	1981	1990	1995	2000	2003
Domestic Patent Registration	n.a	13998	54325	67448	126395	155840
International Patent (USPTO) Registration	2	17	225	1161	3314	3944
Technological Balances (Export/import)	n.a.	0.11	0.02	0.06	0.07	0.25
Importing Technical Licensing (million$)	5.1	107.1	1087	1947	3062.8	3236.5
Exporting Technical Licensing (million$)	n.a.	11.8	21.8	112.4	210	816.2
Number of Researchers (Total)	5320	20718	70503	128315	108370	166379
Government & Public Institutes	2477	5067	10434	15007	12802	13447
Universities	1918	8488	21332	44686	23674	26419
Firms	925	7165	38737	68625	71894	111388
R&D Expenditure / 10000 Population	1.8	5.4	16.4	28.6	34	41.3
Number of Corporate R&D Centres	1	65	966	2270	7110	9810

Note: Research assistants, technicians and other support personnel are not counted for the total researchers.
Source: Compiled by the author from (MOST, Science and Technology Annuals, various year; USPTO various year).

3. Evolution of Economic & Technology Policies: Japan

Japan has long emphasised the importance of scientific technology and innovation. Prior to the end of World War II, the Industrial Council founded in 1910 to strengthen military and develop industrial technologies by establishing public research laboratories and research institutions, for example the Electric Experimental Laboratory (1891), the Tokyo Industrial Experimental Laboratory (1900), and the Institute of Physical and Chemical Research (1917). One of these, the Institute of Physical and Chemical Research was founded for technical cooperation among industry and State (Harayama, 2001; METI, 2008).

In the post-war period, the Ministry of Commerce and Industry was founded in 1948 to draw up and implement the national S&T policy (METI, 2008). In order to build up local innovation capabilities, the government enacted the "Foreign Capital Law" and the "Foreign Exchange Law" to build up local technological capabilities by facilitating technology acquisition, transfer, and diffusion. *"Based on these laws, the Japanese government allocated its scare 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, pp.678). Therefore, this period was characterised by the high dependency of the American and European techniques than own technologies due to the lack of understanding of importance of R&D investment, the incapability to practical utilisation of research results and the underdevelopment of national education system (AIST, 2007). The dominant player of research and innovation is the public sector in the post-war period.

In the 1960s, private companies started to establish their research laboratories and participate in the national research projects under the "Big Project" (1966-1980), which was planned and designed by the Agency of Industrial Science and Technology (AIST) belonging to the Ministry of International Trade and Industry (MITI) (Yamaguchi, 2008). The "Big Project" aimed at the creation of own technologies by encouraging private sectors' R&D activities and their research cooperation with public sector. The

Japanese Industrial Technology Association founded in 1969 as the main purpose of facilitating and controlling knowledge diffusion and technology transfer (Harayama, 2001; METI, 2008) Under the "Big Project", Japan achieved improvements in technique, R&D expenditure in the private sector and joint R&D. However, the technologies and products generated in this period were uncompetitive in international market place due to a huge technical gap compared with developed economies (Harayama, 2000). In order to technologically catch up with the United States, the government cut in the budget for defence (Freeman, 1995) and increased investment in technology-intensive industries (i.e., machinery, material, automotive, biotechnology, chemistry, IT) in the 1970s (Harayama, 2001).

In the 1980s, Japan went into the post-catch up stage. In order to create innovative technologies in the targeted field, a series of R&D projects were designed and implanted by the Minsters and government agencies related to the science and technology. For example, The MITI established the "Next Generation Industry Basic Technology R&D System" in 1981. In the same year, the Science and Technology Agency (STA) initiated the "System for Promotion of Coordinated and Creative Science and Technology" (METI, 2008; Watanabe, 1999). In 1987, The Ministry of Education (ME) designed research centres for research training, and interaction among researchers and engineers to develop academic sciences (Watanabe, 2000).

The 1980s of S&T policies significantly addressed the importance of industrial firms' innovation activities and research collaboration among State-University-Industry in the product and process of innovation (Branstetter and Ug, 2004). With fiscal reforms, all participants in the national R&D projects could receive government funding in this period (Harayama, 2001). As a result, the industrial firms have became the dominate player over the public sector, as the financier and performer of R&D since then. Table 5 presents the international comparison of R&D funding and performance by sectors. It indicates the industrial firms played the largest role in funding and performing R&D activities in Japan among the selected developed countries.

Table 5
International Comparison of R&D expenditure for Selected Countries, by Sources of Funding and Performing Sector (2002-2003)

	U.S.A	Germany	France	UK	Japan
R&D by Source of funding					
government	31.2	31.9	36.9	28.5	18.5
abroad	n.a.	2.3	7.2	18.4	0.4
Other domestic	5.7	0.4	1.7	5.8	8.1
industry	63.1	65.4	54.2	47.3	73.0
R&D by performing Sector					
government	9.1	13.7	16.5	9.9	9.5
universities	16.8	17.1	18.9	21.8	14.5
Industry	68.9	69.2	63.2	66.8	73.7
Other non-profits	5.3	n.a.	1.4	1.5	2.3

Note: the data of U.S.A, France and Japan is based on 2002. The data of Germany and UK is based on 2003.
Source: OECD, 2005

The efficient S&T policies enabled Japanese to rapidly catch up with technologically developed countries and join the ranks of advanced countries. Entering into the 1990s, however, Japanese underwent the drop in competitiveness and the long economic recession caused by the collapse of asset prises and banking system (Branstetter and Ug, 2004). In this context, scientific technology was brought out the importance in sharp relief. In order to recover her economy, Japanese government more actively participated in the national R&D programmes as a planner, performer and coordinator to cover. In 1995, the government enacted the “Science and Technology Basic Law” with the agenda of “Nation Based on the Creation of S&T” to promote innovative technologies and a competitive R&D environment, which led the birth of “the Science and Technology Basic Plan” in 1996 (Watanabe, 2000)

The “Science and Technology Basic Plan I” (1996-2000) proposed the expansion of government budget for S&T development because the government of share of the national R&D expenditure was the lowest compared with the Western industrialised countries, such as the US, Germany, the UK (Sakakibara and Cho, 2005). The government planned to multiply research funding and increase twofold the GERD (Gross Domestic Expenditure on R&D) financed by the government as a percentage of GDP until 2000 (AIST, 2007; Yamaguchi, 2008).

The Basic Plan I aims to (i) strengthen the capabilities of researchers, engineers and technicians by establishing financial support programme for 10,000 post-docs; (ii) coordinate ministries related to S&T for efficiently implementing S&T developmental programmes; (iii) revitalise R&D activities in the private sector; (iv) build the national innovation system based on the tripartite cooperation among industry, university and State (Japan Federation of Economic organizations, 1998; Harayama, 2001; Watanabe, 2000; Nolan, 2007). In order to foster human capital, the Basic Plan I underlined the role of knowledge-creation institution, University and its close relationship with Industry to practically utilise research results. Under the "Law for Promoting Research Cooperation" (1998), universities allowed working as a consultant in private companies, private companies could establish research facilities within the campuses, and jointly conduct researches among them, as well as they acted as a training partner with the internship to foster high-quality human resources (Yamaguchi, 2008; Motohasi, 2005). In the same year of 1998, the "Law for Promoting University-Industry Technology Transfer" was also enforced to promote technology transfer and spin-off. The Technology Licence Organisations (TLOs) acted as the performer of technology transfer between faculty members and private companies by patenting and licensing contract (Takenaka, 2005; Motohasi, 2005).

Table 6
Macroeconomic Indicators of Japan (1995-2003)

	GDP (billion $)	GDP per capita	GDP growth rate	Unemployment rate
1995	5,303.80	42,282	1.9	3.2 (6.1)
1996	4,706.30	37,423	3.4	3.4(6.7)
1997	4,323.10	34,286	1.8	3.4(6.6)
1998	3,946.20	31,217	-1.1	4.1(7.7)
1999	4,469.60	35,291	0.1	4.7(9.3)
2000	4,763.80	37,549	2.8	4.8(9.2)
2001	4,175.60	32,869	0.4	5.0(9.7)

2002	3,993.40	31,407	0.3	5.4(10.1)
2003	4,326.40	34,010	3.0	n.a

Note: ( ) is unemployment rate of young people aged 15-24 years %
Source: World Bank, 2005

In spite of these great efforts, the decrease of international competitiveness lasted over the last decade, the consequent registered the negative GDP growth and increased unemployment in the end of 1990s (see Table 6). In this context, the S&T policies were revised to build internationally competitive high-tech industries in the creation of the cutting edge and socially valuable technologies (Noland, 2007; AIST, 2007). By the revision of the Basic Plan I, the "Science and Technology Basic Plan II" was founded in 2001. The origin and cause of the second Basic Plan are summarised below. First, the first Basic Plan improved the quality of research environment, but it could not attain the desired result to make the internationally competitive universities, good tripartite relationships and competitive environment (Haryama, 2001; Yamaguchi, 2008). Second, Japanese still had the difficulty in the commercialization of academic research because of labour immobility, low availability of venture capital, and weak inter-linkage of research institutes and firms (Bartholomew, 1997). Consequently, the "Science and Technology Basic Plan II" was launched to resolve these problems by upgrading the previous S&T policies.

The Basic plan II proposed; (i) effective R&D evaluation system based on fairness and transparency; (ii) autonomous and mobility of scientists and researchers; (iii) the elevation of R&D management; (iv) the properly operational University-Industry-State relationship; (v) technology transfer to the private sector; (vi) the promotion of high-tech venture firms (vii) international technical tie-up (See Table 7). The Japan Society for the Promotion of Science (JSPS) is in the charge of international S&T collaboration (Sikka, 1998). The Basic Plan II stressed the important role of entrepreneurs and high-tech venture business in the product and process of innovation because the U.S small-sized start-ups greatly contributed to the development of technologies. The venture firms were more productive and innovative that created more patents and new product per employee compared with the large-sized and diversified firms. (Bartholomew, 1997; Hane, 2002; Eto, 2005). As a result, all enabling sources influencing the national technology capabilities dramatically increased under the Basic Plan II. Table 8 shows in overall innovation capabilities of Japan in 2000s.

Table 7
The Targets of Science and Technology Basic Plan II

Items	Aims & Processes
Competitive Environment	Raising research funds allocated on a competitive basis as much as the US level. Increasing non-tenured and public offering positions, especially for young researchers.
Evaluation System	Increasing transparency of the State's decision making process. Building assessment system on R&D activities based on fairness and transparency.
Supporting System	Increasing mobility, autonomy and flexibility of researchers.
R&D Management	Increasing the competency and the responsibility of the head of a research institution.
Tripartite Cooperation	Harmonising the private sector's needs and the public sector's seeds. Facilitating technology transfer.
Technology Transfer to the Private Sector	Enlarging the support of technology transfer organisations. Allowing nationally owned patents to transfer to technology licensing organisations. Building up the incentive system for licensing privately-owned patents and increasing a number of high-tech venture companies.
Internationalisation	Facilitating international exchange of human capital, and technical and R&D cooperation.

Source: Harayama Y. (2001). "Japanese technology policy: History and a new perspective", RIETI Discussion Paper Series 01-E-001, pp.21.

Table 8
Major Indicators of Innovation Activities in Japan (2000-2006)

	R&D				ICT technologies								
	R&D Expenditure	Knowledge Investment	Researchers	Patents	Size of ICT sector				ICT Investment	Computer and Internet access		Communications	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
2000	3.04	4.61	9.92	14943.4	n.a	n.a.	n.a.	n.a.	15.01	n.a.	n.a.	123548.39	101.9
2004	3.27	5.32	10.64	14949.7	n.a	n.a	n.a.	n.a.	14.61	77.5	55.8	124242.14	130.9
2005	3.32	n.a.	11.03	13987.1	n.a	n.a	n.a.	n.a.	14.28	80.5	57.0	121473.77	134.8
2006	3.39	n.a.	11.05	14187.3	12.77	0.20	3.34	2.36	13.78	74.1	60.5	125089.34	136.5

Note: (1) R&D expenditure relative to GDP; (2) Investment in Knowledge (sum of expenditure on R&D, and software, R&D and education) as percentage of GDP; (3) researchers per thousand employees; (4) Triadic patent families, (5) Share of ICT manufacturing in total manufacturing value added; (6) Percentage point change in the share of ICT manufacturing in total manufacturing value added between 1995 and 2006; (7) Share of telecommunication services in total business services value added; (8) Share of other ICT services in total business exercise value added; (9) Share of ICT investment in non-residential fixed capital formation; (10) Percentage of house holds with access to home computers; (11) Percentage of householders with access to the internet; (12) Exports of information and communications equipment; (13) Telephone access

Source: OECE, Statistics Portal
http://www.oecd.org/statspor

3. Empirical Analysis of Causality between Economic Development and Innovation

In absence of natural resources, both Korea and Japan have long focused on the build and development of innovation capabilities as the national objectives. In order to econometrically investigate the interrelationship between the countries' economy development and innovation activities, the Granger Causality test is performed to check the direction of cause: Economic Growth ↔ domestic R&D spending and trade in techniques. For the two-way causation test, Gross Domestic Product (GDP) is employed as the index of economic progress, and four monetary values are used to measure innovation activities in Korea and Japan - R&D expenditure in the public sector and private sector, and the volume of trade in techniques (export and introduction of technologies). All variables are taken from bank of Korea, OECD and KOSIS (Korean Statistical Information Service) during the period of 1970-2007 (see Table 9 and 10: Data Description and Descriptive Statistics). For dedicate estimation, time frame is divided into two periods according to its level of technology development: (i) the technology catch-up stage based on labour and technology-intensive products (Korea: 1971-1990 Korea and Japan: 1971-1980); (ii) the high-tech based stage (Korea: 1991-2007 and Japan: 1981-2007).

The Granger Causality Test proceeds as follows:

$$Y_t = \alpha_0 + a_1 Y_{t-1} + \cdots\cdot \alpha_t Y_{t-\ell} + \beta_1 X_{t-1} \cdots\cdot \beta_t X_{t-\ell}$$
$$X_t = \alpha_0 + a_1 X_{t-1} + \cdots\cdot \alpha_t X_{t-\ell} + \beta_1 Y_{t-1} \cdots\cdot \beta_t Y_{t-\ell}$$

where *Y* and *X* are GDP and innovation variables, *t* is time, and ℓ is the lag length. It is the bivariate regression to test the two-way causation: *X* Granger causes *Y* and *Y* Granger causes *X*. The null hypothesis is that *X* does not Granger causes *Y* in the first regression and *Y* does not Granger cause *X* in the second regression. Granger (1969; 1988) suggests that the change of *X* can predict the change of *Y* if the null hypothesis is rejected in the first regression. On the other hand, *Y* can help predict *X* if the null hypothesis is rejected in the second regression.

In my empirical model, Eviews is employed for the two-way causation test: Log GDP ↔ Log R&D Expenditure in the Public Sector (Model 1), Log GDP ↔ Log R&D Expenditure in the Private Sector (Model 2), Log GDP ↔ Log Introduction of Foreign Technologies (Model 3), and GDP ↔ Log Technology Exports (Model 4). All variables are monetary values. It is to identify whether the activity of innovation (public R&D, private R&D, foreign R&D and technology export) causes economic growth, how much of current GDP can be explained by past values of GDP, and then whether adding lagged values of innovation can improve the explanation. For example, the increase of GDP is said to be Granger-caused by the increase of R&D expenditure in the public sector if the public R&D helps in the prediction of GDP, or equivalently.

The estimation result shows in Table 11. Firstly we found that Firstly, R&D expenditure in the public sector causes GDP while GDP does not cause public R&D during the catch-up stage in Korea (Model 1 in Table 11-1). R&D expenditure in the public sector strongly causes GDP in the model of time lag 1 (1% significance level) and fades over time during the period of 1971-1990. It indicates the public R&D causes economic growth after 1-3 year. In Japan, there is also the one-way causality, but the direction of causality is reversed (Model 1 in Table 11-2). The Japanese case shows that GDP causes R&D expenditure in the public sector, but public R&D does not cause GDP in the 1980s. The results imply that the ratio of R&D expenditure on the public sector to GDP was higher in Japan than Korea, but Korean R&D activities of public sector were more effective and less corrupted in the stage of catch-up.

In the high technology-based stage (1991-2007), there is no causality between GDP and R&D expenditure in the public sector in Korea (Model 1 in Table 11-1). It has the implication of undesired return of R&D expenditure in the public sector in the high technology stage. In the Japanese case, however R&D expenditure in the public sector causes GDP in the third and fourth year while GDP does not causes public R&D during the period of 1981-2007 (Model 1 in Table 15-2). The opposite result compared with the causality test in the catch-up stage implies that the public sector in Japan became innovative in the stage of high technology stage.

Secondly, there are the two-way causality between GDP and R&D expenditure in the private sector during the stage of catch up in both Korea and Japan. In Korea, GDP causes R&D expenditure in the private sector for 3 years, and the causation becomes strong in the second year during the period of 1970-1990. In the opposite direction, the private R&D causes GDP in the first and second year, but the causation is disappeared in the third year (Model 2 in Table 11-1). On the other hand, Japanese GDP causes R&D expenditure in the private sector in the first year and the causation become weaker in the second year during the period of 1970-1980. Inversely, the Japanese private R&D causes GDP in the third year, which has the strong significance (Model 2 in Table 15-2). The coexistent relationship between GDP and R&D expenditure in the private sector implies the active support of government facilitating private sector's R&D and its contribution to technological and economic development in both countries.

In the period of 1991-2007, GDP causes R&D expenditure on the private sector from the second year and the causal effect is maximized after the two years (the fourth year) in Korea. Also, the reverse relationship shows the strongest causality in the second year, but it becomes weaker (Model 2 in Table 11-1). Interestingly, there are 1-2 years gaps for maximizing the causal effect compared with the stage of catch-up. It may be, because R&D in high technologies involves in more time consuming. In Japan, GDP causes R&D expenditure in the private sector and the casual effect is maximized in the second year while there is no reverse causality in the stage of high tech innovation (Model 2 in Table 11-2). It implies economic growth directly facilitated the private sector's R&D activities, but their unsatisfying returns on R&D investment in the high technology stage.

The estimation results of Model 2 (Log GDP → Log R&D Expenditure in the private Sector in the both cases of Korea and Japan have the important implication of long-term based investment in high technologies. The strong significance of R&D expenditure in the private sector and weaker causality between GDP and public R&D in this stage implies that the countries have changed from government enterprise-oriented to individual enterprises-based environment, which is the line with my research of the historical background of economic and innovation policies in the previous section.

Thirdly, GDP causes the import of foreign technologies in Korea, but there is no reverse causality between 1970 and 1990 (Model 3 in Table 11-1). It implies that the growth of GDP facilitated the flow of foreign techniques because copying or imitation is the main channel to build up innovation capabilities in the stage of technology catch-up in Korea. Also, no reverse causality suggests the lack of skills to master, absorb, transfer and improve the imported foreign technologies in the period. For the case of Japan, we could not estimate the causality among GDP and foreign in techniques trade (technology import and export) in the 1980s because of data unavailability.

Entering into the 1990s, however, GDP causes technology imports in the first year while foreign technologies cause GDP in the fourth year in Korea (Model 3 in Table 11-1). It has the important implication that Korean government allocated the budget to import foreign techniques in a very short-tem. On the other hand, the long-term for improving the imported ones, at least 4 years, are required to produce profits in the stage of high technology. In Japan GDP does not cause the import of foreign high technologies, but there is the reverse causality in the third and fourth year (Model 3 in Table 11-2). It has the implication that there is little allocation of budget to introduce foreign technologies and at least 3 years are required to improve the imported high technologies and make profits.

In the last estimation, the 1980s of causation test in Japan could not estimate due to the unavailability of technology export data. For the case of Korea, there is no causality between GDP and technology exports during the period of 1970-1990 (Model 4 in Table 11-1). Therefore we can draw the conclusion that knowledge and technologies generated in this stage are uncompetitive in the global market. However, Korean technology exports cause GDP for 2 years, but the casual effect is disappeared in the third year since the 1990s (Model 4 in Table 11-1). The existence of causality suggests the improvement of technology competiveness in the high technology stage compared with those in the stage of pre-catch-up. On the other hand, Japanese technology exports cause GDP from the first year to the fourth year in the stage of high-tech innovation (Model 4 in Table 11-2). The causation effect is maximised in the first and second year, but it becomes weaker, which has the implication of shorter life cycle of product according to the rapid change of techniques. Also the stronger causality implies the high technology competitiveness of Japan than Korea.

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Table 9 Description of Data

(1) Korea

	Description	Year	Source
GDP	The logarithmic of Gross Domestic Product in national currency, converted to U.S dollars at official exchange rates.	1970-2008	Bank of Korea http://www.bok.or.kr/
Public R&D	The logarithmic of Gross Domestic R&D expenditure in the Public Sector, converted to U.S dollars at official exchange rates.	1976-2006	Korean Statistical Inforamtion Service http://www.kosis.kr/
Priave R&D	The logarithmic of Gross Domestic R&D expenditure in the Private Sector, converted to U.S dollars at official exchange rates.	1976-2006	Korean Statistical Inforamtion Service http://www.kosis.kr/
Foreign R&D	The logarithmic of amount of introduction of foreign technologies.	1986-2006	OECD http://www.oecd.org/ Korean Statistical Inforamtion Service http://www.kosis.kr/
Technology exports	The logarithmic of the amount of technology exports.	1986-2006	Korean Statistical Inforamtion Service http://www.kosis.kr/

(2) Japan

	Description	Year	Source
GDP	The logarithmic of Gross Domestic Product in national currency, converted to U.S dollars at official exchange rates.	1970-2008	OECD http://www.oecd.org/ Japan Exteral Trade Organisation http://www.jetro.go.jp/
Public R&D	The logarithmic of Gross Domestic R&D expenditure in the Public Sector, converted to U.S dollars at official exchange rates.	1976-2006	Korean Statistical Inforamtion Service http://www.kosis.kr/
Priave R&D	The logarithmic of Gross Domestic R&D expenditure in the Private Sector, converted to U.S dollars at official exchange rates.	1976-2006	Korean Statistical Inforamtion Service http://www.kosis.kr/
Foreign R&D	The logarithmic of amount of introduction of foreign technologies.	1985-2006	Bank of Japan http://www.boj.or.jp/en/type/stat/index.htm Korean Statistical Inforamtion Service http://www.kosis.kr/
Technology exports	The logarithmic of the amount of technology exports.	1985-2006	Bank of Japan http://www.boj.or.jp/en/type/stat/index.htm Korean Statistical Inforamtion Service http://www.kosis.kr/

Table 10-1 Descriptive Statistics (Korea)

100 million$

1970-1990	GDP	GERD	Private R&D	Public R&D	Foreign R&D	Tech. Exports
Mean	802.6190	13.63333	10.92667	2.705333	0.492000	7.256000
Median	638.0000	5.300000	3.870000	1.510000	0.520000	6.760000
Maximum	2637.000	44.80000	37.63000	7.460000	0.970000	10.87000
Minimum	81.00000	0.500000	0.180000	0.320000	0.110000	4.110000
Std. Dev.	725.1426	16.19461	13.63847	2.574573	0.343176	2.803860
Skewness	1.212691	1.006677	1.026468	0.898530	0.253205	0.206556
Kurtosis	3.646223	2.438340	2.495491	2.177010	1.790152	1.529909
Jarque-Bera	5.512572	2.730661	2.793174	2.441711	0.358372	0.485798
Probability	0.063527	0.255296	0.247440	0.294978	0.835951	0.784351
Observations	21	15	15	15	5	5

100 million$

1991-2007	GDP	GERD	Private R&D	Public R&D	Foreign R&D	Tech. Exports
Mean	5854.333	132.8125	100.6981	33.36250	3.403125	23.92063
Median	5168.500	123.4000	91.91500	33.92500	1.795000	26.06500
Maximum	10493.00	286.3000	217.5900	68.71000	16.25000	45.25000
Minimum	3081.000	54.70000	44.31000	10.39000	0.350000	9.460000
Std. Dev.	2267.017	62.29806	45.93074	15.85441	4.300131	10.13935
Skewness	0.716138	1.065363	1.257807	0.467137	1.920883	0.141908
Kurtosis	2.360279	3.601012	3.957078	2.969200	5.972221	2.328046
Jarque-Bera	1.845493	3.267470	4.829541	0.582545	15.72884	0.354716
Probability	0.397426	0.195199	0.089388	0.747312	0.000384	0.837480
Observations	18	16	16	16	16	16

Table 10-2 Descriptive Statistics (Japan)

100 million$

1970-1980	GDP	GERD	Private R&D	Public R&D
Mean	6300.755	299.9973	196.6100	103.3864
Median	5934.400	302.0500	194.1000	107.9500
Maximum	10457.70	539.6000	362.0000	177.5900
Minimum	3447.100	137.7100	94.86000	42.86000
Std. Dev.	2292.983	137.7101	90.37270	47.60653
Skewness	0.482235	0.341359	0.448943	0.158825
Kurtosis	2.080705	1.827085	1.991129	1.591759
Jarque-Bera	0.813682	0.844174	0.836010	0.955187
Probability	0.665750	0.655677	0.658359	0.620274
Observations	11	11	11	11

100 million$

1981-2007	GDP	GERD	Private R&D	Public R&D	Foreign R&D	Tech. Exports
Mean	26486.30	1472.066	1013.615	459.2552	68.68455	51.35455
Median	27211.90	1586.570	1082.470	531.7700	58.27000	49.40000
Maximum	42959.40	2056.890	1468.410	625.4700	184.0200	82.40000
Minimum	11775.50	617.9700	418.1800	199.7900	7.230000	23.61000
Std. Dev.	9024.505	456.5425	308.5969	153.4182	53.47404	16.91018
Skewness	-0.035841	-0.591480	-0.527832	-0.586019	0.882223	0.263362
Kurtosis	1.977286	1.940956	2.078464	1.724212	2.718536	1.915591
Jarque-Bera	1.182467	2.626011	2.045475	3.126362	2.926448	1.332266
Probability	0.553644	0.269010	0.359608	0.209469	0.231489	0.513691
Observations	27	25	25	25	22	22

Table 11-1 Granger Causality Test (Korea)

		1971-1990				1991-2007				
Lags		*1*	*2*	*3*	**Test Results**	*1*	*2*	*3*	*4*	**Test Results**
Model 1:										
GDP does not cause R&D expenditure in the Public Sector.	*F statistics*	0.24	0.08	0.94	All is	0.87	0.38	1.05	0.21	All is
	Prob.	(0.62)	(0.92)	(0.48)	accepted	(0.36)	(0.68)	(0.43)	(0.91)	accepted.
R&D expenditure in the Public Sector does not cause GDP.	*F statistics*	10.12***	6.01**	2.51*	All is	0.00	0.02	0.12	0.18	All is
	Prob.	(0.00)	(0.02)	(0.10)	rejected.	(0.98)	(0.97)	(0.94)	(0.93)	accepted.
Model 2:										
GDP does not cause R&D expenditure in the Private Sector.	*F statistics*	3.22*	9.98***	4.61*	All is	1.42	2.76*	2.32*	10.77**	Lag2-4 are
	Prob.	(0.09)	(0.00)	(0.06)	rejected.	(0.25)	(0.10)	(0.10)	(0.03)	rejected.
R&D Expenditure in the Private Sector does not cause GDP.	*F statistics*	4.80***	4.26**	0.59	Lag1&2 are	1.24	4.46**	2.22*	5.73*	Lag2-4 are
	Prob.	(0.05)	(0.05)	(0.64)	rejected.	(0.28)	(0.04)	(0.10)	(0.09)	rejected.
Model 3:										
GDP does not cause Introduction of Foreign Technology.	*F statistics*	57.16*			Lag1 is	3.22*	1.33	0.87	0.91	Lag1is
	Prob.	(0.08)			rejected.	(0.09)	(0.31)	(0.50)	(0.54)	rejected.
Introduction of Foreign Technology does not cause GDP.	*F statistics*	0.15			Lag1 is	0.19	1.66	0.97	9.92**	Lag4 is
	Prob.	(0.76)			accepted.	(0.66)	(0.24)	(0.46)	(0.04)	rejected.
Model 4:										
GDP does not cause Technology Exports.	*F statistics*	2.30			Lag 1 is	1.03	0.25	0.13		All is
	Prob.	(0.37)			accepted.	(0.32)	(0.78)	(0.93)		accepted.
Technology Exports does not cause GDP.	*F statistics*	0.50			Lag1 is	2.66*	2.22*	1.06		Lag1&2 are
	Prob.	(0.60)			accepted.	(0.09)	(0.10)	(0.43)		rejected.

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

Table 11-2 Granger Causality Test (Japan)

		1971-1980				1991-2007				
Lags		***1***	***2***	***3***	**Test Results**	***1***	***2***	***3***	***4***	**Test Results**
Model 1:										
GDP does not cause R&D expenditure in the Public Sector.	*F statistics*	7.73**	4.07*	54.64*	All is	0.00	0.06	0.13	0.49	All is
	Prob.	(0.02)	(0.10)	(0.09)	rejected.	(0.98)	(0.93)	(0.93)	(0.73)	accepted.
R&D expenditure in the Public Sector does not cause GDP.	*F statistics*	0.88	0.15	1.59	All is	0.12	0.70	2.58*	2.21*	Lag3&4 are
	Prob.	(0.37)	(0.86)	(0.51)	accepted.	(0.72)	(0.50)	(0.09)	(0.10)	rejected.
Model 2:										
GDP does not cause R&D expenditure in the Private Sector.	*F statistics*	10.87***	2.76*	7.64	Lag1&2 are	0.32	4.90***	2.94*	1.29	Lag2&3 are
	Prob.	(0.01)	(0.10)	(0.25)	rejected.	(0.57)	(0.01)	(0.06)	(0.32)	rejected.
R&D Expenditure in the Private Sector does not cause GDP.	*F statistics*	1.14	0.26	1632***	Lag3 is	0.68	0.14	0.42	0.31	All is
	Prob.	(0.31)	(0.77)	(0.01)	rejected.	(0.41)	(0.86)	(0.74)	(0.86)	accepted.
Model 3:										
GDP does not cause Introduction of Foreign Technology.	*F statistics*					1.27	0.53	0.17	0.46	All is
	Prob.					(0.27)	(0.59)	(0.91)	(0.76)	accepted.
Introduction of Foreign Technology does not cause GDP.	*F statistics*					0.85	0.70	4.18**	2.00*	Lag3&4 are
	Prob.					(0.36)	(0.50)	(0.03)	(0.10)	rejected.
Model 4:										
GDP does not cause Technology Exports.	*F statistics*					0.35	0.26	2.61	1.69	All is
	Prob.					(0.55)	(0.76)	(0.12)	(0.23)	accepted.
Technology Exports does not cause GDP.	*F statistics*					18.3***	6.37***	4.91**	2.30*	All is
	Prob.					(0.00)	(0.00)	(0.01)	(0.10)	rejected.

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

4. Discussion & Conclusion

This paper has discussed the historical background of technology development in Korea and Japan, with particular attention to the evolution of economic, industrial and innovation polices in the context East Asia. It allows us to analyse in what way they have achieved the rapid catch-up of technologies and innovation despite the 1990s of economic recession and the 1997 of financial crisis. In both countries, the public sector played the central role in the development of S&T and innovation in the early stage of economic development. However, the key actor of the development has been changed to the private sector by various institutions supporting the private sector's technical innovation since the 1980s in Japan and the 1990s in Korea. The appropriate S&T policies in the growth stages corresponding to the level of economic development have capacitated them to climb from imitation or foreign technology-dependent economy to high tech-intensive economy.

It also worthy to note that Korean government intervention and close relationship between State and large corporations (i.e., the State-owned enterprises, business groups) have played the critical role in economic and technology development. In particular, large conglomerates, chaebols rendered great services to the progress of industrial technologies and national technological competitiveness. As the strategy of national development, Korea's government directly and indirectly intervened in chaebols' technical innovation with preferential treatment (Hobday, 1995; 2003). The national S&T policies and innovation system were mapped out to support chaebols' R&D activities, which allowed them to accumulate, exploit and create new technologies (E.M. Kim, 1997; Chang, 2003). Consequently, chaebols made great contributions toward rapid economic growth and technological catch-up in Korea.

In Japan, the inter-linkage of research organisations and inter-firm cooperation (large established firms) are the important factors influencing on the product and process of innovation, rather than venture firms. It may be fundamentally attributable to her socio-cultural system, such as collectivist culture and risk aversion nature of society. By contrast with the individualism characterised by the Anglo-American countries, the collectivist culture values trusts and long-term relationship, as well as attaches a great importance to groups' interests relatively to individual ones (Lee and O'neill, 2003), which is similar characteristics with Germany. This perspective could accommodate the different path of knowledge and technology diffusion in technical innovation. In the context of Japan, the long economic recession brought about the reform of innovation system to resolve the low availability of venture capital, quality of entrepreneurships, and mobility of labour (Japan Federation of Economic organizations, 1998; AIST, 2007). In this sense, the government has reduced or removed legal and culture barriers to promote the dynamics and Industry-University-State tripartite cooperation. Consequently, Japan has become the world top in the U.S patents granted to foreign investors and the ratio of R&D expenditure to GDP respectively in 2003 (OECD, Science &Technology database). Therefore, the study of Korea and Japan show in what ways Korea has attained the development in terms of scientific technology and economy by jumping over many obstacles.

Further, the causality tests between GDP and the activity of innovation in Korea and Japan have some important implications. The stronger causality between GDP and domestic R&D than GDP and foreign technologies implies that Korean and Japanese government undertakes R&D-based growth strategies rather than FDI-dependent strategies for industrial upgrading and technical innovation, which is supporting previous studies of industrialization and innovation by Hobday (2003). He classified emerging or developing economies into four-model: R&D-based growth model (e.g., Korea and Taiwan), import-substitution industry restructuring (e.g., Latin America, India), passive FDI strategies (e.g., Malaysia and Philippines) and MNEs- or FDI-dependent growth model (e.g., Singapore) (also see UNCTAD, 2003). Also, the weak causality between Korean GDP and foreign technology in the high-tech stage may imply that its innovation pattern has been changed from "learning by doing" and "learning by research".

References

AIST (National Institute of Advanced Industrial Science and Technology, 2007). 'AIS management policy and research strategy'.
http://www.aist.go.jp/aist_e/about_aist/strategy/200704strategy.pdf

Bartholomew, S. (1997). 'National systems of biotechnology innovation: Complex interdependence in the global system,' *Journal of International Business Studies,* 28(2), pp.241-266.

Bank of Korea. Economic Statistics Yearbook, Seoul, Bank of Korea.
http://ecos.bok.or.kr/

Branstetter, L. and K.H. Ug. (2004). 'The restructuring of Japanese research and development: The increasing impact of science on Japanese R&D', RIETI Discussion Paper Series, 04-E-021.

Cantwell, J. (1989). 'Technological innovation and multinational corporations,' Oxford, U.K.: Basil Blackwell.

Carmen, G.S.M., C.M. Maite, and A.L. Eva (2000). 'Economic growth and cycles in European Union, USA and Japan 1990-1999: A general vies and analysis of causal relations,'
http://www.uned.es/imaec2000/articulos%20revista/revista3/GuisanAguayoCancelo.pdf

Chang, H. J. (2002). 'Kicking away the ladder', London: Anthem Press.

Chang, H.W. (2003). 'Innovation policy and challenges the Korean case', Institute of Industrial Technology and Planning (ITEP).
http://english.itep.re.kr/download/content/rc/235_1.0_attach_1.pdf

Chun, S.H. (2002). 'Economic development, and tax policy and tax system in Korea', March 6, Korea Institute of Public Finance (KIPF).
http://kipfweb.kipf.re.kr/lis/livedb/sinmungo/file/3.pdf

Dosi, G., K. Pavitt, and L. Soete (1990). 'The economics of technical change and international trade,' New York: New York University Press.

Eto, H. (2005). 'Obstacles to emergence of high/new technology parks, ventures and clusters in Japan,' *Technological Forecasting & Social Change*, 72, pp.359-373.

Etzkowitz, H., and L. Leydesdorff (2000). 'The dynamics of innovation: From National Systems and 'Mode 2' to a Triple Helix of university-industry-government relations,' *Research Policy*, 29, pp.109-123.

Freeman, C. (1995). 'The national system of innovation in historical perspective', *Cambridge Journal of Economics,* 19(1), pp.5-24.

Fujisue. K. (1998). 'Promotion of academia-industry cooperation in Japan – establishing "law of promoting technology transfer from university to industry" in Japan,' *Technovation*, 18, pp.371-381.

Hane, G. (2002). 'Innovation in Japan after the financial crisis: The transition from TechnoNationalism to TechnoRealism', The MIR Japan Program, Canter for International Studies, Massachusetts Institute of Technology.

Harayama, Y. (2000). 'Technological paradigm change and the role of university research: The case of the micromachine and Japanese research universities,' Working paper of department of Political Economy, 2, University of Geneva.

Harayama, Y. (2001). 'Japanese technology policy: History and a new perspective,' RIETI Discussion Paper Series 01-E-001, Research Institute of Economy, Traded and Industry (RIETI).

Hobday, M. (1995). 'Innovation in East Asia: the challenge to Japan', UK: Cheltenham, Edward Elgar.

Hobday, M. (2003). 'Innovation in Asian industrialization: A Gerschenkronian perspective', *Oxford Development Studies*, 31(3), pp.294-314.

IMF (2003). 'The IMF and Recent Capital Account Crises: Indonesia, Korea, Brazil', International Monetary Fund.

Jang, H.S. (2000). 'Corporate governance and economic development: The Korean experience', working paper, Seoul: Korea University.

Japan Federation of Economic organizations (1998). 'Toward the Foundation of a strategic industrial technology policy' In Japanese.
http://www.keidanren.or.jp/japanese/policy/pol210/honbun.html

Kim, L. and C.J. Dhalman (1992). 'Technology policy for industrialisation: An integrative framework and Koreas experience', *Research Policy*, 21, pp.437-52.

Kim, L and R. R. Nelson (2000). 'Technology, learning, and innovation: Experiences of newly industrializing economies', New York: Cambridge University.

Kim, B. (2006). 'Infrastructure development for the economic development in developing countries: Lessons from Korea and Japan', 11, November 2006, Graduate School of International Cooperation Studies, Kobe University.
http://www.research.kobe-u.ac.jp/gsics-publication/gwps/2006-11.pdf

Kim, E.M. (1997). 'Big business, strong state: Collusion and conflict in South Korean Development, 1960-1990', New York: State University of New York.

Kim. K.H (2006). 'The 1997-98 Korean financial crisis: Cause, policy response, and lessons presentation', The high-level seminar on crisis prevention in emerging markets, July 10-11, IMF.

Kim, L. (1997). 'Imitation to innovation: The dynamics of Korea's technological learning', Boston: Harvard Business School Press.

Kim, S.R. (1998). 'The Korean system of innovation and the semiconductor industry: A governance perspective', *Industrial and Corporate Change*, 7(2), pp. 275-309.

Kobrin, S.J. (1995). 'Transnational integration, national markets, and nation-states,' In B. Toyne and D. Nigh, editors, "International business inquiry: An emerging vision," Columbia, S.C.: University of South Carolina Press.

Kogut, B. (1991). 'Country capabilities and the permeability of borders,' *Strategic Management Journal,* 12(Summer/Special Issue), pp.33-47.

Korean Statistical Information Service (KOSIS). Statistics.
http://www.kosis.kr/

Lee, W.Y. (2000). 'The role of science and technology policy in Korea's industrial development', In Kim, L. & Nelson, R. R., editor, "Technology, learning and innovation: Experiences of newly industrializing economies", New York: Cambridge University Press.

Lehrer, M., and K. Asakawa (2004). 'Rethinking the public sector: Idiosyncrasies of biotechnology commercialization as motors of national R&D reform in Germany and Japan,' *Research Policy*, 33, pp.921-938.

Lundvall, B-A. (1992). 'National systems of innovation: Towards a theory of innovation and interactive learning,' London: Pinter.

METI (Ministry of Economy, Trade and Industry, 2008). Summary of the White Paper on Monodzukuri 2007.
http://www.meti.go.jp/english/report/data/Monodzukuri2007-2.pdf

MEXT (Ministry of Education, Culture, Sports, Science and Technology, 2003). White Paper on Science and Technology 2003: Ch.3 Measures adopted for promotion of science and technology.
http://www.mext.go.jp/b_menu/hakusho/html/hpag200301/index.html

Ministry of Information and Communication (MIC) (2004). White paper 2004, In Korean, Seoul: Ministry of Information and Communications.

Ministry of Science and Technology (MOST), various years. Science and Technology Activity Report. In Korean, Seoul: Ministry of Science and Technology. http://www.most.go.kr/(last accessed on 5 Oct 2007).
http://www.most.go.kr/

Motohasi, K. (2005). 'University-Industry collaborations in Japan: The role of new technology-based firms in transforming the National Innovation System,' *Research Policy*, 34, 583-594

Noland, M. (2007). 'From industrial policy to innovation policy: Japan's pursuit of competitive advantage,' *Academic Economic Policy Review*, 2*,* pp.251-268.

Nolan, P. (2001). 'China and the global business revolution', Basingstoke: Palgrave.

Noland, M. (2007). 'From industrial policy to innovation policy: Japan's pursuit of competitive advantage,' *Academic Economic Policy Review*, 2*,* pp.251-268.

OECD (Organisation for Economic Co-operation and Development). Statistics, 2006; 2009.
http://www.oecd.org/statisticsdata/

OECD (2000). Science, Technology and Industry outlook, Paris, OECD.
http://stats.oecd.org/Index.aspx

OECD (2005). ANBERD database, March 2005.
www.oecd.org/sti/ICTindicators

Porter, M. (1990). 'The competitive advantage of nations,' New York: The Free Press.

Sakakibara, M. and D. Cho (2002). 'Cooperative R&D in Japan and Korea: A comparison of industrial policy', *Research Policy*, 31, pp.673-692.

Shan, W., and W. Hamilton (1991). 'Country-specific advantage and international cooperation,' *Strategic Management Journal*, 12(6), pp.419-32.

Sikka. P. (1998). 'Legal measures and tax incentives for encouraging science and technology development: The examples of Japan, Korea and India', *Technology In Society*, 20, pp.45-40.

Song, J. (2006). 'Intellectual property regimes, innovative capabilities, and patenting in Korea,' *Seoul Journal of Business,* 12(2), pp.58-75.

Stern, J. J., J. H. Kim, D.H. Perkins, and J.H. Yoo (1995). 'Industrialization and the State: The Korean heavy and chemical industry drive', GSICS Working Paper Series, Cambridge: Harvard University Press.

Suh. S. M. (1986). 'The evolution of the Korean economy: A historical perspective', Korea Development Institute (KDI) Working Paper, 8603.

Takenaka, T. (2005). 'Technology licensing and university research in Japan,' *International journal of Intellectual Property, Law, Economy and management,* 1(1), pp.27-36.
http://www.jstage.jst.go.jp/article/ijip/1/1/27/_pdf

Teubal, M. (2000). 'Enterprise restructuring and embeddedness: A policy and systems perspective', *Industrial and Corporate Change*, 9, pp.87-111.

UNCTAD (2003). 'Investment and technology policies for competitiveness: Review of successful country experiences', New York and Geneva, United Nations Conference on Trade and Development.
http://www.unctad.org/en/docs//iteipc20032_en.pdf

UNCTAD (2007). 'Information Economy Report 2007-2008', Ch.1-3.
http://www.unctad.org/Templates/WebFlyer.asp?intItemID=4462&lang=1

Watanabe, K. (1999). 'A summary of White Paper on science and technology,' In Japanese, *Journal of Information Processing and Management*, 42 (10), pp.852-866.
http://www.jstage.jst.go.jp/article/johokanri/42/10/852/_pdf

Watanabe, K. (2000). 'A summary of White Paper on science and technology,' In Japanese, *Journal of Information Processing and Management*, 43 (8), pp.685-701.
http://www.jstage.jst.go.jp/article/johokanri/43/8/685/_pdf

Whitley, R. (2003). 'Competition and pluralism in the public sciences: The impact of institutional frameworks on the organization of academic science,' *Research Policy,* 32, pp.1015-1029.

World Intellectual Property Organisation (WIPO). 'World patent report: A statistical review (2008)'.
http://www.wipo.int/ipstats/en/statistics/patents/wipo_pub_931.html#a31

World Bank (WB)
WB General Statistics: http://www.worldbak.org/

World Economic Forum (WEF), Executive opinion survey, 2008, 2009.
http://www.weforum.org/en/index.htm

Yamaguchi, Y. (2008). 'A transition of the government measures involving Industry-Academia collaboration based on the analysis of the White Papers on science and technology', In Japanese, *Journal of the Japan Society for Intellectual Production*, 4(2), pp.54-65.
http://www.jstage.jst.go.jp/article/jjsip/4/2/2_54/_pdf

Ziegler, J.N. (1997). 'Governing ideas: strategies for innovation in France and Germany,' Ithaca: Cornell University Press.