

Universities in India's National System of Innovation: An Overview

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Abstract The status and functioning of Indian universities is explored in the Indian context from an NSI perspective. Whilst NSI is the main guiding post, the very social and economic context of Indian situation reflect the theoretical underpinning of this paper. The First part serves as a background to knowledge institutions and university sector in India. Basically, it identifies the main actors and agencies of India's NSI, namely, public research system comprising national laboratories, main science and technology agencies and councils and the university system. Given the focus of the paper on Indian universities in a macro historical perspective, the Second part is devoted to trace the growth and structure of university sector in terms of three phases, namely, 1940s to 1980; 1980 to 1990; and the era of liberalization after 1991. The Third part of the paper is devoted to knowledge production and knowledge diffusion. There are some important findings coming out of the quantitative data. It is argued that Indian production of doctorates is falling behind countries like China. Further, Indian universities are yet to achieve Humboltian goal. Finally, the paper has a concluding section which concerns with the current and future challenges facing Indian universities and their role in India's NIS.

Keywords Indian universities, national systems of innovation, research university

1. Introduction

With the dawn of 21st Century, universities have come to occupy a very significant role in building and strengthening the national science, technology

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and innovation system and at the same time to catalyse knowledge-based economies. The rise of Asian universities in the global knowledge based economy and international rankings in the last decade are closely associated with the rise of knowledge institutions of higher learning and scientific research. Two features stand out and are indicative of the trend. Firstly the feature of coupling teaching/research with innovation and at the same time forging university – industry links with various actors and agencies in the respective national systems of innovation (NSI). Universities are being re-positioned as frontiers of innovation in this NSI, where in, most new technologies (biotechnology, nano, new materials, ICTs etc) have become science based. This knowledge base for innovation is increasingly dependent on the research strength of universities. The second is the impact of globalization and the emergence of ‘new’ knowledge sites now extended to the Asian region.

Over the last decade perspectives on NSI has come to influence the research on understanding the dynamics of various actors and agencies (R&D labs, policies, universities, business enterprises and society’s vision and culture etc) in the national innovation systems.¹ The status and functioning of Indian universities is explored in the Indian context from the NSI perspective. Whilst NSI is the main guiding post, the very social and economic context, science and technology policies including higher education and the historical understanding of Indian situation reflect the theoretical underpinning of this paper.

1.1 Actors and Agencies of India’s NSI²

India’s national aggregate gross expenditure on research and development (GERD) is about INR 413 billion in 2007-08³. In absolute terms, Indian GERD witnessed substantial increase of 60% from INR 249 billion 2004-05 to INR 413 billion in 2007-08. As proportion of GDP, it witnessed an increase from 0.8% of GDP in 1992-93 to 1.13% in 2003-05. However, it registered a marginal decrease to 1% for the period 2004-07

¹ NSI is defined as ‘the network of institutions in public and private sectors whose activities and interactions create, import, modify and diffuse new knowledge and relevant new technologies (Freeman, 1987, 1995; Lundval, 1992; Lundval et al., 2006; Edquist 1997).

² Quantitative data in this section is drawn from reports on research and innovation policy from European Union Network ERAWATCH, See Analytical Country Report 2011 on India by V.V. Krishna, See http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/reports/countries/in/report_0001?tab=reports&country=in

³ INR indicates Indian rupees throughout.

as estimated by the government sources. Notwithstanding the current ongoing economic downturn, the Prime Minister Dr Manmohan Singh announced recently in January 2011 that the government is committed to increase 2% of GDP for R&D by the end of the XIIth Plan (2012-2017).⁴

A dominant proportion of GERD around 68% is met by the government sources and 30% from the business enterprise sector. The GERD in PPP terms works out to be about INR 1,632 billion. India ranks higher as compared to countries such as Brazil, Mexico, and South Africa but is behind China, which spent 5,508 billion equivalents INR in R&D in PPP terms after United States at almost 14,552 billion equivalents INR in 2006.⁵ India's endowment in terms of total human resources in science and technology is quite modest at 933 per 10,000 labor force compared with 914 for China for the same number of labor force.⁶

Except making explicit the idea of creating NSI in S&T Policy 2003 statement, India is yet to formally define her NSI as such. However the structure and network of relationships and institutional arrangements exist both in the formal and informal sense between different actors.⁷ Such a structure of innovation system is mainly constituted by a) Public Research System; b) Private Business Enterprise and Transnational Corporations-TNCs (Indian and foreign); c) Higher Educational Institutions; and d) State mediation through public policies. We shall briefly explore various facets of the structure and organization of India's NSI and then devote a separate section on the importance of state mediation.

a) Public Research System (PRS): This comprises national laboratories under a dozen science and technology agencies from space, atomic energy, agriculture, industrial research etc, and in-house R&D laboratories in large public sector enterprises in steel, fertilisers, railways, power, transport and aviation, chemicals, petroleum and energy etc. PRS is India's main actor of NSI as it accounts for 68% of GERD in 2007 and 69% (159,000) of the total 230,000 R&D personnel of the country in 2005.⁸ Out of this total 230,000 R&D personnel, 71,300 (31% of total) work in major science agencies such as

⁴ The Prime Minister's speech at the 99th session of Indian Science Congress and India Today Magazine: <http://indiatoday.intoday.in/story/mannmohan-singh-china-overtaken-india-in-field-of-science/1/166999.html>

⁵ All these figures in this introductory section are drawn from the CSSP Database, School of Social Sciences, Jawaharlal Nehru University, New Delhi, India.

⁶ UNESCO Science Report 2010, UNESCO, Paris, p374.

⁷ As noted earlier, NSI in the Indian context makes sense at the sectoral level of understanding rather than at the national level.

⁸ Different years are used for different sets of data as per their availability from reliable sources.

CSIR, DAE, DBT etc, 32,200 (14%) work in universities and 55,200 (24%) in the government based public sector enterprises and state government laboratories. The dominance of PRS in India contrasts with East Asian economies such as Korea and Japan where over 75% of GERD comes from private sources. The role of state governments to GERD is quite marginal and State Science and Technology Councils created in almost all 28 states are just beginning to become proactive in assessing their strengths and weaknesses.

b) Private Business Enterprises and TNCs: This is the second major actor of Indian innovation system which accounts for 30% of GERD in 2007 and 31% of total R&D personnel (71,300) of the country in 2005. In 1990-91 private sector accounted for 13.8% of GERD which is increased to 20.3% in 2001-02 and to 30% in 2006.⁹ The corresponding figure for GERD shows an increase from 2.4 billion Euros in 2002 to 5.5 billion Euro in 2005.

In the recent years business enterprise sector assumed considerable importance with the global competitive edge in pharmaceuticals, automotive, software, telecommunications and biotechnology. Whereas international economic crises created ripples in the US and European markets and industry in so far as the auto and IT sectors are concerned, a more optimistic market scenario emerged in the Indian case. In the midst of crises, Tata launched world's cheapest small car, Nano into the Indian market on 23 March 2009 with an advanced booking for over 120,000 cars.¹⁰ The second Indian auto firm, Mahindra and Mahindra also launched its indigenous new model of 'Scorpio' - semi utility vehicle. Another player that will enter into the market is Bajaj with its mini car RE60 in 2012. Indian automobile production from 5.3 million units in 2001-02 grew to 10.8 million units in 2007-08. In 2006-07, the Indian automotive industry provided direct employment to more than 300,000 people and contributed 5% of India's GDP.

The other sector which witnessed robust growth and expansion is the telecommunications. Indian telecom market is one of the fastest growing markets in the world in 2009 in terms of subscribers behind China. China stands at more than 800 million telecom subscribers and India at more than

⁹ It may be noted that the figures being quoted are from the R&D statistics given by the Department of Science and Technology (DST). However, the DST figures grossly under estimate the foreign R&D inflow that has come into India during the period ending 2005-06. The estimates of a World Bank study (see Mark A Dutz, *Unleashing India's Innovation – Towards Sustainable and Inclusive Growth*, World Bank, Washington, 2007) shows that total private R&D investment has risen from half a billion Euro in 2002 to 2.45 billion Euro in 2005.

¹⁰ India is attracting global auto manufacturers due to country's large middle class population, growing earning power, strong technological capability and availability of trained manpower at competitive prices.

500 million.¹¹ In January 2009 alone India added 15 million subscribers. The third sector which witnessed a reasonable growth despite economic crises is India's IT industry which contributes to over 5.8% of India's GDP in 2008-09. The industry grew by 28 to 29 per cent in the last few years but is slowed down in the current year. For instance among the top 20 firms operating in IT sector in India, all big Indian firms such as Tata Consultancy Services, Wipro, Infosys, HCL and Tech Mahindra – Satyam witnessed modest growth rates between 15 to 20% during 2007-08 and 2008-09.¹² Despite the slowdown, Indian IT-BPO grew by 12% in 2008-09 to reach US\$ 59.5 billion in aggregate revenue.

The trend of the global R&D flows to India is sustained and growing in the situation of economic downslide. About 260 global TNCs operate their R&D centres or laboratories in India in Bangalore, Hyderabad, Delhi, Pune and Chennai regions. Bangalore is the most preferred destination of foreign R&D centres which accounts for 45% of the firms followed by NCR (Delhi) with 22% of the centres. Much of India's FDI in R&D has gone to major cities such as Bangalore which have developed innovation eco-system and knowledge hubs. Compared to the situation of 1980s which the firms were by and large involved in 'adaptive technology' for local market, TNC R&D centres in India in the last few years are oriented towards 'creative technology' for high end Indian industry and global markets.

The rise of business enterprise sector as an important actor of NSI is also evident from various Indian firms which followed Tata who acquired UK steel firm Corus; and Mittal's acquisition of Belgian-French firm Arcelor.

c) Higher educational institutions (HEIs): With over 447 universities with 25,000 affiliated colleges, much of the recent dynamism witnessed in the knowledge based and high technology sectors of Indian economy is the result of human resources, skills and the vast institutional base already created in the higher educational sector. In an effort to sustain this dynamism the government has increased the higher education budget by three times in 2009-10. However, R&D in HEIs in India is a weak link in India's NSI which accounts for mere 14% of R&D personnel compared to 55% of total R&D

¹¹ The launch of advance telecom services like 3G and IPTV will drive the future growth in India. The sector attracted \$2,558 million FDI in the financial year 2009 as compared to \$1261 million in financial year 2008. Telecommunications account for 9.37% share in total FDI inflow.

¹² However, big foreign firms such as Microsoft, IBM, Cisco, Oracle, Intel and Adobe witnessed only a marginal growth rate for the same period between 1 and 10%. For instance, Microsoft which registered 26% growth rate in 2007-08 declined to just 1% in 2008-09 compared to the previous year; and Hewlett Packard from 30% to 2% for the same periods.

personnel of the country in PRS. Higher education R&D is less than 8% of GERD. However, universities accounted for over 52% of India's total 44,126 SCI based publications in 2007-08 which makes the sector a very important actor of the innovation system.¹³ In 2006-07 the government set up the National Knowledge Commission to assess, plan and recommend the knowledge challenges of the 21st Century. Three major developments in the higher educational sector are: a) increase India's competitive advantage in the fields of knowledge by expanding the existing 400 universities to 1,500 by 2015; b) 15 year career support programme through scholarships from high school to PhD level; and c) promote university – industry links and partnerships. The Knowledge Commission's tenure is continuing with the new government in 2009 and its operations are being expanded.

According to various estimates and data from authentic sources, India produces about 2.5 million graduates every year, of which 300,000 are engineers and 150,000 IT professionals. This is in contrast to 70,000 engineers in USA, 33,000 in Germany and 600,000 in China. However, according to Farrell et al. (2005), with 14 million young university graduates (with seven years or less of work experience) India's talent pool is estimated to be the largest in the world, overlapping the Chinese talent pool by 50% and that of USA by 100%.¹⁴

2. Growth of Universities: Three Phases¹⁵

By the time India achieved her independence on 15 August 1947, the country was endowed with higher educational system structured and influenced by British colonial policies since the beginning of 19th Century. The first modern college was established at Serampore near Calcutta and three universities were established in the Presidencies of Bombay, Madras and Calcutta in the year 1857 which were modeled on the British university system. Local Indian contribution to the institutionalization of higher

¹³ However, the figure given by the DST, Government of India based on n core databases the total number of papers has increased from 59,315 in 2001 to 89,297 in 2005. These are non SCI based publications which are covered in one or the other international data bases such PASCAL data base of France.

¹⁴ Some of the figures used here are compared with the data sets given by DST, Government of India. The figure of 14 million science graduates from Farrell et al. (2005).

¹⁵ Figures and other quantitative data in this section are drawn from various sources of Planning Commission, University Grants Commission, Agarwal (2009) and Ministry of Human Resource Development, New Delhi during October 2011. Information and analysis in this section is also drawn from Krishna (1997, 2007).

education came about in parallel to efforts of colonial government up to 1947. By independence, there were around 30 universities and some two hundred colleges affiliated to these universities. The growth of higher education in independent India can be conceptualized in terms of three phases: 1940s to 1980; 1980 to 1990; and the era of liberalization after 1991.

2.1 Phase I: 1940s to 1980

The growth of universities and institutions of higher learning was given top priority by the government led by first Prime Minister Jawaharlal Nehru and his education minister Abul Kalam Azad in the 1940s. Nehru's focus on the expansion of higher education base including setting up of universities was very much an integral part of the process of science and technology (S&T) institutional building and S&T policies. As early as 1947 the government set up the Scientific Manpower Committee with Homi Bhabha (father of India's atomic energy programme) and Shanti Swarup Bhatnagar (Chief of Council of Scientific and Industrial Research Network of Laboratories) as members, among others, to plan scientific and technical human resources needed for post-war and post-independent agenda of development (See Krishna, 1994).

Secondly, Nehru's regime was instrumental in implementing the recommendations of Sarkar Committee Report (1945), which was set up even before independence to recommend the expansion of technical education in India. This led to the establishment of All India Council for Technical Education (AICTE) to systematically plan and expand technical education in India. The first major step in giving expression to the recommendations of Sarkar Committee was the establishment of five Indian Institutes of Technology (at Delhi, Bombay, Madras, Kanpur and Kharagpur) modeled on USA's MIT during 1950s and 1960s. Over the last four decades, these institutes have grown to establish high teaching and professional standards of engineering education and are recognized as one of the world's eminent engineering institutions. Similarly, in the early 1960s two of India's most eminent management institutes were also set up in Ahmadabad and Bangalore modeled on the lines of Harvard Business School and MIT's Sloan School of Management.

Thirdly, in an effort to systematically plan India's higher education and expand the university system, the government established University Grants Commission (UGC) in 1953 under the Chairmanship of S. S. Bhatnagar. The phase between 1947 and 1980, from the perspective of India's science, technology and higher education policies, is marked for building India's S&T infrastructure in more than dozen S&T science agencies in agriculture, industrial research, medical, atomic energy, space, electronics, among others. For this reason there has been an overwhelming domination of governmental

support in building higher education system in the public domain. As shown in Table 4 universities expanded fivefold from just 25 in 1947 to 132 in 1980; and colleges expanded tenfold from around 450 in 1947 to 4,738 in 1980. Correspondingly, from a less than half million students in higher educational institutions in 1940s, the enrolment grew to around 3.5 million in 1980. Even though the government dominated the higher education scene in this phase, as the recent study of Agarwal (2009) points out, the government encouraged and partnered private initiatives in higher education with the introduction of a policy measure known as Grant-in Aid (GIA) institutions or private aided institutions. In 1980s one third of colleges were in fact private aided colleges. In retrospect, from an overall perspective this phase reflects the realisation of a Nehruvian vision of building a reasonable base in science, technology and higher education infrastructure. Though there were initiatives from the private sector such as from Tata's in building Indian Institute of Science, Bangalore and Tata Institute of Fundamental Research, Bombay and Birla's in building Birla Institute of Technological Sciences, Pilani, the public support played an important part.

2.2 Phase II: 1981 to 1990

The growth of higher education is seen to have entered a new phase after 1980. Even though the government support to higher education and expansion of university sector continued, the role of private sector in higher education began to emerge in this phase of growth. Another development that came about in the phase was the introduction of distance education besides further expansion of private aided and self-financing colleges. As the government experienced resource crunch for the rapid expansion of higher education after 1980, the private sector was given some incentives to enter the higher education sector. The fields of engineering and technology, medicine, teacher education and other fields such as hospitality and hotel management courses after 1980s witnessed rapid growth in the private sector compared to public sector as shown in Table 3 Professional Higher Education Institutions: Growth and Private Share. Hence the main feature of this phase was the emergence of public-private partnership in higher education.

Whereas the total enrolment increased from 3.5 to nearly 5 million between 1980 and 1990, the university sector expanded from 135 to 175 universities and college sector expanded from 4,738 to 7,346 colleges during the same period. Whilst the number of students in the distance education sector accounted for 6% of total enrolment in the earlier phase (1947-1980), the proportion increased to 11% in the current phase (1980-1990).

2.3 Phase III: 1990s and Beyond – Reforms and Expansion of Private Sector

Until 1980s the policy discourse on reforms of higher education and the issue of assigning relatively a greater role to private sector was at low key. For instance, even the National Policy on Education (1986)¹⁶ downplayed the role of private sector. It is only since the early 1990s the role of private sector in education drew more and more policy attention as part of liberal economic policies. The period after 1991 in India is generally seen as an era of reforms initiated by P.V. Narasimharao government under his finance minister (who is the current Prime Minister) Manmohan Singh. As Agarwal (2009:47) draws our attention the 8th Plan (1992-1997) signaled the ‘first indication of this paradigm shift’ to promote the role of private sector. This was followed up by Special Action Plan of Prime Minister in 1998 and later a renewed focus on the role of private sector was given in the 10th Plan (1998-2003). Among other liberal economic reforms which were initiated in this phase, the government introduced a bill in Parliament to establishment private universities in 1995. Even though due to lack of political consensus the bill is still under pending, an indirect path to foster and promote private universities found its way through ratification of similar initiatives by state government legislatures. Education under Indian constitution is in the concurrent list or under the state subject which can be regulated and new reforms introduced.

The first private university that came up in India was Sikkim Manipal University of Health, Medical and Technological Sciences in the State of Sikkim in 1995. Another pathway that was chalked out by the government and the UGC to promote private universities was through the higher education policy measure of granting Deemed University status to private institutions. This was indeed an interim measure and an alternative to the pending private university bill. 1990s witnessed initiatives from five state governments such as Sikkim, Uttar Pradesh, Gujarat, Himachal Pradesh, among others, to set up private universities. Currently there are 21 private universities in India which have recognition from UGC.

The major expansion in private unaided sector of higher education in this phase is witnessed in terms of private unaided colleges which have increased more than 138% from 3,202 to 7,720 colleges during 2000 and 2006 in five years. As already noted in an earlier section, much of the expansion of private higher education since late 1990s is reported from professional subjects including engineering and medical as shown in Table 3. For instance, private unaided engineering colleges increased almost tenfold from 145 in 1990 to

¹⁶ <http://www.ugc.ac.in/>

1,402 colleges in 2007, whereas the government and aided colleges increased just 30% from 164 to 215 for the same period (see Table 3).

From an overall perspective of higher education, the enrolment in higher education increased from 5 million in 1990 to nearly 13 million in 2009-10. The global average in 2011 is around 26%. About 30% of total enrolment of students in 2008-09 is in the private unaided institutions.

2.4 Contemporary Reforms in Higher Education

Apart from focusing on private sector's role in the 1990s, the government did not bring in any major reforms till the turn of the present century. A major policy initiative to revamp higher education system in India and its expansion, particularly in the public domain was set in with the establishment of National Knowledge Commission (NKC). Sam Pitroda, who is credited with championing the telecom revolution in the country, was made the Chairperson to lead NKC. The agency directly reports to the Prime Minister and works in close coordination with the Planning Commission and other governmental bodies concerned with education. The primary objective of NKC has been to plan and formulate appropriate policies related to human resource development and knowledge institutions for the 21st century knowledge based society and economy.

The second Report to the Nation submitted in November 2007 covered 20 subjects and outlined about 160 concrete action items. The Commission submitted its recommendations on education, to coincide with the final deliberations on the XIth Plan (2007-2012) document of the Planning Commission. The XIth Plan budget allocations to higher education resulted in over four fold increase over the Xth Plan (2002-2007). Together with the higher education focus both in the NKC and XIth Plan, there has been a notable policy focus to strengthen and revamp the technical education at the level of Industrial Training Institutes and vocational education. National Knowledge Commission has recommended the target of creating 1,500 universities by 2015. This includes establishment of 50 national universities.¹⁷

A further policy initiative in higher education reforms came about with the submission of a Report on 'Renovation and Rejuvenation of Universities' under the Chairpersonship of Yash Pal (former Chairman of UGC and India's one of the eminent space scientist). The committee submitted the report to the Ministry of Human Resource Development (MHRD) on 24 June 2009. Main recommendations which were accepted by the government included:

¹⁷ For the reports on various issues of higher education and recommendations of the NKC see <http://www.knowledge-commission.gov.in/>.

- a) Scrapping of deemed varsities and their transformation to full-fledged universities;
- b) Reiteration of NKC recommendation of creating 1,500 universities through identification of top colleges; and
- c) Creation of higher education commission which in a way replaces or takes over all the existing bodies such as UGC, engineering, medical and other regulatory bodies and councils.

Another noticeable feature of higher education since 2007 has been the focus on inclusive policies on higher education. Both the education ministry and the UGC, in particular, initiated various policy measures and programs to promote inclusive policies to bring in under privileged and various other backward class sections of society under the ambit of higher education. The affirmative action implemented provides up to 50% reservation for first entry degree programs in universities and colleges. Various steps that the government initiated since the last decade to reform higher education and make it relevant to industry and society can be summarized as follows:

- a) Setting up of National Knowledge Commission – establishing 1,500 universities;
- b) Five times rise in the national education budget between Xth (2002-2007) and XIth Plan (2007-2012);
- c) National Commission for Higher Education and Research 2010;
- d) The National Accreditation Regulatory Authority for Higher Educational Bill, 2010;
- e) Bill on Indian version of US Bayh-Dole Act of the Protection and Utilization of Public Funded Intellectual Property Bill, 2008. The Bill is currently pending in the Parliament. In the absence of national law, science agencies and universities have evolved their respective law governing IPR in India in 2010;
- f) National Skill Development Council (2008-09) contribute significantly up-skilling 500 million people in India by 2022, mainly by fostering private sector initiatives in skill development programs;
- g) President of India declared 2010-2020 as the Decade of Innovation;
- h) National Innovation Council (NInC) to prepare a Roadmap for Innovation 2010-2020 under Sam Pitroda;
- i) Public – private partnership in promoting HEI and skills; and
- j) Promotion of knowledge hubs and innovation clusters

As with the Bayh–Dole Act, the Indian bill is premised on the assumption that university ownership of patent rights is likely to increase the number of academia–industry collaborations. And without it, industry may be unwilling to develop academic research into useful products for society.

The Foreign Educational Institutions (Regulation of Entry and Operations) Bill (2010) is part of the process to arrest import of higher education as 130,000 students go to USA, UK, Australia and Europe etc.

2.5 Types of Higher Educational Institutions (HEIs)

The institutional structure of higher education comprises different types of universities and affiliated colleges and specialized institutions which have been granted university status. The structure that has evolved over the years is also partly based on the sources of funding from public and private sources as well as mixed funding from both these sources. From the perspective of governing and setting up of HEIs, seven different types can be seen in operation in the Indian context¹⁸ :

- a) Public universities or institutions which are promoted and set up by the central government;
- b) Universities set up by the state governments;
- c) Private universities or institutions set up and funded by private sources;
- d) Government dependent private institutions which are set up by private sources but are aided to some extent by the government;
- e) Among c and d there are universities which are given the title of ‘deemed university’;
- f) Institutions of national importance and those which are set up by state legislatures; and
- g) University affiliated colleges which offer undergraduate and graduate courses. These are also given the title of deemed universities. Deemed and private universities relatively enjoy greater autonomy compared to public universities and those of aided universities.

The Table 1 shows the growth of different types of HEIs during 2002 and 2007.

¹⁸ The UGC is the apex body which regulates the universities as a whole. However, HEIs in engineering, management and other professional areas are regulated by AICTE and medical institutions are regulated by Medical Council of India.

Table 1 Growth of Different Types of Universities and HEIs

University level institutions	2002	2007	2011
State universities	178	232	250
Deemed universities	52	114	140
Central universities	18	24	25
Private universities	n/a	11	34
Institutes of national importance	12	13	13
Institutes set up by state legislature	5	5	5
Total no. of all universities	265	399	467**
Colleges affiliated to various univ.	16,885*	18,064	25,951

*Figure for 2003-04; ** some institutions are notified.

Source: <http://www.ugc.ac.in/>; <http://www.education.nic.in/>

2.6 Enrolments in Higher Education

Total enrolment of students in India's HEIs increased to 11.5 million in 2007 spread over nearly 447 universities and 25,000 colleges. A cursory look into this table shows that it took 13 years to touch the figure of 1 million students from 1947 to 1960 and then added a million students every decade up to 1980 touch a figure of 3 million. In the last two and a half decades the higher education enrolments increased over almost 3.5 fold to a total of 11.5 million in 2007. Out of this total, about 60% are male and 40% women students. However, India lags behind other developed and developing countries in Gross Enrolment Ratio (GER). For instance, GER's for USA, Australia and UK are 82, 72 and 60 respectively. On the other hand GER for India is 11 compared to 29 in Malaysia and 19 in China for 2004 (Duraisamy, 2008).

Table 2 Higher Education Enrolments in Public and Private Institutions

Type of Institutions	00-01	05-06	Growth(00-06)
Government	3,443	3,752	309 (9%)
Private Aided by Government	3,134	3,510	376 (12%)
Private Unaided	1,822	3,219	1,397 (76%)

Source: Data drawn <http://www.education.nic.in/>; <http://www.ugc.ac.in/>

**Table 3 Professional Higher Education Institutions:
Growth and Private Share**

Course	99-00	06-07 (07 July)	Total Increase(%)	Private Share(%)
Engineering	669	1,617	142	91
Pharmacy	204	736	261	95
Hotel Management	41	80	95	94
Architecture	78	116	49	67
Computer Applications	780	999	28	62
Management	682	1,150	69	64
Teacher Education	1,050	5,190	395	68
Medicine	174	233	32	50
Dentistry	45	189	420	59
Physiotherapy	52	205	294	92
Total	3,775	10,515	178	80

Source: Agarwal (2009)

As noted earlier, the most notable feature of enrolment in higher education came about during Third Phase 1990 with the expansion of private sector's role. During 2000 and 2006 as the Table 2 shows, whilst the enrolments increased between 309,000 (9%) and 376,000 (12%) in government and government aided private institutions respectively; the enrolments in private unaided institutions increased almost four fold to 1,397 million (76%). Much of this expansion is witnessed in professional disciplines, particularly engineering and medicine. As the Table 3 shows, engineering, medicine and management subjects take a lead in the private sector expansion to the extent of 80% compared to 20% in the public institutions for the data available for the period between 1999 and 2007.

As per detailed break up available from the UGC, nearly a third of total 11.5 million students in higher education, that is 30%, are from science and engineering¹⁹;

¹⁹ This includes medicine, agriculture and veterinary sciences

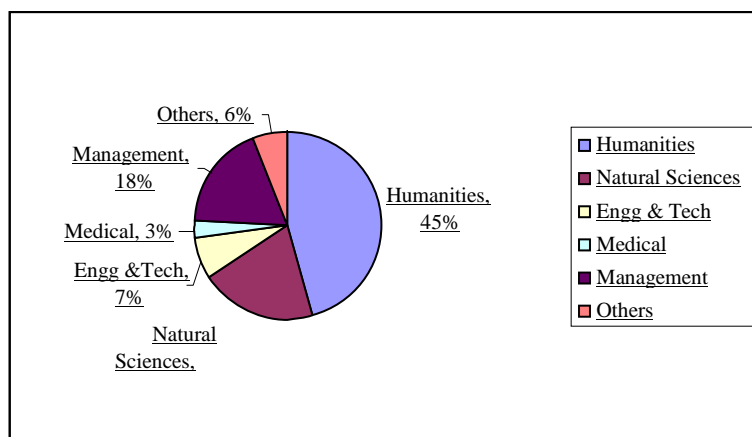


Figure 1 Discipline-wise Enrolments of Students in Universities 2007-08

Table 4 Cumulative Growth of Institutions of Higher Education and Enrolments

Year	Universities	Colleges	Enrolment
1947	25	500	300,000
1955	38	n/a	800,000
1960	50	2,000	1,000,000
1965	68	n/a	1,600,000
1970	87	3500	2,000,000
1975	105	n/a	2,700,000
1980	132	4,100	3,000,000
1985	138	n/a	3,600,000
1990	175	7,000	5,000,000
1995	179	n/a	6,500,000
2000	278	12,296	8,400,000
2005	330	n/a	10,480,000
2007	399	18,064	11,500,000

Source: Data compiled from the Association of Indian Universities (AIU) (2000) *Universities Handbook*, New Delhi: AIU, p.1111.

Table 5 Teaching Faculties by Designation in Universities and Affiliated Colleges

Year (05-06)	Prof.	Assoc.Prof /Reader	Sr. Lect.	Lect.	Tutors /Demons.	Total
Univ.	16,591	24,986	12,059	23,260	1,923	78,819
Affiliated Colleges	23,951	100,520	61,232	210,202	13,279	409,184
Total	40,542	125,506	73,291	233,462	15,202	488,003

Source: Agarwal (2009) & <http://www.ugc.ac.in/>

45% from Arts and social sciences; and 23.5% from commerce, management and law faculties in 2006. As Table 5 shows, half million faculty members are engaged in universities and colleges in India. India's major strength in the human and intellectual capital comes from her HEIs. According to McKinsey Global Institute, San Francisco, study, India had 14 million young graduates in the work force with about seven years of work experience. This makes it world's largest talent pool overlapping China talent pool by 50% and that of USA by 100% (Farrell et.al 2005).²⁰ Despite this overwhelming knowledge and human capital in an aggregate sense, India's top ranking research based universities and science and engineering institutions have not expanded to absorb the demand in the tertiary sector of HEIs. Whereas the top institutions in science and engineering absorb just 3 to 4% of the students who write entrance exams, the other top 20% of students who fail to find places in the top institutions go out of the country. In the last decade, since 2000, on an average of 100,000 students every year went out of India mainly to USA, Australia and UK for higher studies. For instance, in 2005-06, 76,000 have gone to USA; 27,000 to Australia; 23,000 to UK; and about 30,000 students to other countries.²¹

3. Universities in the NSI

3.1 Knowledge Production: 'Narrow' Research Base of Universities²²

²⁰ Quoted in Herstatt et al. (2008)

²¹ France 1500; Malaysia 1800; New Zealand 3300; Canada 6000; Germany 4700; and Singapore 4800.

²² The term 'narrow' is being used from a 'common sense' perspective to indicate that less than 25% of the total universities can be classified as research based universities with peer reviewed publications. Hence 'medium' base would then indicate about 50% of universities with research base and above 70% might be taken as 'broad' research base. Going beyond peer reviewed publications, one can correspondingly relate to number of Ph.ds and post-graduate and under graduate students etc.

Universities occupy a significant position in terms of national R&D effort in industrially advanced countries (Mowery and Sampat, 2008). Universities in OECD - 25 countries accounted for 20% and Japanese universities accounted for around 15% of GERD in 2004-2005. Whilst universities and colleges in China account for around 10% of GERD in 2005-06, Indian universities and colleges accounted for mere 7% in 2008. In contrast, the business enterprise sector accounted for 30% and public research institutions sector accounted for around 62% of GERD during 2006-08. Despite a very low level of GERD devoted to HEIs, the sector accounted for nearly two thirds of total S&T output measured in terms of peer reviewed publications in SCI Extended version data base during 1985-86, 1994-95 and 2001- 02.²³ (Table 6). Between 1980s and 2007, even though the proportion of HEIs contribution in the national output has come down from 69% in 1985-86 to around 52% in 2007, the HEI sector accounted for over half of national output.

Table 6 Publication Output of HEIs, PRIs and Business Enterprises 1980s - 2007

	HEIs*	PRI	Business Enterprises	Others	Total
1985-86 (SCIE)	16,085 (69%)	6,569 (28%)	411 (1.7%)	235 (1%)	23,300
1994-95 (SCIE)	17,302 (62%)	9,218 (33%)	496 (1.8%)	562 (2%)	27,578
2001-02 (SCIE)	23,578 (60%)	13,329 (34%)	708 (1.8%)	1,237 (3%)	38,852
2007-08 (Scopus)	22,945 (52%)	19,415 (44%)	1,325 (3%)	441 (1%)	44,126

* Universities and Institutions of national importance

As the Table 6 indicates, business enterprise is not a major factor in the S&T output as it hardly accounted between 1 and 3% during the last two and a half decades. Another important study on publication output (based on Scopus data base) by India's top HEIs reveals somewhat similar trends. For the decade 1997-2007, HEIs accounted for 52% of total cumulative S&T publications, whereas PRIs accounted for 44% for the same period. These above indicators clearly point out low level of R&D funds devoted to HEIs sector. At the same time they also raise an important issue of the extent of research base and research intensity in the universities and colleges in India. In other words, it is instructive to explore the proportion of universities and

²³ Whilst universities and colleges accounted for 46%, institutes of national importance (which are also counted as deemed universities) accounted for 20%. (Gupta and Dhawan, 2009)

colleges undertaking research as demonstrated through trends in S&T output and other measures such as post-graduate and PhDs.

3.2 Striving towards Humboldtian Goal

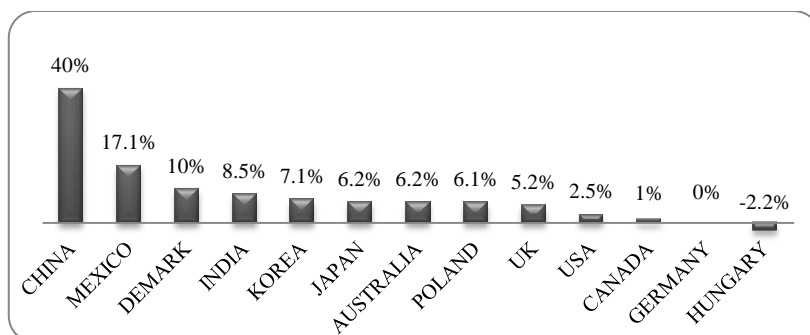
From a policy perspective, Indian universities have a long distance to travel before they are able to accomplish the goal of what has come to be known as the Humboldtian ideals. It signifies the unity of teaching and research in higher educational institutions and at the same time stands for democratic values of free thinking, research and teaching autonomy with a strong public support. However, the most fundamental aspect of this ideology or goal is the attainment of teaching and research in universities of a reasonable quality and excellence. As various writings clearly show, it is this ideology that has governed the best of European universities, particularly the German universities, in scaling the heights of excellence in teaching and research and at the same time contributing to the industrial progress and economic growth.

There are nearly 447 universities and over 25,000 colleges affiliated to these universities in India but the research output data available measured in terms of peer reviewed publications clearly indicates a narrow base of research intensity in the university landscape. Research intensity in universities is taken to mean those universities which have a reasonable publication record. Somewhat moderate research intensity here is seen in terms of at least 120 peer reviewed publications per year from a university. Studies and surveys undertaken by Gupta and Dhawan (2006, 2009) shows that only 18 to 20% can be classified as research based universities which have a publication intensity of over 120 papers per year over a period of a decade.

Further Gupta and Dhawan (2006) study has shown that 80 HEIs accounted for 72% of the total publications for the HEIs sector as a whole indicating that the rest 28% of total publications coming out from some 300 universities. Reflecting on a similar trend, another study by Gupta and Dhawan (2009) indicated that 56 universities accounted for 46.8% of total national publications (322,956) for the decade 1997-2007 based on Scopus data base.²⁴ While the number of total universities including colleges undertaking research and publication activities increased little less than two fold from 894 in 1985 to 1,685 in 2002, all quantitative measures lead us to estimate that only a small proportion of about 20% universities can be counted as research

²⁴ Please note that the Table 7 indicates a total of 52% of total publications by the HEIs sector.

based universities in the Indian context in 2009.²⁵ The quantitative analysis explored above clearly shows that there is a wide gap between the cluster of research universities and the other segment or grouping which can be characterized as predominantly ‘teaching universities’²⁶.



Source: Nature News, 20 April 2011 (Nature 472, 276-279, 2011)

Figure 2 The Rise of Doctorates

The narrow base of research in universities is further revealed by the number of PhD's awarded by Indian universities. If we take 1992-93 as base year, the total number of PhD's in science and engineering and non-science disciplines witnessed almost two fold increase from about 8,800 in 1992-93 to 17,898 in 2004-05 for which data is available from UGC. Whilst the science PhD's grew around 150%, the engineering PhD's increased by 300% during this decade. Similar extrapolations can be assumed for the current period. The growth of PhDs in Indian universities compared to other countries is relatively high as shown in Figure 2. However, this again constitutes a very narrow base of research and knowledge production compared to the total number of post-graduate and research students, which account for nearly 28% (or 3.22 million) of total higher education enrolments of 11.5 million students. Graduates

²⁵ It may be noted that research based universities means which have a track record of peer reviewed research publication output.

²⁶ Teaching universities should not be taken to mean that there is no research activity being undertaken in these universities or no publications are coming out of these universities. These universities do have Ph.D and graduate level programs in all disciplines but it is just that their research base and publication records do not compare well (hence the tag 'teaching universities') with those of the other segment of universities which can be taken as research based universities. Further, our quantitative analysis clearly shows that a bulk of nearly 80% of universities are rather quite weak in relation to the rest 20% which account for bulk of the R&D output in terms of peer reviewed publications. Elsewhere, it is argued that India need to achieve the 'Humboldtian goal' of increasing research intensity in the university sector as a whole.

account for about 67% and 5% diploma holders for the year 2005-06 (UGC Annual Report, 2005-2006).

From a long term perspective of enrolments, in PhDs, post-graduates and technical (engineering and medicine) education, a survey from Duraisamy (2008) shows that whilst the PhDs witnessed a relative stagnation and even declined of the total enrolments from 0.9% in 1980-81 to 0.6% in 2003-04; the technical enrolments witnessed only a marginal increase from 8% in 1980-81 to 9.9% in 2003-04. Even the post graduates witnessed a decline from 9.8% to 7.2% for the same period. This again suggests the narrow base of research and knowledge production in the university landscape.

3.3 Import of Education

During the current phase, Indian is experiencing a trend, which may be characterized as 'import of education'. Every year a large number of Indian students migrate to USA, UK, Australia and other countries spending large sums on a foreign education. In a way India is importing foreign education. Some trends relating to import of education are as follows.

- a) Expenditure of approximately US\$ 4 billion annually on import of higher education abroad
- b) The U.S. continues to remain the most popular destination. Nearly 70% are pursuing postgraduate courses in engineering and management
- c) Australia is a popular destination for vocational training and course in hospitality
- d) U.K. has become important because it squeezes academic sessions to one-year degrees on offer.
- e) China and Russia are emerging as favored destination for medical education due to insufficient places in India.

As we have seen in the first two phases 1940s to 1980s, much of the higher education was funded and dominated by the public sector. After 1990s in the third phase, the higher education market in India is being driven by private sector participation mainly in engineering and medicine, with several high quality private institutes setting standards and pioneering growth. Much of the expansion in private higher education is triggered by the changing market demand pattern in hospitality, private health, leisure and entertainment including media, design and expanding middle class living patterns in the market. The expenditure on higher education in India is estimated to grow at 12% CAGR to reach US \$ 10 billion by 2012 according to some sources.²⁷

²⁷ http://www.rncos.com/Press_Releases/India-Higher-Education-Sector-Set-to-Grow-at-13-CAGR.htm

Private institutions account for 50% of the total medical seats and 80% of the engineering seats available in students in India.

3.4 University – Industry Relations

Historically speaking, most leading universities in Asia have been performing the roles of teaching and research so as to make an impact on the society and economy. However the feature of coupling teaching/research with innovation and at the same time forging university – industry relations (UIR) with various actors and agencies in the respective national systems of innovation has come into sharp focus in the last decade (Etzkowitz and Leydesdorff, 2000). UIR perspectives can be conceptualized at broadly two levels. From the perspective of professionals in institutions or universities, UIR can be seen to take place at the level of institution. UIR as explored in the S&T studies literature draws attention to different types of knowledge transfer underpinning UIR. Broadly four types of knowledge transfer can be easily quantifiable and explored. These are through a) sponsored research; b) consultancy research; c) patents; and d) spin-offs or start up firms which emanate from HEIs or universities.

From a macro level perspective, rather universities are being re-positioned as frontiers of innovation in the NSI, where in, most new technologies (biotechnology, nano, new materials, ICTs etc) have become science based. Universities and knowledge institutions take on a major role as important actors in training, imparting skills and networking with R&D institutions and business enterprises as part of knowledge based clusters. The impact of globalization or globalization of innovation via foreign multinational corporations has led to the emergence of ‘new’ knowledge R&D centers now extended to the Asian region. Universities and colleges and other knowledge institutions have become important sources of skills, knowledge and innovation activities and they have the additional task of tapping into, or networking with, this globally dispersed knowledge networks and institutional sites. From a macro S&T studies perspective, HEIs have come to play an important part in India’s high technology related knowledge and innovation

clusters (KICs) in major cities as shown in Table 7. From the perspective of UIR, the emergence of KICs in half dozen Indian cities such as Bangalore can be seen as a major development. More than 250 multinational corporations such as IBM, GE, Microsoft, Intel and others have established R&D labs and centers in the cities shown in Table 7. These foreign R&D centers basically take advantage of the location and supply of highly skilled science and engineering graduates.

Table 7 India's Emerging Knowledge Innovation Clusters

Cities/States	Areas	Global R&D Centers/Lab. (main city)	Public+Private Indian R&D Lab.(State)
Bangalore(Karnataka)	ICT software, aerospace, biomedical	45	107+38
Chennai(Tamil Nadu)	Automotive and ICT software	7	138+42
Pune/Mumbai (Maharastra)	Automotive, ICT software, chemical/pharma, Bollywood	22	176+105
Delhi/Noida/ Gurgoan (NCR)	ICT software, biomedical, automotive	24	93+40
Hyderabad (Andhra Pradesh)	ICT software and biomedical	9	126+36
Calcutta(West Bengal)	ICT software/biomedical	3	89+31

Table 7-1 India's Emerging Knowledge Innovation Clusters

Cities/States	Univ.+ Colleges (State)	Engin. + Medical Inst.	Paper 10Ys (State)*	Tertiary Enrol. (State)
Bangalore(Karnataka)	16+1,970	180+420	35,000(11.6%)	708,195
Chennai(Tamil Nadu)	17+1,244	270+200	48,000(16%)	841,755
Pune/Mumbai(Maharastra)	20+2,487	185+330	46,000(15.3%)	1,506,702
Delhi/Noida/Gurgoan (NCR)	5+ 285	85+ 25	45,000(15%)	636,093
Hyderabad (Andhra Pradesh)	16+2,131	275+225	21,000(7%)	911,709
Calcutta(West Bengal)	16+565	60+75	22,000(7.3%)	721,762

Source: Constructed on the bases of various sources of information from State Governments, UGC, Ministry of Human Resource Development and the website of software companies (NASSCOM), New Delhi, India.

* Publications in SCOPUS '96-'06 (% of total)

As we have seen in the previous sections, higher education landscape reflects a narrow base of universities in research and knowledge production measured in terms of peer reviewed publications and the proportion of PhDs awarded compared to total higher education enrolments. Thus, given the narrow base of about 20% of universities and their affiliated colleges being research intensive, roughly about one fifth of total universities can be seen to be directly relevant to industry and society. In aggregate terms, however India's higher education base is quite large with 11.5 million

students in HEIs. Thus the sector provides an indirect relevance and support to business enterprises and industrial sector for the supply of skilled human resources which are indeed quite important factor in generating human and knowledge capital. Given the limitations of data and systematic indicators available for the university sector as whole for India, we will explore UIR taking five Indian Institutes of Technology (IITs) – India's leading engineering institutes.²⁸

4. Case Study of IITs²⁹

IITs represent a subgroup of India's premier engineering teaching and research institutions modeled on MIT. IITs have earned world recognition for excellent engineering education and in knowledge creation and knowledge transfer.³⁰ After the creation of Five IITs during 1950s and 1960s, two more were established in 1994 and 2001 (at Gauhati and Roorkee respectively) and three new IITs have been set up in 2008.³¹ More than any other aspect, IITs have earned a big name globally for producing highly skilled engineering graduates. The IITs as a representative set of academic research institutes (ARIs) particularly in science and engineering education are known for their academic excellence.³² Here we shall however explore on aspect of IITs, namely, their contribution to knowledge transfer during the last decade.³³

²⁸ IITs are universities categorized as Institutes of National Importance.

²⁹ Data on IITs is based on and drawn from, the chapter on Indian IITs, - See Krishna and Chandra (2011)

³⁰ The IITs have been in existence for over six decades making significant contributions in terms of knowledge production, creating highly skilled, well educated graduates and post graduates in engineering sciences and social science and management areas to a lesser extent. It is not surprising that admission into IITs is rather a highly competitive exercise in the country with nearly 250,000 students competing for 5,500 students' positions in all IITs combined together. The IITs have come to be recognized for research and innovation in the last decade.

³¹ Five IITs were set up in ten year span starting from 1951 but IIT Guwahati was set up as the sixth IIT in 1994 while IIT Roorkee came into the IIT system in 2001. Three more IITs have been opened in 2008 in the states of Andhra Pradesh, Bihar and Rajasthan.

³² IITs are recognised worldwide for the outstanding quality of engineers, scientists and managers they produce which is evident in the Times Higher Education (2006) where in the World's top hundred technology institutions they were ranked third after Massachusetts Institute of Technology (MIT) and University of California Berkley Source: <http://www.timeshighereducation.co.uk/hybrid.asp?typeCode=163> accessed on 24 August 2007.

³³ Given the limitations of data and information we shall explore knowledge transfer activities of five IITs for the period during 2000 and 2005.

As pointed out earlier, four types of knowledge transfer can be easily quantifiable and explored. These are through a) sponsored research; b) consultancy research; c) patents; and d) spin-offs or start up firms. In all the five IITs, there has been a substantial increase over three fold in the value of sponsored research and industrial consultancy projects from 1999-2000 to 2004-05. As shown in Table 8, the growth has been from a little over INR 700 million to nearly INR 2,300 million in five years or an increase of 227%. This also means that the value of sponsored research and industrial consultancy increased from 17% (1999-00) to 44% (2004-05) of the total government budget. Thus these two modes seem to be the main and important channels of knowledge transfer. The increase indicates the shift in focus of IITs towards research activities.

Table 8 Combined Earnings of Sponsored Research and Industrial Consultancy Projects (SRIC) As a Percentage of Total Grants Given to IITs

(INR million)

IITs	SRIC (99-00) (a)	Gov. Grant (99-00) (b)	(a)/(b)	SRIC (04-05) (c)	Gov. Grant (04-05) (d)	(c)/(d)
Bombay	197.6	671.5	29%	380.0	1,024	37%
Delhi	185.5	820.0	23%	385.6	1,000	39%
Kanpur	84.4	628.0	13%	590.0	980	60%
Kharagpur*	121.0	1,003.0	12%	500.1	1,050	48%
Madras	112.8	943.7	12%	435.5	1,100	40%
All	701.3	4,066.2	17.2%	2,291.2	5,154	44.4%

Source: Computed from the Annual Reports of respective IITs

* IIT Kharagpur, grant-in-aid figure from 2000-01

Incubation and enterprise creation or what is known as spin-offs (we define spin-offs as companies that evolve from academic institutions through commercialization of intellectual property and transfer of technology developed within academic institutions) has come into prominence and sharp focus in the literature on Triple Helix. It is regarded as one of the main indicators for entrepreneurial universities. Creation of enterprises from the knowledge generated in academic research institutions has conventionally been the activity of TTOs in academic institutions such as IITs (see Table 9). In our study, while IITs at Kanpur, Delhi and Bombay have adopted the conventional approach of creating formal incubation units, the spin-offs at IIT Kharagpur and IIT Madras have been created without the formal incubation setup. As Basant and Chandra (2007) characterize, the process of knowledge

transfer and enterprise creation in IIT Madras may be regarded as unconventional mode as this institute did not establish a TTO.

Table 9 Incubation and Entrepreneurial Infrastructure at IITs

Institution	Incubation Unit	No. of Incubatee /spin-offs (94 to June 2008)	Prominent Areas	Other Infrastructure
Bombay	Society for Innovation and ntrepreneurship (SINE); 2004	27	IT, computer science, electronics, design, earth sciences, energy & environment, electrical, chemical, aerospace	Entrepreneurship Cell
Delhi	Technology Business Incubation Unit (TBIU); 1999	19	computer science, electrical , chemical engineering, inter-disciplinary areas, life sciences, chemistry, IT, BT	Entrepreneurship Development Cell
Kanpur	Innovation and Incubation Centre (SIIC); 2001	13	IT, design, weather insurance, navigation systems	Entrepreneurship Cell; Electronic and Animation Cell; Small Scale Industry Cell
IIT Kharagpur	Technology Incubation and Entrepreneurship Training Society (TIETS); 2005	8	IT; computer science; ceramics; energy	Entrepreneurship Cell ; STEP; Biotechnology Park; TTG
IIT Madras	No formal set up Dynamic groups like Tele-communication Network Group (TeNeT); 1999	16	IT; computer science; physics	C-TIDES; Research Park

* STEP: Science and Technology Entrepreneurs Park;

* TTG: Technology Transfer Group

*C-TIDES: Cell for Technology Innovation, Development and Entrepreneurship Support;

* Entrepreneurship Cells are a body managed by students' initiative

The establishment of incubation units at IIT Delhi (TBIU), IIT Bombay (SINE), IIT Kanpur (SIIC) and IIT Kharagpur (TIETS) are relatively recent development in aiding knowledge transfer. Here we need to mention that such initiatives have been supported by the government of India mainly through Department of Science and Technology and the Ministry of Communication

and Information Technology by extending seed grant support. The strategy for setting up of incubation units involves the selection and recruitment of start-up technology businesses such that these ventures graduate from early stage incubation to mature firms generating resources on their own. The start-up firms in the IIT campuses are provided with fully furnished offices with computers, telecom and internet connectivity. The incubator has modern support systems like meeting rooms, conference rooms which are equipped with audio and video conferencing, pantry facilities and other shared facilities. Apart from the physical infrastructure, SINE aims to facilitate networking and mentoring support, organize showcasing events for incubatee companies and conduct training programmes which are relevant for the entrepreneurs.

Table 10 Prominent Strategic Research Coalition at IITs

Location	SRCs at IITs
Bombay	Xilinx FPGA Laboratory (2004), Tata Infotech Laboratory, Intel Microelectronics Laboratory, Tata Consultancy Services (TCS) Laboratory (2000), Laboratory for Intelligent Internet Research (TCS), Texas Instruments Digital Signal Processing (TI-DSP) Laboratory, Wadhvani Electronics Laboratory (2001), Cummins Engine Research Laboratory (2004)
Delhi	IBM Solutions Research Centre, NIIT- Centre for Research in Cognitive Systems, Tata Infotech Research Centre, Intel Technology Lab, Microsoft Advanced Technology Lab, Philips Semiconductors VLSI Design Lab
Kanpur	Samtel Centre for Display Technologies (2000), Prabhu Goel Research Centre for Computer and Internet Security (2003), BSNL Telecom Centre of Excellence
Kharagpur	OPTEL - IIT Optical Fibre R&D Centre, Post Harvest Technology Centre, Space Technology Centre, Micro-electronics Research, General Motors-Collaborative Research Laboratory
Madras	Automotive Research Centre, Microsoft Laboratory, IBM Centre for Advance Studies, Tata Consultancy Centre of Excellence in Computational Engineering

A different view and insight, which is often ignored or overlooked in the case of IITs, is the significant contribution to Indian high technology industry in an 'indirect form' through their ex-students. For instance, many of these ex-students of IITs are either owners or chief managers of big firms. IIT trained engineers who have made a big name in the Silicon Valley, USA, through associations such as The Indus Entrepreneurs (TiE) and Silicon Valley Indian Professionals Association (SIPA) had a good deal of influence in the

evolution of Indian software clusters in Bangalore, Hyderabad and Delhi (see Saxenian, 1996, 2002 and Krishna 2007).

5. Concluding Remarks

One of the major problems for an economy like the size of India, compared to other emerging nations and the international context, is the very low level of gross expenditure on R&D. India is spending just over 1.13% of GDP on R&D, compared to 1.2% to 1.4% for Brazil and China and around 2.2% in the case of the OECD and EU. The government is committed to increase the current 1.13% level to 2% in the coming 5 years. Government need to infuse more research funding into public R&D, particularly in the university sector in the coming decade. Otherwise India will not be able to sustain the international comparative advantage in terms of human resource base in high technology sectors of economy.

The role of universities in the NSI in India has emerged as an important factor in the decade but does not compare well with European and other Asian counterparts. Universities occupy a significant position in terms of national R&D effort in industrially advanced countries. Universities in OECD - 25 countries accounted for 20% and Japanese universities accounted for around 15% of GERD in 2004-2005. Whilst universities and colleges in China account for around 10% of GERD in 2005-06, Indian universities and colleges accounted for mere less than 7% in 2007-08.

In higher education, the major challenge in terms of access to higher education still remains the daunting task of increasing the enrolment ratio from the current 11.5% to 15%. India has over 447 universities and 25,000 colleges but the research intensity in these institutions of higher learning is quite weak. Only 20 to 25% of these institutions are research-based and the rest are teaching-based universities aspiring to achieve the 'Humboldtian ideal' of becoming teaching and research universities. This is an important challenge facing the higher education in the coming decade.³⁴

In a large measure the innovation potential in the higher education sector in India is underutilized because few universities have adopted innovation policies which foster university-industry partnerships and relations.

³⁴ Unfortunately there is no systematic empirical data either from UGC or from the ministry of human resource development. However this insight is emanating from our discussion with various experts and commentators on the state of higher education in India.

As universities and higher education come to play a significant part both in the emerging knowledge based economy and the NSI, the government in the last few years have initiated a number of policy and structural reforms. India is yet to implement these initiatives, which are likely to strengthen the higher education research and innovation base in the country. The main thrust of these reforms is directed to make India competitive in high technology and knowledge base sectors of Indian economy at the global level.

From the perspective of university – industry relations, the universities have been quite conservative to open up to innovation and commercialization of R&D. Universities, in general still consider their main role as teaching and research. Innovation is by and large is seen as the role of R&D and S&T institutions in the public sector. The IITs and other leading universities are possible exceptions to this rule. The major challenge is to infuse academic institutions of higher learning with an-‘innovation culture’. India has just articulated ‘The Protection and Utilization of Public Funded Intellectual Property Bill, 2008’ - an Indian version of the US Bayh-Dole Act. Many are expecting that this Bill will catalyse innovation and technology transfer from public research systems to industry and society.

The high education sector (universities and colleges) and other knowledge institutions have emerged as important actors in what has come to be known as India’s leading knowledge innovation clusters located in Bangalore, Hyderabad, Chennai, Mumbai-Pune corridor, Delhi-Gurgaon corridor, among other cities. Software, biomedical, engineering and automotive and aerospace clusters are located in these cities. From a very low level of less than 134 US \$ million a decade ago, India currently in 2010 attracts approximately 1.9 US\$ billion for R&D every year through foreign firms setting up R&D laboratories and units in India. By 2010, about 250 multinational firms had already set up R&D labs or units. Much of India’s global competitiveness in software, pharmaceutical and aerospace sectors is dependent on sustaining the human resource base in high technology sectors in these cities. This is in turn dependent on the skills and human resource base generated in the higher education sector in these cities. Much of the recent dynamism witnessed in the knowledge-based and high technology sectors of the Indian economy is the result of human resources, skills and the vast institutional base already created in the higher educational sector. A major challenge that is confronting India is to further strengthen the infrastructure and research – innovation eco-system in these cities in the coming decade.

From the perspective of population and skills, all foresight studies predict that India is endowed with good potential to take advantage of what has come to be characterized as ‘demographic dividend’ in the coming decades. Even by 2040 nearly half of India’s 1.5 billion people will be under the age of 25 to 35 yrs. Vocational and higher education, which will infuse skills, training and

knowledge base, is going to be important for Indian higher education sector. The establishment of the national innovation council and national skill development council, among other policy reform measures introduced recently are likely to play a significant part in India's global competitiveness in the coming decades.

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A Model of University Reform in a Developing Country: The Brain Korea 21 Program

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Abstract This paper is a review of a 13-year-old policy for university reform in Korea, the Brain Korea 21 Program, based on current theoretical frameworks. Current theoretical frameworks are classified into three groups: micro and macro perspectives on universities and discussion on world-class universities. The overall purpose of BK21 is to bring up high-level scholarship through manpower and achieve several targets of university reform. The program can be evaluated as a success in terms of following a research university model but not the entrepreneurial university model. However, the fact that a 13-year old policy developed under a research university model had features of the entrepreneurial university shows the direction of change that the research university is currently undergoing.

Keywords University capitalism, university entrepreneurship, world-class university, Brain Korea 21 Program

1. Introduction

Is university reform an internal issue only for university members, educational experts or educational policy makers? Are the issues about university graduates and research outputs only within the confines of university boundaries? Many studies on university reform have been based on the viewpoint of universities and from an educational perspective. The trend is that there is a strong discussion on university capitalism or university entrepreneurship ever since Slaughter & Leslie (1997) and Clark (1998) advanced papers, both coming from advanced countries.

In fact, American universities have been entrepreneurial dating back to the Bayh-Dole Act of 1980, which allowed the ownership of patents generated from Federal research to be used by universities. (Rothaermal, Agung & Jiang

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2007) In addition, the financial crisis of universities because of long recessions and the cut down of research funds from the Federal government after the Cold War forced research universities to make structural changes to achieve selective excellence and enter into entrepreneurial activities. (Barrow, 1996)

Before further discussion, let us remember the root of American research universities, which are models of entrepreneurial change to nearly all universities worldwide. The history of the American research university began with Johns Hopkins University in the 1880s and also from the early 16 member universities of the Association of American Universities set-up in 1900. All of them are current leading universities and most of them are private. (Geiger, 1986; 1993, 2004)

Most studies from developing countries on university reform are focused on the role of universities in the developing process of each country. The basis of research and research infrastructure in universities of developing countries are weak compared to developed countries. Realistically, innovative research does not exist in many developing countries.

This paper wants to evaluate past policies for university reform on a developing country in light of current theoretical frameworks. The inception time of the Brain Korea 21 Program is nearly identical to the development of theoretical frameworks for academic capitalism or entrepreneurship, but still precedes the discussions on the world-class university. The BK21 program made no significant references to discussions of the entrepreneurial university. Therefore, a review of the 13-year-old policy in light of current theoretical frameworks will be a good case for identifying the relationship between theory and policy and for further designing a policy on university reform.

2. Current Theoretical Frameworks

2.1 Micro Perspective

A micro perspective on university reform represents theoretical discussions about the changing shape of university in terms of status, culture, management, and activities of the university. This includes the theoretical framework on academic capitalism (Slaughter & Leslie, 1997) and university entrepreneurship (Clark, 1998; Sporn, 2001, Etzcowitz et al., 2000; Etzkowitz, 2004; Bercowitz & Feldman 2006; Wong, 2007; Rothaermal, Agung & Jiang, 2007; Guerrero, Urbano, 2010; Mars & Cecilia, 2010).

Rothaermal, Agung & Jiang (2007) reviewed 173 articles on university entrepreneurship during 1981-2005. Most studies have appeared from late

1990s, and there were 50 papers alone in the special editions of 11 academic journals during the first half of 2000. The issues can be classified into four groups: the entrepreneurial research university, new firm creation, environmental context including networks of innovation, and productivity of technology transfer. Studies indicate that mostly universities were concerned with this framework until the first half of 2000.

The basic mission of traditional universities is teaching and research, but currently the new mission of entrepreneurship has been included. Academic capitalism is characterized by autonomy from government and university institutions, entrepreneurial activities to attract funding, system based on meritocracy, entrepreneurial education, and education based on demand.

University entrepreneurship first appeared from research universities, but now the trend has expanded to general universities. Yokoyama (2006) reviewed five universities from the UK and Japan and classified the entrepreneurship of universities into five types by the degree of entrepreneurship: prototype, entrepreneurial-oriented university, fledging entrepreneurial university, adaptive entrepreneurial university, and ideal type. Guerrero and Urbano (2010) reviewed Spanish universities and classified university entrepreneurialism simply into three stages: initial, development, and consolidation.

Sporn (2001) identified seven critical factors of the entrepreneurial university such as an environment triggered by crisis or opportunities, clear mission, entrepreneurial culture, differentiated structure, professionalized management, shared governance, and committed leadership. 10 years later, Guerrero and Urbano (2010) also identified critical factors for university entrepreneurialism in two dimensions based on data analysis: missions, governance, and organization structures; support measures, entrepreneurial education, and attitude to entrepreneurialism; incentives for environmental factors, human resources, and alliance; as well as entrepreneurial activities as resources and capabilities in entrepreneurialism.

2.2 Macro Perspective

A macro perspective on universities is the study on the role of universities to a nation's innovation and social and economic development. Some of the frameworks include new growth theory of economics, systems of innovation, framework of the Mode 2 knowledge production, and the Triple-Helix model of innovation. Reddy (2011) clearly mentions three theoretical frameworks recognizing the importance of universities to economic development: systems of innovation, Mode 2 Society, and Triple Helix. All of the theoretical discussions emphasize universities as the center of knowledge production in a knowledge-based economy.

Theory on the systems of innovation stems from the 1980's Japanese study by Freeman (1987) followed by Lundvall (1992) and Nelson (1993).

Freeman identified the systemic difference of Japan and its impact on innovation. The notion of nationwide systems of innovation has expanded to regional innovation systems (Cooke, 1998) and sectorial systems of innovation (Bresch, Malerba, 1997). As any system, this identification contains elements of systems, critical factors, and key actors. The essence of this theory can be summed by realizing innovation is not an isolated phenomenon of the firm. Rather innovation is an output supported by various networks of actors and institutions such as industry, universities, and even financial institutions. Second, universities are the birthplace of new knowledge and technology.

The Mode 2 knowledge production system is a new paradigm towards multidisciplinary, application-orientated knowledge production with a social accountability of universities as opposed to the traditional Mode 1 view of knowledge production as being discipline-based, basic research orientated, and of taking place in isolation from society. (Gibbons et al., 1994) Moreover, the basis of Mode 2 knowledge production led to the Mode 2 society. (Gibbons, 2000; Godin & Gingras, 2000) Although Pavitt (2000) criticized the Mode 2 based on the importance of basic research that should be emphasized, there is no evidence that basic research has deteriorated and weakened, but rather there is clear evidence that university entrepreneurship has deepened and expanded. (Rothaermal, Agung & Jiang, 2007)

Theoretical framework of the Triple-Helix is based on the university-industry-government linkage for evolving innovation. The framework, however, is not only the relationship, but also for the evolving of each institution. (Etzkowitz, Leydesdorff, 1997) The framework is based on three parts: institutional transformation, evolutionary mechanism, and to the second academic revolution. Accordingly, the university is at the core center of this relationship and has a mission towards economic development. Etzkowitz, Leydesdorff (2000) suggest that the Triple-Helix overlay can be a model to explain the social structure of Mode 2.

2.3 World-Class University

The discussion of world-class universities (here after WCU) has begun shortly after that of university entrepreneurialism. (Altbach, 2004; Altbach & Balan, 2007; Huisman, 2008; Mohrman, 2008; Mohrman, Ma & Baker, 2008; Salmi, 2009; Yang and Welch, 2011, Liu, Wang & Cheng, 2011) World-class universities are defined as being famous and prestigious in academics around the world. They are fundamentally research universities, which are key institutions for development of society by the production and distribution of knowledge in the 21st century. (Van der Ploeg & Veugelers, 2008; Ramakrishna & Krishna, 2011) In addition, the prestige of being a World-Class University is often used for further funding. (Potts, 2011)

This discussion has largely been due to the announcement of academic rankings, such as the Academic Ranking of World Universities by the Shanghai Jiao Tong University of China from 2003, THE World University Rankings by the Times from the United Kingdom from 2004, and currently QS World University Rankings by the Quacquarelli Symonds of the United Kingdom, who previously collaborated with THE Rankings. Also, the US News and World Report, which is famous for the rankings of US universities, has announced the US News World Best Universities, which is actually the QS ranking system. Although there are many critics, world rankings has been widely accepted by all research universities.

WCU is sometimes defined simply as the top 100 universities. Hence, they are located in developed countries, which has more than 25,000 US dollars per capita GDP. (Liu, 2007) In the Shanghai Jiao Tong Ranking of 2011, most universities are from the USA, Canada, Australia, and Europe, and some universities in Japan and Israel also made the top 100. In the Times Ranking of 2011, Asian universities from Japan, China, Korea, Hong Kong, and Singapore were included.

Table 1 Location of the World Top 100 Universities

Announcer	Main Region	Asia
Shanghai Jiao Tong	North America, Europe, Australia	Japan, Israel
The Times		Japan, Hong Kong, China, Korea, Singapore
QS		Japan, Hong Kong, Korea, Singapore, China, Taiwan

2.4 Relationship between Theoretical Frameworks

Academic capitalism can be said to be the change of the university towards the market, and university entrepreneurship can be known as the changing shape of the university towards industry, although both concepts are generally used interchangeably.

As for the macro perspectives on universities, the framework on national systems of innovation emphasizes the importance of universities to a nation's competitiveness. The discussion of Triple-Helix can be conceptualized as "how to mobilize" a national systems of innovation. The framework for Mode 2 production shows that the nature of knowledge production in universities is multi-disciplinary and application oriented. Specifically, the Mode 2 framework can be the basis of university entrepreneurship and academic capitalism can be a part of the Triple-Helix mechanism.

On the surface, the discussion on the WCU does not seem to relate to the micro and macro frameworks laid out. The Times Higher Education rankings

apparently uses an index for research earnings, but, more importantly the WCU framework is deeply embedded on a twofold macro understanding; Universities are the centers of knowledge production and the best knowledge means the best national competitiveness.

3. The model in late 1990s Korea

3.1 Background of the Model

Korean university policies had largely focused at the undergraduate level and no intensive policy for graduate school appeared until the Brain Korea 21 Program in 1999. The 21 in BK 21 mean a policy for the 21st century. A previous notable policy for university reform includes the freedom of the establishment of universities and colleges in 1995. Since then, students in tertiary education have dramatically expanded representing an enrollment ratio of about 80% of high school graduates.

In 1997, the Korean government recognized the severity of a lack of research by universities. There were 9,444 papers listed in the Science Citation Index (SCI) and the SCI-Expanded in 1998, ranking Korea 18th in the world. Korean universities' research output was 3.9% of the United States, 13.8% of the United Kingdom, and 15.2% of Japan. A simplified sign of weakness was that the number was only 82% of Japan's two universities. (Ministry of Human Resources, 2006) International papers had grown very quickly in absolute numbers since the early 1970s, but the Korean government recognized the severity in difference comparing Korean universities to international universities and especially in comparison with universities from advanced countries. In the early 1970s, the numbers of SCI papers were only several dozen in the whole nation. (Chung, Seol, 2010)

Because of Korea's historical lack of research, a seven-year program for graduate schools, the Brain Korea 21 Program, was launched in 1999. The vision of the program was towards increasing competition and cooperation suitable for a knowledge-based society. The program was designed under four principles: select and concentration, fostering the next generation, linkage to university reform, and balanced regional development. (Ministry of Human Resources, 2007)

3.2 Model of Grants

The purpose of the program is complex. The official goal was "fostering world-class manpower" by supporting graduate students, but it had multi-purposes such as university reform through a cut-down of undergraduates, building world-class research capabilities and universities, building university

and industry relationships, and building regional research bases. Simply speaking, the goal could be expressed as one official purpose and four strategies to achieve that purpose.

Targets of the program are only graduate students and post-docs, but they have to be affiliated with a selected professor's unit. For example, grants are given to certain units, allocating 45% for scholarships to graduate students, 20% for post-docs, 15% for international activities of students, and 20% for operations. No research funds and allowances for professors were allowed.

Professor's units were selected by size and league regardless of discipline including social science and the humanities. Under the principles of balanced regional development, the leagues of teams were divided into national and regional. Also large and small teams were divided. A large team is a department or a union of a department, and should have at least 10 professors, and also should be consisting of a minimum 70% of the whole department, or collaborating departments.

Master's students were given grants of a minimum 420 US dollars and doctoral students were given 760 dollars per month. Total grant size was not huge, but it was the largest grant to graduate schools in Korean history. Therefore, all universities were eager to receive the grants.

The selected reforms were more interesting and classified into two parts; there were plans for undergraduate reform and for relationship with industry. University reform had several objectives such as a cut-down on the number of undergraduate students towards research universities (large team), adopting a meritocracy for professors, and a set-up of entrepreneurial institutions. The cut-down of undergraduate students was imposed differently based on university status. For public universities a 15% cut on undergraduate students was imposed, and for private universities where student tuition is critical, other methods were used to cut down undergraduate student enrollment, such as a policy of the government to impose universities to hire at least 65% of the government recommended professor total which is based on student enrollment. This in effect controlled the amount of students a department can enroll, because more students would mean more mandatory hiring.

The second reform is the encouragement of industry ties by making industry or local governments match a minimum of 5% to universities, to increase the number of technology transfers from universities, and by giving specialized courses to industry on technology transfer.

This reform is nearly identical with the direction of an entrepreneurial university except autonomy from government. This policy has no concerns about autonomy; therefore matters about autonomy are not discussed.

Table 2 Overview of the BK21 Program

	Contents
Purpose	World-class talents/university
Type	Grants for graduate students/post-docs of selected teams
Grant usage	45% for direct grants, 15% for post-docs 20% for internationalization activities 20% for management
Supporting units	By discipline (S&T 88% > social science & Humanities 12%) By size (union of department/department/team) By league (national/regional)
Target-reform	Reform of undergraduate (cut-down and M&A) Meritocracy for professors University-industry linkage -matching funds -technology transfer -setting-up entrepreneurial institutions
Target-graduate school	Enhancing research power (SCI papers) Internationalization of students Fostering university-industry linkage

Evaluation was done every year for simple checks and performance checks were done at the third year on four categories such as university reform, team management, budget, and output. Output is summarized as education, research, relationship with industry, and the targets of specialized teams who were assembled based on their special talents. Some teams failed at the 3rd year evaluation.

3.3 Extension of the Program

Despite negative criticism at the early stage, overall evaluation showed more improvement than expected. Approximately 18,000 graduate students received grants along with 1,300 post-docs belonging to 120 large teams and 402 small teams with about 4,000 professors each year. Research output represented by SCI papers had grown to 18,497 with an improved world ranking of 13 by 2004. Quality of students had been raised and graduate students could participate and present papers in international conferences. There was no problem of student employment after graduation. In addition, there was the intended effect of undergraduate reform such as a cut-down of undergraduate students at all participating universities and M&A of similar departments. Moreover, there were several signs of the enhanced university-industry relationship.

Although the program was touted as “the best program for university reform” and showed promise on a micro basis, the public still criticized universities during the mid 2000s. Even the President criticized universities in a public speech on May 2006. The criticism at the time was summarized as follows: low level of international competitiveness by universities, no recognition of the threat of decreasing student enrollment, non-equilibrium of demand and supply of graduates between disciplines, and an oversupply of low level graduates. (Won, 2006)

Because of the good evaluation of the program itself and the social demand for university change, the program was extended for another seven years from 2006-2012, which is called the second stage of the BK21 Program. Although there is little difference between the 1st and the 2nd stages, the 2nd can be said to have evolved from the 1st, covering the weakness of the 1st stage. The weakness of the 1st stage were high rates of distribution to Seoul National University, over emphasis on papers, low funding to basic science, and low development of the university-industry linkage. The team size and program budget in stage 2 is nearly identical to stage 1.

The purpose of the 2nd program was “fostering world-class talent.” The target of the 2nd program was to provide grants for 20,000 graduate students, obtain top 10 worldwide ranking in SCI papers, and increase the rate of technology transfer by universities from 10.1% of its total technology base in 2004 to 20% in 2012. Also there were four strategic purposes in line with the official purpose: fostering research groups, building infrastructure for research universities, university-industry linkage, and fostering regional universities.

4. Evaluation of the Program

4.1 Effects on Research

All quantitative studies for research activities such as Kim, Na and Cho (2005), Kim, Lee (2005), Baek (2007) and Shin (2009) proved that there are clear research effects on participating teams and departments. In particular, Choi (2008) analyzed the increase in research by the physics department comparing participants and non-participants with similar conditions. In 2008, SCI papers reached 35,569 bringing Korea a world ranking of 12.

Byun et al. (2011) showed the research performance of the program could be summarized as follows: SCI papers of BK21 participants in science and technology areas averaged 3.0 in 2009. The highest participants were GIST with 5.82 and POSTECH in 2009. Private universities produced more papers than public universities, but had a lower impact factor. Furthermore,

papers and the impact factor in the science areas were better than other disciplines.

Research time of graduate students increased from an average of 45.4 to 61.8 hours per week, and papers from students (1.45) have increased more quickly than those of professors. As for internationalization, clear increases on short-term and long-term research travel abroad and increases of international collaboration were observed.

4.2 Effects on University Structure

One of the original targets for this program was university reform of research universities. One sample of change is Seoul National University, a flagship university in Korea. Around 2000, there was a ratio of 20 students to 1 professor, but dropped down to 15.9 to 1 by 2010. This level of ratio was intended to compete with Harvard University and top state universities of the US. Although this transformation of universities is not solely due to BK21, it is clear the program had big impact.

Table 3 Ratio of Professors to Students

		Seoul National Univ.		Harvard	Michigan
		(2010)	(1999)	(2000)	(2000)
Students (a)	Undergraduate	16,325	21,000	6,704	24,493
	Graduate	16,585	8,700	10,901	10,226
Professor (b)		2,074	1,485	2,300	2,633
(a/b)		15.9	20.0	7.7	13.2

Sources: Moon & Kim (2001) for earlier data, new data at www.academyinfo.go.kr

4.3 Effects on Employment

Studies looking into employment effects showed that there has been no negative effect on employment after graduation. Jang et al. (2006), Kwon et al. (2010), and Jang and Chon (2005) reported that more international experience and those with longer grants obtained higher salary. Byun et al. (2011) showed different effects on employment by discipline: clear positive effects for social science and the humanities, but no effects on graduates from science and technology.

Moreover, my interviews revealed further effects. The program has increased the number of science and technology students both in the team and whole nation, so saying “no problem after graduation” or “no clear change in employment” may mean increasing employment. Also, the quality of employment has increased. Even Master graduates from mid or low-mid level universities are employed as researchers. Graduates from mid to low-mid

universities provide the basis of research manpower for a growing number of businesses and provide R&D for small and medium firms.

4.4 Other Effects

There are different effects that run counter to the traditional culture and attitudes of a Korean University: increasing competition within universities, between universities, and increasing mobility of professors to better universities. Furthermore, BK21 has increased the concerns of policymakers on developing stronger research universities and on making world-class universities in Korea.

4.5 Some Problems

The policy casts many implications for designing research universities and university reform, but also it has raised some confusion as pointed out by Kwon et al. (2010). Although the explicit purpose of the program is bringing up high quality manpower, the real purpose seems to be university reform. This has made the execution of the program confusing as to whether the main target of the program is university reform or support for graduate students. Regardless, the multi-faceted nature of the program urged Korean universities to move towards the research university model.

Is the model based on fair competition and meritocracy? Is the budget responsible and suitable for the social sciences and humanities? All leaders of the program in the social sciences agree to the efficiency and effectiveness of the program, but the answers from those in the humanities tend to diverge. Scholars that were active participants seemed positive, but others disliked the policy.

Another issue known as the “straw effect” in Korea is that BK21 has sparked significant mobility of professors in Korea from regional universities into Seoul, the capital of Korea. Universities with big grants can absorb the best students and faculty, while universities with low budgets have a more difficult time getting grants, thereby making it difficult to attract students and professors.

Also, there appears to be an unprecedented problem. Because of the program’s annual and mid-term evaluation, nearly all teams should measure the performance of participating professors. Therefore, information on performance has been open to all at the team level at participating universities. Previously, this transparency had been unheard of in Korean universities before the program. Prolific professors, however, have not wanted to boast about their performances, as this type of openness is still new within the university system. These professors produce much higher output than that of the average researcher on their team and against professors around the nation.

This program has no functions to solve for this phenomenon, and there have not been enough incentives to accelerate the performance of best professors.

4.6 Overall Evaluation of BK21 by Leaders

The coverage of the program at the moment is quite deep and broad. “If this program did not exist, student enrollment at most graduate schools would have decreased by 1/3 or 1/4 the current student enrollment,” said a leader at one leading university (Seol et al., 2011). This implies severe brain drain to universities of advanced countries could have occurred, if not for the success of BK21.

The budget of the program is only around 200-250 million US dollars per year, and the share among government R&D budgets has been between 2.2-2.5% a year in recent times. Policymakers now evaluate the BK21 Program as “the best program with a minimal budget” for creating research universities, actualizing university reform, and providing a start for entrepreneurial universities.

Continuous grants for graduate students, although it is a minimal amount for each student, are better than any large R&D project because supporting manpower is the key to research and innovation. During an interview, a professor at a regional national university stated to the author, “if there are graduate students without research funds, research can be completed by giving credit, but research is impossible even with large research funds if there aren’t enough students.”

5. Discussions for Theory and Practice

5.1 What Factors made BK21 a Success?

How could the program facilitate dramatic university reform? There is always resistance from professors and universities if government policies to universities contain compulsive or coercive orders. The late 1990s were a turbulent economic period because of the Foreign Exchange Crisis of 1997. The Korean government could urge reform during turbulent times creating opportunities reflecting the socio-economic environment. Importantly, the BK21 program became the first and largest grants program for graduate students in history during the aftermath of tough economic times.

5.2 What Type of Theoretical Model Program is this?

Now let's discuss some issues on the policy model itself. First, is this policy model a pure creature of Korea? At the time of developing this policy from 1997 to early 1998, the idea of university capitalism by Slaughter & Leslie (1997) and Clark (1998) had not reached Korean policy designers, and systems of innovation were only discussed between researchers (Lee et al., 1997). In addition, Min (1998) introduced a 1995 policy for graduate school written by the US Committee on Science, Engineering and Public Policy in late 1998. Song (2003) discussed the issues of graduate schools in recent times.

The concept of research universities, however, was a backbone of the designing team. The officer and designing team of the policy translated the book by Burton Clark written in 1995 (Ko et al., 1999). Furthermore, programs for graduate students in the United States became a model to emulate. The Integrative Graduate Education and Research Traineeship (IGERT) program started in the United States in 1998, in addition to the Graduate Research Fellowships Program since 1952. The BK21 program adopted the supportive policy of GRFP and IGERT to graduate students, adding more fundamental contents to university reform.

The IGERT program is intended to catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. IGERT awards are approximately \$3.0-3.2 million for a 5 year program, with the major portion of the funds being used for Ph.D. graduate student stipends of \$30,000 a year and training expenses. Since 1998 the IGERT program has made 260 awards to over 110 lead universities in 43 states, IGERT has provided funding for approximately 5,800 graduate students. (NSF, <http://www.igert.org/public/about>)

BK21 has shown its limitations viewed under the framework of the entrepreneurial university or academic capitalism. Under the program, meritocracy has only been adopted at a few universities and entrepreneurship activities and education lag far behind American counterparts. Furthermore, some industry leaders still complain that the program did not do enough to strengthen the university-industry relationship. Regrettably, a study on the university-industry relationship of BK21 has not been conducted during the last 13 years.

Most respondents interviewed by the author, however, answered that there are considerable changes in the university-industry relationship from the program. Yet, it is still difficult to ascertain how far universities have gone towards the entrepreneurial university model or towards academic capitalism, except in the case of a few universities. This weak linkage between Korean

universities and industry in general leads to a heavy dependence on government for financial support and policy.

BK21 did not develop under the framework of an entrepreneurial university, even though there has been considerable change. The program can be classified as supporting the research university model, although the program has stated that one of its purposes was to enhance university and industry linkage. The fact that a 13-year old policy constructed under the research university model had features of the entrepreneurial model shows the direction of change by current universities.

To further strengthen university and industry linkage policymakers will start a new program named LINC (Leaders in Industry-university Cooperation) for enhancing university-industry relationships in 2012. In addition, another policy for developing the WCU is currently underway.

Whatever the real purpose of BK21, the evaluation of this policy suggests that in developing countries, an entrepreneurial university cannot be formed by a policy developed for research universities. Even though this policy contains some objectives to achieve critical elements of the entrepreneurial university, it still has a long way to go into developing entrepreneurial universities.

5.3 Role of Government in Developing Areas

Hong Kong and Singapore are the early adopters among developing countries who recognized the changing trends towards the entrepreneurial university from the late 1990s. (Lee, Gopinathan, 2005; Mok, 2005; Wong, 2007) Both are small and open economies, but put great emphasis on high quality manpower. Their policies have been in the same direction as the core contents of university entrepreneurship. As a result, their policies are reflected in the ranking on WCU's as shown by Table 1.

The announcement of world rankings on universities from the mid 2000's has made nearly all developing countries seek to develop good research universities and world-class universities. It is interesting that these discussions are shown in edited books from around the world, such as Zajda (2005), Altbach and Balan (2007), Yang and Welch (2011), Liu, Wang & Cheng (2011), Goranson and Brundenius (2011).

Singapore and China are prime examples of aggressive reform to develop WCU's and Taiwan, Korea, and Japan follows. Hong Kong is somewhat exceptional compared to other countries since they are accustomed to the UK tradition of university autonomy, competition, and entrepreneurship.

European Union also has a deep concern for university reform. Brugel Institute, an EU think tank (Agion, Dewatripont & Hoxby, 2007) reacted to world universities rankings and analyzed the status of EU universities using the Shanghai Jiao Tong Rankings. They concluded that the level of EU

universities is far below that of the US. They identified the primary reason as 25 member countries only spend 1.3% of GDP on universities as compared to 3.3% in the US. Respectively, that equals to spending 10,000 Euro and 35,000 Euro per student every year.

Unlike university entrepreneurship of advanced countries, the WCU discussion in East Asia and the discussion of university reform on less-developed countries appear to have the same issue: the role of government as one of the main drivers of reform. (Salmi, 2009, Salmi, Liu, 2011; Yang, Welch, 2011; Yonezawa, 2011) Although research universities and entrepreneurial universities are based on autonomy from government, the infrastructure for autonomy is still based on government policy in East Asian countries.

6. Concluding Remarks

This is a study on an old model of university reform in Korea based on current theoretical frameworks. What was the theoretical basis of BK21, and what are the limits of the policy? This research is based on the view that university reform is not only confined to those in higher education, but rather should be viewed in light of universities as being national systems of innovation, and a key factor for the modern growth and development of a nation.

This paper is a byproduct of giving a recommendation on designing a new policy successive to the Brain Korea 21 Program. Hence, it is based on future-seeking aspects: entrepreneurial universities in autonomy, universities as innovation for society and development, and world-class universities for edge in national competitiveness.

BK21 aimed to construct research universities by utilizing the scholarship of graduate students, although there were efforts to get benefits in line with the entrepreneurial university model. If the target of the program was confined to research universities, then it can be evaluated as successful. However, this policy had aspects that strove to be entrepreneurial, and if viewed from that perspective, our evaluation cannot give high credit on efforts to develop an entrepreneurial university.

Review of an old policy based on new theoretical frameworks gives rise to further questions. How many universities can become world-class in a nation? How many professors and research teams are needed to make a university world-class, thereby strengthening the competitiveness of a country? Except some English speaking countries who traditionally have had strong universities, Northwestern European countries such as Sweden, Denmark, and the Netherlands put higher input into their universities, yielding more world-

class universities then other nations in Europe. Should developing countries look there for finding a good model to create its own WCU's?

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Technology Innovation in Korean Manufacturing Firms: Intra-Firm Knowledge Diffusion and Market Strategy in Patent Production

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Abstract This paper analyzes the factors that determine technology innovation in Korean manufacturing firms, focusing on the role of intra-firm knowledge diffusion and market strategy in patent production. For empirical analysis, zero-inflated negative binomial (ZINB) regression is applied to the 2009 Human Capital Corporate Panel data. The empirical findings confirm the critical role of intra-firm knowledge-sharing processes in technology innovation; firms with a market-leading strategy oriented to new product development also tend to be prolific in patent production.

Keywords technology innovation, knowledge diffusion, market strategy, patent, ZINB

1. Introduction

With the emergence of knowledge-based economy, intangible assets such as knowledge and technology have become critical factors that determine the competitiveness of firms and countries. It is thus important for firms and countries to generate, accept, and propagate new knowledge and technology in order to maintain a competitive edge over others and sustain their growth in the global market. Accordingly, individual firms and nations are dedicating their efforts to promoting technology innovations, which they use to boost their technological and economic achievements.

Technology innovation, which is an intangible asset, is actually difficult to measure, apart from its significance in strategy and policy. Thus, the input and output factors related to technology innovation are used as indicators of

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technology innovation, but there are limitations in that they are only proxies regardless of the variables used. This study focuses on the patent as an indicator of technology innovation. Although a patent cannot be completely free from the common limitations of proxy variables, it can at least guarantee technological achievement and commercial utility and is growing in importance as an intellectual property right amidst fierce technological competition.

The number of patent applications in the world in 2010 was 1.98 million, which is a 7.2% increase from the previous year despite the global economic crisis (WIPO, 2011). This is the biggest increase in the last five years and signifies that technological innovation has been actively taking place worldwide. With respect to the number of filed patent applications, South Korea ranked 4th in the world in 2010 with slightly over 170,000 filed patent applications, following the U.S. (490,000), China (391,000) and Japan (344,000). In particular, China has shown the fastest growth with an average annual increase of 22.6% between 2001 and 2010.

Granted that, which factors contribute to the increase in the number of patent applications? Considering the number of patent applications as a performance indicator of technology innovation, the increase in the number is thought to be highly affected by increases in R&D investment, investment efficiency, and patent propensity. Precedent studies usually point to input factors such as R&D expenditure and R&D personnel as well as R&D infrastructure such as the R&D organization, strategies and other corporate characteristics of companies as the determinants of technology innovation.

The objective of this study is to analyze the factors that determine technology innovation through an estimate of the patent production function of manufacturing firms in South Korea. In particular, this study focuses on the internal knowledge-diffusion mechanism and market strategies of firms as the determinants of technology innovation. If the firm's internal knowledge-diffusion mechanism is well established, the knowledge spillover among the staff members is expected to lead to significantly greater technological innovations with the same R&D investment. Also, it can be deduced that firms that are actively engaged in the development of new products and in the pioneering of new markets will be more aggressive in technologically innovative activities compared to other firms. However, previous studies rarely dealt with these factors as the determinants of the technology innovation of firms. This study is therefore expected to provide important implications in setting corporate strategies and relevant government policies through its analysis of the effects of the important strategic variables of firms on their technology innovation.

This paper is organized as follows. In section II, the determinants of technology innovation and its economic achievements will be reviewed,

centering on patents discussed in precedent studies. Next, in section III, a model and data will be explained for the analysis of the determinants of technology innovation. Then in section IV, a concrete estimation method will be explained. The major findings of the analysis will be presented in section V and the significance and implications of the results of the analysis will be explained in section VI.

2. Literature Review

2.1 Technology Innovation, Patents and Economic Outcome

As mentioned above, technology innovation is itself an intangible asset and is thus difficult to measure. It is commonly measured by either input indicators such as the R&D expenditure or output indicators such as patent or total factor productivity. There are both advantages and disadvantages of using input and output indicators, but in terms of technological innovation achievements, the most commonly used indicator is patent statistics. Patents are widely used as indicators of innovation of individual companies, regions and countries as they are considered as the latest technical knowledge that displays originality, generating economic value through licensing and technology transfer, and possessing the potential to be widely utilized in many industries (Acs and Audretsch, 1989; Griliches, 1990; Fung and Chow, 2002; Johnstone et al., 2010; Tseng et al., 2011).

Studies on the economic effects of patents as indicators of technological innovation show that patents play an important role in national economic growth and the business achievements of companies. Yang and Chen (2003) analyzed the relationship between the market value and the number of registered patents of electrical and electronic companies and confirmed that the number of registered patents had a positive impact on the market value of the companies. The findings of the study performed by Czarnitzki and Kraft (2004) revealed that the patent stock was an important factor that enhanced the credit rating of a company. Park, Park and Cho (2006) analyzed the relationship between the technological innovation and business performance of domestic high-tech companies and determined that the number of domestically registered patents per 1,000 employees had a significant effect on the net income per employee. Chen (2011) also identified a positive relationship between registered patents in an important technological sector and corporate growth. Lee (2007) discovered that the rate of increase of patents had a positive effect on the economic growth rate through a regression analysis, while Hasan and Tucci (2010) showed that nations with larger numbers of patents had a higher economic growth rate.

2.2 Factors Determining Technology Innovation

If a patent, as an indicator of technological innovation, is an important factor for improving corporate performance and promoting economic growth, our next concern should be the factors that promote patent output. Based on the fact that patents are produced as a result of R&D activities, we can infer that the R&D input factors and the R&D-related corporate organizational capabilities are critical factors that determine patent output.

According to the resource-based view of the firm, corporate resources and organizational capabilities are the key factors that determine corporate competitive advantage and its sustainability (Barney, 1991; Wernerfelt, 1984). It applies to corporate knowledge creation (e.g., technological innovation), which has been increasingly important in securing corporate competitiveness and its long-term growth. Put differently, corporate knowledge resources (e.g., R&D personnel) and its strategic management capabilities (e.g., strategic human resource management) are critical for corporate knowledge creation, which, in turn, largely determines the firm's competitive advantage in this knowledge-based economy.

With respect to the firm's technological innovation, the existing literature mostly confirms the significant role of corporate R&D resources. Although the size of the effect and its statistical significance vary depending on the study, most previous studies reported that the R&D expenditure or R&D intensity had a positive relationship with patent output or corporate performance (Bound et al., 1984; Jaffe, 1996; Crépon, et al., 1998; Kwon, Kim and Choi, 2009). The number and quality of R&D personnel were also important determining factors in technological innovation. In particular, the more advanced the technology is, the more importance the high-quality R&D personnel and enhanced research productivity have in determining the achievements of technological innovation (Audretsch and Stephan, 1996; Zucker, Darby and Brewer, 1998; Kang and Seo, 2005; Jung, 2006; Jung, Roh and Cho, 2008).

Organizational capabilities to acquire a knowledge resource, articulate and amplify it, and put it into use in the most efficient way are also critical in corporate knowledge creation, especially in a dynamic and rapidly changing environment (Nonaka, 1994; Grant, 1996; Lee and Kim, 2001). Among others, the corporate knowledge diffusion system constitutes a key element of organizational capabilities for knowledge creation (Davenport and Prusak, 1998; Ernst and Kim, 2002; Tsai, 2008). Damanpour (1991) proposed that the creative behaviors of the members of an organization vary depending on the characteristics of the organization; if the decision-making power is concentrated among the top executives and the company has extremely strict operating rules and regulations, it poses difficulties for the members to suggest

and experiment with their creative ideas, which, in turn, inhibit corporate innovation.

Firms' market strategy is also closely related to corporate organizational capability. Miles et al. (1978) asserted that the firms that find and exploit new product and market opportunities (prospectors, in his classification) are likely to be active innovators, while those with a stability strategy (defenders, in his classification) are not likely so. Ahuja (2000) analyzed that strategic alliances between companies which share technologies that can mutually benefit one another and increase the accessibility of important information can become an important source of technological innovation. Park and Kim (2010) confirmed that such an R&D alliance increases technological innovation when the company has a strong resolution or motivation to explore new technology and has the appropriate capacity to do so; however, such an alliance produces no positive effects for companies that do not fit these criteria.

Corporate R&D organization and strategies are also pointed out as important determinants of technological innovation (Damanpour, 1991; Nesta and Saviotti, 2005). Strategic factors such as the proportion of the total R&D investment directed towards demand-led R&D activities or projects proposed by the R&D division were identified to have an influence on the success of the R&D activities of a company (Mansfield and Wagner, 1975). Kwon, Kim and Choi (2009) pointed out that the degree of capital intensity and the proportion of export influenced technological innovation. Song and Oh (2010) explained that corporate size and market concentration were important factors that promoted the technological innovation activities of firms.

3. Model and Data

3.1 Analysis Model

Considering the patent as a result of resource allocation for technological innovation activities such as R&D, the patent production function of firms can be expressed as follows:

$$y = f(X, Z) \tag{1}$$

where Y is the output of technological innovation activities, which is captured by the annual number of patent applications of a company in this study. The explanatory variable vector, X , refers to the R&D resources to be directly used for technological innovation activities; it includes R&D investment and the size and quality of R&D personnel. Z denotes the organizational capability vector that has bearing on the efficiency of the knowledge production process;

it is measured herein by the knowledge-diffusion system, market strategies and other corporate characteristic variables related to knowledge production infrastructure. The corporate knowledge-diffusion system, in turn, includes the education and training organization and knowledge-sharing processes within the firm. The variable for the education and training organization is a dummy variable on whether there is an organization that is in charge of education and training within the firm, and the variable for knowledge-sharing processes is a dummy variable that indicates whether there is a knowledge acquisition program for changes in production processes or R&D.

3.2 Data

For the empirical analysis, data from the Human Capital Corporate Panel (HCCP) were used. HCCP comprises of data collected from biennial surveys that have been conducted since 2005 to identify the human resource accumulation process and contents of companies under the supervision of Korea Research Institute for Vocational Education and Training (KRIVET). The target companies are those which are registered in the *KIS Corporate Data* (Korea Information Service, Inc.), and have over 100 employees (1st~3rd year) with over 300 million KRW in capital (3rd year). The information on the human resources of the subject companies is collected through surveys and is integrated with the secondary data from the Korea Information Service, Inc. on the financial information and from the Korean Intellectual Property Office (KIPO) on the patent information to be provided as a linked-survey-secondary-dataset. This process allows an integrated analysis of the human resource development and management, R&D activities, knowledge-formation process and technological innovation achievements of companies.

Unlike the 1st and 2nd year surveys, there were some changes made in the population and sampling methods in the 3rd year survey. In this study, the most recent survey data from the 3rd year (2009) were used. All variables except the patents are based on the statistical data of 2008 that were collected in 2009, and the information on the patents was obtained from the 2009 statistics provided by the KIPO. Among the total of 473 companies, the firms in the service industry that are not significantly relevant to patent application and those with omitted data on key variables were excluded. Data on the remaining 317 companies in the manufacturing industry were used in the analysis.

3.3 Variable Construction

In this study, the number of patent applications filed by a company in 2009 was used as an indicator of the company's technology innovation. The R&D resources used for R&D activities and the organizational capabilities represented by the in-house knowledge-sharing system, market strategies and

other corporate characteristic variables were used as the explanatory variables of the technological innovation achievements of the company.

First, as for R&D resource variables, R&D intensity and the number of researchers were included as proxy variables for R&D investment, and the proportion of employees with a master's or doctorate degree was used as an indicator of the quality of R&D personnel. R&D expenditure is commonly used as an R&D investment variable, but because of its strong correlation with the number of R&D personnel, the R&D intensity (ratio of annual R&D expenditure to sales) was used instead in this study. Although the proportion of R&D personnel with a master's or doctorate degree is a suitable indicator of the quality of R&D personnel, such information was not on hand; thus the ratio of M.S./Ph.D. degree-holders to total employees (in %) was used as an indicator of the quality of personnel.

Secondly, dummy variables were used for the knowledge-sharing processes and the internal education and training organization with respect to the internal knowledge production infrastructure of a company. The variable for education and training organization is a dummy variable on whether there is an organization that is in charge of education and training within the company, and the variable for knowledge-sharing processes is a dummy variable that indicates whether there is a knowledge acquisition program for changes in processes or R&D.

Thirdly, dummy variables were created to indicate whether there is the presence of a market strategy for the leading products of the companies and a strategic alliance with another company. With respect to the question on market strategy for the leading products, the companies that responded "We develop new products before our competitors to play a leading role in creating changes among consumers and in the market" were categorized as 'market-leading type'; the companies that responded "We do not enter new markets or act as leaders in developing new products, but target the market by selectively developing new products according to the achievements of the leading companies" were categorized as 'catch-up type'; and the companies that responded "We maintain a stable position in the market by improving our existing products and do not actively attempt to enter new markets or develop new products" were categorized as 'stability type.' Among them, the catch-up type was designated as the reference group and dummy variables were created for both the leading-type and the stability-type for analysis.

Table 1 Variable Definition and Summary Statistics

Variable	Definitions and Measures	Mean	S.D.
Tech Innovation			
<i>Patent</i>	Number of patent applications (2009)	22.71	139.86
R&D Resource			
<i>R&D_sales</i>	Ratio of annual R&D expenditure to sales	0.02	0.03
<i>R&D_pers</i>	Number of researchers	54.31	176.99
<i>Adv_degree</i>	Ratio of M.S./Ph.D. degree-holders to total employees (%)	3.67	4.64
Knowledge-Diffusion			
<i>Training</i>	1 If there is an organization dedicated to education and training within the firm, 0 otherwise	0.58	0.49
<i>K-sharing</i>	1 If there is a knowledge-acquisition program for R&D or changes in production processes, 0 otherwise	0.81	0.39
Market Strategy			
<i>Leading</i>	1 If the firm develops new products before competitors and plays a leading role in the market changes, 0 otherwise	0.34	0.47
<i>Stability</i>	1 If the firm improves existing products rather than develops new products to maintain a stable position in the market, 0 otherwise	0.24	0.43
<i>Alliance</i>	1 If the firm established a strategic alliance with (an)other companies, 0 otherwise	0.21	0.40
Firm Properties			
<i>Capital</i>	Total capital per employee (in million KRW)	521.95	510.68
<i>Subsidy</i>	1 If the company receives government subsidy for technological development or commercialization, 0 otherwise	0.49	0.50
<i>Firm_age</i>	2008 – year of company foundation	32.00	17.13
<i>Firm_size2</i>	1 If the number of employees is between the range of 300–999	0.37	0.48
<i>Firm_size3</i>	1 If the number of employees is over 1,000	0.14	0.35
N		317	

Note: The number of patent applications is based on the 2009 statistics, while the other variables are based on the 2008 statistics.

Lastly, the variables of capital per employee, utilization of government subsidy, and firm age and size were used as the other corporate characteristic variables related to the technological innovation of firms. The degree of capital intensity was the total capital per employee (in million KRW), and the government subsidy was a dummy variable on whether the company received tax deductions or utilized government subsidy with respect to technological development or commercialization. The firm age was determined by subtracting the year of company foundation from year 2008. As for the firm size, companies with 100-299 employees were designated as a reference group, and dummy variables were created for a group of companies with 300-999 employees and a group of companies with over 1,000 employees for comparison.

Table 1 shows the basic statistics and the method used to measure these variables. The number of patent applications in 2009, which is the indicator of the technology innovation of firms, was 22.7 on average; in addition, there is a significant difference among the numbers of patent applications of companies as detected from the size of standard deviation. Forty-five percent of the companies did not file patent applications in 2009 and the number of patent applications filed by 50.8% of the companies ranged from 1 to 99. The remaining 4.4% are companies that filed more than 100 patent applications.

Regarding the R&D resource variables, firms, on average, invested 1.8% of the corporate revenues towards R&D activities and had 54 researchers; about 3.7% of employees, on average, were those with masters or doctorate degrees. There was also a large variation in the R&D resource variables among the companies. Pertaining to the knowledge-sharing variables, the knowledge-diffusion infrastructure was well established within the companies with nearly 60% of companies operating an organization dedicated to education and training and over 80% of them operating knowledge-acquisition programs with respect to R&D and changes in production processes. As for market strategies, the firms were mostly the catch-up type (41%), followed by the leading-type (34%) and stability-type (25%). Approximately 20% of the companies have formed strategic alliances with other companies and nearly half of the companies utilized government subsidy towards technological innovation.³⁵

³⁵ As shown in Table A.1 (in Appendix), the correlation among the explanatory variables was relatively low and all variables were included in the regression analysis for the estimation.

4. Estimation Method

For empirical estimation of the patent production function, where the number of patent applications is the dependent variable, we use count-data models. We start with the Poisson regression model, which is the most basic model that explicitly addresses the nonnegative integer-valued aspect of the dependent count variable. The probability mass function for the Poisson regression model is specified as:

$$f(y; \mu) = \frac{e^{-\mu_i} \mu_i^{y_i}}{y_i!} \quad \text{for } y = \{0, 1, 2, \dots\}, \quad \mu > 0 \quad (2)$$

$$\ln(\mu_i) = x_i' \beta$$

$$E[y_i | \beta, x_i] = \text{Var}[y_i | \beta, x_i] = \mu_i = \exp(x_i' \beta)$$

where μ is the mean rate parameter.

The log-likelihood function for the Poisson regression model is then the following:

$$\mathcal{L} = \sum_{i=1}^n \{y_i(x_i' \beta) - \exp(x_i' \beta) - \ln(y_i!)\} \quad (3)$$

The Poisson distribution assumes equidispersion, i.e., the mean and variance being equivalent. The Poisson regression is thus not appropriate in cases of over-dispersion in which the response variance is greater than the mean. The negative binomial (NB) regression model can be used instead when over-dispersion occurs.

The negative binomial regression has the following probability mass function:

$$f(y; \mu, \alpha) = \frac{\Gamma(y_i + 1/\alpha)}{\Gamma(y_i + 1) \Gamma(1/\alpha)} \left(\frac{1}{1 + \alpha \mu_i} \right)^{\frac{1}{\alpha}} \left(1 - \frac{1}{1 + \alpha \mu_i} \right)^{y_i} \quad (4)$$

for $y = \{0, 1, 2, \dots\}, \quad \alpha \geq 0$

where α is a heterogeneity or over-dispersion parameter. The Poisson regression is a special case of negative binomial regression with $\alpha = 0$. The log-likelihood function for the negative binomial regression is the following:

$$\mathcal{L} = \sum_{i=1}^n y_i \ln \left(\frac{\alpha \exp(x_i' \beta)}{1 + \alpha \exp(x_i' \beta)} \right) - \frac{1}{\alpha} \ln(1 + \alpha \exp(x_i' \beta)) + \ln \Gamma \left(y_i + \frac{1}{\alpha} \right) - \ln \Gamma(y_i + 1) - \ln \Gamma \left(\frac{1}{\alpha} \right) \quad (5)$$

Since the negative binomial regression model reduces to the Poisson regression model when $\alpha = 0$, we can test for over-dispersion by testing $H_0: \alpha = 0$. Our likelihood-ratio test yields strong evidence of over-dispersion, and thus the negative binomial regression model is preferred to the Poisson regression model (see Table 2).

Our next concern is how to deal with a large number of zero counts in our patent data set, in which zero is the most common number of patent application.³⁶ A vast number of these firms might have a positive probability of patent application but happened to have no patent application for the observed year. Some of these firms, however, might have virtually a probability of zero for patent application whatsoever, inflating the number of zeros in the data set.

Zero-inflated count models provide a way of modeling the excess zeros (Greene, 1994; Hilbe, 2011). We use herein the zero-inflated negative binomial (ZINB) model, taking into account the excess zeros as well as the over-dispersion problem. The probability function for the zero-inflated negative binomial regression model is specified as:

$$P(y_i = 0|x_i, z_i)F_i + (1 - F_i)(1 + \alpha\mu_i)^{-\alpha^{-1}}$$

$$P(y_i|x_i, z_i) = (1 - F_i)\frac{\Gamma(y_i + \alpha^{-1})}{y_i! \Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu_i}\right)^{\alpha^{-1}} \left(\frac{\mu_i}{\alpha^{-1} + \mu_i}\right)^{y_i}, y_i > 0 \quad (6)$$

The log-likelihood function of the zero-inflated negative binomial with logit is specified below. In this study, we assume that the predictors for the binary process and those for the count process are equivalent.

$$\begin{aligned} \mathcal{L} = & \sum_{i:y_i=0} \ln \left[\exp(z_i'\gamma) + (1 + \alpha \exp(x_i'\beta))^{-\alpha^{-1}} \right] \\ & + \sum_{i:y_i>0} \sum_{j=0}^{y_i-1} \ln(j + \alpha^{-1}) \\ & + \sum_{i:y_i>0} \left\{ -\ln(y_i!) - (y_i + \alpha^{-1}) \ln(1 + \alpha \exp(x_i'\beta)) + y_i \ln(\alpha) \right. \\ & \left. + y_i x_i'\beta \right\} - \sum_{i=1}^N \ln[1 + \exp(z_i'\gamma)] \end{aligned} \quad (7)$$

³⁶ See Figure A.1 (in Appendix) for the histogram of the corporate patent application distribution.

The Vuong (1989) test result favors the zero-inflated negative binomial model for fitting the data most appropriately (see Table 2). Accordingly, we present our empirical results hereinafter, based on the ZINB regression estimation.

Table 2 Estimates of Patent Equation: Count Data Models

Variable	Poisson	NB	ZINB
R&D Resource			
<i>R&D_sales</i>	-2.4994*** (0.4454)	9.5313* (4.5578)	4.2998 (3.3830)
<i>R&D_pers</i>	0.0015*** (0.0000)	0.0047** (0.0016)	0.0035** (0.0013)
<i>Adv_degree</i>	0.0721*** (0.0030)	0.1140*** (0.0276)	0.0991*** (0.0231)
Knowledge-Diffusion			
<i>Training</i>	0.3061*** (0.0432)	0.2836 (0.2100)	0.0371 (0.2200)
<i>K-sharing</i>	0.7043*** (0.0999)	0.5881 (0.3080)	0.8602** (0.3182)
Market Strategy			
<i>Leading</i>	-0.1855*** (0.0413)	0.7113** (0.2363)	0.7897*** (0.2253)
<i>Stability</i>	0.0189 (0.0520)	0.0298 (0.2588)	0.3487 (0.2772)
<i>Alliance</i>	0.7946*** (0.0303)	0.0780 (0.2514)	-0.0176 (0.2377)
Firm Properties			
<i>Capital</i>	0.0003*** (0.0000)	0.0000 (0.0002)	0.0001 (0.0002)
<i>Subsidy</i>	0.7801*** (0.0429)	0.3704 (0.2325)	0.2119 (0.2289)
<i>Firm_age</i>	0.0058*** (0.0007)	-0.0138* (0.0064)	-0.0142* (0.0063)
<i>Firm_size2</i>	0.8258*** (0.0594)	1.1249*** (0.2297)	1.3615*** (0.2280)
<i>Firm_size3</i>	2.2902*** (0.0572)	2.478*** (0.3937)	2.3154*** (0.3917)
<i>Constant</i>	-1.0173*** (0.1083)	-0.9529** (0.3570)	-0.7090* (0.3619)
Alpha		2.4758***	1.8249***
Vuong			3.02**
Log-likelihood	-	-751.6009	-726.8829
LR χ^2	387.0799 30457.41	251.89	239.50

Note: 1) Standard errors in parentheses.

2) *** p<0.001, ** p<0.01, * p<0.05.

5. Empirical Results

Table 3 presents the zero-inflated negative binomial (ZINB) regression results for the patent equation. In regard to the R&D resource variables, both the number of R&D personnel and the ratio of the advanced degree-holders among employees significantly raise the number of patent applications of the firms; the corporate R&D intensity also tends to increase the number of patent applications, but lacks statistical significance. It thus confirms the notion that securing qualified research personnel is a prerequisite for technology innovation in the firm.

As for intra-firm knowledge diffusion, which is of main interest in this paper, the knowledge-sharing system within a firm significantly contributes to the firm's patent production. The operation of the knowledge-sharing system within the firm increases the expected number of corporate patent applications by a factor of 2.36, holding all other variables constant. It thus behooves the firm to encourage knowledge sharing and diffusion among its workforce, especially in the occurrence of R&D and other innovation-related activities, for it will enhance the productivity of such activities. The firm that runs its own employee training system is also likely to render more patent applications, but such an advantage over those firms without an employee training system is not sufficient enough to be statistically significant.

A firm's market strategy is also related to its technology innovation output. Firms that adopt a market-leading strategy and are aggressive in new product development and market creation opt to have more patent applications, *ceteris paribus*, as compared to their counterparts utilizing the catch-up strategy. On the other hand, a strategic alliance of firms does not improve the corporate performance in patent production.

Among the various firm properties, both the age and the size of the firm are significantly related to the firm's technology output, but in opposite directions. Firms tend to be more fertile in patent production the younger and the larger they are, other things being equal. The large positive correlation between the firm size and the number of patent applications may be, to a large extent, due to the relative affluence of corporate resources of large firms. The negative correlation between the firm age and the number of patent applications insinuates that younger firms tend to be more inclined to engage in technology innovation than older firms, *ceteris paribus*. Governmental financial subsidies for corporate R&D activities are positively related to the firm's patent production, but warrant no statistical significance; it thus implies

that currently, government subsidies may not be effective, from a public policy standpoint, to promote patent production.³⁷

Table 3 Estimates of Patent Equation: ZINB Regression Results

Variable	Coeff.(β)	Exp(β)	Exp(β)_Stdx	dy/dx
R&D Resource				
<i>R&D_sales</i>	4.2998	73.6873	1.1548	19.6379
<i>R&D_pers</i>	0.0035**	1.0035	1.8556	0.0160*
<i>Adv_degree</i>	0.0991***	1.1041	1.5835	0.4522***
Knowledge-Diffusion				
<i>Training</i>	0.0371	1.0378	1.0185	0.1693
<i>K-sharing</i>	0.8602**	2.3636	1.3984	3.0904**
Market Strategy				
<i>Leading</i>	0.7897***	2.2027	1.4548	4.1945**
<i>Stability</i>	0.3487	1.4173	1.1616	1.7497
<i>Alliance</i>	-0.0176	0.9826	0.9929	-0.0798
Firm Properties				
<i>Capital</i>	0.0001	1.0001	1.0425	0.0004
<i>Subsidy</i>	0.2119	1.2361	1.1119	0.9720
<i>Firm_age</i>	-0.0142*	0.9859	0.7835	-0.0650*
<i>Firm_size2</i>	1.3615***	3.9021	1.9332	7.9787***
<i>Firm_size3</i>	2.3154***	10.1288	2.2465	29.9892**
<i>Constant</i>	-0.7090*			
Log-likelihood	-726.8829			
LR χ^2	239.50			

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

³⁷ The full evaluation of the government R&D subsidy program requires further scrutinized inspection, so our results here should be interpreted with caution.

6. Conclusion

This paper analyzed the factors that determine technology innovation in Korean manufacturing firms, using patent application statistics as a proxy for corporate technology innovation. The major contribution of this paper is that it focuses on the role of intra-firm knowledge diffusion and market strategy in corporate patent production, which had drawn little attention in previous studies in this arena. It was hypothesized that firms which are active in intra-firm knowledge diffusion are likely to have higher odds for success in technology innovation. A firm's market strategy was also assumed to bear upon its technology innovation, since this will affect the firm's resource allocation and patent strategy.

For empirical analysis, we utilized the zero-inflated negative binomial (ZINB) regression analysis, taking into account both the over-dispersion (violating the equidispersion assumption of the Poisson regression) and the inflation of the number of zeros (an excessive number of outcome zeros with two possible processes to reach a zero outcome). The data was drawn from the 2009 Human Capital Corporate Panel (HCCP) data, which render the firms' patent statistics (patent application in 2009) along with the data on corporate human resource management and extensive firm-specific characteristics.

The empirical findings confirm the critical role of intra-firm knowledge-diffusion in technology innovation. The firms are substantially more prolific in patent production if they have a knowledge-sharing process that offers an educational or training program for their employees in the occurrence of R&D activities or changes in the production process, as compared to the firms without such a process. Firms that have a market-leading strategy oriented to new product development are also more active in patent production. The empirical results of this paper also confirm the significant effect of the size and quality of the R&D personnel utilized for the firm's R&D activity on corporate technology innovation as measured by patent production. Other things being equal, firms yield more patent applications the larger and the younger they are. Governmental subsidies for firm's R&D investment, however, appear to be ineffective in increasing patent production, at least in the firms analyzed in this paper.

Some implications can be drawn from our analysis of corporate technology innovation. First, firms need to invest in the intra-firm knowledge diffusion process and in human resources development in order to take full advantage of their R&D efforts. Firms' R&D investment will yield higher odds of technological success, if reinforced by the positive spillover effect through knowledge sharing and diffusion among the workforce and human

capital accumulation. Secondly, a market-leading strategy for the firm – being active in new product development and new market creation – works to stimulate the firm's technology innovation. Third, government financial subsidies for firms' R&D investment should be scrutinized for ways to improve its effectiveness in facilitating firms' technology innovation.

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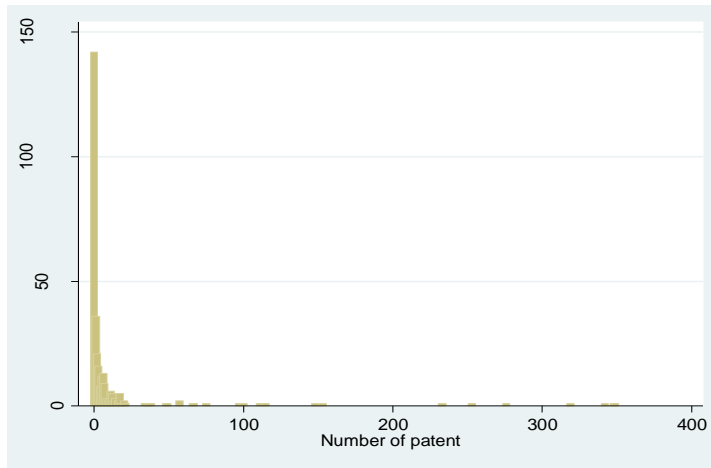
Appendix

**Table A.1 Correlation among the Explanatory Variables
(Pearson Correlation Coefficients)**

	1	2	3	4	5	6	7
1.R&D_sales	1.0000						
2. R&D_pers	0.2008 ***	1.0000					
3. Adv_degree	0.3069 ***	0.2122 ***	1.0000				
4. Training	0.1050 *	0.1305 **	0.1184 **	1.0000			
5. Learning	0.0963 *	0.1025 *	0.1311 **	0.1979 ***	1.0000		
6. Lead	0.1057 *	0.1812 ***	0.0769	0.0627	0.1898 ***	1.0000	
7. Stable	-0.1288 **	-0.0921	-0.0587	-0.0812	-0.2016 ***	-0.4072 ***	1.0000
8. Strategic	-0.0129	0.1514 ***	0.1096 *	0.0234	0.1425 **	0.0965 *	-0.0872
9. Assets	-0.1371 **	0.0291	0.1474 ***	0.0726	0.0865	0.0446	0.0055
10.Subsidy	0.1948 ***	0.1708 ***	0.2617 ***	0.1162 **	0.2540 ***	0.0471	-0.0943 *
11.Firm_age	-0.1355 **	-0.0132	0.0198	0.1238 **	0.2071 ***	0.0904	-0.0248
12.Firm_size1	-0.1008 *	-0.0704	-0.0800	-0.0016	0.1000 *	-0.0165	0.0204
13.Firm_size2	0.0249	0.4015 ***	0.2269 ***	0.2200 ***	0.1248 **	0.1653 ***	-0.1461 ***

	8	9	10	11	12	13
8. Strategic	1.0000					
9. Assets	0.1171 **	1.0000				
10.Subsidy	0.2098 ***	0.0213	1.0000			
11.Firm_age	0.0271	0.1367 **	-0.0895	1.0000		
12.Firm_size1	0.0453	-0.0886	0.0349	0.1677 ***	1.0000	
13.Firm_size2	0.1069 *	0.2761 ***	0.0025	0.1169 **	-0.3132 ***	1.0000

Note: ***p<0.01, **p<0.05, *p<0.1



Note: Firms with more than 400 patent applications in 2009 were not depicted in this figure

Figure A.1. Distribution of Patent Applications by Firms

An Empirical Study on the Success Factors of Inter-Firm Alliances for New Product Development: With a Focus on the SMEs in Korea

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Abstract The purpose of this study is to identify the major determinants of performance of the R&D alliances, with an aim toward raising the success rate in cooperative relationships. In particular, this study assesses whether the success factors of purchasing relationship identified in the literature apply equally to SMEs in Korea. The results of this study indicate that inter-firm cooperation, experienced cooperation, and efficiency of government support have positive impacts on the purchase rate of new products. On the other hand, R&D intensity and resources of competencies of the firm do not influence it. Additionally, market attractiveness does not moderate the effects of the five independent variables on the purchase. The extracted determinants according to the results of surveys give valuable and practical hints to the SMEs when they make a decision on their R&D alliances with large enterprises.

Keywords: R&D alliances, purchase rate of new products, R&D intensity, resources and competencies of the firm, market attractiveness

1. Introduction

It is well known that inter-firm cooperations are becoming a pervasive mode of R&D activities, as well as a general modality for conducting business. An emerging body of recent literature on the firm's performance demonstrates an increasing reliance on inter-firm alliances to develop new products (e.g., Ettlie & Pavlou, 2006).

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The advantages of inter-firm arrangements include cost sharing, technology transfer, and information sharing (Barnir and Smith, 2002). Researchers have concluded that firms participating in inter-firm cooperation benefit from complementary resources, new markets, technology transfer, and learning (Contractor & Lorane, 1988; Hagedoorn, 1995; Das & Teng, 2004). Additional advantages of inter-firm cooperations which are especially relevant to small and medium sized enterprises (SMEs) include improved ability to outmatch a stronger competitor, easier entry into new markets, and access to resources.

However, SMEs have resource constraints, and are therefore motivated to enter into cooperation (Gomes-Casseres, 1996, 1997). In fact, they are vulnerable in partnerships, particularly with larger firms (Teece, 1986). Despite the recent trends of alliance formation for the development of new products, however, many of these new product alliances fail.

In Korea, government has taken a variety of measures to promote win-win partnerships between large enterprises and SMEs, and to promote technical cooperation between them. One of these programs is "the Purchase-Conditioned New Product Development Project," which has been active since 2002. Thanks to pre-agreements regarding the purchase of the newly developed products by large enterprises or public institutions, SMEs can carry out new product development with far less risk, including market uncertainty.

However, according to a recent study, the real purchasing rate by the preappointed large enterprises was 74.4% as of 2010 (Large, Small, and Medium-sized Enterprises Cooperation Foundation, 2010). Although this level of performance is higher than the average of inter-firm cooperations, considering that all the R&D products were predetermined to be purchased, it does not yet appear to be very successful. In this context, this study was conducted to identify the major determinants of performance of the R&D alliances, with an aim toward raising the success rate in cooperative relationships. In particular, this study assesses whether the success factors identified in the literature apply equally to SMEs in Korea.

2. Theoretical Framework and Hypotheses

2.1. Relational Network Theory

Relational network theory views economic activity as being nested in a network of inter-firm relationships (Granovetter, 1985). In particular, it highlights how firms prefer to work with partners with whom they have an embedded relationship to reduce risk and uncertainty associated with inter-organizational exchange (Chung et al., 2000; Gulati and Gargiulo, 1999;

Podolny, 2001). Relational network theory highlights the role of embeddedness in mitigating the agency costs in a relationship (Granovetter, 1992). Organizational decision makers, by focusing on embedded relationships, may mitigate risk and uncertainty when selecting collaborative partners (Chung et al., 2000; Gulati and Gargiulo, 1999; Li and Rowley, 2002; Uzzi, 1996).

Strategic alliances require a different approach to managing buyer-supplier relationships. The importance of relationship management is apparent in the extant literature, which focuses largely on a) commitment; b) trust and coordination; c) interdependence as important attributes of the relationship (Anderson & Narus, 1990; Dyer, 1994; Frazier, Gill, & Kale, 1989; Handy, 1995; Nishiguchi, 1994; Ring & Van de Ven, 1994).

a) Commitment: Commitment refers to the willingness of buyers and suppliers to exert effort on behalf of the relationship. Commitment to a relationship is most frequently demonstrated by committing resources to the relationship, which may occur in the form of an organization's time, money, facilities, etc. Only recently have theorists begun to describe how the commitment of assets can influence the nature of interorganizational relationships. A variety of studies have found a relationship between resource commitment and the joint action or continuity between parties within interorganizational relationships (Friedman, 1991; Heide & John, 1990; Yoshino & Rangan, 1995). These results indicate that successful alliances result when both buyers and suppliers demonstrate willingness to commit a variety of assets to a set of future transactions.

b) Trust and Coordination: McAllister (McAllister, 1995) concluded that trust occurs in two forms. One of these has its roots in reliable role performance, cultural-ethnic similarity, and professional credentials; the other has its roots in "citizenship" behavior and interaction frequency. Both forms have been found to enhance coordination by lowering administrative costs. Trust has also emerged as an important component of alliances, and several studies have corroborated the importance of trust and coordination in cooperative relationships (Pilling & Zhang, 1992; Smith & Aldrich, 1991; Smith et al., 1995).

c) Interdependence: Interdependence exists when one actor does not entirely control all of the conditions necessary for the achievement of an action or a desired outcome. Resource dependence theory (Emerson, 1962; Pfeffer & Salancik, 1978) specifies the conditions under which one social unit is able to obtain compliance with its demands when interdependence is present. These relationships have been explored in empirical studies,

which investigate the relationship between dependence and control in buyer-supplier relationships (Handfield, 1993a). For instance, the relevant literature suggests that successful strategic alliances are expected to be characterized by higher levels of commitment, trust and coordination, and interdependence. On the contrary, Suh (1994) and Mohr (2010) argue that the potential loss of independence and damage of confidentiality may result in a failure of R&D alliances.

In the case of the alliance in developing new products between the SMEs and large enterprises, inter-firm cooperation carried out in the presence of openness of relationship, trust, informal communication, etc. will create stronger relationships and directly influence the outcome.

Based on the above discussions, the relationship between the level of inter-firm cooperation and the performance of R&D cooperation is hypothesized as follows.

H1: The level of inter-firm cooperation will have a positive effect on the percentage of purchase.

2.2 Organizational Learning Theory

According to organizational learning theory, Park & Russo (1996) and Gulati (1995) concluded that the experience of cooperation creates trust and commitment. Powell et al. (1996) have demonstrated that the more the experience of cooperation increases, the more profoundly the performance of cooperation will improve. In the same manner, Kale & Singh (1999) have also demonstrated that the greater the experience of cooperation is the more likely cooperation will succeed. Based on the argument above, this study proposes the following hypothesis:

H2: The experience of cooperation will have a positive effect on the purchase rate of new products

2.3 Resource Based Theory

The resource-based view of strategy views inter-organizational relationships as resource linkages that provide synergies by sharing and transferring resources (Eisenhardt and Schoonhoven, 1996). Hagedoorn (1993) found that larger firms seek small partners that can provide complementary cutting-edge technologies, thereby reducing their innovation time and costs. From a resource-based perspective, firms that are able to accumulate resources and capabilities that are rare, valuable, non-substitutable, and difficult to imitate will achieve a competitive advantage over other competing firms (Barney 1991). The characteristics regarded as important and attractive by a

partner in an alliance are financial and technological resources, market position, reputation, etc. Accordingly, this study formulates the following hypothesis;

H3: resources and competences of the SMEs will have a positive effect on the purchase rate of new products.

On the basis of resource-based theory, Barney (1991) suggested seriously that R&D competency is one of the company's resources. Schoenecker & Swanson (2002) employed R&D expenditure, R&D intensity (expenditure/sales), patents, and new products as performance metrics. Lopez (2008) identified R&D intensity as an important variable that represents the resource and competencies of enterprise. The results of the study conducted by Roller et al. (2002) and Colombo & Gerrone (1996) demonstrate that R&D intensity has a positive impact on R&D cooperation. On the contrary, Lee and Kang (2006)'s research demonstrates that R&D ability does not influence the performance of an alliance. We believe that the R&D intensity of the SMEs is crucial for the large companies to fulfill their pre-agreement regarding the purchase of newly developed products. Based on this idea, this study formulates the following hypothesis:

H4: R&D intensity of the SMEs will have a positive effect on the purchase rate of new products

2.4. Efficiency of Government Support

Government efforts to promote inter-firm R&D cooperations include both direct funding supports and indirect supports. Considering the large amount of supports recently provided by government, questions should be raised as to whether they are meeting expectations. Carpon & Cincera (2007) confirm the importance of government support as a significant driver for R&D cooperation. Folster analyzed a sample of 540 R&D projects of Swedish firms and their research competitors. His findings indicated that R&D subsidy programs that allow firms to select the form of cooperation do not increase the probability of cooperation, but do increase the incentive to invest in R&D. Anrique Un et al. (2009) also determined that in the process of innovation, governmental financial support positively affects cooperation performance.

The Korean government has provided a variety of supports to stimulate the cooperative R&D activities among the industries to increase competitiveness and to encourage new product development. Whatever the size and type of support, the initiatives of the government to promote the alliances must be efficient. If it is efficient, such assistance should exert a

positive effect on alliance performance. Accordingly, this study proposes the following hypothesis:

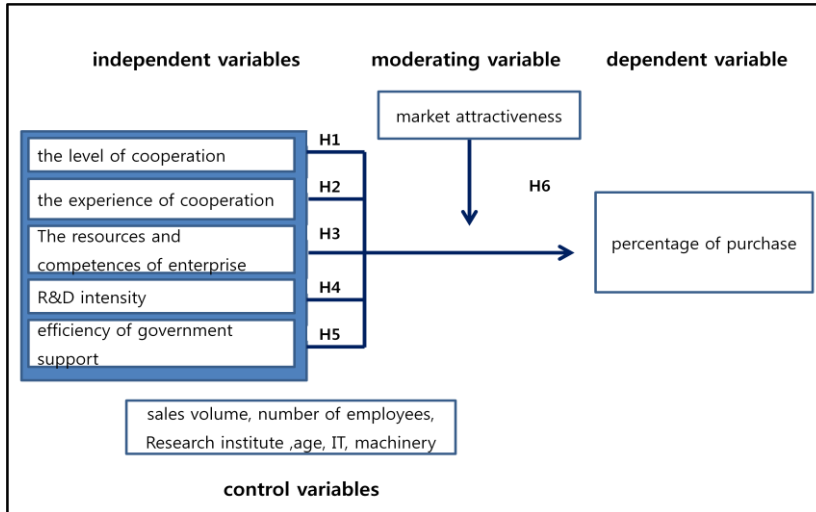


Figure 1 Research Model

H5: Efficiency of government support will exert a positive effect on the purchase rate of new products

2.5 Moderating Effect of Market Attractiveness

It goes without saying that every company is affected by the environment. Among the complex environmental factors, market attractiveness is a key element of marketability. Generally, market attractiveness consists of market size, market growth, and profitability. The dynamics of the environment provide new opportunities to the enterprises (Chandler & Jasen, 1994; Covin & Slevin, 1989). In the literature, the market attractiveness is considered to be a factor influencing directly the R&D performance as well as a moderating variable between the independent variables and the performance of inter-firm cooperation. If collaborative relationships are not appropriate for market conditions, these relationships will fail (Powell, 1990). Market attractiveness appeals to the purchasers' requirements for products. It means new market opportunities. If the opportunities of market expand, inter-firm collaboration would be increased in order to use the partner's resources and exploit the opportunities. In other words, market attractiveness may induce a higher degree of participation by partners into that market. According to Lee (2005), market condition is one of the determinants of performance of R&D collaboration sponsored by the government. According to changes in market

conditions, the buyers will be hesitant to purchase. There is a recent study which shows that market dynamics moderates the relationship between the cooperation activities and R&D performance (Kim J.H. & J.H. Park, 2011). Market attractiveness is supposed to moderate the relationship between the independent variables mentioned above and the performance of inter-firm cooperation. Based on the above discussions, this study proposes the following hypothesis:

H6: The market attractiveness will moderate the impact of the level of inter-firm cooperation, the experience of cooperation, the resources and competencies of enterprise, R&D intensity, and adequacy of government assistance on the purchase rate of new products.

3. Method

3.1 Sample and Data Collection

The population of this study is comprised of 807 medium and small enterprises which participated as a principal organization in the Purchase-Conditioned New Product Development Project. Data was collected from all 807 of the SMEs for three weeks from August 16, 2010 to October 5, 2010 with structured self-administered questionnaires conducted via an Internet web survey. A total of 136 questionnaires were completed, at a response rate of 15.3%. The sample for this study is comprised of 136 SMEs. SMEs in the IT (47.5%) and machinery (35.3%) sector account for 47.5% and 35.3% of the sample, respectively. A total of 86.3% of sample SMEs have their own research institutes. SMEs whose R&D intensity is equal to or greater than 5% constitute 48.1% of the sample. The mean levels of their organizational age, sales volume, and number of employees are 29.7 years, 182.2 billion KRW, and 180 people, respectively.

3.2 Measurement

With regard to the independent variables, inter-firm cooperation was assessed by seven items assessing openness of relationships, trust, smoothness of communication, friendly atmosphere, friendship, interest in the cooperation companies, and informal communication (Andraski, 1998). Experience of cooperation was measured using two items assessing previous cooperation experiences with universities/public organizations and previous cooperation experiences with other companies (Barkma et al., 1997). Resources and competencies of enterprise were assessed by seven items assessing financial situation, bargaining power, product know-how, existence of a department in

charge of marketing/sales, and possession of facilities/equipments (Cooper et al., 1997). Efficiency of government support was measured using two items assessing the necessity of novel government policy and the necessity of company-based policy (Huang et al., 2009). Finally, R&D intensity as a proxy variable of technological capacity was measured by the ratio of R&D investment to sales volume. Market attractiveness, the moderating variable of this study, was assessed by two items assessing market size and market growth potential at the product completion stage (Copper et al., 1997). For each of the multi-item measures, responses were made on the five-point scales with verbal anchors (ex: strongly disagree (1) to strongly agree (5)), and the sum of the scores divided by the number of items was used as a scale value for each respondent.

Exploratory factor analysis was used to assess the validity of the measures employed in this study. Five multi-item measures (inter-firm cooperation, experience of cooperation, resources and competencies of enterprise, efficiency of government support, and market attractiveness) were subjected to factor analysis. R&D intensity was excluded from factor analysis because it was measured using a single-item measure. In conducting factor analysis, the principal axis factoring method of extraction was employed and Varimax rotation was utilized to determine the factor structure. Five factors were extracted from the input data and 68.84% of the variance was explained by the five factors. Additionally, items from each of the five measures factored together respectively with factor loadings greater than 0.50. These results demonstrated that the multi-item measures used in this study evidence satisfactory convergent and discriminant validity.

Table 1 Measurement of Variables

	Variables	Measurement	Source
Dep. Var.	% of Purchase	The ratio(percentage) of the actual sales volume of the SMEs to their planned sales volume	Seo(2000)
Ind. Var.	Inter-Firm Cooperation	Openness of relationships, trust, smoothness of communication, friendly atmosphere, friendship, interest in the cooperation companies, informal communication	Sazali et al. (2009) Andraski (1998)
Ind. Var.	Experience of Cooperation	Previous cooperation experiences with universities/public organizations, previous cooperation experiences with other companies	Barkma et al. (1997)
Ind. Var.	Resources & Competencies of Enterprise	Financial situation, bargaining power, product know-how, existence of the department in charge of marketing/sales, possession of facilities/equipments, supply chain, protection of partenar,	Azhdar(2010) Cooper et al. (1997)
Ind. Var.	Efficiency of Gov. Support	The necessity of novel government policy, the necessity of company-based policy	Huang et al. (2009)
Ind. Var.	R&D Intensity	The ratio of R&D investment to sales volume	Mohr(1994)
Mod. Var.	Market Attractiveness	Market size and market growth potential at the stage of product completion	Hall(1993) Cooper et al. (1997)

Table 2 Descriptive Statistics and Reliabilities of Measures

Variables	# of Items	Range	Mean	S.D.	Cronbach's α
Inter-Firm Cooperation	7	1~5	3.85	0.73	0.931
Experience of Cooperation	2	1~5	2.42	0.99	0.723
Resources & Competencies of Enterprise	7	1~5	3.75	0.58	0.844
Efficiency of Gov. Support	2	1~5	3.37	0.70	0.776
Market Attractiveness	2	1~5	3.37	0.77	0.766

The reliabilities of the five multi-item measures were also assessed on the basis of Cronbach's alpha coefficients. Descriptive statistics and Cronbach's alpha coefficients are presented in Table 2. As shown in Table 2, Cronbach's alphas for the multi-item measures used in this study are all above 0.70, which indicates that all the multi-item measures employed herein have a satisfactory level of reliability.

3.3 Data Analysis

Hierarchical regression technique was used to analyze data. Five demographic variables (industry, number of employees, sales volume, organizational age and existence of research institute) were used as controls in conducting hierarchical regression analysis. Industry was converted into two dummy variables, IT (IT=1, others=0) and machinery (machinery=1, others=0). Existence of research institute was also converted into a dummy variable so that possession of research institute had a value of one, and no possession of a research institute was assigned a value of zero.

Hierarchical regression analysis was conducted through three stages. In stage 1, percentage of purchase, the dependent variable of this study, was regressed on six control variables--IT, machinery, and number of employees, sales volume, organizational age, and existence of a research institute. At stage 2, in addition to the six control variables, five independent variables (inter-firm cooperation, experience of cooperation, resources and competencies of enterprise, R&D intensity, and efficiency of government support) and one moderating variable (market attractiveness) were entered into the regression equation. In stage 3, five interaction terms between the five independent variables and market attractiveness were added to the regression equation in order to test the moderating effects of market attractiveness. In order to avoid the multicollinearity problem, as suggested by Jaccard et al. (1990), all the theoretical variables were standardized so that they had means of zero and a standard deviation of one, and then five interaction terms were created using those standardized variables.

Regression analysis assumes linearity and the absence of high multicollinearity. The linearity assumption was assessed for the dependent variable with each of the independent variables using the SPSS MEANS procedure. For those relationships which were found to evidence significant deviations from linearity, R^2 s were compared with Eta^2 s, along with a graphical examination of the relationships. These test results indicated that deviations from linearity were either nonsignificant or sufficiently minor that no transformations were required for the variables included in this study.

The multicollinearity problem was also checked via two methods. Correlations among variables were assessed to detect the multicollinearity problem. Correlations exceeding 0.80 were considered as indicative of the

existence of a serious multicollinearity problem. As shown in Table 5, none of the correlations exceed 0.80. The eigenvalues of the independent variable correlation matrix were decomposed and examined to further check the multicollinearity. Generally, eigenvalues of less than 0.05 are considered indicative of high multicollinearity. None of the decomposed eigenvalues were found to be less than 0.05 in this analysis. These results demonstrate the absence of any serious multicollinearity problem in this study.

4. Results

4.1 Correlation Analysis Results

Correlations among the variables included in this study are presented in Table 3. As shown in the table, all five of the independent variables exhibit significant relationships with percentage of purchase; inter-firm cooperation, experience of cooperation, R&D intensity, and efficiency of government support are positively associated with percentage of purchase, whereas R&D intensity is associated negatively with percentage of purchase. Additionally, market attractiveness, the moderating variable of this study, has a significantly positive correlation with percentage of purchase.

With regard to control variables, four of them were found to be significantly correlated with percentage of purchase; sales volume and number of employees were positively associated with percentage of purchase, whereas IT and the existence of a research institute were negatively related to percentage of purchase.

Table 3 Correlations among Variables

	1	2	3	4	5	6	7	8	9	10	11	12
% of Purchase												
Market Attract.	.223 **											
Efficiency of Gov. Support	.206 **	.192 **										
R&D intensity	-.142 *	.057	.014									
Resources & Comp.	.347 ***	.334 ***	.202 **	-.138								
Exp. of Coop.	.292 ***	.032	.092	.051	.222 ***							
Inter-Firm Coop.	.404 ***	.268 ***	-.001	-.008	.571 ***	.147 *						
Research Ins. ¹⁾	-.150 *	-.166 *	-.060	.155 *	-.278 ***	.044	-.251 ***					
# of Employees	.291 ***	.151 *	.137	-.165 *	.321 ***	.492 ***	.257 ***	-.082				
Sales	.322 ***	.187 **	.146 *	-.176 **	.347 **	.445 ***	.272 ***	-.272 ***	.807 ***			
Age	.066	.181 **	.096	-.175 **	.200 **	.231 ***	.143 *	-.208 **	.263 ***	.276 ***		
IT ²⁾	-.150 *	.025	-.051	.151 *	-.149 *	-.147 *	-.060	.211 **	-.146 *	-.079	.079	
Machinery ³⁾	.024	-.009	.023	-.081	.085	.096	-.015	-.189 **	.099	.066	-.054	-.702 ***

Note: * p<0.10, ** p<0.05, *** p<0.01;

1) 1=possession of research institute, 0=no possession of research institute;

2) 1=IT industry, 0=others;

3) 1=machinery industry, 0=others;

4.2 Hierarchical Regression Analysis Results

As mentioned previously, a hierarchical regression analysis technique was used to estimate the causal model of this study. Hierarchical regression analysis was conducted through 3 stages. In stage 1, percentage of purchase was regressed on six control variables; in stage 2, in addition to the six control variables, six theoretical variables were entered into the regression equation. Finally, at stage 3, five interaction terms between the five independent

variables and market attractiveness were added to the regression equation to evaluate the moderating role of market attractiveness. The results are shown in Table 4. Figures presented in the table are standardized coefficients.

First, consider the results for Model 1, in which six control variables were regressed on percentage of purchase. As shown in the third column of the table, Model 1 explains 15.3% of the variation in percentage of purchase, which is significant at 0.01. Additionally, three out of the six control variables are significant; machinery and IT exert negative effects on percentage of purchase, whereas the number of employees has a positive effect on it. These results indicate that percentage of purchase is lower for SMEs in the IT and machinery sectors than those in other industries, and that as the number of employees' increases, the percentage of purchase also increases.

Next, consider the hierarchical regression results for stage 2, where six theoretical variables were added to Model 1. As shown in the fourth column of Table 4, the six theoretical variables additionally explain the variation of percentage of purchase by 15.2%, which is significant at 0.01. As presented in Model 2 of the table, four out of the five independent variables are significant; inter-firm cooperation, experience of cooperation, and efficiency of government support exert a positive impact on percentage of purchase. On the other hand, market attractiveness, the moderating variable of this research, exerts no significant effect on percentage of purchase. These results indicate that as inter-firm cooperation, experience of cooperation, and efficiency of government support increases, percentage of purchase increases.

Finally, consider the results for Model 3, where five interaction terms between the five independent variables and market attractiveness were entered into the regression equation. As presented in the fifth column of the table, those five interaction terms additionally explain the variance of percentage of purchase, but not significantly so, at 0.10. This indicates that the addition of the five interaction terms does not significantly contribute to the explanation of percentage of purchase. In other words, this result means that market attractiveness does not moderate the relationships between the five independent variables and percentage of purchase. However, the results for Model 3 show that the interaction term between market attractiveness and experience of cooperation (MA*EC) exerts a significantly positive impact on percentage of purchase. The significance of the term, MA*EC, appears to be a statistical artifact, as the variation additionally explained by the addition of the five interaction terms is not significant. In summary, the results for Model 3 indicate that market attractiveness does not perform a moderating function in the relationships between the five independent variables and percentage of purchase.

Table 4 Hierarchical Regression Analysis Results

Dependent = % of Purchase		Regression Coefficients(β)		
		Model 1	Model 2	Model 3
Control Var.	Machinery ¹⁾	-0.237*	-0.157	-0.152
Control Var.	IT ²⁾	-0.278*	-0.175	-0.174
Control Var.	Organizational Age	-0.041	-0.121	-0.237*
Control Var.	# of Employees	0.245	0.137	0.132
Control Var.	Sales Volume	0.096	-0.025	-0.033
Control Var.	Existence of Research Institute ³⁾	-0.062	0.002	-0.031
Independent Var.	Inter-Firm Cooperation		0.283**	0.305**
Independent Var.	Experience of Cooperation		0.207*	0.153
Independent Var.	Resources & Competencies of Enterprise		0.021	-0.015
Independent Var.	R&D Intensity		-0.121	-0.089
Independent Var.	Efficiency of Gov. Support		0.154*	0.187*
Moderating Var.	Market Attractiveness		0.104	0.072
Interaction Terms	MA*IC			-0.001
Interaction Terms	MA*EC			0.250*
Interaction Terms	MA*RCE			-0.128
Interaction Terms	MA*R&DI			-0.032
Interaction Terms	MA*EGS			0.149
R ² (adjusted R ²)		0.153(0.109), F(6,115)=3.473, p=0.003	0.306(0.229), F(12,109)=3.996, p=0.000	0.352(0.246), F(12,104)=3.332, p=0.000
ΔR^2		0.153, F(6,115)=3.473, p=0.003	0.152, F(6, 109)=3.979, p=0.000	0.046, F(5, 104)=1.489, p=0.200

Note; * p<0.05, ** p<0.01

1) 1=Machinery Industry, 0=Others;

2) 1=IT industry, 0=others;

3) 1=Possession of Research Institute, 0=No Possession of Research Institute

5. Discussion and Conclusion

The results of this study indicate that inter-firm cooperation, experienced cooperation, and efficiency of government support have positive impacts on the purchase rate of new products. On the other hand, R&D intensity and resources of competencies of the firm do not influence it. Additionally, market attractiveness does not moderate the effects of the five independent variables on the purchase rate of new products.

The most important action to be taken to facilitate the purchase of new products and to improve the performance of the SMEs is to strengthen inter-firm cooperation. These findings are consistent with much of the social embeddedness literature. Bilateral open communication may perform a significant function in determining the success of inter-firm alliances. Active information sharing behaviors between large enterprises and SMEs appear to be important in managing the relationship and result in conflict resolution orientation, which is an important predictor of success. It is important, as well, to nurture and strengthen a sense of trust with the buyer. Additionally, formal as well as informal commitments of time and energy appear to be significant predictors of the performance of inter-firm alliance.

This study makes a significant contribution to the literature on inter-firm cooperation in that the results of this study showed that the relationship with the present partner is more important than the past experience of cooperation with other partners. The beta coefficients of the two variables in the regression model are .283 and .207, respectively. Appropriate cooperative procedures and structures ensure that the right individuals contribute to the external cooperation at the right moment, and they also encourage more attractive inter-firm cooperation. Moreover, in the SMEs, internal cooperation needs to be encouraged during new product development.

The results of this study partly demonstrate the necessity of government support for private R&D activities. Government support can not only guarantee the commercial success of sponsored projects but can also promote the purchase decision by customers. C. Anrique Un, et al. (2009) demonstrated that process innovations that enjoyed public fund support exhibited superior performance. This finding has important implications for Korean policy makers. The government needs to make efforts to facilitate a strong and continual inter-firm relationship in the process of selection and determination of public R&D support activities.

In contrast with the predominant literature that assesses the success factors of inter-firm alliances in new product development, the results of this study demonstrate that neither resources nor competencies of enterprise nor R&D

intensity affect the alliance performance. Prior studies have demonstrated that, in particular, in advanced economies, decisions to enter into research partnerships, as well as the effects of different types of R&D alliances, are determined primarily by the external R&D resources that a firm can obtain from its partners. The findings of this study also contrast with the relevant literature that emphasizes the importance of assets in determining inter-firm alliance success (Nishiguchi, 1994). These findings, along with the other results of this study, could be interpreted to indicate that it is not so much the R&D competencies that lead to successful inter-firm performance, but rather the management relationship with the customer company.

Market attractiveness is one of the major characteristics of the marketplace in which a newly developed product competes. A firm must analyze the situations and trends of a potential market for a newly developed product. Additionally, for the success of the venture company at various stages, market factors have proven to be very critical. Prior to beginning a new product development initiative, a firm should know that it will fit the target market. Considering that market attractiveness is employed to determine whether or not a market might be a profitable one for investment, this research has resulted in unexpected findings. However, the reason for these findings appears to be that market attractiveness had been already assessed by the customer company when it predetermined to purchase a new product that would be provided afterward by an SME. This indicates that market attractiveness will not make a great deal of difference among the respondents, which might lead to a statistically insignificant moderating effect of market attractiveness.

In summary, the findings of this study imply that factors related to inputs necessary for inter-firm cooperation require more attention in Korea. CEOs of Korean SMEs need to commit themselves to trustworthy relationships and open communication with their partners. The findings also have implications for Korean policy makers. They need to pay special attention to the facilitation of strong relationships which will be achieved, for instance, by strict evaluations and incentives in the process of selection and determination of SMEs for the provision of government support.

Our study focuses the degree of cooperation during the development of new products, the experiences of cooperation, R&D resources, R&D intensity and adequacy of government support. The technical completeness including quality, cost, matching with the market trend should have strong effect on the dependent variable in our research. If we included such variables in our research model, the R^2 could have risen considerably.

This study has several limitations, which in turn provide opportunities for future research. One critical issue is related to the definition and measurement of the dependent variable - alliance performance. Aside from the general

performance of R&D activities, this study attempted to measure one observable consequence of a firm's purchase behavior of the product developed by an SME with which it was preassigned to buy in accordance with the agreement made in advance.

Second, as data were collected from SMEs participating in a government sponsored program, there might also exist a limitation involving the generalization of the findings of this study to all the SMEs. Future research will be necessary to determine whether the results observed herein hold in other settings.

Finally, this study was conducted in Korea and applied to a specific governmental support program. Therefore, the results of this study should not be considered generalizable to other countries. Further research is expected to provide a deeper understanding of the issues explored herein.

A more concrete study is necessary considering the actual situations the SMEs have faced in real alliance activities. Some case studies can also be applied to the super SMEs having made successful achievements of inter-firm alliance together with the reasonable purchase rate. There still exist the other factors, such as technical completeness including quality, cost, and matching with market trend. This maybe is the next step of the research.

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The Use of Feed-forward and Feedback Learning in Firm-University Knowledge Development: The Case of Japan

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Abstract The problem Japanese universities face is exactly the same as that of German universities: no international recognition in world rankings of universities despite their high levels of postwar economic and technological developments. This was indeed one reason why world-class Japanese firms, such as Toyota and Sony, have avoided working closely with Japanese universities for R&D partnership and new technology commercialization. To resolve this problem, the Japanese government has continuously implemented aggressive policies of the internationalization, privatization, liberalization, and privatization of universities since the onset of the economic recession in 1989 in order to revitalize the Japanese economy through radical innovation projects between universities and firms. National projects of developing medical robots for Japan's ageing society are some of the ambitious examples that emphasize feed-forward learning in innovation. However, this paper argues that none of these programs of fostering university-firm alliances toward feed-forward learning has been successful in promoting the world ranking of Japanese universities, although they showed potentials of reinforcing their conventional strength of introducing *kaizen* through feedback learning of tacit knowledge. It is therefore argued in this paper that Japanese universities and firms should focus on feedback learning as a way to motivate firm-university R&D alliances.

Keywords Feed-forward learning, feedback learning, organizational learning, inter-organizational learning, firm-university alliances, innovation, national innovation system, Triple Helix, Japan

1. Introduction

Like their German counterparts, Japanese universities pose one puzzle: no international recognition in world rankings of universities despite their high levels of postwar economic and technological developments. Notwithstanding

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nine Nobel prizes Japanese professors have garnered in the area of natural science since the end of the war, the world rankings of Japanese universities, especially those of Tokyo and Kyoto National Universities, have never reached beyond the 24th place. One of the results of this mixed blessing is the low R&D investment by Japanese multinational enterprises (MNEs) in their local universities. Not only Japanese MNEs, but foreign firms also shied away from collaborating with top notch Japanese universities for technology commercialization. Instead, such giant Japanese firms as Toyota, NEC, and Sony built their own internal R&D centers and/or worked closely with foreign R&D centers for developing and commercializing cutting-edge technologies. The majority of university-firm research collaborations in Japan have been based on personal ties that did not necessarily result in technology commercialization (Katô and Enomoto, 2006; Itô, 2008).

To resolve this problem, the Japanese government has continuously implemented aggressive policies to encourage and consolidate university-firm R&D alliances (e.g., “Seeds Innovation”) since the onset of the economic recession in 1989 (MEXT, 2008). This new policy drive was also part of the bigger project of reforming Japanese universities, which intended to boost global competitiveness of Japanese universities and to attract more fee-paying foreign students and world-class scholars. However, the whole reform package was based on the traditional Japanese technology management practices of emphasizing radical or leading technological innovation projects that would “produce innovation from [traditionally strong] fundamental scientific research that can be sustainable through not only domestically but internationally viable strategies” (MEXT, 2008). Radical innovation projects utilize what many call feed-forward learning, an innovation process that requires the exploration of new knowledge, instead of the exploitation of existing knowledge. New firm-university projects of developing medical robots for Japan’s ageing society are some of the ambitious examples that emphasize feed-forward learning in innovation. Japan’s robotics market is the largest in the world, which is valued at \$7 billion, and the government intends to expand and dominate the market globally through industrial and consumer (e.g., medical, sanitation, and entertainment) robots (JETRO, 2011).

However, this paper finds that most of these programs of fostering university-firm alliances toward feed-forward learning have not been as successful in fostering R&D investments from the MNEs on the one hand and boosting the global competitiveness of Japanese universities as the claim made for them by the program administrators. It is therefore argued in this paper that Japanese universities and firms should shift their focus to feedback from feed-forward learning as a way to reform the lackluster performance of firm-university R&D collaboration. This paper first discusses theoretical backgrounds of feed-forward and feedback learning in university-firm alliance

toward radical and incremental innovation. After establishing core theoretical distinction between feed-forward and feedback learning in innovation and identifying problems associated with these two types of learning, I analyze the case of Waseda University for its leading role in creating university-based venture startups in Japan in a way to leverage Japanese firm-university research alliances. The paper also provides a short discussion of a possible expansion of feedback to feed-forward learning.

2. Feed-forward and Feedback Learning

In the study of university-firm alliances for organizational learning and new knowledge development, researchers have mainly focused on the issues of facilitating factors of university-firm alliances (Geisler, 1995; Cassiman and Veugelers, 2002; Santoro and Chakrabarti, 2002; Tether, 2002; Fontana et al., 2006); finding structural or firm-level contingencies for preferring university over private firm partners for R&D alliances (Teece, 1985; Kogut, 1988; Rosenberg and Nelson, 1994; Berkovitz and Feldman, 2005); the role of the government in galvanizing alliance formations (Capron and Cincera, 2003; Mohnen and Hoareau, 2003; Eom and Lee, 2010); and developing the legal and governance framework of such alliances (Cassiman and Veugelers, 2002). However, to many universities in Japan, Germany, France, Italy, Spain, and Scandinavia, a lingering question is: how to attract major multinational enterprises (MNEs) for their university-firm alliance projects. The harsh reality is that most of these MNEs elect to work with their internal or international R&D hubs and/or prestigious U.K. or U.S. universities for feed-forward knowledge development (Love and Roper, 1999; Santoro, 2000; Monjon and Waelbroeck, 2003; Freel and Harrison, 2006).

In Japan high ranking universities like Tokyo National University, Kyoto National University, Keio University, Waseda University, Tokyo Institute of Technology, and Osaka University are having tough time attracting not only fee paying foreign students or internationally renowned faculty, but collaborative research projects funded by globally leading MNEs like JP Morgan, GE, Exxon Mobil, HSBC, BP, AT&T, Wal-Mart, P&G, IBM, and other Forbes top 100 firms. As Tables 1 and 2 show, the bulk of the research funding awarded to universities between 2005 and 2009 were from big Japanese firms, while the number of collaborative projects with foreign MNCs was negligible (less than 1% of total projects). Furthermore, small and medium enterprises (SMEs) and private universities have continuously and systemically been excluded from the Japanese style firm-university R&D partnerships. Among the top ten recipients of R&D funds from Japanese firms,

only one university was a private: Keio University. Although Waseda University's world ranking was higher than that of Keio in 2011, Waseda couldn't secure a top ten spot on the national funding list. The nine national universities that received the most of the firm-university R&D funding, however, fared miserably in the world rankings, especially Kyushu, Hokkaido, and Kobe.

Table 1 Number of Firm-University Joint R&D Projects

	2005	2006	2007	2008	2009
Big Firms	10,684	8,563	9,703	10,825	10,511
SMEs	3,570	3,926	4,087	4,149	4,268
Foreign MNCs	51	83	111	127	179
Central Gov.	1,353	1,534	1,618	1,800	1,876
Local Gov.	344	368	349	365	307
Others	764	757	1,210	1,743	1,932
Total	16,766	15,231	17,078	19,009	19,073

Source: MEXT (2010)

What's worse, just like foreign MNEs, Japanese MNEs have also shied away from the firm-university R&D projects. As Table 3 shows, Japanese firms have allocated R&D funding to foreign R&D centers two to four times what they have spent for domestic universities. This is a clear indication that Japanese firms would work closely with foreign R&D centers for breakthrough knowledge (i.e., feed-forward learning), whereas they would not be as much interested in working with Japanese universities for similar innovative projects.

Table 2 Total Firm-University R&D (2009) and University Rankings (2010)

Unit=¥1,000

University	Category	Amount	Japan Rank	World Rank
Tokyo	National	3,938,126	1	25
Kyoto	National	2,694,098	2	32
Osaka	National	2,328,664	3	45
Tohoku	National	1,948,433	5	70
Keio	Private	1,278,122	11	188
Kyushu	National	1,225,357	7	122
TIT	National	1,143,157	4	57
Nagoya	National	914,511	6	80
Hokkaido	National	711,328	9	139
Kobe	National	476,096	12	247

Note: Japan and world rankings are based on QS World University Rankings

Source: MEXT (2010), QS (2011)

Table 3 R&D Spending by Japanese Firms

Unit: ¥ bill.

	2003	2004	2005	2006	2007	2008
Total to Japanese Universities	834	836	900	932	967	948
Total to Foreign R&D Centers	1,985	2,012	2,742	2,666	3,075	3,399

Source: METI (2010)

To analyze the declining nature of the university-firm alliance in Japan, I employ the concept of “barriers” to (inter-)organizational learning (Coopey, 1995; Berthoin-Antal et al., 2003; Lawrence et al. 2005; Schilling and Kluge, 2009). The barriers to the firm-university alliance toward interorganizational learning in Japan usually occur at the level of “integration,” if I use Crossan et al.’s (1999) famous 4I model (intuition-interpretation-integration-institutionalization). This integration of firm-university R&D cannot be consolidated because leading Japanese MNEs and SMEs refuse to accept the “interpretation” proposed by the Japanese universities. The 4I model is useful in that it uses four cyclic stages of feed-forward and feedback learning.

Barriers to integration in interorganizational learning include political obstacles (Coopey, 1995; Lawrence et al. 2005) and cognitive biases and mind-sets held among actors, groups, and organizations (Berthoin-Antal et al., 2003). However, others have also noted structural and environmental factors

(March, 1991; Van de Ven and Polley, 1992; Kim, 1993; Nonaka, 1994; Zander and Kogut, 1995; Edmondson and Moingeon, 1996; Inkpen and Crossan, 1996; Schilling and Kluge, 2009). Barriers therefore occur at the levels of individuals, groups, organizations, and environments. Political obstacles and cognitive biases and mind-sets mainly include self or group interests that are incongruous with structural or organizational interests. Informal politics within organizations often affirms the existence of informal charismatic leadership that espouses to perpetuate employees' gold bricking. Under informal leadership, employees can be motivated to defect from learning or pursue other activities that are irrelevant to organizational learning toward innovation (Coopey, 1995; Zell, 2001; Szulanski, 2003, Beer et al., 2005; Lawrence et al. 2005).

Fear of disadvantages, punishment from organizational learning and/or failures (Argyris, 1990; Cannon and Edmondson, 2001; McCracken, 2005; Sun and Scott, 2005), lack of authority within the university (Popper and Lipshitz, 2000; Starbuck and Hedberg, 2003), lack of top management support (Elliott et al., 2000; Lawrence et al., 2005), and defensive routines of MNEs ("not invented here syndrome") (Zell, 2001) are other individual-group level barriers of interorganizational learning.

As Table 3 shows, it is obvious that Japanese MNEs do not spend R&D money in collaboration with Japanese universities as much as they do with universities and R&D centers in North America and the E.U. In addition, corporate decision makers do not want to risk their resources by commissioning new explorative projects to Japanese universities, unless these projects are politically beneficial to the firm or pertain to necessary fundamental technologies that are conducive to feed-forward learning for future commercial projects. Even when Japanese universities present to Japanese MNEs new explorative knowledge with high levels of tacitness, the latter's defensive routine or the "not invented here" syndrome persists. This is because the fear of failure on the part of both MNE decision makers and university researchers is abnormally high in Japan vis-à-vis their counterparts in North America or Western Europe (Morioka, 2007).

Among the structural-organizational factors, low turnover rates and high level of workforce homogeneity, especially among top management teams (March, 1991; Virany et al., 1992); competition with other MNEs that are tied with universities in North America and Western Europe (Sun and Scott, 2005); competence traps within the MNEs through long term success in their cooperation with universities other than Japanese ones (Levitt and March, 1998; Berthoin-Antal et al., 2003); inadequate communication between MNEs and universities (Elliott et al., 2000; Zell, 2001); political and power structures (Coopey, 1995; Beer et al., 2005); ineffective resource allocation (Beer et al., 2005); lack of learning values (Sun and Scott, 2005); and lack of cultural fit

between innovation needs and organizational culture (Sun and Scott, 2005) are considerably powerful variables in explaining the barrier to interorganizational learning.

In the Japanese case, professors are too homogenous with low turnover rates, whereas Japanese MNEs face stiff competition in the global market, where their competitors constantly work with leading research universities in North America and Western Europe. The long term success that Japanese MNEs have enjoyed in their alliance with other universities than the Japanese also reaffirmed their corporate norm not to associate with Japanese research centers. Political and power structures within the nation also discouraged interorganizational learning between Japanese MNEs and universities, mainly because a strong line of distinction has existed between universities and industries. University professors always consider themselves as part of an ivory tower with influential positions in Japanese power and politics (Itô, 2008). However, lack of communication, ineffective resource allocation, and lack of learning values do not seem to apply to the Japanese case.

Among the societal-environmental factors, industrial structures not welcoming innovation (Spender, 1989) and failure traps (i.e., time lag between organizational actions and environmental responses) (Berthoin-Antal et al., 2003; Hedberg and Wolff, 2003) stand out as critical hindrances to integration. In the case of Japan, universities usually maintain an industrial structure that encourages fundamental studies with long term perspectives. This is in large part due to their success in getting Nobel prizes in physics, chemistry, and physiology or medicine (Ito, 2008). However, the basic nature of the fundamental research is still focused on the “catching up” of the fundamental research in the U.S. and the U.K. (Morioka, 2007). Government funding also targets at long term fundamental projects, inadvertently forgetting the fact that Japanese universities continue to charge higher R&D and licensing fees to Japanese companies during and after R&D collaboration, using template contracts [*hinagata keiyaku*] that contain clauses of running royalties and fines for not commercializing licensed technologies (Morioka, 2007). Furthermore, the selection of faculty often depends on informal connectedness to informal power cliques, candidates’ age, gender, and other ascriptive criteria. Even when they hire candidates based on credentials, Japanese universities recruit applicants hailing from domestic national universities, which is a common problem in Germany and France as well.

In sum, the Japanese failure of integration in the interorganizational learning model derives from all three levels of causes: individual/groups, structure/organizations, and societal/environment. This fact requires a solution at each stage of the four-steps of interorganizational learning (IOL) progression (i.e., intuition, interpretation, integration, and institutionalization).

3. Overcoming Barriers to Intuition and Interpretation through Feed-Forward Learning

Japan is the only G7 member from Asia with the third largest GDP in the world. Notably, the country is known for its ability to narrow the technology gap between Western leaders and Japan and to make products and technologies better than their predecessors. This process is often referred to as *kaizen* [making it better], although Japan has also shown tremendous competency in generating new knowledge as a breakthrough to existing knowledge bottlenecks. As Table 4 shows, Japan is still No. 1 in new patent registration in the world. Simultaneously, Japanese universities put their names on the world's top 5 citation board in four natural science fields, namely, Material Science, Physics, Chemistry, and Biology (Table 5). These Japanese national universities have therefore overcome the barriers to the first three stages of feed-forward learning, namely, intuition, interpretation, and integration, although MNEs still prefer to work with foreign R&D centers for feed-forward learning.

Table 4 Number of New Patent Registrations (WIPO)

Nationality	2002	2003	2004	2005	2006	2007	2008
Japan	174,528	182,505	187,588	186,561	217,532	232,442	239,206
US	139,059	147,728	142,979	134,482	155,978	146,046	147,154
Korea	36,917	39,301	45,365	63,865	102,668	106,599	79,567
Germany	47,216	53,021	51,448	49,600	56,920	51,916	54,032
China	6,300	11,936	18,943	21,519	26,298	33,409	48,815
France	21,844	24,233	23,291	21,825	26,128	24,802	25,776
UK	13,486	14,714	14,053	13,385	13,433	12,243	12,328
India	949	1,133	1,497	2,124	2,789	1,025	1,282

Source: METI (2010:42)

Crossan et al. (1999) defined intuition as an individual or group level experience of new ideas and insights for a possible future innovation. In a similar vein, interpretation is the next step of articulating these new ideas and insights to other individuals and groups within an organization. Finally, integration is the third process of integrating individual and group interests together for innovation within an organization. The 4I model can be expanded to IOL, as individual and groups at a university can experience new ideas and insights and decide to articulate them to an MNE for a potential collaboration

toward commercialization. If both parties agree, universities and MNEs can integrate their group interests together to produce innovation for the two organizations (Figure 1).

Table 5 International Citation Rankings in Natural Sciences (1999-2009)

Rank	M. S.	Chem.	Physics	B. B.	P. T.	Immunology	C. S.
1	CAS	CAS	MPI	Harvard	UNC	Harvard	MIT
2	MPI	MPI	Tokyo	MPI	Merck	NIAID	AT&T
3	Tohoku	UCB	MIT	Tokyo	NCI	UCSF	UCB
4	AIST	Kyoto	CAS	UCSF	Harvard	Yale	IBM
5	MIT	Tokyo	RAS	UCSD	Vanderbilt	NCI	Stanford
Others	Osaka (9)	Osaka (12)	Tohoku (10)	Kyoto (19)	Tokyo (6)	Osaka (6)	Shuto (11)

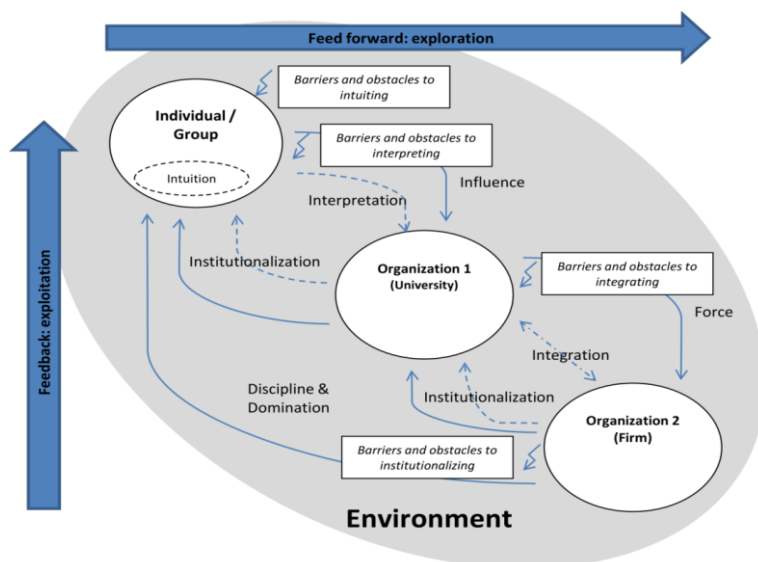
*M.S: Material Science; B.B: Biology Biochemistry; P.T: Pharmacology Toxicology;

C.S: Compute Science

Source: METI (2010:38)

Leading Japanese MNEs like SONY and Toyota, on the other hand, have completed all four stages of intuition, interpretation, integration, and institutionalization either within their own organizations (OL) or with other organizations (IOL) and successfully created the cutting edge technologies in their own markets. However, since Japanese national universities refuse to be part of the 4I process for the Japanese MNEs as feedback learners for the stage of institutionalization, Japanese MNEs could not institutionalize IOL with Japanese partner universities, reducing the total R&D support provided to the universities vis-à-vis foreign R&D centers (Table 3).

In a nutshell, the Japanese path to development and world leadership in science and technology research during the postwar years has been typified by the ivory tower image of the national universities that boasted their splendid track record of success in fundamental research along with Nobel prizes in three science fields. Concurrently, Japanese MNEs boasted their international success in new patent registration, commercialization of fundamental research with foreign R&D centers, and *kaizen*, resulting in the second highest GDP in the world until the late 2000s.



Source: Schilling & Kluge (2009); modified by the author for the IOL model

Figure 1 Stages of Feed-forward & Feedback Learning in IOL

Shockingly however, Japanese global competitiveness fell to the 9th place in 2011 from the 1st in the 1980s, mainly because of Japan's devastating 28th and 11th ranks in the world, respectively, in the category of "basic requirements" and "efficiency enhancers" (WEF, 2011). The reason Japanese basic requirements are worse than those of Taiwan (15th) or Korea (22nd) lies in the macroeconomic management failure. The snowballing government's debt servicing, along with its inability to ease the quantitative shortage of the Yen stock, fundamentally harms the ability of the private sector to make an effective investment and other financial decisions, despite the fact that Japan still maintains the 3rd place in innovation and sophistication factors. In addition, the reason Japan's ranking was only the 11th in "efficiency enhancers" mainly derives from the weakness in higher education and training, financial market development, and technological readiness.

The declining efficacy of Japan's higher education and training has been continuously discernible since the 1990s. Japanese universities began experiencing rapidly declining student enrolments due to the sinking birth rate. Many students elected to attend universities in North America, Australasia, and Western Europe, as the strong Yen made it possible for them to afford education in the West. Many regional and private universities had no other option but to recruit Chinese and Korean students *en mess* at a lower tuition through government scholarship programs in order to replace outbound Japanese students.

The government's response to the overall devastation of the Japanese universities and their incompetence in creating new economic values amid economic recession in the 1990s was to abandon the catching up model of economic development. Instead, it emphasized the leadership knowledge management model that involves an endless feed-forward and feedback flow among educational institutions, firms, and the market, where new technologies are disseminated. To ensure this, the government strengthened intellectual property (IP) protection by strictly enforcing IP law and expanding the range of IP protection. The liberalization and deregulation of the knowledge market entailed the privatization of education, which technically enabled universities and graduate schools to freely open and/or close degree programs based on market demands, actively recruit renowned foreign faculty members, and strictly implement course and teaching evaluations (Daigaku Shingikai, 1998).

This new reform blue print for the Japanese higher learning was put into action in part by the Science and Technology Basic Plan (2001-2006). The Japanese government pledged to provide \$240 billion to science and technology research projects over the course of five years, the second largest sum in the world after the U.S. expenditure (Taguchi, 2003:156). The program is now in its second phase, encouraging incessantly the linkage between universities and firms [*sangakurenkei*] toward feed-forward IOL. Consequently, each university in Japan is now equipped with what many call Triple Helix organizations, including TLO (technology licensing office) and campus based venture or spinoff firms (Katô and Enomoto, 2006; Tamura, 2006; Nishio, 2007).

However, the Japanese Triple Helix is fraught with structural and institutional problems and/or immaturity. First and foremost, firms and universities maintain no clear agreement as to how they will utilize research results. As mentioned earlier, firms usually do not have a clear idea of commercialization when universities produce research results based on some fundamental research. Making things worse, universities often require a contractual clause that requires settlement fees for the failure of technology/knowledge utilization [*hinagata keiyaku*]. Second, amid the ambiguity surrounding technology commercialization, firms or universities (or both) abruptly suspend existing collaborative research projects without any further notice on how they will commercialize new knowledge. Third, university and firm researchers do not always share the same goals, despite the fact that "integration" in IOL starts on the assumption that actors (i.e., universities, government funding agencies, and firms) agree upon one common goal. Fourth, given the nature of university-led research and its infrastructure, which are inherently fundamental, few research topics can actually motivate firms to develop tools of commercial applications. Finally, university and firm researchers do not have a commonly agreed idea as to

when or how fast they have to finish the project with a mandate of commercialization (Katô and Enomoto, 2006; Nishio, 2007; Oh, 2011a).

The Science and Technology Basic Plan (STBP) further worsened firm-university R&D relationships, particularly over the issue of sharing research results and overheads. As the 2004 amendments to the Patent Law indicate, Japanese universities showed an enormous level of uneasiness about sharing research overheads and patent-related fees. Firms, however, detested the idea of information sharing between universities and corporate R&D centers, because they did not want to see their corporate secrets being disclosed to the participating universities and potentially to competitors. Universities hesitated paying for the patent application fees, expecting additional subsidies from the firm or the government under the rubric of STBP. The 2004 amendments therefore reduced patenting fees, as long as university TLOs send in patent applications just to ease this tension between universities and private firms (Miyata and Nishimura, 2007).

In sum, the top-down pressure for publications in international journals and monetary incentives for university-industry alliances easily motivated universities and professors to seek R&D partners with MNEs, if not with SMEs. However, since the ties with MNEs were fraught with difficulties and usually one shot in length, wholly relying on the governmental and corporate funding, the successful institutionalization of IOL still looks unlikely in the near future. Hesitant Japanese MNEs that would rather rush to foreign R&D centers than beg the Japanese national universities for a better R&D contract also signals that the full integration of innovative ideas, originating from Japanese universities, has not yet taken place within the Japanese MNEs. Therefore, if both universities and MNEs rely on feed-forward learning only, it is deemed impossible for them to realize the final two stages of integration and institutionalization in IOL. Japanese MNEs want Japanese national universities as feedback learners, whereas university professors want to be feed-forward learners. How can Japanese policymakers motivate some of their professors to be feedback learners?

4. Motivating Feedback Learning for Integration and Institutionalization

Feedback learning involves the exploitation of knowledge until a learner can master or improve it. Exploitive learners would also try to expand, if possible, the practical and commercial applicability of new knowledge to unexplored areas through procedural memory. *Kaizen* could be one example of feedback learning, and it is inherently different from feed-forward learning

that requires explorative knowledge creation through declarative memory (for procedural and declarative memories, see *inter alia* Cohen, 1991; Cohen and Bacdayan, 1994; Moorman and Miner, 1998; Nooteboom, 2000:273-275). Most studies of OL emphasize exploration and exploitation without highlighting the feed-forward and feedback nature of learning. This theoretical lacuna results in the neglect of motivational studies of OL, which I think is pivotal in the analysis of firm-university R&D alliances.

Motivating feed-forward learning (i.e., intuition and interpretation) is relatively easier for organizations to handle than feedback learning (i.e., integration and institutionalization), although it is equally difficult for organizations to ensure desired performance results from both types of learning. If we summarize the previous literature review, feed-forward learning is much more individually or collectively challenging and therefore fascinating than feedback learning. As long as organizations don't punish OL failures, and political culture encourages radical innovation as in Silicon Valley, individual and group learners can freely enjoy the thrills they experience in exploring new knowledge. However, internalizing extant knowledge for standard operation procedures is dull, repetitive, and monotonous. This is why feed-forward learning is individually motivated (i.e., empowering individuals to change organizations), whereas feedback learning is organizationally motivated (i.e., depowering individuals to accept new organizational norms and procedures). Also, a huge difference in the resulting monetary rewards exists between each type of learning. A typical Toyota worker who is a leader of *kaizen* in her factory would nonetheless be paid far less than what late Steve Jobs and his employees used to make for forward learning to develop iPhone apps and operating systems.

How can we then motivate Japanese universities toward feedback learning in their R&D alliance with Japanese MNEs? According to recent findings in psychology, melancholia is a stronger motivator of feedback learning than simple nostalgia (Berlant, 1988; Greenfeld, 1990; Streip, 1994; Eng, 2000; Žižek, 2000; Diaz, 2006). Nostalgia occurs simply with ageing, a natural human psychological tendency to idealize things of *passé*. Melancholia on the other hand can occur in all ages, whether in their 20s or 60s. Melancholia is a psychological disorder diagnosed among the patients who are not allowed to express mourning even at the time of utmost sadness (Freud, [1917]1963; Kristeva, 1989). For example, even though one's mother is executed by the government for treason, her daughter cannot openly express her sadness of losing her mother for fear of the political repression surrounding her.

What is interesting about melancholia is that many of the melancholic patients pursue learning while they suffer from the psychological disorder (Oh, 2011b). A famous example is Bill Murray, the depressed and possibly melancholic hero in the movie, *Groundhog Day* (1993), where the only joy he

finally discovers is learning to play the piano and read French poetry repeatedly every day, while he could not express to anyone of his tragic entrapment of having to wake up again on the same Groundhog Day eternally. McDonald's employees, who find it impossible to express their tragic lifestyle to anyone of flipping burgers every day from early morning to late night, also decide to seek exhilaration through learning how to flip burger while dancing to the music they hear on their headphones (Garson, 1988). In these two cases, learning involves repetitive and monotonous memorization of already existing routines.

Experiencing *juissance* or flow through feedback learning that is motivated by melancholia is the final reward that learners can claim after a long period of painstakingly repeating the routines that were choreographed from above. This is a clinically interesting process of transmogrifying *ressentiment* or deep rooted psychological anger against their deep seated enemies (Lacan, [1966]2001; Csikszentmihalyi, 1996; Žižek, 2000).

Some of the Japanese private universities can certainly motivate themselves toward feedback learning in order to transcend their *ressentiment* against world class universities in the West on the one hand and national universities on the other into *juissance*. Group *ressentiment* can be easily developed into group or national identity, which can in turn fan and feed collective actions toward learning, such as catching up or feedback learning (Reginster, 1997; Meltzer and Musolf, 2002). Indeed, with Germans, the Japanese have been the best at catching up learning, as if they had been under the strong influence of *ressentiment* or *urami*. Catching up automatically means regurgitation, repetition, and fine-tuning of the knowledge that has been developed by the West. Like melancholia, *urami* or personal and collective rancor against enemies easily develops into a psychological disorder when victims are not allowed to redress their wounds by punishing the foes. Like melancholia, *urami* therefore works as a strong catalyst of learning, as much as it was in Korea (Oh, 2010). In this sense, Waseda University stands out in Japan for their success in creating the second largest number of university-based ventures in Japan, although the university is not a national university and therefore has never posted its name on the top 10 list of universities that received the largest amount of firm-university R&D funding (see Table 2).

5. The Case of Waseda University Ventures

Some of the leading Japanese universities have started university based ventures [*daigakuhatu benchô*] and TLO approved projects, both of which

use feedback learning, such as creating technologies for developing economies, IT software development using standardized technology, and the sophistication of the existing technologies in manufacturing. Among these, Waseda University deserves a close look.

As Table 6 shows, Waseda is the only private university in Japan that is ranked 2nd in Japan in terms of the total number of university-based ventures it has created until 2010. Provided that national universities would receive most of the governmental funding and firm-level support, the second place in 2007 and 2010 that Waseda garnered is phenomenal (see also Table 2).

As Table 6 indicates, 63.4% of all top 10 university-based ventures were created by national universities in 2007, while the number for private universities was only 29.5% (Ogura, 2008:133). However, since the majority of these start-ups are concentrated in the areas of life sciences (35%) and IT software (30.2%) in 2008, we can argue that the majority of these national universities still emphasize feed-forward learning in developing new medical robots and their IT software (METI, 2010:140). However, only 10% of these university ventures carry out technology commercialization in the area of manufacturing, such as automobiles (Ogura, 2008:135). This is clearly a Japanese phenomenon, because the manufacturing sector has traditionally relied on their own R&D centers or C&D with U.S. and E.U. research centers and/or universities for technology commercialization.

Table 6 Total Number of University Based Venture Startups

Rank	2007	2008	2010
1	Tokyo (107)	Tokyo (125)	Tokyo (147)
2	Waseda (96)	Tsukuba (76)	Waseda (107)
3	Osaka (68)	Osaka (75)	Osaka (82)
4	Tsukuba (61)	Waseda (74)	Kyoto (79)
5	Keio (52)	Kyoto (64)	Tsukuba (76)
6	Kyushu (48)	Tohoku, TIT (57)	Tohoku (66)
7	Kyoto (45)	N/A	Kyushu (60)
8	Kobe (42)	Kyushu (55)	TIT (52)
9	TIT (40)	Keio (51)	Keio (50)
10	KIT (39)	KIT (45)	Hokkaido, Kobe (46)
Total	598	679	811

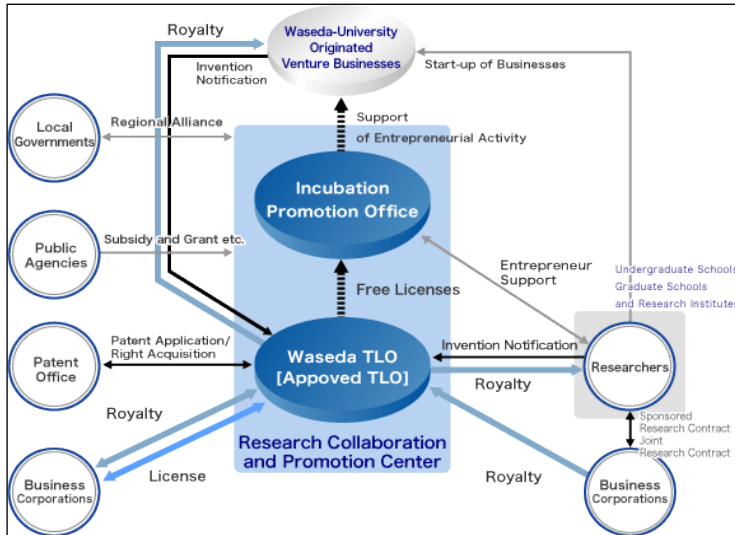
Source: Ogura (2008:136); METI (2010:140); JST (2011)

The key to Waseda's rise to the 2nd place in Japan derives from the fact that the university focused on feedback learning and non-patent based

technology transfers through high-tech human resources vis-à-vis the commercialization of new patents in creating venture startups. Consequently, Waseda's IT software ventures that utilize standard technologies are currently the single most important group of venture firms that the university has created over the years, as they account for 35% of total ventures, whereas bio-ventures of feed-forward learning account for only 14% in 2011. Furthermore, non-patent based technology transfers to private firms through human resources account for 69% of all venture types in 2011 (WTLO, 2011).

Along with Tsukuba University, Waseda's TLO (WTLO) was created four months after Tokyo University established its own for the first time in Japan in December, 1998. Since the amount of funding from the Japanese MNEs to Waseda has not been colossal, the most important financial source for the IT software ventures at Waseda has been the royalty payments from the MNEs after inventions in the form of *kaizen* or new commercial application were notified to WTLO by the ventures (see Fig. 3). What's peculiar about WTLO is threefold. First, the proportion of IT software ventures to all WTLO-related ventures is the highest among the top ten university TLOs. Second, the ratio of student created ventures to all WTLO ventures is the highest (44.9%) among top ten university TLOs (JST, 2011). Third, WTLO is the only Japanese university that has received government funding to start WTLO-related international ventures to work with the governments, firms, and universities in developing countries for *kaizen* projects of developing and commercializing technologies for their sustainable economic development. These three facts clearly indicate that WTLO emphasizes feedback learning more than feed-forward learning for IOL with Japanese MNEs.

Although there is no crucial evidence at the moment, we can propose a hypothesis for future tests that the motivation toward feedback learning at Waseda was related to melancholia or *urami*. The university and its students have suffered too long as members of a private university that couldn't receive nationally funded research resources mostly awarded to national universities. However, by emphasizing the international aspect of higher learning and research, Waseda could secure more foreign students than its rival private university, Keio, while simultaneously expanding its TLO to Asia, the E.U., and North America. Waseda's venture startups are now two times in number those at Keio.



Source: WTLO (2011)

Figure 3 The Royalty-based Feedback Learning at Waseda TLO

6. Discussion

The Waseda case is enlightening for the Japanese economy that is striving to revolutionize its national and private university education system through firm-university alliances toward explorative knowledge development. However, the emphasis put on the national university system, which insists on fundamental scientific research, along with rigid ivory tower style R&D contracts (*hinagata keiyaku*), discouraged Japanese MNEs from participating in firm-university R&D collaboration. Indeed, Japanese MNEs preferred to work with North American and EU universities over their Japanese counterparts, which MNEs thought clearly lacked the capacity of creating explorative knowledge.

Instead of fostering firm-university alliances for an economy that excelled in some industries but lagged behind in the quality of higher education, this paper argued that Japanese universities should envisage an alternative path toward a new Japanese style Triple Helix that specializes in feedback learning. The Waseda case suggests that the alternate path to firm-university alliances would result in a remarkable success, when facilitating conditions and other catalysts are present. This shift in the strategy of IOL requires changes in individual, group, and interorganizational motivation structures toward feedback learning. I postulated that one of the reasons Waseda succeeded in

motivating feedback learning among their faculty was melancholia, which was present within the university-wide cultural structure. Putting feedback learning into action requires manageable programs and learning curricula. Based on the Japanese university-based ventures in general and the Waseda case in particular, successful feedback learning involves IT software development and servicing, which is based on standardized technology.

If feedback learning has been successful even when there was no significant monetary reward for learners, can it be developed into feed-forward learning for breakthrough knowledge? The answer to the question can be in the affirmative when it is confined to the Japanese case. As I argued, Japan has a long successful track record of breakthrough innovations, including analog technologies, parts productions, and lean manufacturing systems. Japanese universities continue to be global leaders in some fields of fundamental science studies. Through several cycles of feedback IOL between universities and MNEs, Japanese firms can teach universities new technologies and processes of explorative knowledge development, which the firms learned from their joint R&D projects with the U.S. and the E.U. R&D centers. In other words, if Japanese universities and MNEs recover trust by feedback IOL, MNEs will be less reluctant in transferring feed-forward IOL processes to these universities that has competency in improving Western institutions.

7. Conclusion

Using the revised 4I model with the distinction of feed-forward and feedback learning, I analyzed that the reason Japanese MNEs do not want to participate in the firm-university alliance was because national universities in Japan unanimously pursued feed-forward learning. In order to change this tendency and to galvanized more MNE participation into triple helix projects, I showed that the success of Waseda University in creating and sustaining venture startups derived from its emphasis on feedback learning. I contended that melancholia or *ressentiment* might have motivated Waseda toward feedback learning. Furthermore, *ressentiment* had to be transmogrified into *jouissance* among learners at the end of the cycle of feedback learning. Melancholia and *ressentiment* are needed because there is far less monetary inducement involved in feedback than in feed-forward learning. Finally, this case study found that the most successful feedback learning curricula were ICT or similar software ventures that utilize standardized technologies.

Further empirical and theoretical studies of the same topic can be devised using general data sets. The limitation of this study is not to have established

the link between *ressentiment* before the feedback learning and the *jouissance* learners have experienced after a cycle of learning. This can be done through an ethnographic study that measures qualitative experiences of personal *ressentiment* and *jouissance* using specific groups of researchers at each laboratory. The construct of questionnaires and the actual observation of researchers depend on how we define *ressentiment* and *jouissance*. Since this is a new attempt in innovation studies, it requires a more in-depth discussion of how we can utilize these psychoanalytic concepts in innovation studies than it is hurriedly presented in this paper.

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Chinese Patterns of University-Industry Collaboration

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Abstract This paper deals with university – industry collaboration movement in China in recent years. By summarizing related development background in Government-Industry-University framework, the paper specifies Chinese pattern through analysis of technology transfer between universities and industries, collaborative R&D between universities and industries in practical fields, and university-run high-tech companies, especially through analysis of joint patenting between universities and their industrial partners in China. The research provides clear picture of Chinese universities' increased development with industrial entities in comprehensive and wider technology fields.

Keywords University-industrial collaboration, entrepreneurial university, joint patenting, china

1. Introduction

University-industry relationships are easily found in current universities throughout the globe, reflecting so-called science-based innovation or science-based industry. Then, are the patterns of this collaboration the same in all countries? Is the only difference found in the degree of development of each country? Aren't there country-specific patterns? This paper is an answer to these theoretical questions. These questions will add a contribution to the theoretical discussion of entrepreneurial universities, of which the relationship is a main function.

One start to the discussion is the relationship in China, as it is not a natural phenomena developed by industries. Rather the relationship is motivated by government policy. In 1992, a policy oriented "University-Industry Alliances on Collaborative Development Engineering" was jointly initiated in China, by

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the former State National Economic and Trade Committee (the main body of current Ministry of Commerce and National Economic Development & Reform Committee), Ministry of Education of China (MOE), and the China Academy of Science (CAS). Policies for this relationship have been going since then, but we will discuss the relationship during the 10th 5-year Development Plan from 2006 to 2010 because of data.

We will discuss literature review in the second section. In the third section, three domains of the university-industry relationship are analyzed. In the fourth section, joint patenting is analyzed in depth. And in the last section, we will summarize the Chinese patterns of this relationship.

2. Literature Review on University-Industry Collaboration

The first academic revolution taking off in the late 19th century made research a university's major function in addition to the traditional task of teaching. (Storr, 1952; Metzger, 1955; Veysey, 1965; Jencks and Reisman, 1968). The second academic revolution, integrating a mission for economic and social development, has been transforming the traditional teaching and academic university into an entrepreneurial university. The entrepreneurial university encompasses and extends the functions of the academic university, although, this academic entrepreneurship is sometimes challenged by arguments on possible deformation of the research university. (Slaughter and Leslie, 1997)

The 1950s, "Silicon Valley Model" at Stanford University provides an exciting example in promoting regional economic development by close cooperation between academia and industries. Etzkowitz and Leydesdorff (1995) first proposed the famous Triple-Helix notion, emphasizing that the interaction among university-industry-government (UIG) is the key to improve conditions for innovation in a knowledge-based society. In part because of influence from typical university revolutions, the linkage of academia, industry, and government have indeed been getting closer for innovation activities. In fact, the so called knowledge economy firstly appeared in the late 1980s, when scientific research was merged into an innovation system with an interdisciplinary nature, which in turn gradually formed a UIG based research paradigm.

Other important studies include Clark and Fujimoto (1991), Clark and Bower (2002), Richard and Goodman (1997), Xu (1998), and Miller et al. (1997). The University-Industry relationship has ever since become one of the key elements in a innovation system, including the National Innovation System (NIS), Regional Innovation System, and the Industrial Innovation System, with significant and comprehensive research findings by famous

scholars as Freeman (1987, 1995), Lundvall (1992), Nelson (1993), Mowery (2003), and Patel and Pavitt (1994). The UIG related research emphasizes highly technology transfer and technology diffusion between universities and industries, or decisive roles played by universities in university-industry collaborations.

Also, other studies has been dealt empirically on university-industry collaboration in such various countries as Italy (Abramo, et al, 2009), Japan (Motohashi, 2005; Woolgar, 2007), UK (D'Este and Patel, 2007), China (Motohashi, 2008; Lei, et al., 2011), Australia (Harman, 2004), Sweden (Okubo and Sjöberg, 2000), and Austria (Schartinger, et al., 2002). In Korea, Lee (1998) considered technology transfer and the university-industry collaboration relationship, and many studies including Mowery (2001), Motohashi (2008), Lei, et al (2011), and Petruzzelli (2011) attempted to inquire into the patterns and impact of university-industry collaboration based on patent analysis. In particular, Lei et al. (2011) performed a co-patent analysis for China and found that the collaboration between university and industry is the strongest and most intensified in recent years, but other forms of collaboration between the UIG have been weak.

The entrepreneurial university (EU) is a new type of university aiming at combining universities' knowledge generation and development capacity with industrial production power to create higher value-added wealth on a regional or national level. The EU is strongly market or industry oriented, rather than being purely focused on its academic mission. Apparently, knowledge generation, diffusion, and transformation can be best realized through university reform towards an EU model and as a side effect, efficiency of university-industry collaborations is usually improved.

At the same time, having an entrepreneurial culture and internal knowledge generation capacity, might be the key sources to fullfull the EU mission. Etzkowitz (1983) initiated the phrase of entrepreneurial universities to describe a series of changes that define active roles universities have to take in promoting directly and actively the transfer of academic research to industry. According to Etzkowitz (1983), knowledge-based entrepreneurship is a core concept of the EU. The concept of knowledge capital and the practices for industrialization of university research are now entering into the university agenda, which emphasizes very much the university revolution from so called ivory towers to the entrepreneurial paradigm (Leydesdorff and Etzkowitz, 1997). Meanwhile, the entrepreneurial environment, preferably supported by government policies, is also a key resource in the region or nation, to help and encourage such university reform.

In both developed and developing economies, a dual overlapping network of academic research groups and start-up firms, cross-cut with alliances among large firms, appears to be the emerging pattern of academic-business

intersection in bio-technology, computer science, and fields alike (Herrera, 2001).

3. General Trend of Reform in University-Industry Collaboration in China

By 2010, there were 1,983 common higher educational institutions in China, including 792 universities for four-year undergraduate programs in various kinds of specialties. Among them, there are 103 universities selected as member universities of the 211 consortium, and another 44 more prestigious universities selected as the “985” group, representing clusters of the best universities in China in terms of advanced scientific research and well developed educational systems.³⁸⁾

With rapid development in knowledge based economies characterized by typical industries such as computer and information services, software engineering, biotechnologies, and advanced materials, universities have played a major role in generating and creating new knowledge and product designs, as well as initiating new high-tech companies. Based on general information and special data collected through this research, we can summarize that there are three ways universities in China collaborate with industrial organizations in typical technology and industrial fields: 1) technology transfer between universities and industries, 2) collaborative R&D between universities and industries in practical fields, and 3) finally university-run high-tech companies.

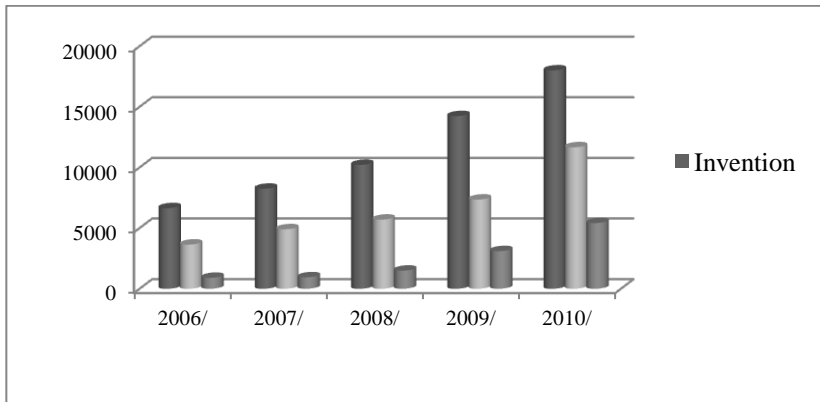
3.1 Technology Transfer from University to Industries

The most common path for universities to transfer knowledge-based research output to industries is through license deals, especially university generated patents. Within the last 5 years, Chinese universities produced a tremendous output of patents. Those inventions and designs are important technology resources for university-industry collaborations.

Figure 1 shows the patenting trends by higher educational organizations in China, especially between 2006 and 2010. It provides the detailed structure of Chinese universities’ output in terms of patented technologies. Among them,

¹⁾ The 211 scheme, named after 21 (the 21st century) and 1 (100 universities in China), was initiated in 1993 and aimed at well developing advanced universities in 21st century through continual effort by Chinese government. The “985” scheme was initiated in May 1998 by Chinese government to well promote internationally advanced universities, firstly in 34 and later on extended to additional 4 selected universities all over China.

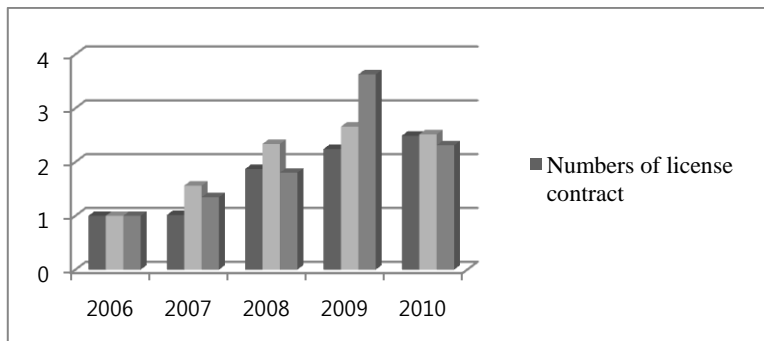
invention is a major part of the universities' patented technological assets. Meanwhile, it should be noted that industrial designs have increased faster in universities in recent years.



Source: Statistical Yearbook on Higher Education University S&T, 2007-2011

Figure 1 Granted Patent by Higher Educational Organizations in China

University patenting has been on a fast pace as well as licensing, albeit at a slower rate. (Refer to Figure 2).



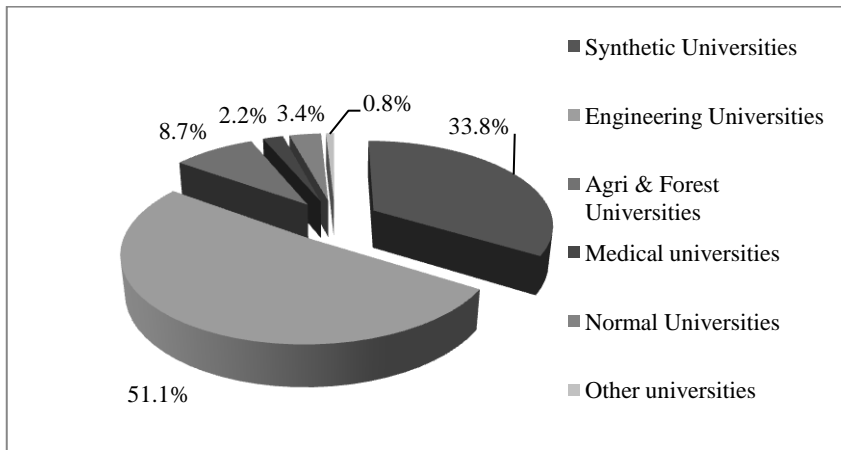
Note: 2006=1

Source: Statistic Yearbook of Higher Education University Science & Technology, 2011

Figure 2 University Patent Licence

Figure 3 and 4 show various data about technology transfer from universities to industries. Figure 3 shows licensing targets or major distribution of licensees from university transfer, while Figure 4 shows that

the important contributors of those universities licensing are primarily from regional universities and universities under MOE.



Source: Statistical Yearbook on Higher Education University S&T, 2007- 2011

Figure 3 University Licenses by Types of Universities

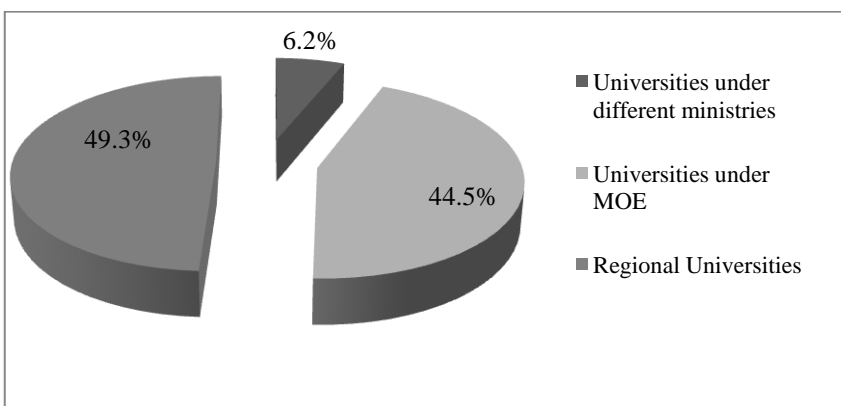


Figure 4 University Licenses by Types of Governance System of Universities

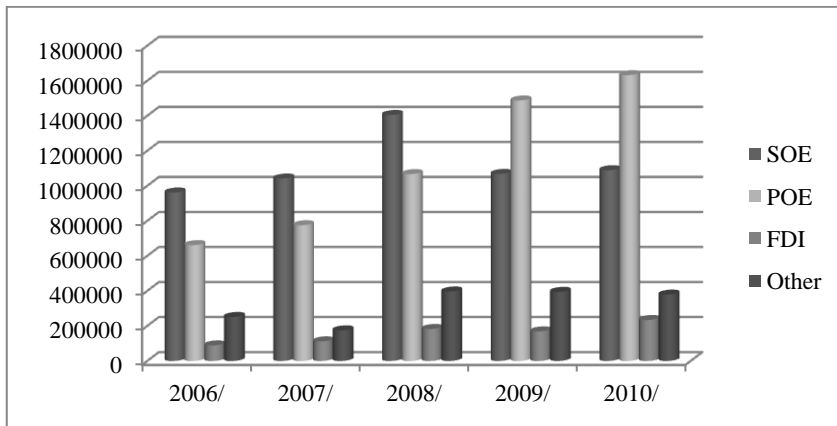
It is interesting to note that although contracts have decreased, revenue from licensing has increased significantly. This indicates there has been increasing demand for higher-quality university-generated technologies and correspondingly the value of those technologies has been increasing.

Figure 5 shows licensees or major recipients of university licensing. State-owned enterprises (SOEs) used to dominate but technology transfer to private-owned enterprises (POEs) has been increasing in recent years. The technology

market for POEs has been in great demand, and universities have been approached by these industries for collaboration. Currently, foreign firms and their parent companies are a primary means of access to technology.

3.2 R&D and Institutions for Facilitating Collaborative Research

The second way for university-industry collaboration is to conduct research projects directly for or with industrial firms. This is commonly seen as the most direct way to collaborate on specific solutions with industrial technologies and with engineering development. This can be promoted by increasingly larger research funds attributed to industries.



Note: SOE: State Owned Enterprises, POE: Private Owned Enterprises, FDI: Foreign Direct Investment Firms

Source: Statistical Yearbook on Higher Education University S&T, 2007-2011

Figure 5 Universities' Technology Transfer by Recipients

Table 1 Research Funds from Industries

(0.1 billion RMB)

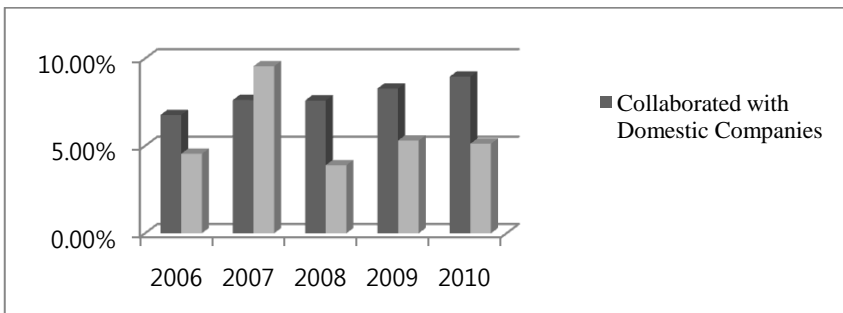
	2006	2008	2010
Total	45.73	65.45	94.03
'211' Universities	32.36	46.46	67.93
Other Universities	13.17	18.66	25.52
Colleges	0.21	0.33	0.57
MOE Universities	24.16	34.76	52.19
Regional Univ.	16.09	22.99	31.27
Synthetic Univ.	14.6	21.29	32.17
Engineering Univ.	24.38	34.37	46.7

Note: Total is a summation of 211 Universities, Other Universities, and Colleges.

Source: Statistical Yearbook on Higher Education University S&T, 2007-2011.

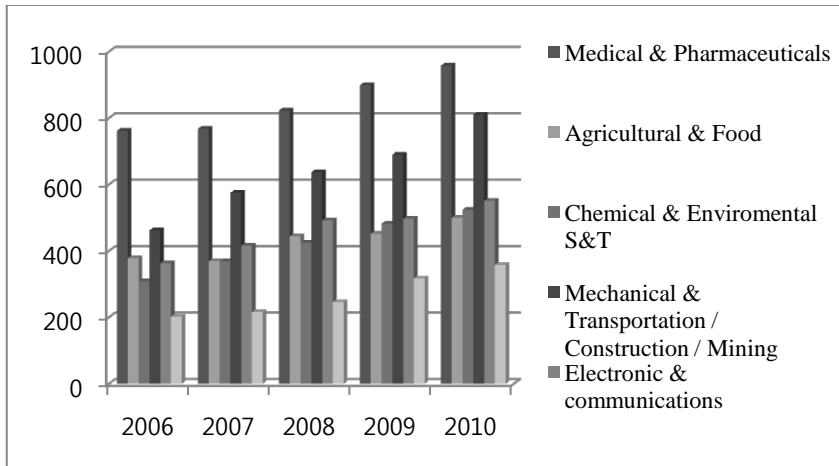
Table 1 provides information about funds from industries. Funds from industries increased sharply from 1.8 billion RMB in 2006 to 3.2 billion RMB in 2010, but the percentage share from industry is decreasing. The reason for this is because of huge increases from other sources.

Collaborative R&D centers between regional higher education bodies and industrial firms are shown on Figure 6. It seems such kind of joint R&D centers with companies are still infant in Chinese universities, compared with their own research bodies. It is interesting to note that collaboration with overseas companies is playing an important role, although it is limited. For instance, in 2010, among all university R&D centers, less than 10% of the centers set up collaborative relationships with domestic companies and only 0.5% R&D institutions are organized with foreign companies.



Source: Statistical Yearbook on Higher Education University S&T, 2007-2011

Figure 6 Universities' Joint R&D Centers with Domestic and Foreign Firms



Source: Statistical Yearbook on Higher Education University S&T, 2007-2011

Figure 7 University-Industry R&D Collaboration by Technology Area

Figure 7 shows university-industry R&D collaboration by technology area. Medical and pharmaceuticals are the condensed fields, followed by mechanical and other typical engineering fields such as transportation, construction, and mining. Electronic and telecommunications, together with chemical & environmental S&T are in third. In general, we can conclude that medical & pharmaceutical, mechanical, electronic & telecommunications, and agriculture are important areas for university-industry collaborations in China in recent years.

3.3 University-Run High Tech Companies

The third effective way for universities to work with industries is to directly operate on industrial production based on universities' own intellectual property or technology resources through university-run business companies. This is clearly shown from university-run business firms in high-tech zones in different regions in China.

Table 2 shows that although university-run high-tech firms are smaller in numbers, compared to all companies in high-tech zones, their assets and operations are generally dominative. On an economic return investment basis, university-run business companies generally out-perform non-university companies. Innovation indicators of these companies are also significantly higher than other firms in the high-tech zones. Therefore, university-run high-tech companies are usually key forces for regional and national innovation progress in China.

Table 2 University-Run High-Tech Firms in National Development Zones

Year	Number	Assets	Revenue	Employees	Innovation
2007	11.79%	51.07%	60.39%	35.97%	-
2008	10.24%	79.76%	89.44%	34.81%	53.22%
2009	10.68%	84.84%	88.57%	34.62%	56.09%

Source: China University Run Industries: 2007-2010

Another important nature of university-run high-tech firms is that the concentration rate of a few companies is quite high. For example, among top 100 university-run high tech companies, the top 10 companies own 84% of total assets, so only the top 14 companies are above the average size asset. (1.595 billion RMB) In total revenue, concentration is even higher; the top 10 firms control 94% of total revenues by nation-wide university-run companies. Again, only 7 companies are above the average level. (2.472 billion RMB)

4. University-Industry Collaboration in China: Joint-Patenting Movement and Its Nature

We further analyzed the collaborative patenting movement between universities and industrial companies.

4.1 Overview

Joint patenting is an important phenomenon for both innovation studies and entrepreneurial university studies because this movement reflects crucial demand from both sides for knowledge generation. It is especially important because from the university side, it is clearly an entrepreneurial intention to come closer to market demand for advanced technologies, and from the industrial side, the involved companies are very keen on technology-based competition in a specific market.

The patterns of the joint patenting movement in China can be contrasted in Figure 8. We can see clearly that inter-firm joint application is higher than inter-university joint applications. The joint patenting between universities and business firms was the lowest compared to inter-firm and inter-university groups. In Figure 8, continued drops during recent years have been due to time lag between applications and disclosures in the patenting system. Therefore, the decrease on each pattern is purely a matter of administration within the patent office. Hence, there is a clear trend for each of the three joint-patenting patterns, including the one between university and industries.

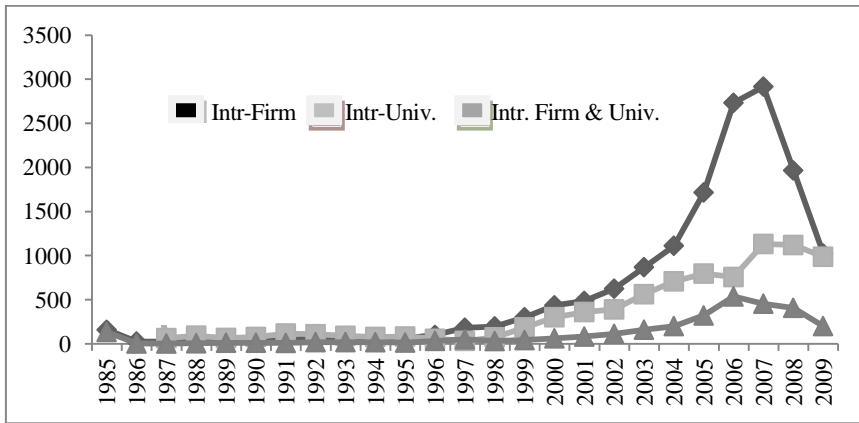


Figure 8 Types of Joint-Patenting

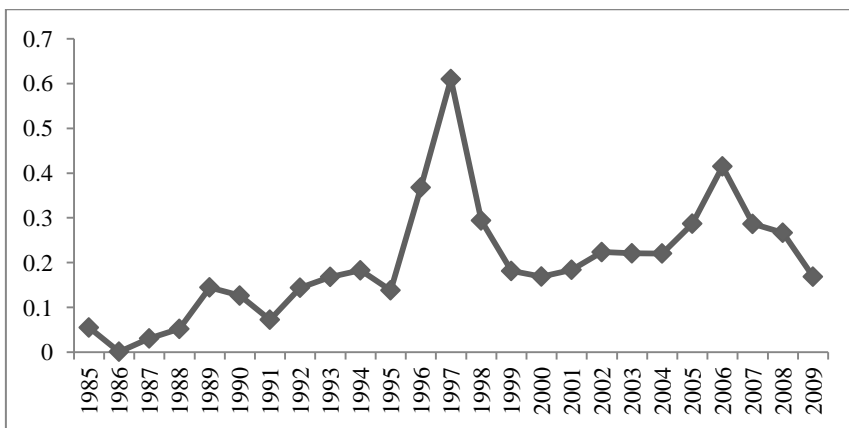


Figure 9 Share of University-Firm Joint Patenting against Intra-University Patenting

The joint patenting between universities and between firms are contrasted with joint patenting between university and firms in Figure 8. Although absolute terms of joint-patenting intra-firms is higher than between firms-universities, the ratio of intra-firm joint-patents to all patents of firms is lower than the ratio of intra-university joint-patents to all university patents.

Table 3 University-Industry Collaborative Patenting by Technology Fields

(IPC Subclass, % to Each Year Total)

2000		2001		2002		2003		2004		2005		2006		2007	
C07K	67	C07K	37	G01N	30	G01N	12.7	G01N	20.8	A61K	11.2	G01N	10.7	G06F	8.9
C12N	24	A61K	22	A61K	21	A61K	10.3	A61K	13.5	G01N	8.8	H04L	10.0	G01N	8.6
G01N	9	C12N	18	B01D	14	C07C	7.9	H01J	11.22	H04L	7.4	G06F	9.8	A61K	7.6
		G01N	13	C12N	12	C09D	7.9	B01D	10.7	C01B	7.1	A61K	8.2	B01D	7.2
		B01D	10	H04M	11	B01D	7.3	C07C	9.0	H01L	6.4	H01J	8.2	H04L	7.2
				H04N	11	C02F	7.3	G02B	8.4	H01J	6.1	C07C	7.3	C07C	5.8
						C04B	7.3	C04B	7.9	C07C	5.4	H04N	5.2	C02F	4.6
						H04N	7.3	C02F	6.7	C12N	5.1	C02F	4.6	H01L	3.6
						C12N	6.7	C07D	6.2	C07D	4.7	C07D	4.6	C01B	3.4
						C12Q	6.7	H05B	5.6	C02F	4.4	B01J	4.3	C07D	3.4
						H01J	6.7			C09K	4.4	C01B	4.3	H04N	3.4
						Co8L	6.1			B01J	4.1	C12N	3.9	A01K	3.2
						H04L	6.1			H04N	4.1	F24F	3.4	G05B	3.2
										B01D	3.7	H01L	3.0	H01M	3.2
										C01G	3.7	C04B	2.7	B01J	3.0
										C04B	3.4	Co8L	2.7	H01F	3.0
										G02F	3.4	Co8F	2.5	D04H	2.8
										G06F	3.4	Co8G	2.3	H05B	2.4
										H01Q	3.4	G05B	2.3	C04B	2.2
														C09D	2.2
														C09K	2.2
														C22B	2.2
														H01J	2.2
														A23L	2.0
														B23K	2.0

Note: Total sample 1,913

4.2 Types of Co-patenting in Universities

We analyzed co-patenting between universities and industry by university type. 200 sample universities that had more than 100 patents between 1985 and 2010 were selected. Among them, 79 sample universities were additionally selected, and their co-patents accounted for 51.8% of total patents from the 200 sample universities.

Figure 10 shows 4 types of patenting activities: The first type is high share of patenting and low rate of co-patenting or simply high share - low co-patenting, such as Zhejiang University and Shanghai Jiotong University. The second type is low share - low co-patenting universities. Third type is low share - high co-patenting.

This type is mostly shown at the professional universities, or in other words, special universities with industrial specialties, such as China Petrol University, China Forest University, etc. In the fourth type with high share and high co-patenting, there is only one university, Tsinghua. In addition to this typology, it is noteworthy that Tsinghua University and Peking University show high rate of co-patenting which may reflect their brand status.

4.3 Fields of Co-patenting between University and Industry

We include another analysis about university-industry co-patenting by technology fields from the IPC (International Patent Classification) sub-class using 1,913 co-patenting data as shown in Table 3. The IPC sub-classes on the table show more than 10 co-patenting types. The table shows that the technology span of co-patenting has become increasingly wider during the 8 years after 2000, and the speed of widening is remarkable.

G01N and A61K are the highest and second highest fields for co-patenting between the university and industry during 2000-2007, and the next is B01D. H04L and C07C are also frequent fields for co-patenting.³⁹⁾

If we see the bigger classification, most frequent collaborative technical fields between university and industry are typically pharmaceutical, chemical, and electronic & telecommunications, which strongly implies that the university plays an important role in innovation for advanced industrial sectors as well as frontier technology.

³⁹⁾ Each IPC subclass indicates the technology field as follows. G01N: Investigating or analysing materials by determining their chemical or physical properties; A61: Preparation for medical, dental, or toilet purposes; B01D: Separation; H04L: Transmission of digital information; C07C: Acyclic or carbocyclic compounds.

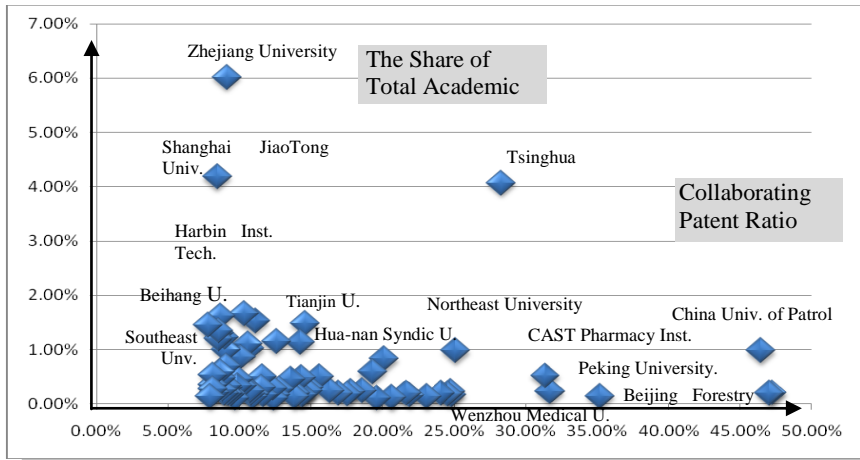


Figure 10 Patenting Share and Ratio of Universities

6. Summary and Conclusion

This paper reviews the patterns of university industry collaboration in China by three paths: technology transfer, collaborative R&D, and university-run companies. And we added the analysis of co-patenting between university and industry. The patterns in university industry collaboration are summarized as follows:

- a) Although the speed of growth of university patenting during the second half of 2000 was very fast, it is a little slower than the growth speed of university licencing.
- b) The speed of revenue growth is faster than the speed of contract growth. That means each contract is worth more.
- c) About 100 good universities or the so-called 211 universities accounts for 42% of total technology transfers by all univesities.
- d) Technology transfer to private-owened companies has increased very fast and surpassed the number of technology transfer to public-owned companies from 2009.
- e) University-run companies in the national high-tech development zone dominates the zone; in 2009, they had 84.8% of total assets and 88.5% of revenues.
- f) Top 10 university-run companies recorded shares of 94% of total revenues, and 84% of total assets from the top 100 university-run companies. The concetratation ratio to a few universities is noteworthy.

The patterns in co-patenting are as follows:

- a) Every type of co-patenting such as “between university and industry”, “between firms” and “between universities” has increased sharply since 2000.
- b) Although co-patenting “between university and industry” is lower than co-patenting “between firms” and co-patenting “between universities”, the share of co-patenting of universities among all university patenting is higher than that of industry patenting.
- c) Universities having industry specialties are in the low share - high co-patenting type such as China University of Petroleum, CAST Pharmacy Institute, Beijing Forest University, and Wenzhou Medical Universities.
- d) Technology span of co-patenting has become increasingly wider during these 8 years since 2000, and the speed of widening is remarkable.
- e) G01N and A61K are the highest and second highest fields for co-patenting between university and industry during 2000-2007, and the next field is B01D. H04L and C07C are also frequent fields for co-patenting.
- f) Pharmaceutical, chemical, and electronic & telecommunications are the typical fields for co-patenting.

This paper is an analysis of university industry collaboration based on patents. Also, this paper is an analysis of statistics, so further analysis on case studies or a conceptual framework for the university industry collaboration will have to be conducted.

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