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Contents

Academic Entrepreneurship: An American (Individualistic) Perspective

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Abstract
Universities have traditionally served as places for teaching and learning, generators of new knowledge and understanding, repositories and preservers of knowledge, transmitters of values and builders of citizens, and neutral spaces for debate. In the United States public universities also took early on the role of assisting local economic development. In recent years, universities across the developed world have been expected to serve as prime sources of new ideas, generators of new technology, founders of new companies, and critical contributors to economic growth. Ironically, however, while society increasingly focuses on this latter role, it still compensates universities and their faculty in pretty much the old way, that is primarily on the basis of research and teaching. This inconsistency has created deep tensions that policy makers are desperately trying to resolve. This paper deals with this newly acquired role of universities through the lens of incentives for both individuals and organizations. It argues that proper incentive alignment is badly needed, that the nurturing of individual learned entrepreneurs is achievable under the right conditions, and that all sides of the triple helix have an important role to play.

Keywords: University Entrepreneurship, University-Industry Relations, Cooperation

"Knowledge is not simply another commodity. On the contrary, knowledge is never used up. It increases by diffusion and grows by dispersion"

Daniel J. Boorstin (1914-2004)

1. Introduction

Government and industry are increasingly looking toward universities to help lift the United States out of the recent economic crisis. The hope is that research transferred from universities will generate new product innovations and inventions. Knowledge transferred from universities would take the form of expanded capacity of existing firms or increasing the number of start-ups and spin-offs created by graduating students or entrepreneurial-minded research professors. This appears to be more than just hoping. The number of spinoffs generated by universities research has more than doubled between 1996 and 2005, from 200 to 450 (Hayter, 2011). Most research universities have created Technology Transfer Offices (TTO's) to encourage the transfer of knowledge to industry or to help students and faculty members establish start-ups

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or spinoffs.

Universities were established to collect, refine, organize, and disseminate knowledge in a useful and productive manner. The word university comes from the Latin universitas magistrorum et scholarium, meaning "community of teachers and scholars." In Western Europe, the Latin word "universitas" was applied to degree granting institutions of higher learning. There has always been the presumption of academic freedom within the culture of higher learning. The acquisition of knowledge is seen as a goal in itself. This is at odds with the guild model that taught a trade according to standards that maintained high degree of quality and reliable standards for goods and services. Medieval guilds were specialized associations of teachers and students that took shape as urban life developed. Guilds usually had some legal standing guaranteed in the form of a charter issued by the state. The Guild members adhered to standards and practices that produced a useful and marketable skill (Boorstin, 1983). It was an organization built on the notion of learning for the purpose of acquiring a skill that was useful in the market place. Members of the guild were trying to acquire a skill that made its members money. This is at odds with some of those in the university system who see learning as something more than the pursuit of a moneymaking talent. To them, learning is a noble pursuit, an end in its self.

Learning is a noble pursuit. However, it is the practical application of knowledge that has changed the world and not merely the acquisition of knowledge. The acquisition of knowledge without the application of knowledge – as has often happened in the past (Mokyr, 1991) – may have private value but, from the point of view of society, it can be argued to be a wasteful endeavor. Thomas Edison was an inventor and entrepreneur, not an academic. He experimented and developed new products to make money. He invented and innovated to produce a marketable commodity so it could be sold in the market place and he abandoned research once he determined there was no profit in it. He is credited with the establishment of the world's first research laboratory in what is now Edison, New Jersey (Wikkisource; Thomas Edison). Edison did this without any formal schooling or university degree. The research laboratory was built to acquire the knowledge necessary to invent, market, and patent products or processes that made Edison money. This is not an indictment of the university system. Many people graduate from universities with marketable skills and apply what they have learned to their careers and are extremely productive. What does the student gain by attending the university? Was it the ability to make money or the motivation to make money?

Universities are storehouses of knowledge. They teach what has been learned through the course of time and produce new knowledge through research. For example, a student may have chosen engineering because he was interested in the field or because he had talent for math or because his parents were engineers. The ability to get a job or make a lot of money may have only been a secondary motivation. The school of engineering prepares the engineering student to enter the business world armed with all that the university could teach him in four years. The graduate understands the principles of engineering and has learned the newest engineering techniques. But, that is not enough to be successful. The graduate must apply the knowledge he has acquired and he must work hard. He must adapt to his new environment. He must become useful. He must earn income. He may have to change to do it. He must be motivated to become successful. Where would this motivation come from? Did it come from what was learned in the university or did it come from the individual?

Are individuals successful because they have applied what they have learned in a meaningful and marketable way? How does the individual measure success? Successful entrepreneurs may not have been successful academically and successful academics may not be successful entrepreneurs. They may in fact be different people with different talents.

It has long been recognized that invention and innovation are essential to a strong economy. An educated work force is the keystone of invention and innovation. Governments have done much to improve the level of education of their citizens and attract talented individuals to enhance existing or start new industries. In fact, the federal government has promoted education since the nation was formed. President George Washington was a strong proponent of education to the end of his presidency, calling for in his farewell address to congress "Institutions for the general diffusion of knowledge" (Ellis, 2002). The Morrill Act of 1862 started universities in every state. The federal government gives billions of dollars to universities to do basic research and acquire new knowledge. The Bayh-Dole Act allows universities to patent their discoveries from federally funded research. A university can sell licenses on the patents they produce or researchers can start companies of their own and profit from their discoveries. The money from the federal government is meant to ensure that innovations and inventions reach the market place.

This paper discusses the concept of academic entrepreneurship and the effects of university-derived research on the economy. It also discusses the researcher and the entrepreneur as individuals. The paper intentionally takes a provocative stand in order to elicit discussion on the topic.

2. Morrill Act of 1862

President Abraham Lincoln passed the Morrill Act into law on July 2, 1862. Under the act each state received 30,000 acres of federal land for each member of congress the state had as of the 1860 census (Homer A. Neal, 2008). The land was to be used for the establishment and funding of universities to educate the populations of each eligible state. The universities were originally intended to enhance the skills of the citizens in existing industries. They supported agriculture and mechanical arts. The universities were known as Land- Grant Colleges. The curriculum was formulated by the state legislature with a few conditions set by the federal government. Provision six of the act did not allow states in rebellion or insurrection to benefit from the act. This excluded several southern states until after the civil war. Most of the universities were public with the notable exceptions of the Massachusetts Institute of Technology and New York's Cornel University. The universities were established "in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life" (Homer A. Neal, 2008). This act was intended to give the population access to practical and useful knowledge. A university-educated workforce trained with skills that were applicable to the market place enhanced agriculture and industry. The federal government gave land to the states that could be sold or used to educate the state's population in order to produce positive results in the market place and expand the economy. The federal government saw the benefit of investing in education: money spent on education transferred into market efficiencies and increased innovation in the market place. The more the economy expanded the more the country could generate in revenue. There are certainly altruistic motivations behind the passage of the act, but there was also a bottom line consideration. The federal government saw the Land-Grant Universities as a profitable investment.

3. Bayh-Dole Act

Passed on December 12, 1980, the Bayh-Dole Act gives the Intellectual Property Rights (IP) to Universities, small businesses, and non-profit organizations for their discoveries and inventions that resulted from government funding. Prior to the passage of Bayh-Dole only, 5% of the federal government's 28,000 patents were commercially licensed and less than 250 patents were issued to universities each year (Homer A. Neal, 2008). Most of university patents were not commercialized and the public did not receive a marketable benefit from the research. The law provided a vehicle for the transfer of inventions and innovations from universities into the market place. Prior to the passage of the act there was no formal process. The Bayh-Dole Act created and incentive for university researches to work with industry and pursue research that had practical applications. The act also was passed with the intention of making research universities less dependent on money from the federal government (Lipinski 2008). While there are certainly descending voices (Mowery and Sampat, 2005; Pascoe and Vonortas, forthcoming), there is widespread belief that Bayh-Dole Act has lived up to its promise. In FY 2005 universities received 3,300 new patents and had reached almost 5,000 new licensing agreements producing over a $1 Billion of revenue (Homer A. Neal, 2008).

This process ensures that industry has access to useful research findings and can develop and exploit the findings into new innovations. It also allowed for the technical transfer of knowledge and skills to a wider range of users. More than 5,100 new companies or “start ups” have been created since 1980 based on the transfer of technologies created by academic institutions (Homer A. Neal, 2008).

The number licenses have granted by universities has grown from 936 in 1970 to 3,295 by 1999 (Feldman M., 2003). The act encourages researchers to disclose their discoveries to the universities. In return, the universities share a portion of the royalties with the researchers. The university share of royalties, if any, must be applied to future research. A small portion may also be applied to university technical transfer efforts.

Despite the oft-called success of the Bayh-Dole Act, there has been criticism (Pascoe Vonortas, forthcoming). There is a deep-rooted fear that research departments of universities are becoming too commercialized. It is also feared that university faculties are losing their objectivity and are pursuing profits rather than teaching students. This has, until now, been primarily a philosophical argument. This argument is only a short step from the semi religious “knowledge for knowledge’s sake” philosophy that robs universities of much of their usefulness. There is also the criticism that the federal government has already paid for the research once with taxpayer money and the benefits of the research should be free to the taxpayer. This is a fair criticism and deserves a fair hearing. However, before the Bayh-Dole Act the pace of technology transfer from universities to industry was glacial compared with pace of nowadays. The purpose of the act was to improve communication and collaboration between researchers and industry and take advantage of the capabilities of both institutions to stimulate the economy. The financial incentive was necessary to ignite the entrepreneurial fires of university researches by creating an incentive for research with practical applications. It also gave university students a chance to see the importance of their research in the market place. University research developed in conjunction with industry provides the economy with competitive advantages that would not normally be affordable to most companies. It also encourages the formation of start-ups by individuals associated with the university. This creates jobs in the economy and the taxpayer is rewarded for their investment.

4. The Researcher

What is an academic entrepreneur? Is he a scientist who is trying to make money? What motivates the researcher to leave the laboratory and enter the business world as an entrepreneur? Is success as a researcher indicative of someone’s potential for success as an entrepreneur? Are the same talents required? If not can these talents be learned?

Researchers are creative people. A recent study conducted by MIT indicates external motivation does not ensure that the researcher will perform better. It may actually have the opposite effect. External motivators like a year-end bonus appear to be most effective on those people doing rote or routine tasks (Glei, 2011). Monetary rewards do not seem to be a significant incentive to create.

Researchers are self-motivated or motivated intrinsically. They are self-motivated by three key factors: autonomy, mastery, and purpose (Glei, 2011). Autonomy, working alone in the researcher laboratory, is a motivator that could easily be shared by an entrepreneur. It appears to be a primary motivator for the researcher and may only be secondary for the entrepreneur, but there is a connection. The effect of the motivation is, however, different. The process of developing new technologies is time consuming and expensive. The researcher is concerned with the answering of questions. To discover the how and why things work the way they do. They are discoverers. The process of discovery does not stop when a commercial application for the research is stumbled upon. The research is stopped when the answer is found. That was the purpose of beginning the research. This is not the same motivation an entrepreneur has when he tries to answer a question. In fact, the entrepreneur is not motivated by the how or the why something works. He is motivated by the commercial application of what he has found. Once the commercial application of something is found to be successful or unsuccessful he stops his research and moves on to something more promising.

Mastery of a subject is closely linked to autonomy. The researcher is motivated by curiosity to discover what can or may be learned. He will pursue a particular area of study and strive to learn all that can be learned. The end of the pursuit is signaled when the researcher has answered his question or made his discovery. This gives the researcher a feeling of self-satisfaction. His discoveries earn him the respect of his peers. The researcher is a scientist in search of all available knowledge in his area of exploration. If he cannot answer all the questions he has by reading the work of others he will conduct his own research until he has taken it as far as he can. His is the quest for knowledge. It is possible that an academic may actually stop at some point during his research and try to assess the marketability of a discovery or a particular line of research, but it is not clear that he would recognize it if he was not searching for it from the start. Or if industry did identify a commercial application for the research, would the researcher change the direction of the research to satisfy the commercial requirements.

The purpose of the research is perhaps the strongest of all motivators to some researchers, whether they are seeking the cure for cancer or just making the world a better place to live in for the rest of us. Their name linked to an important discovery or their name listed on a ground breaking research paper may be the reward they desire. Money gained from royalties could be quickly spent and offer no lasting reward compared to the linking of their name to something that benefited the human race. Altruism comes to mind. Doing good for good's sake.

Research from Duke Medical Centre indicates that there is a section of the brain that is responsible for altruism (Booth, 2007). Researchers conducted an experiment that identified the part of the brain called the posterior superior temporal sulcus as the likely root of altruism. This is the same part of the brain that is associated with understanding relationships. The results also showed that people with a more sophisticated understanding of social situations are more likely to act on the behalf of others. It can be clearly seen that being able to understand social settings or society has advantages to the researcher and the entrepreneur. However, the researcher is motivated by his understanding of society in order to help satisfy the needs of society. The entrepreneur uses this same insight to make a profit by exploiting the needs of society. Some academics would characterize the contrast between the use of knowledge by researcher and the use of knowledge by the entrepreneur as reminiscent of the contrast between good and bad. This hardly is the case, but the two groups are motivated in fundamentally different ways.

5. The Entrepreneur

The entrepreneur pursues opportunities. Entrepreneurs view opportunities in the economy by measuring their profit-making potential. Profit is their primary motivation. The entrepreneur will not pursue a societal need unless he can successfully make a profit. He does not choose to satisfy society's greatest needs. He rather seeks to satisfy his greatest needs summed up by the accumulation of wealth and the need to achieve (Scott Shane, 2003). Entrepreneurs are risk takers. They do not seek out the most risky opportunities, but they are willing to take on a certain amount of risk to satisfy their needs. Entrepreneurs evaluate opportunities in the market place differently depending on how each perceives the level of risk and his capacity for mitigating the risk. There are a number of external factors that influence the level of risk such as environmental regulations, political attitudes, industry regulation, health of the industry, current state of technology, market size, and the availability of resources such as, venture capital, skilled labor (Hayter, 2011). This is a much more complicated set of constraints than the researcher typically encounters. But, there are similarities between what motivates the researcher and the entrepreneur. A 2005 study of entrepreneurial motivators by the San Francisco State University conducted interviews and a survey of the explosive growth of high-tech start-ups in India. The first three items listed by the respondents were autonomy 57%, making money 43%, and saw business opportunity 27% (McCline, 2005). The first motivator compares well with the first priority of the researcher. They both enjoy autonomy. This does indicate that both groups are self-motivated and seek to achieve for achievement's sake. However, autonomy may mean different things to these groups. It can be that the researcher desires autonomy so they may pursue their own goals without interference, to discover what may be down the next road to satisfy a personal curiosity. Autonomy to the entrepreneur means he has the freedom to take risks, to turn down the next road to exploit an opportunity. Each group feels the need to create or attract creative people. Creativity requires freedom. However, the second item in the survey, making money, indicates that there are fundamental differences.

Another major motivator noted by a number of respondents was that they enjoyed the excitement of being an entrepreneur. This is shown in the comment: "We are not sure what's coming down the curve but it is a thrill." The interviews also showed that money was never the primary objective or pursued for its own sake. These comments must be balanced by the method in which this research was conducted. It was a collection of interviews, not an analysis of empirical data. It is probable that the respondents placed money secondly to show themselves in a more favorable light. The fact that money was listed as high as second does seem to at least partially attest to the honesty of the respondents.

Bill Bither's Insights lists five personality traits of an entrepreneur:[1)]

1. Desire to build a better mousetrap
2. Willing to take risks
3. Supportive family and friends
4. Motivated to the point of being obsessive
5. Jack of all trades

The first thing that jumps out at the reader is that making a profit is not listed. Here again, this is a list of personality traits that we are being provided by someone who wants be viewed favorably. He is probably talking about his personality traits or the traits he believes he possesses. However, Bither does list the willingness to take risks as second most prominent personality trait.

Researchers and entrepreneurs are different people motivated by the desire for autonomy and the desire or need to create. This describes two groups of self-motivated and intelligent people. But, the fundamental difference between the two groups may be the willingness to take risks. It may not be that researchers are risk adverse, but they do not need to take risks to achieve success. The entrepreneur may actually need to take risks to validate his successes.

It is clear that the economy needs both researchers and entrepreneurs to be successful. And membership in one group does not exclude membership from the other. Universities and industry are linked together by the two groups. But how is the relationship best formed to the best advantage? A number of approaches could be used. The university could ask industry what appeared to be the most promising areas for product innovation and invention or industries could ask what current research had the most commercial applications. Each must see the value of the relationship in order for any approach to be successful.

6. The University

As indicated earlier in this paper, American research universities have traditionally been seen by the federal and state governments as a source of innovation and invention for industry. The role of universities as

1) Bill Bither is the Founder and Chief Executive Officer of Atalasoft a leading software development toolkits. The five personality traits were on his company's blog.

engines of innovation and invention is deeply rooted in the country. Nevertheless, the relationship between universities and industry has not always been a close one. Since they gained international preeminence around the middle 20th century, however, universities have appeared content with graduating students and publishing the results from their research. The primary motivation for a university research department has been more closely linked to the recognition it received from its research findings or its ability to promote its "star scientist" (Hayter, 2011). University presidents measured the success of their university by level of prestige it attained. Working with industry to conduct commercially applicable research for sometime was almost considered impure.

The passage of the Bayh-Dole Act in 1980 allowing research universities ownership of the intellectual property rights resulting from federally funded research did stimulate the entrepreneurial appetites of some research departments. Universities now attempt to shift their emphasis and make commercially viable research a priority. Technology Transfer Offices (TTO) are a part of almost every major university campus with the purpose of creating and maintaining a productive relationship with industry and establishing the intellectual property rights in the form of patents and copy rights. This is not an indication of a sure source of revenue. Only a small number of university patents generate income. The success rate is generally considered to be rather slim: one hundred invention disclosures will generate ten patents, which will in turn generate one successful product (Feldman M. , 2003). Some universities have always been more commercially orientated than others. The University of Wisconsin was the first to establish a TTO (Feldman M. , 2003). The Wisconsin Alumni Research Foundation (WARF) was established in 1925 to maintain patents derived from Professor Harry Steenbock's work on Vitamin D. Today WARF lists over 1,800 new patents on its web site. WARF was so successful in generating income for the university that it became a template for other TTOs.

The University of Wisconsin proved the benefits of patenting research results over 80 years ago. That university does have the two key factors associated with the early adoption of technical transfer, the presence of a medical school and the status as a land grant institution (Feldman M., 2003). The success could be traced back to the Morrill Act, which invested in the state with the hope that the citizens of Wisconsin would become self sufficient and less dependent of the government. Why did it take other universities so long to follow this example?

The answer may be rooted in the basic culture of the university. Research is the systematic investigation to establish facts, solve problems, and prove or develop theories. Discovering what is yet unknown in directions divined by intellectual curiosity rather than the bottom line. Scientific research relies on the application of the scientific method to explain the world around us. The "ivory tower" culture associated with a noble yet disconnected institution may accurately describe part the problem. The atmosphere of the research laboratory may yet be permeated by the esoteric pursuit of knowledge that is fundamentally disconnected from practical concerns of everyday life. The researcher devotes countless hours pursuing answers to questions that may have no immediate or obvious practical application. Once an area of research reaches an end the findings are published or recorded. Papers are written and published in the appropriate scientific journals and the researcher moves on to other pursuits. A patent may be applied for by the university and registered with the TTO. Researchers may be discovers of a different kind, motivated by their private inner workings. George Mallory who took part in the first three British attempts to climb Mount Everest famously replied to the question "Why do you want to climb Mount Everest" with the retort "Because it's there" (Anker, 1999). There was nothing practical about Mallory's search for the summit. Mallory wanted to go where no man had been before and do what no man had done before. Researchers at some universities may be searching for summits of their own. Once the answer is found the journey is ended.

Technology transfer begins when the answers are found. People facilitate the transfer of technology and knowledge, not papers. The next step is to make the work meaningful. The university either through the TTO or the researcher himself must get the research into the right hands. The researcher could, by chance, have an entrepreneurial spirit and shop his discovery around to local industry. This is expecting much of the researcher who is trained in the scientific methods of discovery. It would also take the researcher out of the laboratory and away from his work. The TTO should be the marketing and advertising department of the university.

The research department should exploit the successes of their researchers much the same way the athletic department exploits the successes of its athletes. Successful and popular sports programs such as football or men's basketball are viewed as a revenue generating resource for all university sports programs. University sports teams generate millions of dollars and raise the visibility of the entire university. A successful football program can support all other university sports and still return a profit to the university. Stadiums and athletic facilities are built with the revenue generated from profitable programs and are used by the entire student body.

The coaches still coach the athletes and the athletes still play the games but the marketing of athletics is handled by marketing professionals. For a university TTO to be successful it must adopt a similar posture. The researcher should be focused on his research and leave the marketing of the research department to those in the TTO with the ability to market.

Technology transfer has been called a "contact sport" (Foley, 1996). This requires that individuals from research departments and individuals from industry interact on a personal level and establish relationships. This cannot be accomplished by reading each other's work. Knowing each other on a personal level and developing an understanding each other's perspectives is essential to establishing a productive relationship. The two must get together and learn from each other. This is not a task that the researcher is ideally suited for and individuals conducting industrial research may not see any need for the relationship. The university TTO should be the conduit for these relationships. TTO's must become the marketers for the research departments.

7. The Community College

Community Colleges do not conduct research. They are discussed in this paper to add some perspective to the meaning of higher education and the role higher education plays preparing students for their part in the economy.

There are more individuals enrolled in community colleges that any other kind of higher education (Bus, 2010). Community Colleges or Junior Colleges are two-year institutions that serve the local community. Many of the students take only one or two classes during the evening after work or on the weekends. They are funded by state and local tax money and allow any student to attend. The curriculums of a community college are designed to give students' job training or technical skills that can be applied to the students' current position or be used to seek a better position.

As an example, an automotive technology program gives the student working at the local Ford Dealer the skills to move from the parts room as a shelf stocker into the garage as a mechanic. This is a direct link from the community college to the economy. There is an obvious and direct benefit to both the student and to the dealership. This is not a technical transfer of research findings from the community college to the dealership, but it is the direct application of knowledge learned by the student at the community college. Community Colleges must keep in constant contact with the auto industry advances to maintain a relevant curriculum for the student. The Ford dealership and the Community College in this example need each other and maintain a close relationship.

Community Colleges employ part time professors still active in their professions in an effort to maintain a direct link with local businesses and ensure the relevancy of course material. The professors also gain by keeping abreast of aspects of their profession that they may have not known if not for their interaction with other faculty members.

There are two points that are worth noting. The first, knowledge gained at the Community College is intended for immediate use by the student and provides immediate benefit to the economy. Community colleges are established by local governments to provide a vehicle for local citizens looking for a way to help themselves. This was the intent of the Morrill Act. The second, the college administration, the local government, and local businesses maintain a close and personal relationship. They need each other. This may be the element that is lacking at universities without successful Technology Transfer Offices.

8. The Technology Transfer Office

Technology Transfer Offices (TTO's) are meant to be the entrepreneurial arm of the university. They establish the intellectual property rights (IP) for inventions and innovations produced by the university in the form of patents, copyrights, and trademarks (Feldman M., 2003). The transfer of technology depends on the marketability of the innovation and the ability of the TTO to get the innovation into the hands of a company or entrepreneur willing to invest in a license. The TTO must do more than establish the rights to every submission they receive, however, they must determine the value of the submission or at least be able to separate the more promising innovations from the rest. The assessment and transfer of knowledge is difficult. This would seem to put the TTO in the unenviable position of trying to market products that they do not understand to customers that do not want what they are selling.

The purpose of the TTO is to protect and to sell university IP. This has been successful to some degree, but more could be done. The Association of University Technology Managers (AUTM) purports to support and advance academic technology transfer globally. Their web site (www.autn.net/Public_Benefits) admits that many of the benefits of technical transfer are not immediately visible, taking the form of educational advancements and contributions to the academic research enterprise. Instances of technology licensing are recorded in the annual AUTM U.S. Licensing Activity Survey. The 2010 report includes an impressive number of 657 commercial products introduced by TTO's. What was not clear from the report was the effect these new products had on the economy and what revenue was generated for the university. The AUTM does provide statistics that are required for the tracking of the number of technical transfers, but not the quality and usefulness of the transfers. AUTM's White Paper In the Public Interest: Nine Points to Consider in Licensing Technology (March 2007) listed eight of the nine points legal protections.

A TTO's function should be much broader than patent protection. They should function as a profit seeking organization. They should make money. It should be influenced by the needs of the market. This would require the TTO's to be on equal footing with research departments and have some influence on the direction of research. This could be done by having the TTO facilitate an active relationship with researchers and their industrial counter parts by allowing industry to be involved from the earliest stages of research. TTO's would have to evolve from an administrative organization into an entrepreneurial organization.

9. Innovation Clusters

Science-based innovation is commercialized by the triple helix of: universities, industry, and government (Etzkowitz, 2006). Clusters are geographic concentrations of interconnected companies and specialized suppliers associated with a particular industry that are present in a definable area. High tech clusters are typically composed of a number of new technology companies with connections to one or more research universities. On aggregate, clusters follow a traceable path. A student graduates from the university with an idea for a new product innovation. The graduate starts a new company to market his idea and becomes an entrepreneur. The entrepreneur acquires angel and venture capital and expands his company while maintaining a close relationship with the university. As other graduates leave the university they seek employment from the entrepreneur or emboldened by the entrepreneur's success they seek to start companies of their own by leveraging what the entrepreneur has established. As the number of successful companies increase the cluster takes form.

This appears to be a straightforward process, but it has proven difficult to repeat. What motivated the university graduate to start his own company? How did he acquire venture capital, and how did he market his innovation successfully?

Maryann P. Feldman suggests in her work on biotech firms in the U.S. capital region that there are three exogenous sets of factors that are necessary to provide a region with the proper environment to generate cluster growth: pre-existing resources, entrepreneurship incentives, and infrastructure provided by the government (Feldman M.P., 2007). The biotech cluster is concentrated along interstate 270 and is located predominately in three cities in Maryland, Frederic, Gaithersburg, and Rockville.

The National Institutes of Health (NIH) is located in Bethesda Maryland and provides the biotech companies with the financial resources necessary to conduct research. The research by several of these companies has proven to be successful. Maryland ranked fourth in the number of patents issued in 1997 (Feldman M.P., 2007).

Placing a company near a prime revenue source like the NIH is an obvious advantage, but it would seem hardly enough on its own to start an innovation cluster. There are other recourses that must be available locally. The location of Johns Hopkins University and several other research universities nearby are necessary for the generation of basic research, but also to supply the biotech firms with a steady supply of talent. There must be a continuous supply of new talent and new ideas to make a cluster viable.

Silicon Valley is perhaps the most famous innovation cluster, a glowing example of what can happen when all the right ingredients are in place. However, this may not have been a case of spontaneous generation as popularly believed. Silicon Valley may not have begun in 1955 when William Shockley invented the transistor at Bell Laboratories and founded Shockley Transistor Corporation in Palo Alto, California. And Fairchild Semiconductor may not have been the first spin-off. An engineer named Cyril Elwell employed at the Federal Telegraph Corporation (FTC) based in Palo Alto may have signaled the true start of the region's development in1912 (Sturgon, 2000).

In January 1909, the United States navy was soliciting bids for a ship to shore radio system capable of reaching a ship 3,000 nautical miles at sea. The system had to function day and night and in all weather. This was outside the capabilities of radio equipment at the time. The contract went to the lowest bidder, NESCO. However, a few years later Elwell demonstrated a new radio technology, the Poulsen Arc, which generated continuous long radio waves with an electronic arc operating in an atmosphere of hydrogen contained by a strong magnetic field. The system became the first global scale radio communications system. (Sturgon, 2000)

Cyril Elwell graduated from Stanford University in 1909. Cyril had seen Dr. Vladimir Poulsen of Copenhagen Denmark demonstrate his invention of the spark-based transmitter in Paris in 1900. Elwell's own attempts to produce the technology were unsuccessful. In 1908, Elwell went to Denmark and acquired the patent rights from Dr. Poulsen. Elwell had trouble attracting investors and eventually turned to Stanford University to acquire financing. Stanford University agreed to finance the company and the Poulsen Wireless Telephone and Telegraph companies was born. Elwell marketed his wireless system by holding public demonstrations and engaging the public.

Cyril Elwell is an important figure if we are to understand innovation clusters and the birth of the Silicon Valley. He is important for two reasons. The first, if he did start Silicon Valley, he started it long before 1955. Innovation clusters may take much longer to take shape than previously thought, even when all the conditions are right. The second, who he was and what he was in the innovation process. He was a Stanford University graduate. He was an engineer that could not produce the product he desired. He was an entrepreneur. He believed in his product. He worked hard. And he took risks. These are ingredients provided by the individual and cannot be provided by others.

10. Start-ups and Spin-offs

University start-ups and spin-offs are viewed as a means to energize local economies by transferring new product innovations and new more efficient production process directly into the local community. Local entrepreneurs can license patents from the research university and spark economic growth in the area. A university may license a patent to anyone and are not constrained to the local economy; however, entrepreneurship is seen as a local activity. Local governments fund university research in the hope that there will be some benefit to local or regional firms. University TTO's serve as the conduit between university researchers and the local government, industry, and entrepreneurs.

There are three mechanisms that the TTO can use to transfer technology to the local economy, sponsored research, licensing, and spin-offs. Sponsored research by a local industry is the most traditional form of university to industry technical transfer (Foley, 1996). For example, a company, such as U.S. Steel, funds research at Carnegie Mellon University to develop a more efficient method of steel production. Once the research is complete the research findings are transferred to U.S. Steel and the process ends. The relationship also ends. U.S. Steel gains efficiency, but no new firms are started in the economy. This may benefit the local economy by keeping U.S. Steel competitive in the global market and preserve existing jobs, but it does not create new jobs for the local economy.

Licensing of university patents to local firms is beneficial to local industries and to the university by providing the university with a means of revenue for more research. Industrial products, including but also extending well beyond IT and biotechnology, are becoming increasingly science based. Increasingly, governments hope that the license purchaser will start a new company or even lay the foundations of a new industry. University start-ups and spin-offs are becoming fast the great hope of economic development agencies.

The research required to bring most high tech innovations from concept to the market place is expensive and time consuming. Investors bridge the gap between invention and innovation. For each innovation a business case must be developed and supported to attract entrepreneurs and investors. Some innovations are worthless without the researcher and will attract no interest unless the researcher agrees to become part of the spin-off. Some high tech spin-offs generate extraordinary returns to their investors (Branscomb, 2003). The purchasing of a license and the willingness of the researcher to participate in a start-up or spin-off will not guarantee the interest of investors. However, there are sources of financing for new technology.

The tremendous profits generated by some high tech start-ups and spin-offs do tempt some investors. These include venture capital firms, corporate venture funds, incubators, law firms, university TTO's, and local governments (Branscomb, 2003). The key to making an innovation an attractive investment may lay with the entrepreneur. He must be the one person that ties the entire venture together. He must first recognize an opportunity and find a way to exploit the opportunity for profit. He must be able to distinguish between what appears to be a good idea and what is a marketable invention. He must also have a proven track record of success. For the entrepreneur to be a creditable advocate and sell the product to investors he must be able to prove he has been successful in the past. The guarantee of the researcher is a foregone conclusion. He believes in his invention and is certain that others will see its value. He has invested himself in the pursuit of an answer and has found it. He has the backing of other researchers and the university to attest to the value of the research. The entrepreneur is investing himself in the venture and using himself as collateral.

The successful entrepreneur is the most elusive member of the community. There are plenty of researchers, investors, and government officials all brimming with good ideas and intentions. Each is certain that they have something to contribute to the marketplace, an idea that is certain to work if only someone would just start the ball rolling. Once someone else has taken the initiative and made progress, they would be right there to help. But nothing happens until someone is willing to take a chance and put himself at risk. There are examples of researchers who have taken chances and left universities and started highly successful companies, but these are rare when compared to the number of patents issued. Investors are risk averse. They are only willing to take a chance when there is collateral against the risk of failure and will only take the smallest share. Government officials have the answers to all of the problems all of the time, but they do not take chances with their own money. They can facilitate entrepreneurship, but they cannot create it.

11. Conclusion

Knowledge is a commodity. The triple helix of universities, industry, and government provide the source, the vehicle, and the mechanism for trading knowledge. The economy of the United States could be greatly improved by the proper application, marketing, and selling of scientific knowledge domestically and internationally. The United States has a well-established educational system. Education is available for every child through the 12th grade. If a student performs well scholarships for higher learning are available on a competitive basis. The founders of the country viewed education as essential to the economic and military strength of the country. The Morrill Act established universities throughout the country to provide the citizens of each state the opportunity to acquire an education and better themselves. A series of legislation in the past few decades including the Bayh-Dole Act gave universities the ability to profit from research they conducted using money provided by the federal government.

The state of Wisconsin established a university in Madison, the state capital, in 1848. It became a land-grant institution in 1866. It is now organized into 20 schools offering 135 undergraduate majors, 151 masters degree programs, and 107 doctoral programs. UWM is categorized as an RU/VH Research University (very high research activity) in the Carnegie Classification of Higher Education. The university has grown and now has nine universities and four freshman-sophomore branch campuses. (University of Wisconsin, 2011) To highlight a just a few scientific discoveries from this university: The first Ph.D. in Chemical Engineering in 1905; Vitamin A discovered in 1913; Vitamin B discovered in 1916; Invented the process for adding vitamin D to Milk in 1923; The drug Coumadin was developed in 1951; The first isolated and cultured human embryonic stem cells in 1998 (University of Wisconsin, 2011). Those are the accomplishments of one land grant university. There are 57 land grant universities including those residing in the U.S. territories and many more institutions of higher learning.

Industry is doing their part to improve the economy and contribute to innovation and invention. They do this by seeking profits. This requires industry to be innovative and efficient in the market place. Greater collaboration with university researchers would benefit the production and transfer of science based innovation. University TTO's should facilitate coordination between university researchers and their industry counter parts. TTO's need to be part of the entire process, from the formulation of new product ideas, to the direction of university research, to the active promotion of the university as a source of profits for industry. TTO's should become the entrepreneurs and risk takers of the university. They need to develop business plans and have the authority to conduct business and make contracts between the university and industry.

The government cannot innovate or invent. The government cannot produce entrepreneurs or develop an innovation cluster. They can only fan the flames of entrepreneurship once someone else produces the sparks. They can do this by giving tax breaks, by passing helpful legislation, and by staying out of the way and allowing the marketplace to choose the winners and the losers.

Thomas Edison, Cyril Elwell, and Steve Jobs achieved success by hard work and believing in themselves. They would not take no for an answer. They had an idea and the motivation to succeed. They certainly got lucky here and there and they also had help along the way, but they were successful because they believed in what they were doing and were willing to take risks. They were entrepreneurs.

The university researcher is not a risk taker. He may take some risks, but this is not what he does best. The researcher is doing his best by conducting research and pursuing answers. The university should take risks by directing TTO's to become more engaged in the technical transfer process and fostering an entrepreneurial spirit in the TTO by hiring fewer technocrats to run the TTO and hire more creative and entrepreneurial-minded people. This would require more than a policy statement from the university president. It would require a change in institutional attitude. Some universities, like UWM above, seem to have always had that attitude or at least enough of it to make a difference. It may take hiring someone away from a successful university TTO and investing in an aggressive campaign. It would require taking a risk.

The entrepreneur is the one person that everyone needs. Industry and the government need him to start new businesses and preserve existing industries. He is the idea man. He will work until he succeeds or fails trying. The government needs the entrepreneur to employ people and generate revenue to pay salaries and taxes. Universities need the entrepreneur to attend their institutions and transfer knowledge into the economy. The entrepreneur is society's risk taker. He is the winner and the loser. He places himself, his fortune, and his family at risk to succeed. He is the one we all rely on to take risks for the rest of us.

The academic entrepreneur is out there right now. He is sitting in a classroom preparing to take advantage of what opportunities he can find. There are not many of them and some will never get their chance, but some will go out and do great things. We cannot really create them. We can only help them.

Universities can attract the academic entrepreneur and help him by engaging in the market place and adopting aspects of the community college model. The university should also employ researchers who hold jobs in industry. Industry experience directly related to the research being conducted may even be turned into a requirement for part of university research employment. This should encourage undergraduate and graduate students to hold positions in industries related to their majors while they are attending school and allow them to receive credit and payment for their work. It would also create a direct link between the research laboratory in the university and research efforts in industry that have a practical and marketable application. The researchers and students could work on school projects at work and work projects at school, because it would be similar work. This would be the same network of people working together on the same projects.

While a lot of complications remain to be resolved, such an approach will take a fundamental shift in institutional thinking by universities. It will be resisted by those invested in the traditional role of the university. However, education is a lifelong activity, for students, teachers, employees, employers, entrepreneurs, industries, and universities. Some universities will fail and some will succeed. The fittest will survive.

"Technology is so much fun, but we can drown in our technology. The fog of information can drive out knowledge."

Daniel J. Boorstin (1914-2004)

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Determinants of Corporate Commercialization of Public Technology Transfer: Evidence in Korea

JaeWoong Min[1], YoungJun Kim[1*]

Abstract

This study investigates the potential factors that might affect the successful commercialization of public technology transfer (TT), i.e., technology transfer from universities and public research institutions. We conduct an inductive and qualitative approach to identify the key organizational issues in promoting commercialization of public TT with the help of a unique survey data. The important explanatory factors relate to the researcher's technology consultant service, R&D intensity of the company, and the prior experience of TT from the same institution. However, the TT productivity (i.e. royalty income/R&D expenditure) of the universities and public research institutions, and the engagement of technology transfer intermediary appear to be negative to successful commercialization.

Keywords: Public Technology Transfer, Technology Commercialization, Absorptive Capacity

1. Introduction

As technological innovation has been attracting attention as a core means of national competitiveness reinforcement, the government's support for R&D has been continuously increasing. According to a research and development activity survey report (KISTEP, 2012), in the case of Korea, the amount of the government's R&D investments rapidly increased by 14.4% per year on average from KRW 6,632.1 billion in 2006 to KRW 13,003.3 billion in 2011. As a result, the importance of R&D investments in the national economy is very high, to the extent that the ratio of the entire inputted research and development costs to national GDP as of 2011 was 4.03%, which was the second highest in the world next to Israel. A noteworthy part is that public research institutions & Universities (PRI&Us) play very important roles in the national R&D ecosystem to the extent that KRW 10,668.5 billion, which corresponds to 82.0% of the 2011 government R&D finance, was invested into PRI & Us.

To diffuse PRI & Us' research outcomes and promote the commercialization of the outcomes, the government not only established and amended laws such as the Technology Transfer and Commercialization Promotion Act (established in 2000), the Special Act on the Support of Daedeok Special Research and Development Zone, (established in 2005), and the Promotion of Industrial Education and Industry-Academic Cooperation Act (amended in 2003), among others but also has established and implemented diverse support policies such as establishing mid- to long-term technology transfer commercialization promotion plans

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for four times. As a result, organizations dedicated to technology transfer (TLO, Technology Licensing Office[1]) were installed in PRI & Us and diverse technology transfer intermediaries appeared, resulting in increases in activities intended to transact technological assets, such as patents followed by the formation of technology transaction markets in Korea.

As PRI & Us' social responsibility increased, records of technology transfer to enterprises continuously increased. The total amount of technology licensing revenue received by PRI & Us increased by 2.6 times from KRW 49 billion in 2003 to KRW 125.8 billion in 2011 and the number of cases of technology transfer increased by 4.8 times from 1,076 in 2004 to 5,193 in 2011. Nevertheless, when seen from the viewpoint of research fund productivity (the ratio of technology licensing revenue to input research fund), the performance of PRI & Us' technology transfer in Korea was found to be approximately one-third of that in the USA because the productivity in Korea as of 2011 was 1.32%, while the productivity in the USA as of 2010 was 4.06%. Therefore, additional effort for the improvement of technology transfer efficiency is necessary.

Thus far, many studies have been conducted from the viewpoint of enhancement of PRI & Us' technology transfer capacity and performance. Studies on the correlation between diverse factors and PRI & Us' technology transfer performance have been continuously conducted such as those that divided PRI & Us' resources into financial, physical, human, and organizational resources (Power, 2003) from a resource- based viewpoint (Barney, 1991) believing that the sources of competitive advantages are differentiated resources and capacities possessed by organizations, those that considered compensation systems (Siegel, 1999), cooperation systems (Santoro et al., 2002), licensing strategies, and patent application registration speed (Markman et al., 2005) in terms of transferred technology commercialization, and those that considered surrounding enterprises' R&D intensity (Siegel, 2003; Friedman et al., 2003) and venture capital availability (Wright et al., 2006; Lockett, 2005) from the viewpoint of market structures considering industrial environments (Porter, 1979).

From the viewpoint of enterprises that are actual implementers of technology commercialization, open technological innovation through unceasing cooperation with external organizations is indispensable for ensuring continuous growth by responding to environmental changes including intensifying competition resulting from rapid globalization and shortening product life cycles (Chesbrough, 2003). Through diverse studies indicating that cooperation with external organizations positively affects enterprises' performance (Powell, 1996; Ledwith, 2005; Stock, 2012 et al.), cooperation with external organizations has come to be recognized as a mandatory requirement for enterprises' current success. Diverse studies on enterprises' external cooperation have also been conducted such as those regarding the relationship between the selection of effective methods of technical cooperation (outsourcing, joint research, licensing, M&A, and joint venture establishment, etc.) in relation to internal capacity and environments faced and those regarding the effectiveness of vertical cooperation with demanding/ supplying enterprises or horizontal cooperation with non-related enterprises (Podolny, 2001).

In this study, PRI & Us and enterprises will be integrated into one analysis unit to examine whether enterprises that introduced technologies from PRI & Us actually accomplished commercialization success such as sales occurrence and cost saving. Through the foregoing, the scope of technology transfer performance analysis that has been limited to PRI & Us will be expanded and special relationships between enterprises and PRI & Us will be mainly analyzed instead of conducting general comparison and analysis of the relationship between enterprises and organization in diverse cooperation networks in order to find factors for success of public technology commercialization. To this end, the present state of enterprises' commercialization of technologies transferred from 29 institutions in Korea that comprise universities and

1) Pursuant to article 2 of the Technology Transfer and Commercialization Promotion Act, the establishment of a department dedicated to TLO is mandatory to public research institutes.

research institutes with excellent technology transfer performance were examined.

The composition of this paper is as follows. First, in Chapter 2, previous studies related to the analysis of the effects of PRI & Us' technology transfer, enterprises' introduction of external technologies, and technology transfer intermediary on the performance of technology transfer·commercialization are examined and their research hypotheses are presented. In Chapter 3, a research model is presented based on the results of questionnaire surveys about technologies transferred from 29 universities and research institutes and in Chapter 4, success factor hypotheses are verified through regression analysis. In Chapter 5, policy alternatives for enhancing the efficiency of public technology transfer are presented based on the results of verification of the hypotheses.

2. Previous Studies and Research Hypotheses

2.1 Public Research Institutions and Universities Technology Transfer

As the importance of public technology transfer was magnified, the USA acknowledged PRI & Us' ownership of technologies and specified technology transfer as a major duty of them in 1980 through the establishment of Bayh-Dole Act[2)] and Stevenson-Wydler Technology Innovation Act[3)] so that technology transfer activities began in earnest. In Korea, PRI & Us' technology transfer began to be promoted in earnest in 2000 when the Technology Transfer and Commercialization Promotion Act was established to construct a series of bases for technology transfer such as making the installation of organizations dedicated to technology transfer (TLO, Technology Licensing Organization) mandatory and providing incentives for technology transfer.

As shown in Figure 1, general procedures for public technology transfer can be divided into reporting of invention, evaluation of invention, applications for patents, technology marketing for discovery of subject enterprises, transfer contracts, and licensing management stages. To overcome the problem of limited capacity of TLO organizations, technology marketing works such as the discovery of demanding enterprises are entrusted to external technology transfer intermediary when necessary. When a researcher has

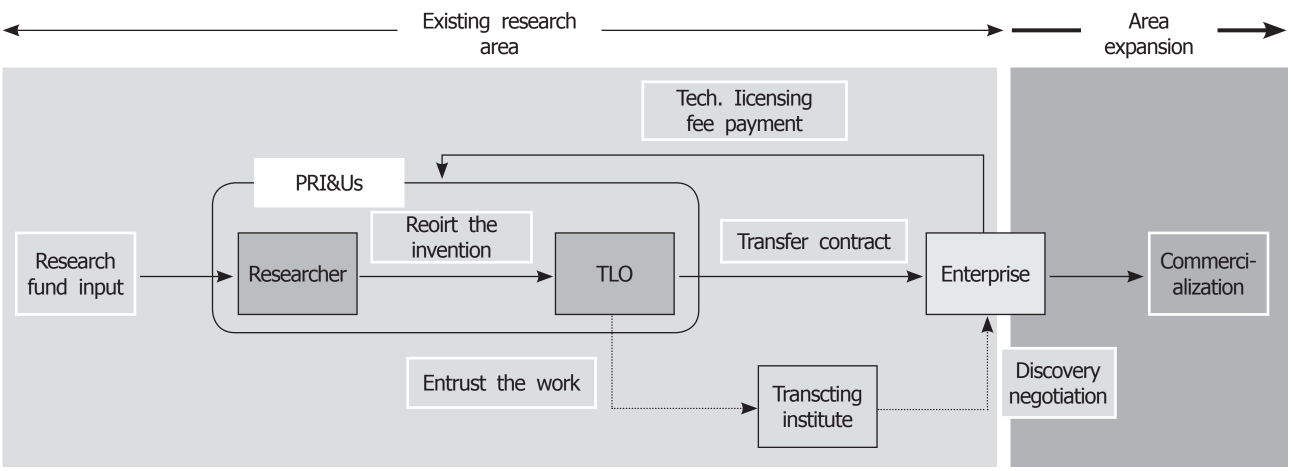

Figure 1 Technology transfer process of PRI & Us

2) Bayh-Doyle Act (P.L. 96-517, 1980): Based on the judgment that there should be no effort for commercialization without ownership and protection of invention, universities' and non-profit institutions' acquisition of ownership for inventions made by the federal government was allowed

3) Stevenson-Wydler Technology Innovation Act (P.L. 96-480, 1980): specified government departments' technology transfer and related effort as major duties such as mandatory technology transfer budget allocation to departments having research institutes (at least 0.5% of R&D budgets), mandatory establishment of technology transfer offices (ORTA: Office of Research and Technology Applications) in research institutes

reported an invention as an outcome of technology development to an organization dedicated to technology transfer (TLO), if the TLO judges that the invention should be protected because it has business value, the TLO will apply for a patent to obtain intellectual property rights. Thereafter, the TLO publicly promotes the technology or searches for enterprises that require the relevant technology to make a technology transfer contract to transfer the intellectual property rights or permit the right of implementation, or elect to found a business firsthand with the technology as an investment in kind as an alternative.

Previous studies on PRI & Us' technology transfer can be largely divided into those with the viewpoint of the inside of organizations, those with the viewpoint of external environments, and those with the viewpoint of dynamic relations to review the studies. From the viewpoint of the inside of organizations, Power (2003) divided factors that affect patent creation, technology licensing, etc. into financial, physical, human, and organizational resources based on the resource based theory (Barney, 1991) to conduct a comprehensive analysis. To review those studies in more details, there are studies on the effects of different attributes of input research funds (government fund, private funds, etc.) on transfer performance (Foltz et al., 2000), the relationship between the scales of organizations dedicated to technology transfer and business history (Di Gregorio et al., 2003; Markman et al., 2005; Lockett and Wright, 2005), distribution of researcher resources (Thursby, 2002), the efficiency of technology licensing compensation systems (Siegel, 1999), study outcomes such as papers (Santoro, 2002; Di Gregorio, 2003), and the speed of technology transfer processes (Markman et al., 2005). From the viewpoint of environments, some studies examined the relationship between external environmental factors and the performance of public technology transfer based on the industrial organization theory (Porter, 1979) emphasizing that external environments surrounding organizations are important factors. Major contents of study results presented include the relationships between surrounding enterprises' R&D intensity and regional economy's GDP (Siegel, 2003), high-tech enterprise density (Friedman, 2003; Audretsch, 2005), and venture capital availability (Di Gregorio, 2003; Wright et al., 2006) and the performance of technology transfer. Major studies from the viewpoint of dynamic relations examined the relationships between smooth communication between organization members (Smiler, 1991; Greiner, 2003; Santoro et al., 2002), ties between researchers, TLO organizations (Siegel et al., 2003), etc. and technology transfer performance. In Korea too, studies on public technology transfer mechanisms have been actively conducted including those that examined research fund finances, research manpower, internal capacity of institutions such as TLO (Cho, 2012), cooperation with external organizations and external environments such as social capitals (Kim, 2011), the effect of consortiums among technology transfer related parties (Park, 2007), incentive distribution methods and technology information management (Ok, 2009), and marketing activities, educational systems, and technology transfer efficiency (Lee, 2012).

This study will begin from the viewpoint that the ultimate objective of PRI & Us' technology transfer is transferred technologies' market entry. That is, the focus of analysis was moved from the technology licensing revenues of PRI & Us to the successful commercialization of transferred technologies for the reinforcement of national competitiveness. Therefore, the subjects of analysis were increased to include enterprises to which PRI & Us' technologies were transferred with a view to verifying whether PRI & Us' activities actually positively affected successful commercialization through follow-up surveys of transferred technologies. To verify whether the PRI&Us' technology transfer performance supported in previous studies actually affected enterprises' commercialization performance, the first and second hypotheses were established as follows.

Hypotheses 1. Public research institutions and Universities that have higher technology transfer performance will positively affect enterprises' commercialization success.

Hypotheses 2. Additional researchers' support after technology transfer will positively affect enterprises' commercialization success.

2.2 Enterprises' Introduction of External Technologies

Due to rapid increases in the speed of technological innovation and shortening of product life cycles, the necessity to cooperate with external organizations along with in-house research and development has become larger (Hagedoorn, 1994; Chesbrough, 2003). Risks and costs involved in research and development can be reduced by quickly acquiring diverse knowledge and ideas through external research and development while reinforcing core capability through internal research and development (Laursen & Salter, 2006) General processes for enterprises to introduce external can be divided into the stages of defining necessary technologies, decision making on technology introduction, negotiation and contract, and additional development. When necessary in order to overcome the problem of enterprises' limited capability to search for external technologies, works such as searching for institutions having necessary technologies and negotiations are entrusted to external technology transfer institutions.

Enterprises' absorptive capacity was defined as the ability to commercialize external knowledge by evaluating and utilizing the external knowledge using the prior knowledge and experience accumulated in the organization (Cohen & Levinthal, 1990). That is, some studies regarded absorptive capacity as a means to effectively utilize introduced technologies and measured human resources' technology levels, the ratio of skillful R&D manpower, and the amounts of R&D investment from the viewpoint of country units (Mowery & Oxley, 1995) and some other studies argued that high absorptive capacity could be possessed if amount of prior knowledge was large and the intensity of effort was high from the viewpoint of learning ability and problem solving ability (Kim, 1998). Zahra and George (2002) expanded the existing absorptive capacity to Dynamic Capacity, divided it into Potential Absorptive Capacity and Realized Absorptive Capacity, and concretized them as a series organization routines and process stages to recognize, assimilate/digest, transform, and exploit necessary knowledge.

In the case of technologies developed by PRI & Us, channel type transfer without any particular subjects is universal (Podolny, 2001). That is, since technologies developed by PRI & Us have the nature of public goods, they are not delivered to certain subjects but correspond to the type of sowing the seeds of technologies. Therefore, differences in the performance of technological innovation are assumed to be very big between enterprises with high absorptive capacity and those with low absorptive capacity. In this study, absorptive capacity is divided into Potential Absorptive Capacity and Realized Absorptive Capacity applying the study conducted by Jansen (2005) and the effects of these absorptive capacities on commercialization success after public technology introduction will be figured out.

Hypotheses 3. Enterprises' high technology absorptive capacity will positively affect public technology commercialization success.

Hypotheses 3-1. Enterprises' high potential absorptive capacity will positively affect commercialization success.

Hypotheses 3-2. Enterprises' high realized absorptive capacity will positively affect commercialization success.

2.3 Technology Transfer Intermediary

In compliance with the transaction cost theory (Williamson, 1979), which argues that market activities evolve toward cost saving, technology transfer organizations that conduct business activities through the reduction of transaction costs existing in the market appeared. These organizations have been naturally settling as an axis of the technology transfer market through the role of reducing the cost to obtain reliable information in the complicated technological innovation system and finding appropriate enterprises to link necessary technologies to them.

In the case of Korea, a 'technology transfer intermediary' designation system was made under the former Technology Transfer and Commercialization Promotion Act established in 2000 and has been operated so that the government has been designating technology transfer intermediaries firsthand, based on work contents such as grasping those technologies that are to be transferred or commercialized, technology demand surveys, analysis, and evaluation, information establishment/management/distribution, construction of related information networks, and technology transfer mediation/conciliation. Thus far, 61 institutions (as of the end of 2012) have been designated and are currently active. These institutions can be divided into 38 private institutions and 23 public institutions (regional technopark, etc.). The government organized cooperation networks among technology transfer intermediaries to strengthen their capacity in order to promote technology transactions thereby implementing projects to support region based technology enterprises' growth (Technology Transfer Promotion Network Projects).

Studies conducted on these intermediaries include those that presented core functions divided into information retrieval, knowledge processing, mediated negotiation, and approval standardization (Howells, 2006), those that proved that among the forms of intermediaries, patent firms have positive effects of making environments in which researchers can be immersed in research and development by reducing transaction costs (Lamoreaux, 2002), and those that indicated that venture capitals are creating outcomes by expanding the scope of their works from those of simple investors to those of the functions of intermediaries such as participating in technology and management support (Kirk & Pollard, 2002). Other studies verified the effect of the composition of technology transfer consortiums among intermediaries (Park, 2007).

In this study, whether those intermediaries that are playing the role of activating technology transfer markets by reducing transaction costs actually have positive effects on public technology transfer's actual commercialization success will be verified.

Hypotheses 4. Public technology transfer made through technology transfer intermediaries positively affect commercialization success.

2.4 Cooperative Partnership

R&D cooperation refers to the formation of special relationships between at least two parties surpassing the simple market transactions made for creation, acquisition, exchange, and utilization of technical knowledge (Hagedoorn et al., 1994), and enterprises' R&D cooperation refers to the formation of cooperative relationships between enterprises for joint research and development and technology transfer, etc. in order to consolidate their positions in the market. To create competitive advantages in the management environment where competition between enterprises is intensified, the speed of changes in technologies is increasing, and product life cycles are shortened due to globalization, enterprises are increasing not only their own efforts but also cooperation with external enterprises in order to effectively utilize external knowledge and technologies (Verspagen, 2004) and some studies indicated that differences in, performance between enterprises that were conducting R&D cooperation and those that did not conduct R&D cooperation increased gradually (Powell, 1996; Laursen & Salter, 2006). R&D cooperation is being made because of diverse motives such as R&D cost reduction, technological risk sharing, market entry acceleration, technical standard creation, and linkage to innovation processes (Dodgson, 1993). R&D cooperation can be divided based on the subject of cooperation into vertical cooperation such as product development outsourcing within demand and supply value chain and horizontal cooperation made by relationships with competitors, supplementing businesses, research institutes, and universities, etc. based on the subject of cooperation and into cooperation for the same resources that mainly pursues the economy of scale and cooperation for supplementary resources that pursues economies of scope based on the types of resources that are the subjects of cooperation (Ireland, 2002).

Some studies pointed out that measuring technology cooperation success factors is very difficult work.(Hamel, 1991; Khanna, 1998). There are studies conducted on the relationship between the frequency of interactions between cooperating parties (Ledwith, 2005) and new product development performance and other studies conducted on the relationship between effective communication, adjustment, cooperative relationships with those who have technology sources and successful technology acquisition (Stock & Tatikonda, 2008). In particular, a study indicated that trust between cooperating institutions is a core factor that determines sucess (Lado, 2008) and there is a study case where the relationship between the concentrating power of cooperation, whether cooperated previously, technology similarity and enterprises' performance (Arbor, 2009).

Since the technologies developed by universities and research institutes which are the subject of this study are relatively low in the degree of completion and are not for certain enterprises but are for public interests, continuous cooperative activities for overcoming large gaps between enterprises and suppliers will be addressed as an important factor. Some studies indicated that if research organizations such as enterprises and research institutes have experience of past cooperation, results would be better not only in the frame of the relationships between enterprises (Levinthal & Fichman, 1988; Hakanson, 1993) but also in the cooperative relationships between enterprises and public research institutes (Cyert & Goodman, 1997; Davenport., 1999a). In particular, from the viewpoint of enterprises, cooperation activities with universities or research institutes are regarded as acting as a very important actor in overcoming cultural heterogeneity and establishing trust because universities will become to well understand the characteristics of enterprises (Jeong, 2008) and positively affecting enterprises' commercial performance. (Oh, 2006). That is, enterprises' and universities' experience of cooperation will enable relatively reducing necessary costs incurred in the process of transfer by enhancing mutual understanding of each other's organization characteristics.

Hypotheses 5. Partnerships between enterprises and public research institutions and universities have positive regulation effects on public technology commercialization success.

3. Study Method

3.1 Data

3.1.1 Survey Subjects

Questionnaire surveys were conducted about the present state of commercialization of 5,411 technologies transferred from a total of 29 public research institutes comprising 16 universities and 13 research institutes that had participated in the 'leading TLO[4] support project (Connect Korea support project)' jointly planned by the former Ministry of Knowledge Economy and the former Ministry of Education, Science and Technology from 2006 through 2010 to enterprises. Since the TLO support project was implemented with selected public institutions with relatively excellent technology commercialization capacity and performance with a view to strengthening the TLO organization's capacity, the implementing institutions can be said to be major institutions that can represent Korean PRI & Us from the viewpoint of technology transfer. Among a total of 1,589 questionnaires collected from enterprises that received technologies from the foregoing institutes, 1,087 questionnaires with faithful responses to survey items from enterprises of which the financial information could be secured were finally analyzed.

3.1.2 Survey Item

Whether the enterprises that received technologies from PRI & Us succeeded in commercialization was surveyed to divide the levels of success into three (success,

4) Technology Licensing Office (TLO): Pursuant to article 11 (Public research institutes' organization dedicated to technology transfer) of the Technology Transfer and Commercialization Promotion Act, public research institutes in Korea should install an organization dedicated to technology transfer mandatorily.

in progress, postponed/failed) and technology transfer related items divided into three categories; technology supplier, technology demander, and transferred technologies, as shown in Table 1, were surveyed.

3.1.3 Survey Result

The present state of enterprises that received public technologies by scale based on the number of employees and research and their development costs concentration levels (research and development costs/total sales) at the time when the technologies were introduced are as shown in Table 2 set forth below. Whereas the large enterprise group accounted for 146 cases (13.9%), the small and medium enterprise group accounted for most of technology transfer cases at 941 (86.1%). In particular, small and medium enterprises with the number of employees in a range of 10-299 accounted for 764 cases (70.3%) indicating that most technologies were transferred to small and medium enterprises. In the case of R&D intensity that indicate the ratios of R&D investment amount to enterprises' sales, where as the 2011 average of Korean enterprises was 2.56%, and the average of enterprises high ranked in sales was 4.04% (KISTEP, 2012), among enterprises that received public technologies, 670 ones or 61.6% showed 5% or higher R&D intensity which are relatively very high (20.6% on average). Whereas 20.5% of enterprises in the large enterprise group showed 5% or higher R&D intensity, 68% of

Table 1 Major questionnaire survey items

Category	Item	Content
Technology supplier	• Licensing revenue (A) • Input research and development costs (B) • Research fund productivity (A/B) • Degree of ex post facto support	• Licensing revenues received from 2006 through 2010 • R&D investment from 2006 through 2010 • Ratio of technology licensing revenues to input research funds • Whether the developer taught the technologies and supported the development of additional technologies
Transferred technologies	• Technology area • Technology Readiness Level (TRL)	• Korea Standard Industry Classification System (medium classification) • Technology readiness level based level 1(basic)- level 9 (commercialization)
Technology demander	• Present state of implementation of commercialization • Technology introduction channel • Major business type area • Number of employees • Motive of introduction of technologies • Number of times of public technology introduction • Distance from the supplier	• Three levels; success, in progress, postponed/failed • Researcher, organizations dedicated to technology transfer, private intermediary, online market • Korea Standard Industry Classification System (medium classification) • Number of regular employees as of the end of 2011 • Advancement into new business, new product development, new process improvement, IP response • The number of times of contract execution with public institutions before the technology introduction • The same/adjacent region, distant region

Table 2 Present state of research fund concentration ratios by scale of enterprises that introduced technologies

enterprise scale \ R&D intensity		-1%	1-5%	5-10%	10-50%	50%-	total
Large enterprises (1,000-)	Frequency	32	52	10	5	0	99
	%	32.3%	52.5%	10.1%	5.1%	0.0%	100.0%
Medium large enterprises (300-999)	Frequency	14	18	7	8	0	47
	%	29.8%	38.3%	14.9%	17.0%	0.0%	100.0%
Medium enterprises (50-299)	Frequency	51	122	95	83	10	361
	%	14.1%	33.8%	26.3%	23.0%	2.8%	100.0%
Small enterprises (10-49)	Frequency	28	71	73	181	50	403
	%	6.9%	17.6%	18.1%	44.9%	12.4%	100.0%
Micro enterprise (-10)	Frequency	7	22	26	83	39	177
	%	4.0%	12.4%	14.7%	46.9%	22.0%	100.0%
Total	Frequency	132	285	211	360	99	1,087
	%	12.14%	26.22%	19.41%	33.12%	9.11%	100.0%

enterprises in the small and medium enterprise group showed 5% or higher R&D intensity thereby showing a tendency for research fund concentration ratios to grow as enterprise scales decrease. Therefore, it can be seen that mainly enterprises with high R&D intensity received public technologies.

The average R&D productivity (the ratio of total technology licensing revenues to input research funds) of the 29 public research institutes for five years was identified to be 1.8% in the survey results. This shows higher performance than the average from entire Korean PRI & Us at 1.32% (KIAT, 2012). Research institutes showed higher R&D productivity levels compared to universities in general. This seems to be attributable to differences in focus areas by technology development stage between universities focusing on basic research and research institutes focusing on applied research. The productivity is below that of the universities, research institutes at 4.06% in the USA in particular among major advanced countries. In the case of individual institutes, whereas the value shown by the research institute (ETRI) with the highest R&D productivity was 7.2%, the average value of productivity of ten highest ranked institutes was 20.9% (AUTM, 2011). Therefore, the fact that Korea PRI&Us should make continuous effort to improve technology transfer performance could be identified.

The results of survey of whether enterprises' public technology commercialization was successful are as shown in Table 4 set forth below. Here, commercialization success refers to the results of qualitative responses to questions asking whether the initial purpose has been achieved such as cases where introduced technologies were utilized to launch products thereby contributing to sales increases if the purpose of introduction was product development and cases where introduced technologies were utilized to reduce costs and shorten working time to achieve the initial purpose if the purpose of introduction was process improvement. The commercialization success rate of the entire public technologies transferred was 15.1% which was relatively higher compared to general enterprises' commercialization success rate at 6.8% (Park et al., 2011). The state 'in progress' in which success or failure is not yet certain accounts for 35.0% of the entire cases. The reason for this seems to be the fact that time to market entries or failure is long because public technologies' readiness levels are low.

Table 3 Present state of public research institutes'(29) research fund productivity

Category \ R&D productivity		~-1%	1-3%	3-5%	5%-	Total
Universities	Frequency	9	7			16
	%	56.3%	43.7%			100.0%
Research institute	Frequency	1	7	4	1	13
	%	7.7%	53.8%	30.8%	7.7%	100.0%
Total	Frequency	10	14	4	1	29
	%	34.5%	48.3%	13.8%	3.4%	100.0%

3.2 Research Model and Definition of Variables

3.2.1 Research Model

A research model prepared to verify the research hypotheses presented earlier based on previous studies is as shown in Figure 2. Whereas many studies conducted thus far have been limited to technological innovation activities of individual parties, this study included all suppliers and demanders in the scope of analysis to examine the entire cycles of public technology transfer and commercialization, ranging from public technology development to market entry through transfer to enterprises to pursue differentiation and tried to draw persuasive results by analyzing data on all representative institutes in Korea. Variables were divided into categories of transferred technology commercialization related parties, that is, suppliers, introducers, and intermediaries. The effects of the capacity of individual elements on technology commercialization success were utilized as independent variables and partnership, which corresponds to a relational factor between the parties, was utilized as

Table 4 Present state of commercialization of transferred technologies

Category	success	in progress	Postponed/failure	Total
Number of cases	164	380	543	1,087
Ratio(%)	15.1	35.0	49.9	100

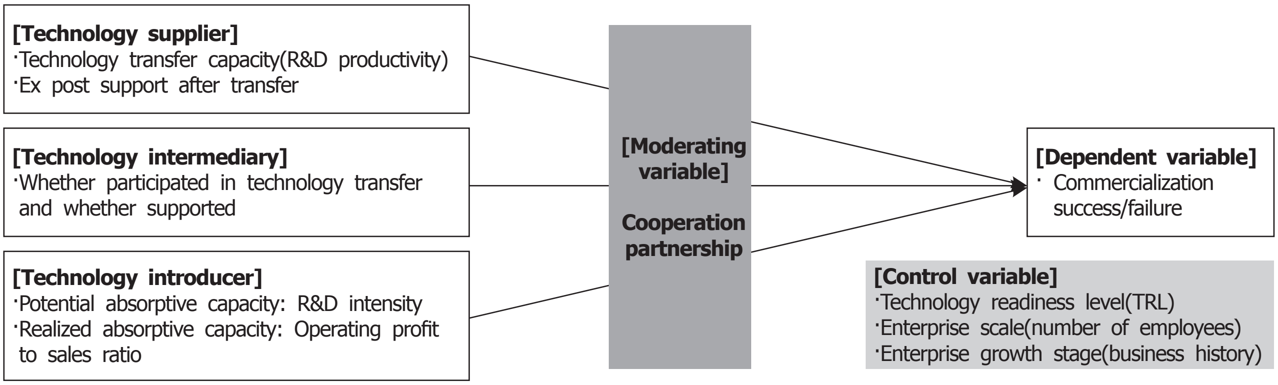

Figure 2 Analysis model

a moderating variable to analyze moderating effects between the capacity of the parties, in particular, the capacity of enterprises and partnership.

3.2.2 Definition of Variables

To test the effects of commercialization party variables that are to be examined in this study, technology readiness levels, enterprise scales, and enterprise growth stages were controlled in the research model. Conflicting study results have been presented for enterprise scales for long. That is, there are arguments indicating that the larger enterprise scales are, the more actively technological innovation occurs because abundant resources are held such as research manpower and research and development funds along with the acquisition, management, and utilization of external technology information (Cooper, 1964; Graves & Langowitg, 1993; Simonin, 1997; Becherer et al., 1999) and arguments contrary to the foregoing indicating that more active innovation occurs in smaller enterprises because smaller enterprises can obtain many things through active technology cooperation with external parties since smaller enterprises have limited resources and access to markets (Horowitz et al., 1981; Rothwell et al., 1994; Huizin, 2011). Technology readiness levels were controlled because their effects on transferred technologies' commercialization were considered very large since even public technologies may be diverse in technology readiness levels.

With regard to technology suppliers' technology transfer capacity, the results of studies that utilized diverse variables such as internal factors, environmental factors, and relational factors were presented in section 1. Since the scope of analysis was limited to PRI & Us, previous studies utilized papers and patents (Di Gregorio, 2003; Santoro, 2002), the number of cases of technology transfer and the amount of technology licensing revenue (Markman, 2005; Powers, 2003), or the number of cases of business founding (Lockett & Wright, 2005) as dependent variables. However, in the case of this study, since the scope of analysis includes transferred technologies' commercialization success, various factors identified through studies conducted thus far were integrated to select R&D productivity that means the ratio of earned technology licensing revenue to input research funds as an indicator that can represent PRI & Us' technology transfer capacity; provided that, to reduce the variability of annual technology licensing revenues resulting from large technology transfer cases occurring irregularly, data accumulated for three years were utilized. In addition, attempts were made to grasp the effects of whether or not researchers provide ex post facto support as supplying institutions' transfer capacity such as active technology guidance after the execution of contracts so that technologies can be actually transferred to enterprises instead of just making technology transfer contracts on commercialization performance.

Enterprises' technology absorptive capacities were divided into potential absorptive capacity and realized absorptive capacity (Jansen, 2005). Since enterprises'

R&D investments are one of essential components for improving the ability to understand, assimilate, and internalize external knowledge (Zhao, 2005), R&D intensity (the ratio of the amount of R&D investments to sales) were regarded as a variable that represents potential absorptive capacity. Since realized absorptive capacity refers to commercial applications of acquired external knowledge (Lane & Lubatkin, 1998), the operating profit to sales ratios obtained through enterprises' own activities were regarded as a variable that represents realized absorptive capacity. Whether intermediaries participate in the process of technology transfer to perform supporting works such as finding out technologies and demanding enterprises, marketing, negotiations, and contracts was utilized as a dummy variable to figure out the effect of intermediary participation on commercialization success. In the case of partnership between cooperating institutions (Lado, 2008) as a variable that moderates effects on the performance of technology transfer between suppliers and demanders, the result of checking of whether the enterprise had experience of technology transfer with the relevant PRI & Us in the past was utilized as a dummy variable.

Finally, determining whether commercialization was successful or not was already pointed out as a very difficult study although diverse forms of measuring methods were utilized (Hamel, 1991; Khanna, 1998, Laursen, 2006). Commercialization success might be measured utilizing financial indicators such as sales, growth rates, and profitability in some cases (Lumpkin & Dess, 1996; Bantel, 1998) and be qualitatively measured using the number of new products launched and commercialization speed (Zahra & Nielsen, 2002; Ledwith & Coughlan, 2005). In this study, commercialization success was simplified and measured utilizing the results of intuitive responses of respondents to questionnaires asking whether original purposes of technology introduction have been achieved such as sales, cost saving, and technological power internalization. The definition and details of the aforementioned variables are as shown in Table 5 set forth below.

3.2.3 Analysis Method

In the case of the analysis model to be used for estimation in this study, applying general standard linear models is not desirable. Since the dependent variables use dichotomous nominal scales composed of 'success(1)', 'failure(0)', the assumption of normality is not satisfied. Therefore, if standard linear models

Table 5 Operational definition of the variable and evaluation indexes

Variable name		Operational variable	Proxy variable
Control variable	Technology readiness level	technology Readiness Level: level 1(experiment)-level 9 (commercialization)	ordinal scale (1-9)
	Enterprise scale	natural logarithm of the number of employees	ratio scale
	Business history	natural logarithm of year of survey (2012) -year of establishment value	ratio scale
Independent variable	Technology transfer capacity	three-year (`09-`11) average research fund productivity (%) = technology licensing revenue/research and development costs	ratio scale
	Supplier ex post facto support	whether supplying institute provided ex post facto support after technology transfer	yes(1), no(0)
	Potential absorptive capacity	R&D investment concentration ratio (%) in the previous of technology introduction = R&D investment amount/sales	ratio scale
	Realized absorptive capacity	operating profit to sales ratio (%) in the previous of technology introduction = operating profit/sales	ratio scale
	Intermediary support	whether intermediaries intervened in technology transfer processes	yes(1), no(0)
Moderating variable	Cooperation partnership	experience of introducing technologies from the relevant public institute before the technology introduction	yes(1), no(0)
Dependent variable	Commercialization success	whether original purposes were achieved such as sales increase and cost saving	success(1), failure(0)

are applied, estimating parameters will be difficult due to inappropriate model setting. Therefore, binomial logistic regression models to fit data to logit curves between 0 and 1 in order to estimate event occurrence were used to conduct analyses.

4. Analysis Result

4.1 Basic Statistics and Correlation Analysis

A total of 686 responses that comprise 'commercializa -tion success' and 'commercialization postponed/failed' excluding 380 cases of 'commercialization in progress' and cases with omissions of responses for some items out of the 1,087 responses in the entire questionnaire survey were finally analyzed. To review basic statistics of the variables, in the case of technology readiness levels, the average is 4.2 which corresponds to the stage of experiments according to technology development stages (baseline→experiment→prototype f abrication→manufacturing→commercialization). This seems to be the level of technologies introduced from PRI & Us recognized from the viewpoint of enterprises. The average value of experience of introduction was 0.44 indicating a little fewer than a half of the enterprises have experience of receiving technologies from PRI & Us in the past. The value of intermediary intervention was below 10% indicating that most technology transfers were made through direct transactions between suppliers and demanders. Therefore, the fact that the roles of intermediaries in the market were insignificant.

Before regression analysis, the Pearson correlation analysis was conducted first to figure out independent variables', control variables', and moderating variables' basic statistics and multicollinearity. The results as shown in Table 6 set forth below were obtained and since the correlations between the variables were not high in general, it was assumed that no multicollinearity existed between independent variables.

4.2 Regression Analysis Result

According to Table 7, Model 1 includes control variables and independent variables, Model 2 verified main effects of moderating variables, and Model 3 verified moderating effects between enterprises' absorptive capacity and moderating variables. With regard of the goodness-of-fit of entire models, the Chi-Square values that show model explanatory power increased toward Model 3 at significance levels below 0.01 and -2logL(deviance) decreased thereby showing increases in the goodness-of-fit of models in general.

According to Model 1 in Table 7, as research institutes' R&D productivity increased, enterprises' commercialization success rates statistically

Table 6 Basic statistics and analysis of correlations between variables

	Mean	S.D	1	2	3	4	5	6	7	8	9
1. Number of employees(person)	1,504.34	8,887.22	1								
2. Business history (year)	16.69	13.07	0.405***	1							
3. Technology readiness level(TRL)	4.20	1.84	0.019	0.078**	1						
4. Technology transfer capacity	3.67	2.62	-0.048	-0.169***	0.004	1					
5. Potential absorptive capacity	20.57	53.05	-0.053	-0.184***	-0.031	0.044	1				
6. Realized absorptive capacity	-3.78	67.89	0.021	0.068**	0.029	0.012	-0.678***	1			
8. Supplier ex post facto support	0.46	0.50	-0.092***	-0.112***	-0.016	0.099***	0.031	-0.018	1		
9. Intermediary support	0.09	0.29	-0.051	-0.055	-0.106***	0.112***	0.010	-0.001	0.232***	1	
7. Cooperation partnership	0.44	0.49	0.064**	0.104***	0.115***	0.121***	-0.056	0.071*	-0.040	-0.012	1

*** significant at 1%; ** significant at 5%* significant at 10%,

Table 7 Results of logistic regression analysis

Variable	Model 1	Model 2	Model 3
Control variable			
Number of employees(log)	-0.225(.076)***	-0.233(0.077)***	-0.215(0.077)***
Business history(log)	0.222(.220)	0.194(0.221)	0.217(0.223)
Readiness level	0.380(.058)***	0.374(0.058)***	0.382(0.058)***
Independent variable			
technology transfer capacity	-0.177(0.041)***	-0.182(0.041)*	-0.178(0.041)***
potential absorptive capacity	0.004(0.002)*	.004(.002)*	0.003(0.002)
realized absorptive capacity	0.001(0.002)	0.000(.002)	0.001(0.002)
supplier ex post facto support	0.611(0.203)***	0.681(0.204)***	0.566(0.206)***
intermediary support	-1.088(0.425)**	-1.078(0.426)**	-1.088(0.431)**
Moderating variables' main effect			
cooperation partnership		0.410(0.205)**	0.144(0.253)
Moderating variables' moderating effect			
potential absorptive capacity×cooperation partnership			0.012(0.007)*
realized absorptive capacity×cooperation partnership			-0.003(0.008)
N	684	684	684
-2logL	633.346	629.348	623.731
Nagelkerke R2	0.217	0.225	0.235
Chi-squared	106.024	110.022***	115.639***
Correct classification %	80.2	79.8	80.1

*** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are in parentheses.

significantly decreased. That is, despite that PRI & Us were earning relatively large amounts of technology licensing fees from enterprises through the establishment of effective technology transfer processes and active support activities of TLOs, etc,, the situation had negative effects on enterprises' commercialization success. Therefore, the initial Hypotheses 1 was dismissed. However, the effects of researchers additional effort after technology transfer such as ex post facto support for complete teaching of technologies on enterprises' commercialization success were shown to be statistically significant in Model 1. Therefore, Hypotheses 2 was adopted.

Enterprises' technology-absorptive capacity showed statistically different results. In Model 1, whereas potential absorptive capacity (R&D intensity) and enterprises' performance showed statistically weak positive (+) correlations, realized absorptive capacity(operating profit to sales ratio) did not showed significant correlations with enterprises' performance. Therefore, Hypotheses 3-1 was supported and Hypotheses 3-2 was dismissed. That is, it was proved that public technologies introduced brought about effective performance to enterprises that prepared technologies rather than contributing to enterprises' performance in a short time.

In cases where technologies were transferred through the intervention of diverse commercialization intermediary organizations such as technology transfer intermediaries, negative effects on enterprises' commercialization success were identified. (Model 1) Therefore, Hypotheses 4 was dismissed.

The main effect of experience of introduction of technologies from PRI & Us in the past on enterprises' commercialization success was identified to be significant through Model 2. Moderating effects between enterprises' commercialization success and enterprises' potential absorptive capacity (R&D intensity) were significant in Model 3 but moderating effects between enterprises' commercialization success and realized absorptive capacity(operating profit to sales ratio) were identified not statistically significant. Therefore, in the case of Hypotheses 5, only the main effect and moderating effects with potential absorptive capacity could be adopted.

5. Conclusion

In this study, the determinants of technology commercialization that were transferred from PRI & Us were examined. This study can be said to be different from previous studies and meaningful in that, while many previous studies have been conducted by analyzing data on PRI & Us from the viewpoint of technology transfer performance, this study expanded the subjects of analysis to include enterprises that introduced public technologies and analyzed whether the transferred technologies were actually made into products and successfully commercialized utilizing factors such as suppliers' technology transfer capacity, enterprises' absorptive capacity, mutual cooperation partnership, and transfer intermediaries' intervention effects.

Unlike initial expectations, even when universities' and research institutes' technology transfer capacities (=R&D productivity) were high, transferred technologies' commercialization success was not affected at all. That is, although PRI & Us' licensing revenues were increasing through efforts for effective technology transfer system such as establishing organized processes and increasing manpower in TLO, enterprises' actual commercialization success was not promoted. This results should be reviewed in terms of the technology licensing contract system and practice in government R&D projects in Korea. That is, because technology licensing contract have been institutionalized to be called at specified fixed ratios of the amounts of the government's R&D investments, in the case of technology transfer of the government R&D project outcomes, licensing contracts are made based on the sizes of input funds regardless of transferred technologies' commercialization performance. On reviewing the contents of a survey of the form of technology licensing contract of PRI & Us in 2012, it can be seen that revenues earned as running royalty based contracts are only 9.5% of the entire technology licensing revenues (Korea Institute for Advancement of Technology, 2012 technology transfer commercialization survey analysis data). However, the fixed amount technology licensing contract regulations were amended in 2012 to specify that licensing contracts for the results of joint research with universities or research institutes should be collected according to autonomous contracts with enterprises. Therefore, future changes in progress should be examined. .

However, enterprises that introduce public technologies also want to determine technology licensing fee amounts in advance (=fixed amount licensing fee), rather than dividing profits that may occur in future through current technology licensing contracts in many cases because they do not want future uncertain profit dividends. In particular, larger enterprises show this tendency more clearly. Although this is to be autonomously selected in terms of enterprises' technology introduction strategies, given the low technology commercialization stages despite that the ripple effects of technologies developed by PRI & Us are large, the fact that the effects of researchers' continuous help on commercialization success are very large should be considered. As shown in the results of analysis, the fact that researchers' ex post facto support after technology transfer significantly affect enterprises' commercialization success was verified. That is, technologies are different from products. Due to their implicit nature, for technology transfer to be actually complete, the participation of original technology developers in technology transfer processes is very important. In particular, changes in paradigms are in progress in relation to the responsibility of PRI & Us' researchers who make public goods and deliver the goods to markets. Along with basic research and applied research, active technology transfer and diffusion is socially required. Although many studies and evaluations have been conducted as the importance of PRI & Us' technology transfer was magnified as a result, the scope of technology transfer should be reviewed again now. That is institutional devices should be prepared at the national level so that the scope of technology transfer is expanded from simple technology transfer contracts to effective implementation of commercialization of the technologies through actual transfer of the technologies to relevant enterprises after the contracts to ensure that government's R&D funds input into PRI & Us are connected to actual commercialization performance.

When technology transfer intermediaries participated in technology transfer processes through finding technologies to be transferred and institutes that possess the technologies, technology marketing, and negotiation and contract support activities, negative effects on enterprises' commercialization success were identified through the survey. These organizations began to appear when technology transfer organizations and technologies evaluation organization designation systems were promoted in 2000 through the establishment of the Technology Transfer and Commercialization Promotion Act, and have been making effort to become as parties for technology transfer market by expanding their capacity utilizing some support programs. Causes that can explain the commercialization failure after these intermediaries intervention in transfer processes despite the foregoing may include some environmental factors but more fundamental one is considered to be the intermediaries' poor capacity. That is, small private intermediaries with fewer than 10 employees account for 74.1% of all private intermediaries, new organizations that began mediating work in 2005 or thereafter account for the majority of private intermediaries (Park, 2011), and technology transfer related works performed by them were identified to account for less than 20% of all works performed by them. Based on the results of the 2012 survey of private technology transfer institutions (KIAT) their revenues through technology transfer were only KRW 7 million on average and large part of their sales was directly/indirectly connected to government R&D funds. Eventually, the foregoing showed that the transaction market was not activated through enterprises' voluntary demand for technology transfer and that government-led artificial market support has continued.

Along with enterprises' absorptive capacity, mutual partnership and commercialization success were analyzed and according to the results, potential absorptive capacity (=R&D intensity) and partnership positively affected commercialization success. Since the technologies developed by PRI & Us were not made for certain enterprises (Podolny, 2001). Since they have the nature of public goods, they have been developed for public interests targeting many and unspecified entities. Since the readiness level of developed technologies is relatively lower compared to the R&D outcomes of enterprises that pursue commercialization firsthand, relatively more effort and time are required for introducing enterprises to properly internalize and utilized. Eventually, despite that public technologies have technical excellence, because of their low readiness level and the characteristics that they are universal, enterprises' R&D absorptive capacity is very important for enterprises' commercialization success. Furthermore, since the construction of partnership between enterprises and PRI & Us was identified to be an important factor that would lead to the securing of excellent technologies and even to commercialization success, from the viewpoint of enterprises, rather than utilizing PRI & Us single-shot as R&D partners, effort to exchange knowledge through the formation of continuous relationships is considered necessary.

Based on the above-written analysis results, these authors would like to present several policy proposals for improvement of public technology transfer and commercialization success. First, the technology licensing system should be improved so that PRI & Us' technology transfer performance can be interlocked with enterprises' commercialization success. In fact, researchers' cannot guarantee enterprises' commercialization success. However, in the case of licensing fees received by PRI & Us through technology transfer, collecting them based on the act of transfer itself should be reviewed again. Eventually, institutional devices are necessary that can induce increases in the ratio of running-royalty fee collection instead of fixed amount licensing fees occurring at the moment of technology transfer. In addition, transfer processes should be improved so that the scope of technology transfer can be expanded to include technology teaching and technology transfer contracts can be concluded through written technology transfer confirmation when the enterprise has finally learned the technology. By supporting even digestion and absorption by enterprises instead of simply transferring technologies though such expansion of current technology fees and the scope of the concept of technology transfer, not only the rate of commercialization success of transferred technologies can be enhanced but also the ecosystem of technology transfer and commercialization with virtuous circles can be constructed since incentives will be given to researchers through the foregoing.

The next issue is regarding the dispersed capacities of diverse technology transfer intermediaries. To date, more than 10 years has passed after the beginning of the government's active transferred technology commercialization fostering policies. The situation where technology transactions cannot spontaneously grow in the market in spite of the long period of time should be recognized and the government's effort to continuously expand and develop the market with government intervention should be reviewed again. The effort to expand infrastructures for technology transfer commercialization through increased investments in the areas supported by the government for market activation such as the provision of infrastructures having the attributes of public goods, that is, systematic collection, processing, and provision of national R&D information, the standardization of forms necessary for various transactions such as contracts and marketing, the preparation of stages for periodic networking to expand partnership between transfer/commercialization parties, and the expansion of technology management related education programs. However, the reduction or abolition of various attempts of the government to first compose transaction markets, that is, various certification systems for technology transaction institutions, technology evaluation institutions, technology transfer experts, dedicated commercialization companies, etc. and programs that directly support commercialization parties to activate their operations should be positively reviewed.

Several limitations of this study are as follows. It is true that the characteristics of transferred technology commercialization are very complicated. Therefore, the depth of variables is required along with the expansion of diverse variables because explaining phenomena through several variables. In terms of the expansion of variables, factors for public technology commercialization success may vary with exogeneous variables in industrial environments, that is, diverse characteristics of industries. In addition, the fact that the depth of variable was not fragmented further for measurement is regretful. That is, if the depth of variables such as the strength of partnership, the intensity of commercialization success, and the intensity of researchers' ex post facto support were fragmented further for the approach, more diverse results might have been drawn.

Nevertheless, this study can be considered meaningful in that it widely analyzed data on 1,087 cases of technology transfers from PRI & Us over the last 5 years in order to expand the scope of previous studies limited to PRI & Us' technology transfer and analyze actually how public technologies are actually connected to enterprises' commercialization success and what the affects on commercialization success are. Despite some limitations of the study, these authors hope that public technology commercialization in Korea will be activated further through the enhancement of technology transfer commercialization parties' mind regarding transferred technology commercialization and effort to construct mutual partnership along with the government's policy improvement through the results of this study.

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Analysis of Performance-Improving Factors of International R&D Collaborations Conducted by Universities in South Korea

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Abstract

Hence the recent global R&D trend towards large-scale, interdisciplinary co-work and technological development within a single country or company has been becoming increasingly difficult. The world has become a single enormous market, as in the case of the patent dispute between Apple and Samsung, and, consequently, there is intense competition in the field of new technology development.

In view of these changes, South Korea, along with other major developed countries, is emphasizing the need for international R&D collaboration on S&T policy. However, recent OECD reports show that the indices related to the S&T internationalization of South Korea have remained at a low level compared to the OECD average. Therefore, constant efforts to enhance S&T globalization and the performance of international R&D collaboration are necessary in South Korea.

In this study, given that in South Korean universities not only conduct most international collaborations with government-funded R&D projects (74.6%) but also train and produce high-quality R&D manpower, an analysis was conducted on the performance-creating factors for international collaboration on government-funded R&D projects conducted by universities based on such outputs as papers and patents, as well as on the performance-improving factors concerning output-produced international R&D collaborations. In conclusion, implications for performance enhancement were suggested through a comparison of these factors with those discussed in previous studies.

On the other hand, a survey of research outputs other than papers and patents, and performance-influencing factors used by researchers with experience of international collaboration in the R&D field, was conducted and the results analyzed. As a result, additional performance evaluating indicators were also suggested to be considered for performance enhancement, because they were thought to connote the practical characteristics of international R&D collaboration.

Keywords: Performance-improving Factor, International R&D Collaboration, Universities

1. Introduction

Due to the ever increasing trend towards the development of large-scale interdisciplinary sciences and technologies (S&T), technological development by a single nation or company is becoming increasingly difficult. Accordingly, the world has become a huge single market, and the struggle for technology development is becoming fiercer, as can be seen in the recent dispute between Samsung and Apple over patents. Amid such environmental changes, the S&T paradigm is changing from one of closed-type R&D to one of shared-type technology R&D involving joint R&D between nations and R&D collaboration networks

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between various institutes (Hong, 2010).

With these changes in the S&T paradigm, major nations are emphasizing the need to bolster international R&D collaboration in their S&T policies, and South Korea has formulated and is pushing ahead with national policies for S&T internationalization and the activation of international R&D collaboration. However, given the recent report that South Korea's S&T internationalization is at the lowest level among the OECD member nations, its S&T globalization level needs to be enhanced (NSTC, 2011).

In fact, as shown in Table 1, of all the South Korean government's R&D projects, international collaboration projects numbered just 1,308 (366.12 USD million) in 2011, accounting for only 3.1% (2.8%) of the grand total of 41,619 projects (12,906.16 USD million). The rate of increase has remained at a low level since 2008 (around 1%), attesting to the slow progress of international R&D collaboration.

On the other hand, as a result of comparing the research outputs (in terms of paper and patent productivity) of international R&D collaboration and total government-funded R&D projects, it was confirmed that, although the government's R&D projects have not boosted international collaboration significantly, the productivity of international R&D collaboration was far higher than that of the total number of R&D projects, as shown in Table 2. International R&D collaborations produced about one more SCI paper and patent application/registration per research project than the total R&D projects in 2008 and 2009, while the difference declined in 2010. For every one million USD invested in research project budgets, international R&D collaborations produced a higher number of SCI papers and patent applications and registrations than the total R&D projects did, and the difference continued to increase.

An examination of international R&D collaboration by research organization revealed that paper output was higher for universities and government-funded research institutes (GRIs), while patent output was higher for large companies and GRIs, as shown in Table 3. In 2008, the number of papers per project was higher for GRIs, whereas, from 2009, the number

Table 1 Government-funded international R&D collaboration in South Korea

(US million* / No.)

Category	2008		2009		2010		2011	
	Total R&D	Intl. collaboration	Total R&D	Intl. collaboration	Total R&D	Intl. collaboration	Total R&D	Intl. collaboration
Budget (portion)	9,659.02	300.10 (3.1%)	9,279.30	332.12 (3.5%)	11,358.50	385.74 (3.4%)	12,906.16	366.12 (2.8%)
No. of projects (portion)	37,449	1,068 (2.9%)	39,471	1,020 (2.6%)	39,179	1,192 (3.0%)	41,619	1,308 (3.1%)

* Converted from KRW according to the yearly average exchange rate for the corresponding year (www.irs.org)
※ Taken from the government R&D project survey and analysis report (2008~2011)

Table 2 Outputs: total number of R&D projects vs. international R&D collaboration projects

Category	2008		2009		2010	
	Total government R&D	international collaboration	Total government R&D	international collaboration	Total government R&D	international collaboration
No. of papers (per project) (per million USD*)	17,635 (0.47) (1.84)	1,517.6 (1.42) (2.06)	19,519 (0.49) (2.12)	2,542.4 (2.46) (3.99)	17,486 (0.45) (1.57)	1,936.4 (1.98) (5.55)
Total number of patents (per project) (per million USD*)	16,285 (0.43) (1.72)	1,505.6 (1.41) (2.06)	14,314 (0.36) (1.60)	1,750.3 (1.69) (2.66)	16419 (0.42) (1.45)	1,214.4 (1.24) (3.45)

* Converted from KRW according to the yearly average exchange rate for the corresponding year (www.irs.org)
※ SCI-level papers, i.e. total number of domestic and foreign-registered and filed patents.

Table 3 International R&D collaboration outputs by research organization

Organization	2008			2009			2010		
	Paper (per project) (per million USD*)	Patent (per project) (per million USD*)	No. of projects	Paper (per project) (per million USD*)	Patent (per project) (per million USD*)	No. of projects	Paper (per project) (per million USD*)	Patent (per project) (per million USD*)	No. of projects
National and public research institutes	59.8 (0.62) (2.29)	28.8 (0.3) (1.15)	96	38.2 (1.16) (5.32)	9.8 (0.30) (1.33)	33	5.5 (0.79) (4.34)	3.4 (0.49) (2.65)	7
Large companies	8.3 (0.35) (0.11)	70 (2.92) (1.38)	24	18 (0.55) (0.13)	8 (0.24) (0.13)	33	4.7 (0.36) (0.12)	37 (2.85) (1.09)	13
Universities	798 (1.52) (4.93)	557.6 (1.06) (3.44)	526	1719.6 (3.10) (10.38)	1028.3 (1.85) (6.25)	555	1652.2 (2.27) (8.08)	840.5 (1.15) (4.10)	729
SMEs	3.7 (0.06) (0.23)	59.1 (0.88) (3.33)	67	5.5 (0.06) (0.27)	101.5 (1.07) (3.86)	95	8.9 (0.12) (0.36)	86.6 (1.15) (3.62)	75
GRIs	608.9 (1.89) (1.38)	762.1 (2.36) (1.72)	323	707.6 (2.47) (2.26)	574.2 (2.00) (1.73)	287	259.6 (1.94) (3.86)	230.7 (1.72) (3.38)	134
Others	38.9 (1.50) (1.15)	28 (1.08) (0.80)	26	53.5 (2.33) (2.53)	28.5 (1.24) (1.33)	23	5.5 (0.31) (0.36)	16.2 (0.9) (1.21)	18
No. of output-reported projects*	-	-	1,062	-	-	1,026	-	-	976

* Converted from KRW according to the yearly average exchange rate for the corresponding year (www.irs.org)
※ Non-reported outputs were excluded, causing a statistical difference.

was highest for universities, which also had a higher number of patent applications and registrations. Also, the number of papers and patents per million USD for universities were considerably higher than that for any other organization from 2008 to 2011, suggesting that universities were outstanding in terms of the research outputs obtained from international R&D collaboration.

As seen above, even when the statistics are used for nothing more than a simple inter-group comparison, they suggest that the activation of international R&D collaboration from government R&D projects and the promotion of research performance can be an effective way of enhancing South Korea's S&T globalization. Hence, this study examined the research outputs derived from government R&D projects involving international R&D collaboration in order to analyze and determine the factors which improve performance. In particular, together with the factors which can create performance as regards paper and patent outputs, a number of performance-improving factors were analyzed to determine how research output can be enhanced for projects aiming for paper and patent outputs. Thus, this paper discusses determinants of activation of international R&D collaboration and performance-improving factors in South Korea. Furthermore, in addition to papers and patents, the output and the determinants of such performance, deemed important by researchers, are surveyed to propose performance-evaluating indicators for international R&D collaboration.

2. Target of Analysis : University-Conducted International R&D Collaboration

With the aim of analyzing S&T, this study analyzed the details of international R&D collaboration on government R&D projects reported in the NTIS[1)] over three years (2008~2010) up to August 2012, excluding

1) N

the humanities and social science sectors.

A review of international collaboration research projects by research organization reveals that universities steadily increased their share, as shown in Figure 1, accounting for 74.6% in 2010. This suggests that, to boost their international competitive edge, universities have been pushing ahead with internationalization efforts, and that universities with a shortage of research infrastructures appear to be pursuing international collaboration in order to use overseas infrastructures. On the other hand, the share of other research organizations has declined, suggesting that universities are leading the way in terms of international collaboration.

Participation in international collaboration, based on the entry criteria of the NTIS Survey-Analysis Data, as shown in Table 4, was classified into six types[2)], revealing that collaboration was focused on international agreements and the attraction of foreign researchers, and that a growing number of international agreements and researchers were being sent overseas, while information exchange had declined. Of these, the government's international R&D collaboration projects conducted by universities also involved the attraction of many foreign researchers, the dispatch of a growing number of researchers overseas, and the signing of international agreements, showing a similar trend in the overall participation types.

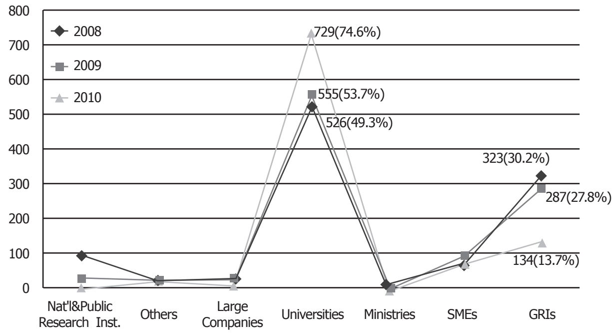


Figure 1 Classification of international collaboration research projects by carrier

Table 4 Number. of international collaborations by participation type

(USD million, no. of cases)

Participation type	2008		2009		2010	
	Total	University conducted	Total	University conducted	Total	University conducted
International agreement	388 (17.3%)	173 (14.5%)	368 (16.4%)	180 (13.5%)	520 (19.9%)	228 (13.9%)
Technical training	54 (2.4%)	31 (2.6%)	63 (2.8%)	30 (2.2%)	39 (1.5%)	33 (2.0%)
Dispatch of researchers overseas	25 (1.1%)	10 (0.8%)	392 (17.5%)	264 (19.8%)	478 (18.3%)	350 (21.4%)
Attraction of foreign researchers	758 (33.7%)	597 (50.0%)	896 (40.0%)	734 (55.0%)	987 (37.8%)	833 (50.9%)
Commissioned project	288 (12.8%)	45 (3.8%)	276 (12.3%)	45 (3.4%)	302 (11.6%)	57 (3.5%)
Information exchanges	735 (32.7%)	337 (28.2%)	247 (11.0%)	81 (6.1%)	283 (10.8%)	136 (8.3%)
Total	2,248	1,193	2,242	1,334	2,609	1,637

* Converted from KRW according to the yearly average exchange rate for the corresponding year (www.irs.org)

1) National Science & Technology Information Service

2) Based on the entry criteria of the 'NTIS Survey-Analysis Data', international collaboration participation types

① International agreements: Concluding international agreements with foreign research institutes for R&D collaboration

② Technical training: Sending domestic researchers to overseas research institutes, etc. for technical training for over 15 days

③ Dispatch of researchers overseas: Dispatch of domestic researchers (including students on masters and Ph.D. courses) to foreign research institutes for joint R&D collaboration for over 3 months.

④ Attraction of foreign researchers: Foreign researchers participating in joint R&D collaboration at domestic institutes, etc.

⑤ Commissioned project: Commissioning of parts of R&D projects to foreign research institutes

⑥ Information exchange: Exchange of information with and seeking advice from foreign research institutes for the purpose of R&D

Thus, this study examined international R&D collaboration by universities which, in carrying out government-funded R&D projects in South Korea, conduct the most international collaborations (74.6%, excluding the humanities and social science sectors), and which produce significant research performances, in a bid to analyze the determinants of performance creation and improvement.

3. Data and Method of Analysis

3.1 Differentiation from Previous Studies

According to general research, performance-creating factors include the size of the project budget, the number and research capabilities of participating researchers, and the research period. According to many studies, in general R&D projects, the size of a project budget is an influential factor, but it may or may not influence performance improvement (Grimaldi & Tunzelmann, 2003; Choe, 2007; Michael Schwartz et al., 2010; Jang, 2010; Kim, 2010; Choe et al., 2011; Ryu, 2011; Kim, 2012). The number of participating researchers may also either influence performance enhancement or not (Grimaldi & Tunzelmann, 2003; Choe, 2007; Kim, 2012), while the research capabilities of the participating researchers, and the research period have effects on performance improvement (Choe, 2007; An, 2009; Choe et al., 2011; Ryu, 2011; Kim, 2011; Gwon, 2012; Kim, 2012).

In simple collaboration research projects, performance-influencing factors such as experience of collaboration on joint technology development, etc., frequency of contact and depth of communication with counterpart institutes, and the level of mutual trust were also studied. Collaboration experience, frequency of contact with counterpart institutes, and the level of mutual trust all had effects on performance improvement (O, 2004; An, 2009; Yang et al., 2010; Kim, 2011), whereas communication had significant effects or no effects at all (O, 2004; Kim, 2004; An, 2009). Regarding corporate business performance, Ryu (2011) revealed that corporate network size has an influence on performance improvement.

On the other hand, very little research has been conducted on performance-improving factors with regard to international R&D collaboration. Choe (2007) revealed that joint research with foreign researchers produces higher productivity compared with single-party research and joint industrial research, while Kim (2010) revealed that the greater the number of overseas network degree, the more positive effect it had on research performance. Kim (2012) also reported that researchers' human networks influence the writing of international joint papers. Regarding corporate performance, Kim (2006) reported that the diversification of overseas network collaboration does not necessarily produce positive results.

In reviewing previous studies on the performance-influencing factors of international R&D collaboration, although based on empirical data, only an analysis of the performance-creating factors was carried out, and this was based only on research organizations or R&D programs, thereby limiting the scope of the research. Thus, this study sets analysis units based on projects, and confirms the performance-improving factors of international collaboration on government-funded R&D projects that produced research outputs, papers or patents.

3.2 Analysis Model

This study aims to confirm the performance-improving factors of international collaborations under government-funded R&D projects. Thus, the analysis model used in this study includes 'frequency of international collaboration,' which was used as a performance-influencing factor in Kim study (2010), and has been modified from 'degree of exchange' and adjusted to research projects for this study. Two further performance-influencing factors, namely 'international collaboration participation type' and 'continuity of international collaboration,' have been added to the analysis model, thus enabling the analysis of research projects.

Also, given that certain research projects were under way, the 'related research year-period,' which was measurable based on the research projects rather than on the total research period, was newly added to the analysis model as a control variable.

The dependent variables are 'research performance', which targets papers and patents derived from S&T performance, as defined Article 2, Section 8 of the Act on Performance Evaluation, and Performance Management of R&D Programs, etc.

A diagram of the analysis model is shown in Figure 2. Logistic regression analysis and multi- regression analysis are used as the analysis methods.

3.3 Gathering of Data

This study analyzed the data of government-funded R&D projects, which were surveyed and analyzed each year by the government, according to the Master Act for S&T - Article 12 (Survey, Analysis and Evaluation of Government R&D Projects). These data are entered into the NTIS system after verification by KISTEP, and provided to the general public.

Such NTIS data (as of August 2012) entered over the past three years (2008-2010) were analyzed, with the limitation to the universities-conducted international collaboration research projects from the government-funded R&D projects.

Of the total of 1,394 such research projects, 1,024 were selected and analyzed, while 319 research projects with unclear research outputs, as well as 51 research projects conducted by research centers and project centers, and those based on the joint use of equipment with large-scale manpower and budget, were excluded so as to avoid any distortion of the statistics (continuous research projects were determined as one project).

As shown in Figure 3, the data showed a skewed distribution, with a pattern showing a high frequency of "0", and a tilt in one direction. Thus, the performance-creating factors and the performance-improving factors were analyzed separately; "0" was included in determining the performance-creating factors, but excluded in determining the performance-improving factors, as explained below in Section 3.4.

3.4 Method of Analysis

To confirm the performance-creating factors, logistic regression analysis, which is effective in identifying useful covariance for the prediction of whether specific events occur, was applied in this study. The dependent variable concerns the creation or non-creation of

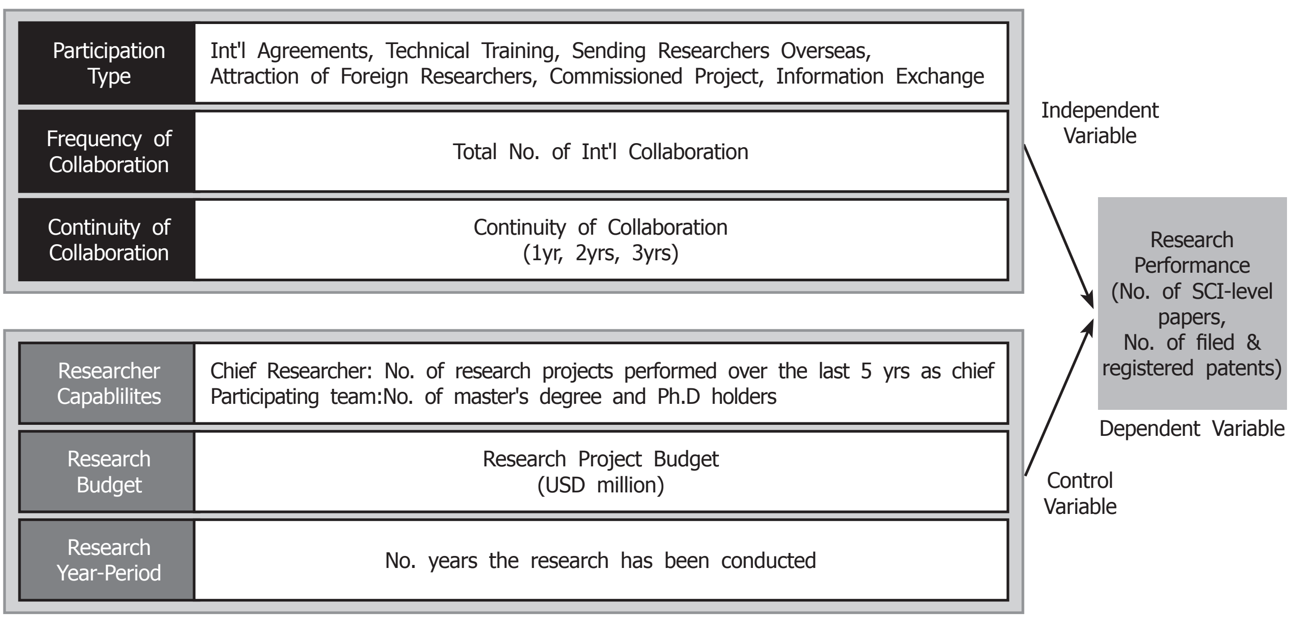


Figure 2 Empirical analysis model

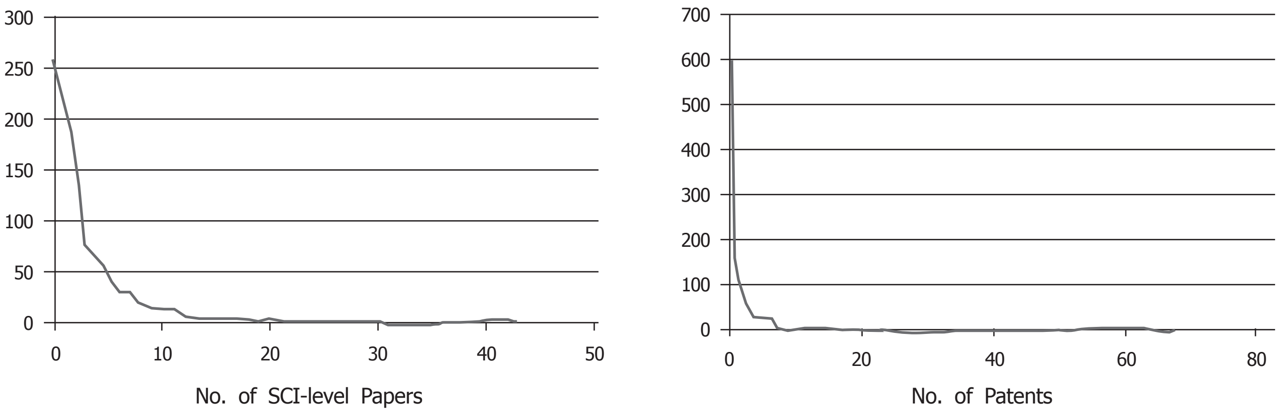


Figure 3 Distribution of research outputs

research outputs, thus allowing the probability concept (p: probability of research output creation) to be applied; and, since there are several independent variables and control variables, the basic regression analysis model was used as per equation 1.

To confirm the performance-improving factors with regard to the research projects that produced research outputs, multi-regression analysis, which is generally used when there are several independent variables influencing the dependent variable of continuous data, was conducted. Since the dependent variable is the research outputs of continuous data and there are several independent variables and control variables, the basic-multi regression analysis model was used as per equation 2. However, since the data showed a skewed distribution, to meet the regression analysis assumption, they were analyzed using the analysis model with the natural logarithm as the dependent variable, as expressed in equation 3.

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \quad (1)$$

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \quad (2)$$

$$\ln(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \quad (3)$$

3.5 Measurement of Variables

The independent variables include 'international collaboration participation type', 'frequency of collaboration', and 'continuity of collaboration'. These data were acquired from the NTIS survey-analysis data related to international research collaboration. International collaboration participation type, as shown in Chapter 2, can be classified into six types, and the number of collaborations carried out for each participation type was measured to analyze the effect of collaboration type on research output. For instance, there could be two cases of technical training and three cases of information exchange conducted within a research project, and such information on each project was arranged into a database. The frequency of international collaboration was determined by adding up the number of the six participation types in each research project. International collaboration continuity was determined by measuring whether the international R&D collaborations were conducted sporadically for a year, or continually over 2~3 years during the 3-year period (2008-2010) considered in this study.

The control variables include 'research budget', 'researcher capabilities', and 'research year-period'. These data were acquired from the NTIS survey-analysis data. 'Research budget size' was determined by measuring the amount of government funds invested in each research project. Since the chief researcher of a government-funded R&D project is selected by competition, 'chief researcher's ability' was measured according to the number of government R&D projects led by a chief researcher over the past five years. 'Participating researchers' research ability' was measured by totaling the number of masters and Ph.D. holders participating in each research project.

'Research year-period' was determined by measuring the number of years into the research since project start, from the point where international collaboration was last conducted. Through examining this, the effect of research project development according to its stage can be analyzed.

The dependent variable, 'research performance', was determined by measuring the number of SCI-level papers published and the number of patent applications and registrations deriving from each research project. 'NTIS data related to research output' reflects the contribution ratio of the related research projects, and therefore is considered as a more appropriate index than the simple number of research outputs.

4. Results of Analysis

4.1 Factors Influencing the Paper Output of International R&D Collaborations

For the multi-regression analysis of the analysis model, PASW Statistics (SPSS) 18 was used, while the Hosmer and Lemeshow test was used to verify the analysis model. This confirmed that, as shown in Table 5, the significance probability was 0.380, which is greater than 0.05, suggesting that the analysis model was suitable. The Negelkerke R2 value, i.e. the explanatory power of the analysis model, as shown in Table 6, was 0.273, suggesting that the analysis model had an explanatory power of 27% regarding the creation of paper outputs.

Table 5 Hosmer and Lemeshow test

Stage	Chi-square	Degree of freedom	Significance probability
1	8.572	8	.380

The regression analysis revealed that, of the control variables, 'research project year-period' and 'chief researcher capability' had a significant effect on paper output, as shown in Table 7. Of the independent variables, the dispatch of researchers overseas had a significant effect on paper output. This suggests that while personal research capabilities are crucial for paper output, research project budget, having an OR (Odds Ratio) of 1.001, would have a small effect on the creation of paper output.

Table 6 Explanation power of the analysis model

Stage	-2 Log likelihood	Cox and Snell R-square	Nagelkerke R-square
1	956.627[2]	.186	.273

Table 7 Results of logistic regression analysis of paper output

	Variables	β*	Significance probability	Exp(B)**
	(Constant)	.086	.915	1.090
Control	Research project year-period	.426	.000	1.531
	Chief researcher capability	.287	.000	1.332
	No. of Masters and Ph.D. holders	-.008	.596	.994
	Research project budget	.001	.029	1.001
Independent	International agreement	0.370	.819	1.038
	Technical training	.191	.515	1.210
	Overseas dispatch	.494	.005	1.639
	Attraction from overseas	.207	.114	1.230
	Commissioned research projects	-.076	.792	.927
	Information exchanges	-.195	.171	.823
	Continuity_2nd year	-.619	.036	.538
	Continuity_3rd year	-.888	.152	.421
	Frequency of collaboration LN	-.201	.572	.818

*Regression coefficient, **Odds ratio(OR)

4.2 Factors Influencing the Patent Output of International R&D Collaborations

The suitability of the analysis model was verified using the Hosmer and Lemeshow test. As shown in Table 8, the significance probability was 0.145, which is greater than 0.05, confirming the suitability of the analysis model. As can be seen in Table 9, the analysis model's explanatory power, namely, Negelkerke R2, was 0.174, indicating that the model has an explanatory power of 17% regarding its ability to identify the creation of patent output.

The regression analysis revealed that, of the control variables, 'chief researcher capabilities' had a significant effect on the creation of patent output, as shown in Table 10. Of the independent variables, 'international agreements' and 'frequency of collaboration' had a positive effect on the creation of patent output. Presumably, international positive collaboration at the institute-level, rather than at the personal-level, can influence the creation of patent output, and the higher the frequency of collaboration, the higher the probability of patent output creation. However, since the various types of international collaboration participation (excluding international agreements) are not significant, and the regression coefficient has a negative direction, it is important to choose appropriate ways of international collaboration. On the other hand, the number of masters and Ph.D. holders participating in the research projects shows an OR of 1.027, suggesting that it would have a small effect on the creation of patent output.

Table 8 Hosmer and Lemeshow test

Stage	Chi-square	Degree of freedom	Significance probability
1	12.131	8	.145

Table 9 Explanatory power of the analysis model

Stage	-2 Log likelihood	Cox and Snell R-square	Nagelkerke R-square
1	1253.813[2]	.129	.174

4.3 Factors that Improve the Paper Output Performance of International R&D Collaborations

The analysis model of the multi-regression analysis that the significance probability of F-statistics was 0.000, implying significance, as shown in Table 11. Meanwhile, the revised R2 value was 0.245, confirming the research model's explanatory power of 25% regarding the improvement of paper output, as

Table 10 Results of logistic regression analysis of patent output creation

Variables		β*	Significance probability	Exp(B)**
	(Constant)	-1.338	.009	.262
Control	Research project year-period	.075	.058	1.078
	Chief researcher capability	.163	.000	1.177
	No. of Masters and Ph.D. holders	.026	.002	1.027
	Research project budget	.000	.486	1.000
Independent	International agreement	.188	.045	1.207
	Technical training	-.090	.635	.914
	Overseas dispatch	-.130	.152	.878
	Attraction from overseas	-.068	.040	.934
	Commissioned research projects	.242	.278	1.273
	Information exchanges	-.111	.164	.895
	Continuity_2nd year	-.136	.522	.873
	Continuity_3rd year	-.168	.609	.845
	Frequency of collaboration LN	.451	.015	1.571

*Regression coefficient, **Odds ratio(OR) shown in Table 12.

The multi-regression analysis revealed that, of the control variables, 'research year-period' and 'number of masters and Ph.D. holders participating in the research projects' had a significant effect on the improvement of paper output, as shown in Table 13. Furthermore, of the independent variables, 'international agreements' also had a significant effect on paper output improvement. This result is consistent with the result of Kim's study (2010), which reported that the sharing of R&D resources and co-work through international agreements had the effect of improving research output, but it is inconsistent with the finding of his study that 'frequency of collaboration' did not have a significant effect on paper output. This suggests that the analysis was based on research projects, presumably allowing many collaboration frequencies to be input into the analysis model, meaning that a greater frequency of collaboration does not necessarily improve paper output. Also, 'research year-period' has a significant effect on improving paper output, meaning that paper output cannot be improved in a short period; while the fact that a positive correlation was found between the 'number of participating masters and PhD holders' and the improvement of paper output was consistent with the result of Ryu's study (2011). Contrary to the authors' expectations, researchers who carried out more government-funded R&D projects as chief researchers produced fewer papers. This suggests that chief researchers' production of papers is influenced not only by their research capability but also by such

Table 11 Significance of the analysis model

Model		Sum of squares	Degree of freedom	Mean square	F	Significance probability
3	Regression model	234.101	13	18.008	19.980	.000
	Residual	673.254	747	.901		
	Total	907.355	760			

Table 12 Explanatory power of the analysis model

Model	R	R-square	Revised R-square	Standard error of measured value	Durbin-Watson
3	.508	.258	.245	.94936	1.970

Table 13 Results of multi-regression analysis of paper output improvement

Variables		Non-standardized coefficient	Standardized coefficient	Significance probability	Multi-co-linearity statistics	
		β*	β*		Common difference	VIF
	(Constant)	.278		.006		
Control	Research year-period	.117	.205	.000	.874	1.144
	Chief researcher capability	-.061	-.095	.003	.968	1.033
	No. of Masters and Ph.D. holders	.010	.202	.000	.423	2.366
	Research project budget	7.491E-5	.052	.261	.460	2.176
Independent	International agreement	.086	.082	.020	.797	1.255
	Technical training	.029	.010	.765	.971	1.030
	Overseas dispatch	.059	.054	.138	.766	1.305
	Attraction from overseas	-.001	-.003	.950	.536	1.867
	Commissioned research projects	.007	.003	.939	.824	1.214
	Information exchanges	-.023	-.023	.506	.852	1.174
	Continuity_2nd year	.160	.062	.122	.621	1.610
	Continuity_3rd year	.120	.034	.430	.520	1.924
	Frequency of collaboration LN	.141	.110	.072	.268	3.737

* Regression coefficient

factors their leadership skills, age, and the burden of research administration.

4.4 Factors that Improve the Patent Output Performance of International R&D Collaborations

The analysis model of the multi-regression analysis revealed that the significance probability of the F-statistics was 0.000, implying significance, as shown in Table 14. Meanwhile, the revised R2 value was 0.225, suggesting that the analysis model has an explanatory power of 23% with regard to the improvement of patent output, as shown in Table 15.

The multi-regression analysis revealed that, of the control variables, 'research year-period' had a significant effect on the improvement of patent output, as shown in Table 16. Furthermore, of the independent variables, 'commissioned research project' also had a significant effect on the improvement of patent output. This is consistent with the results of the study by Choeg et al. (2011) targeting government-funded institutes, but further study should be conducted to identify how commissioned research improves patent output. As with the results of the regression analysis of paper output improvement, 'collaboration frequency' did not have a significant effect on patent output improvement, while 'research project budget size' had the most significant effect. This suggests that, unlike paper output, a huge research project budget for materials and devices is required to generate a good patent output (Choe et al., 2011). One finding of this study, i.e. that the number of participating masters and Ph.D. holders does not have

Table 14 Significance of the analysis model

Model		Sum of squares	Degree of freedom	Mean square	F	Significance probability
3	Regression model	121.956	13	9.381	10.681	.000
	Residual	368.881	420	.878		
	Total	490.837	433			

Table 15 Explanation power of the analysis model

Model	R	R-square	Revised R-square	Standard error of measured value	Durbin-Watson
3	.498	.248	.225	.93717	1.858

Table 16 Results of multi-regression analysis of patent output improvement

Variables		Non-standardized coefficient	Standardized coefficient	Significance probability	Multicollinearity statistics	
		β*	β*		Common difference	VIF
	(Constant)	.256		.066		
Control	Research year-period	.077	.135	.005	.783	1.276
	Chief researcher capability	-.045	-.071	.106	.933	1.072
	No. of Masters and Ph.D. holders	-.004	-.108	.163	.298	3.354
	Research project budget	.001	.373	.000	.313	3.197
Independent	International agreement	.020	.023	.650	.717	1.395
	Technical training	-.155	-.053	.227	.939	1.064
	Overseas dispatch	-.050	-.044	.381	.720	1.389
	Attraction from overseas	.010	.032	.639	.393	2.544
	Commissioned research projects	.295	.142	.004	.759	1.318
	Information exchanges	.012	.015	.754	.775	1.290
	Continuity_2nd year	.251	.103	.058	.608	1.644
	Continuity_3rd year	.270	.087	.138	.519	1.926
	Frequency of collaboration LN	.009	.007	.942	.207	4.827

* Regression coefficient

the effect of improving patent output, differs from the result of Ryu's study (2011), but this is presumably because the analysis in this study only targeted research projects conducted by universities.

4.5 Comparison with the Results of Previous Studies

Unlike previous studies which derived ‘number of participating Ph.D.-holding researchers’, ‘number of international agreements’, ‘international exchange’, and ‘number of domestic and overseas society presentations’ as the factors determining the creation of paper output, this study revealed that ‘research year-period’, ‘chief researcher capabilities’, and ‘number of researchers sent overseas’ influenced the generation of papers as research outputs, while ‘research project budget’ showed only a low correlation therewith. Such factors as ‘number of participating masters and PhD researchers’, and ‘number of international agreements’ influenced the improvement of performance in research projects where research outputs were produced, rather than the creation of paper outputs. In fact, the longer the research year-period, the greater the paper output produced.

Both previous studies and this study revealed that ‘number of international agreements’ and ‘collaboration frequency’ were derived as factors that influence the creation of patent output. In this study, ‘chief researcher capabilities’ also had a significant effect on the creation of patent output. As regards the improvement of patent output, ‘research year-period’ and ‘number of commissioned research projects’ were effective. And, unlike previous studies in which ‘governmental research budget’ had a low correlation with ‘patent output creation’, this study concluded that it had an effect on patent output improvement Table 17.

5. Researchers' Perception of International R&D Collaboration

5.1 Survey Outline

The findings of the empirical analysis have the limitations of being confined to research outputs to such as papers and patents. Thus, on site of the research field, a survey was conducted to identify the types of research outputs that may result from international R&D collaboration, and the factors which contribute to improving performance. The survey targeted the chief researchers of 1,048 international R&D collaborations conducted under government-funded R&D projects during the past three years (2008-2010). Online surveys were also conducted, to which a total of 125 respondents replied.

5.2 Researchers’ Perception of Research Outputs of International R&D Collaborations

The respondents cited the expansion of international

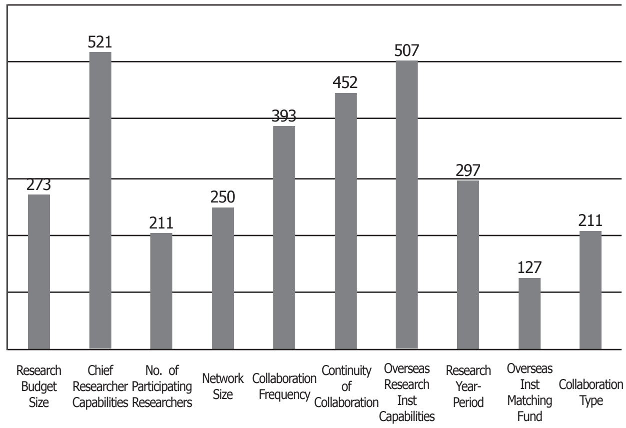
Table 17 Comparative analysis of performance-influencing factors used in previous studies and the present study

Research outputs	Performance	Performance-influencing Factors	
		Previous studies	Present study
Papers	Creation	· Participating Ph.D. holders · International agreements · International exchange ※ Governmental research budget has low correlation	· Research year-period · Chief researcher capabilities · Sending overseas ※ Governmental research budget has low correlation
	Improvement	-	· Research year-period · Participating masters and Ph.D. holders · International agreements
Patents	Creation	· International agreements · International exchange ※ Researcher capabilities have low correlation ※ Governmental research budget has low correlation	· Chief researcher capabilities · International agreements · Collaboration frequency
	Improvement	-	· Research year-period · Research project budget · Commissioned research project

collaboration human networks as the greatest research output obtainable from international R&D collaborations, as shown in Table 18. In addition, they perceived the production of papers, the fostering of domestic researchers and the gathering of overseas technical trends and information as major research outputs. Patents were indicated as the least well-regarded research output, presumably because the survey targeted universities only.

5.3 Researchers' Perception of Factors Influencing the Performance of International R&D Collaborations

As shown in Figure 4, researchers perceived 'chief researcher capabilities' and 'overseas research institute capabilities' as major performance-creating factors with regard to the output of international R&D collaborations, as shown in Table 18. This suggests that in addition to 'domestic researchers' capabilities', it is very important to collaborate with outstanding overseas research institutes. However, unlike the results of our empirical analysis, they perceived the 'continuation of international collaboration' and 'exchange frequency' as very crucial, presumably because it is difficult to build and maintain international collaboration human networks. Also, they did not regard such factors as 'research budget size', 'number of participating researchers' or 'international collaboration participation type' as significant as in the empirical analysis.



* The scores given above represent the degree of contribution to research outputs of international R&D collaborations.[3)]

Figure 4 Factors influencing the performance of international R&D collaborations

6. Conclusion

In a bid to research measures for enhancing the level of South Korea's S&T globalization through the promotion of international R&D collaboration, this study analyzed the outputs of university-conducted international collaboration on government-funded R&D projects. Based on the NTIS-data, the performance-improving factors for papers and patents were analyzed.

Table 18 Researchers' perception of research outputs of international R&D collaborations

Research outputs	No. of respondents	Response (%)
Expansion of international collaboration human networks	110	88.0
Paper output (published and presented in high-level journals)	87	69.6
Domestic research manpower (fostering of graduate school students)	62	49.6
Gathering of overseas technical trends and information	60	48.0
Research capability enhancement compared with before in international collaborations	55	44.0
Establishment of academic research groups with overseas research institutes (researchers)	51	40.8
Introduction and acquisition of overseas advanced technology	50	40.0
DDomestic researchers' entry into international communities such as international organizations, international journals' steering committees, etc.	25	20.0
Patent achievements (patent application and registration)	7	5.6

* Multiple response to survey questions

3) Of the 5-point survey scale, a weighted value (4, 5) was added to 'high' and 'very high,' and the number of multi responses was multiplied by it. Thus, the statistics were totalled.

Analysis proved again that, in the case of the creation of research paper output, the research project budget had a low correlation, while research year-period, the capabilities of the chief researcher, and the dispatch of researchers overseas all had a significant effect. In the case of the generation of patent output, chief researcher capabilities and collaboration frequency had a significant effect.

As a new result of this study, in the case of paper output improvement, research year-period had a significant effect, and in the case of patent output improvement, research year-period, and research project budget, each was found to have a significant effect. In particular, research year-period was derived as a performance-improving factor for both paper and patent outputs.

The analysis results of the 'NTIS Survey-Analysis Data' alone, which targeted only papers and patents, could have limitations of being generalized. However, they will be inducive in considering the major performance-influencing factors depending on achievements aimed at pursuing international R&D collaboration efficiently and strategically.

Meanwhile, field researchers' perceptions were surveyed in order to supplement the limitations of the research data, to identify what field researchers perceive as research achievements (besides papers and patents), and to determine which factors contribute to performance enhancement.

The field survey revealed that researchers perceived, as major achievements, the expansion of international collaboration human networks, the fostering of domestic researchers and the gathering of information on overseas technical trends, while domestic chief researcher capabilities, overseas research institute capabilities, and the continuation and frequency of collaboration were perceived as performance-influencing factors. These may be considered as additional performance-evaluating indicators of international R&D collaboration together with paper and patent outputs.

To further the analysis of international R&D collaboration performances, in addition to papers and patents, diverse performance-evaluating indicators and the corresponding ripple effects on performance should be analyzed.

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Are Science Valleys and Clusters Panacea for a Knowledge Economy? An Investigation on Regional Innovation System (RIS) - Concepts, Theory and Empirical analysis

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Abstract
This research elucidates the concept of regional innovation systems (RIS). It argues that RIS can be a platform to apply classroom innovation ideas into practical context. Key definitions are given and distinctions drawn between national and regional innovation systems. Then, by suggesting to a number of important variables portraying innovation such as education, knowledge transfer, linkage and communications, regulatory quality, cost of doing business, trade openness, R&D expenditure and high-tech export for twenty emerging and developed knowledge based economies from Asia-Pacific, Europe and Latin America are differentiate. We empirically study these features of innovative ability in our sample regions by applying nonparametric robust partial frontier order-m approach in cross-section data analysis collected from the WDI and WCY-2011 dataset for the period 2011. The empirical results highlight that South Korea, Singapore and Malaysia are the frontier region or best practice nations and follower region can emulate the best practice nations by learning their policy implications while building up a successful regional innovation system. Moreover, our study reveals that techno or science valleys and high-tech clusters are one of the panacea for a regional and thus overall economic development.

Keywords: Regional Innovation System, Nonparametric Order-m Analysis, Techno and Science Parks, High-Tech Clusters

1. Introduction

The Regional Innovation System (RIS) concept is recently becoming one of the most powerful policy tools for designing regional development strategies. RIS concept derived from the former concept of National Innovation System (Freeman, 1987; Lundvall, 1992; Nelson & Rosenberg, 1993). National Innovation System (NIS) is often defined as the complex interaction of individuals, institutions and organizations to generate new ideas and innovation for creating wealth of nations. In other words innovation does not always follow a linear path where R&D institutions are producing new ideas and products rather national or regional innovation system indicates that within an innovation system we can define their elements, the interactions, the environment and the frontiers that produce economically useful ideas and components (Lundvall, 1992). The very idea of regional innovation system is to promote innovation culture, competition and competitiveness for regional economic development. The relationship among

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local University, government and business firm are extremely important in the RIS. Particularly, local university can play a predominant role to establish a successful RIS. Universities in general produce, nourish and build skilled human resources for the community by providing tertiary education, training, research facility so on and so forth. Once the a critical mass of skilled human resources has been build in any region, the next step is to create proper employment opportunities for the mass. In this regard establishing a university based science park in local community can play a significant role by creating huge employment opportunities in the form of technology transfer, innovation, spin-offs, R&D activities, business incubators etc in today's world.

Historically, Philipe Cooke is the earliest one to deeply research the regional innovation system, and published the "Regional Innovations Systems: The role of governances in a globalized world", in Cardiff university in 1992, which got much attention in the academe. Another reason why the academes attach importance to the regional innovation system is the huge success of the Silicon Valley in USA; Cheaboll in Korea, the miracle improved the importance of region in the innovation system.

There are many concepts of RIS these years from the different aspect. From a regional point of view, innovation is localized and locally embedded, not placeless, process (Storper, 1997; Malmberg & Maskell, 1997, Cooke, 2003). This view specially emphasizes on the role of proximity, prevailing sets of rules through the process of knowledge creation and diffusion (Lung, 1999; Chen, 2008). Cooke (2003) conceptualized the RIS from social aspect of innovation. In the aspect, he stressed the learning process between different departments within a company, including the department of R&D and University. He also added that bringing innovation from University classroom to commercial showroom depends on education, knowledge transfer, R&D linkage, investment in venture capital and ICT communications. Additionally, there are other arguments, such as Ashim and Isaksen (2002) considered the RIS as the regional clusters which are surrounded by supporting knowledge organizations for instance, universities, research institutes etc. Where Doloreux, 2002) argued that the RIS can conducive to the generation, using the agglomeration concepts and diffusing the knowledge and technology through the interacting interests among formal institutions and other organizations. In short we can say, the theory and concept of RIS raises in late 1990s based on theory of agglomeration economies, cluster theory and national innovation system. In a knowledge-based economy (KBE), speed and first mover advantage are central aspects of industrial competition. Therefore, information, technology and network economy become the necessary conditions for regional industrial development.

Technology-driven competition is technically difficult and links with Higher Education Institute (HEIs) enable local industry to grow early entrée to knowledge-based economies. This will fulfill the objective of local and national government to develop high technology sector as a source of direct and indirect employment opportunities and HEIs are seen as essential to facilitating the growth of the local high technology cluster. This makes universities as most productive source of skill human resources provider and boost local science park development by creating regional employment. Very few countries in the world successfully implement this theory and become the frontier of technology driven development phenomenon. Among them, South Korea, Singapore, Taiwan, Hong Kong, Japan, U.S.A, Germany, U.K, France are most notable countries. Now, the question is how university or research institute driven science parks works in regional innovation system for a particular region or country? Let's consider a local firm innovating a specific kind of automotive components, becomes the partner of a local university engineering department. The partnership is centered on an innovative programme, administered by the university, but funded jointly by the national research council, the regional industry ministry and the firm itself. The university will advertise accordingly for the doctoral candidate to enable a doctoral student to write his or her thesis on a subject of direct relevance to the firm's innovation needs. As one student completes the dissertation and eventually may become an employee of the firm, the programme yields up a new doctoral candidate to solve the next generation of innovation problem. In this way university become the centre of regional innovation hub and part of regional economic resilience. Side by side regulatory quality cost of doing business, trade openness, Gov. R&D expenditure and high-tech export plays a crucial role in regional innovation development. Hence, no matter how we can divide the innovation system, the foundation and the target is the same, both of them, NIS and RIS aim at creating more innovation and speed the regional economic development.

1.1 Statement of the Problem of This Research

A consent to accept RIS as a regional development model seems to have been reached. The question is how to set benchmarking strategy for the follower countries. Which model or policy should follower regions follow: Silicon Valley model, one of the western European success model, model of Asian tigers for instance Singapore, Korea or hybrid Japanese model? A more fundamental question is whether valleys and clusters are a panacea for a nation and a region? For example, Singapore jumped from old and traditional industries to forge manufacturing, but South Korea moved into a mature industry and then tried to move to new industries as catching up regions. South Korea starting to invest mature industries for instance, steel, iron, cement during 1970 and forming a government guided Cheaboll industrial clusters. Samsung, LG, Hyundai are the results of this initiatives afterwards (Nelson, 1993). Another set of difficulties occur in the application of the RIS concept into diverse regional perspective. Therefore building a RIS in follower regions is extremely important and, by applying non-parametric frontier analysis, we can answer the question what follower regions can learn from frontier countries to become more competitive. To solve our questions above we apply frontier approaches in compare to production function approaches. This research paper comprises six major sections. Starting from introduction, problem statement in section 1, section 2 highlights theory, some concepts of RIS and the distinction between NIS and RIS, section 3 explain the variables and descriptive statistics of the sample, section 4 explains the quantitative methodology for empirical analysis of RIS, section 5 discuss the results findings, policy implications and finally section six draws the conclusion and contribution of this research.

2. Theory Behind RIS Concept

RIS concept is based on three main approaches of sources of innovation:

Firstly, models of idea-driven endogenous economic growth theory by Romer (1986) and Jones (1998). According to them economic growth depends on the production of the idea-generating sector of the economy. The rate of new ideas production is a function of the stock of knowledge which implies previous generated ideas and the extent of efforts meaning human and financial capital devoted to the ideas- producing portion of the economy (Furman, 2002).

Secondly, the cluster-based theory of national industrial competitive advantages by Porter (1990) regards the manner in which microeconomic process interact with macroeconomic environment and national institutions to affect the overall level of innovation capacity in an economy. Porter identifies four major drivers in the regional innovation clusters: the quality and specialization of innovation outputs, the context for firms' strategy and rivalry and the demand conditions.

Finally, The National Innovation System (NIS) approach by Nelson (1993), Dosi, 1998, Lundvall (1992) and Edquist (1997) emphasizes the array of national policies, institutions and relationships that drive the nature and extent of country innovative output in RIS (Lim, 2006). This literature highlights the nature of the university system, the extent of intellectual policy protection, the universities and government in R&D performance and funding. Finally a brief distinction between NIS and RIS is given in Table 1.

3. Variables and Sample Statistics

3.1 Data and Variables

Influencing factors of RIS efficiency (Table 2) involve a lot of elements, including demographic structure, ICT infrastructure, Knowledge Transfer between industry-university, firm-level and Government R&D and innovation activities, economic and market size, trade openness, reliance on natural resources, financial structure, market circumstance, and government level. This is conformed to the relevant arguments of NIS or RIS approach and the New Growth Theory (Balzat, 2004). Firm is the most active and important factor in the process of commercialization of innovation which is represents by the output variable high-tech export as % total manufacturing export. The more firms are involved in R&D and innovation activities, the better would the RIS efficiency be. This is according to the arguments of Austrian school and Lundvall where they said free interaction of knowledge can create, disseminate economically useful knowledge that develop the wealth of nation (Afzal & Lawrey, 2012a). Schumpeter named this process as creative destruction of innovation process (ibid).

The age structure of population affects the RIS efficiency as well, since young people are thought to be more creative than the old. ICT infrastructure and

Table 1 The distinction between NIS and RIS

	NIS	RIS
Elements of the system	Mass production economy, process innovation	Knowledge economy, outcome of NIS policy
Inter-firm relationships	Market, emphasis on competition	Network economics, cluster policy
The knowledge infrastructure	Formal R&D laboratories, public R&D funding mostly	University Research, triple helix model using University on top, government funding and focus new product R&D
Institutions of the financial sector	Formal financial sector	Venture capital, informal financial sector
Firm strategy, structure and rivalry	Difficult to start new firms due to government control and formal financial sector	Easy to start new firms and venture capital plays a big role

Source: Lim, (2006), Cooke, (2003)

Table 2 Potential influencing factors for RIS efficiency and their proxy input-output indicators year 2011

Input factors	Proxy Indicators	Abbreviation	Source of variable
Demographic structure	Population ages 15 to 65 (%of total) as labor force	Lab	World Development Indicators (WDI) 2011
ICT infrastructure	Computer users per 1000	CU	World Development Indicators (WDI) 2011
Financial structure	Domestic credit provided by banking sector(% of GDP)	DCP	World Development Indicators (WDI) 2011
Research and Development	R&D expenditure % GDP	RDE	World Development Indicators (WDI) 2011
Education	School enrollment, secondary(%gross)	SE	World Development Indicators (WDI) 2011
Market circumstance	Cost of business start-up procedure(%of GNI per capita)	CBS	World Development Indicators (WDI) 2011
Knowledge transfer**	Knowledge transfer is highly developed between companies and universities	KT	World Competitiveness Yearbook (WCY) 2011
Openness	Trade (%of GDP)	TO	Penn Table version 0.7
Natural Resources endowments	Total natural resources rents(% of GDP)	TNR	World Development Indicators (WDI) 2011
Output indicator			
Economically valuable knowledge creation	High-tech export as % total manufacturing exports	HTE	World Development Indicators (WDI) 2011

** (Updated: MAY 2011, IMD WCY executive survey based on an index from 0 to 10) trade openness would affect the speed and scope of knowledge diffusion and in turn affect RIS efficiency. Furthermore, economic size and degree of openness determine the scale of domestic and international market for firms. The economy of scale and economy of scope are much easier to be achieved in a bigger market, and in turn influence the RIS efficiency indirectly (Balzat, 2004). Moreover, overdependence on nature resources would reduce the innovation capacity and RIS efficiency. Finally we already explained the importance of knowledge transfer between university to industry in the introductory part for successful RIS.

The twenty emerging and developed countries that we have chosen have some characters in common, particularly high university-industry relationship, skilled labor force and high degree of trade openness. The above mention features of RIS presence in our sample economies more or less. Table 3 shows the descriptive statistics of our sample year 2011 (cross-section sample).

4. Quantitative Methodology for Empirical Analysis of RIS

One of our objectives of this research is to do an empirical analysis of RIS model. Most of the existing works on RIS model are based on case study and descriptive technique. Very few of the studies use parametric or non- parametric methods to analyze RIS model in macroeconomic study for comparison on different emerging countries or regions (see Table 2A in Appendix section). Therefore as we mentioned earlier, this study apply non-parametric frontier technique to find out best practice region from our sample. Usually, Data Envelopment Analysis (DEA), Free Disposable Hull, partial frontier analysis technique are used under the umbrella of non-parametric analysis. To know more about DEA technique, we refer to Afzal & Lawrey (2012b, 2012c, 2012d, 2012e, 2012f). In this particular study, we apply unconditional partial order-m frontier approach. Nonparametric approaches have a clear advantage as the estimated functions can take almost any forms. In additionally, real world observations are often difficult to be described in a single dimension or dependent variable. One of the strength of the Non parametric technique is that it allows for an easy handling of multiple input factors as well as multiple innovativeness outcome or output factors. In contrast, the consideration of innovativeness measures as multiple dependent variables particularly is difficult to achieve relying on conventional regression technique (Broekel, 2008).

4.1 Unconditional Order-m Frontier Approaches

We discuss this technique in non- technical way so that common readers can understand the concept. In contrast to the FDH or DEA approach, the idea behind the order-m approach is that instead of evaluating a region's innovation performance with respect to the performance of all other regions/countries; Cazals (2002) propose to compare a region with a randomly drawn (sub-) sample of regions. The sub-sample size has to be specified by the researcher and is denoted by m, giving the name to the procedure. For instance, in our study we have 20 observations; therefore we can choose m= 5, 10, 15, 20 likewise in each step for calculating efficiency of the best practice region. This makes a partial frontier analysis by taking sub samples instead of all observations. Based on these partial

Table 3 Descriptive statistics of the input-output variables

	TO	TNR	SE	KT	RDE	LAB	HTE	DCP	CU	CBS
Mean	116.0	3.4644	88.63	5.38	1.98	67.30	21.71	130.78	565.73	9.2950
Median	88.720	2.343	92.23	5.02	1.97	67.0	16.09	132.8	798.91	3.300
Maximum	409.2	13.14	103.2	7.89	3.96	73.58	67.82	325.9	937.8	56.50
Minimum	29.31	0.0000	63.21	2.90	0.08	60.9	1.9	36.4	39.7	0.0
Std. Dev.	106	3.9	11.9	1.6	1.2	3.2	16.2	66.8	372.4	13.4
Observations	20	20	20	20	20	20	20	20	20	20

frontiers the evaluation of regions/country's' innovation performance are done in an identical style as in the DEA or FDH approach. Cazals (2002) exhibits order-m performance measure contains most of the characteristics of the FDH or DEA model; in addition, because the partial frontier is not enveloping all observations, it is less sensitive to outliers and noise in the data. For more technical details see Daraio and Simar (2007), Simar and Wilson (2006) for robust nonparametric frontier techniques and our appendix 1.1A.

5. Results and Discussion

The result presented in figure 01, 02, 03 and 04 are returned from software command namely FEAR (Frontier Efficiency Analysis with R) described by a Paul W. Wilson (2008). We select twenty emerging and developed knowledge-based economies to find out best practice country/region (see Appendix-1A). We try to demonstrate how empirical analysis can be done in the field of RIS. So far at our knowledge, no significant study has been done using our sample countries and order-m quantitative methodology. The obtained performance measure represents a Monte-Carlo rough calculation with 200 imitations (Cazals et al. 2002). Researchers have shown that in many applications, research conclusions are not really embroidered by particular choices of m, provided the value of m are less than the sample size, n (Simar and Wilson, 2006). To know how to calculate order-m efficiency, see package 'FEAR' by Paul W. Wilson (2010), p-27.

The first spider diagram (Figure 1) represents the order-m=5 partial frontier results where South Korea, Malaysia, Switzerland and Singapore are the best practice region in 2011 compare to other sample countries. The second diagram (Figure 2) exhibits the consecutive results of fig: 01 in the case of m=10. In Figure 3 China along with Asian 3 are appeared as best practice region in the case of m=15. The final Figure 4 show the full frontier analysis and South Korea, Malaysia and Singapore come as best practice frontier region in the RIS context. These 3 ASEAN (Association of South East Asian Countries) countries are consistently efficient in different partial frontier analysis (m=5, 10, 15 and 20). It implies that follower region or inefficient region (efficiency score less than 1) can learn the policy implications from them and apply according to the need of their economy. Our study briefly discussed South Korea, Malaysia and

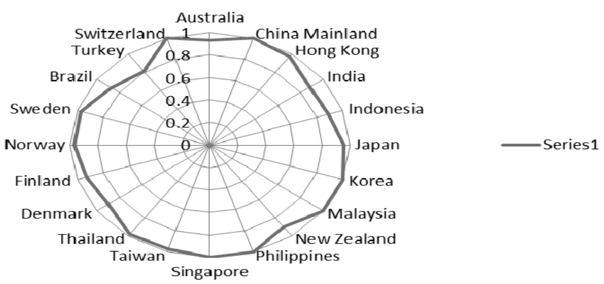

Figure 1 m=5 efficiency results

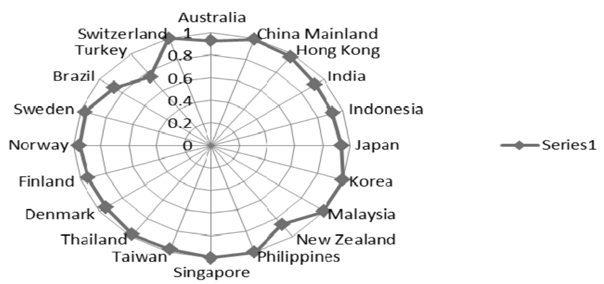

Figure 2 m=10 efficiency results

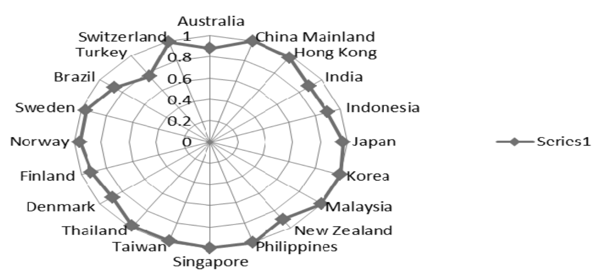

Figure 3 m=15 efficiency results

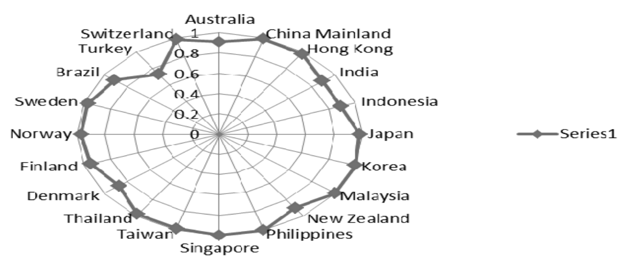

Figure 4 m=20 efficiency results

Singapore's RIS policies in the discussion section. We try to answer how these countries become best practice countries and achieve remarkable success in RIS using potential RIS input-output factors.

5.1 Policy Discussion

At the beginning of our paper, we stated the research problems as which model or policy should follower regions follow? And find out a more fundamental question is whether valleys and clusters are a panacea for a nation and a region? Now from our empirical results we got three best practice countries namely South Korea, Singapore and Malaysia compare to other sample DMUs (countries) in RIS framework. Therefore follower regions can now follow or emulate one of the RIS policies of frontier countries. We shall discuss the key RIS policies taken by these frontier countries and try to give the answer whether science park, high-tech clusters or region are the answer of a successful RIS for a nation. We start with South Korea; in order to boost the regional economy and enhance national competitiveness South Korea has established number of techno parks in the country. The main mission of establishing science or Techno Park is to transforming industry structure; attracting foreign high-techs, creating more jobs, accelerate technological innovation through networking industry, college, university, research center and local government collaboration and increase Korean global competitiveness by regionally specialized high technology. South Korea has high speed internet service, high number of computer users per 1000 population, low cost of doing business, availability of venture capital and well-structured government regulatory policy (Seo, 2006; Nelson, 1993). By using these resources, South Korea has established 16 high-tech parks within 1998-2005 periods and forms a business cluster named Cheaboll. This Cheaboll grouped followed a Japanese Keiretsu cluster model where government deliberately facilitates the business group in order to promote high-tech export (Nelson, 1993). During this short period of time, Korea has achieved remarkable growth of high-tech export (42.9% high-tech export as total manufacturing share, WDI-2010). Establishment of Techno-parks not only increase the high-tech export, but also establish the incubation of business, increase research and development, equipment utilization, pilot production, information sharing and education and training. During 1998-2003, the Korean government first took the initiatives to build institutional network among university, industry and local government and start business incubation of high-tech firms while in the second stage after 2003 until now, government emphasizes regional development by decentralizing Techno-parks to provide a balance national development. Due to this reason South Korean skill labor force, financial infrastructure, ICT network, secondary and tertiary education enrolment has been remarkably up surged (Nelson, 1993).

In line with economic geography theory location factors positively influenced economic development in Singapore. Singapore has leveraged the location advantages in order to drive to technological development to become a regional hub for R&D (Monroe, 2006). In 1980, seeking to emulate the success of science and high-tech clusters like Silicon Valley and Route 128, the government established the Singapore Science Park (SSP). The SSP has since been an integral part of the technological policy that underpins Singapore's economic growth strategy. The primary reason to develop the SSP was to provide and upgrade local infrastructure to attract MNCs and new industries that favor locations with proximity to research institutions for instance universities (Monroe, 2006). In addition the SSP was perceived to serve as an incubator for high-tech industries and be the locus for R&D growth, skilled human resources development, well financial structured, availability of bank credit for new venture, employment generation and overall ensure high-tech driven growth. Venture capital is another important component for successful RIS in Singapore. The growth of new high-tech or medium tech manufacturing firms depends on venture capital availability in Singapore. In reality venture capital follows the innovation initiative (Lim, 2006). Theoretically venture capital is money provided by an outside investor to finance a new, growing or troubled business. The venture capitalist provides the funding knowing that there's a significant risk associated with the company's future profit and cash flow. Capital is invested in exchange for an equity stake in the business rather than given loan, and the investor hopes the investment will yield a better-than-average return. Venture capital typically looks for new and small businesses with a perceived long term growth potential that will result in a large payout for investors. Therefore it plays a vital role for generating finance to back idea driven venture in a knowledge -based economy. In 2011, Singapore scored 6.05 which are the highest in Asia-Pacific region in venture capital easily available for business index (Updated: MAY 2011, IMD WCY executive survey based on an index from 0 to 10).

Unlike Singapore, Malaysia which is one of our best practice regions from our calculation, develop and strengthen their country around the vision 2020, which also serve as the nation's roadmap for economic development. Under this roadmap Malaysia has established number of key institutions that are related ICT growth and high-tech clusters. Malaysian Development Corporation (MDC) one of these key institutions that builds Multimedia Super Corridor (MSC), the country's most prominent science and high-tech cluster. The MSC is Malaysia's flagship science and high-tech research project. It encompasses Kuala Lumpur and five other key infrastructural projects that are PETRONAS Twin Tower, Putrajaya, Cyberjaya- an intelligent research and development city, Technology Park Malaysia and Kuala Lumpur tower. The main objectives of MSC are successfully developed science and high-tech parks in order to 1) raise the level of technological sophistication of local industries, through the promotion of R&D; 2) promote foreign investments, especially in higher value added activities and finally 3) accelerate the transition from a labor intensive to a knowledge-based economy (Nelson, 1993).

Hence, this discussion indicates that all three best practice countries from our calculation have bought into theories from economic geography, NIS and cluster approach that location does matter in RIS context. In other words, valleys and clusters are one of the panaceas for a regional development. These countries are following policy prescription to develop strong regional and national innovation systems by giving emphasize on Techno parks, high-tech clusters. In additionally these parks are leading the overall economic development by creating employment opportunities, increasing skilled human resources, widening market for high-tech products by high degree of trade openness, maintaining well financial structure and spur ICT driven growth. Initially South Korea, Singapore and Malaysia follow the policies of frontier regions in RIS for instance Silicon Valley, Route 128 or Japanese Keiretsu cluster models to build similar kind of strategy in their respective countries (see Appendix 2A, the explanation of common socio-economic factors that encourage these countries to pursue best practice RIS policies). Hence, our methodology and policy discussion also indicates that there is a need of frontier analysis for successful RIS policy implication in the follower nations.

6. Conclusion

In this study, the strategic intellectual and policy concepts of regional innovation systems has been introduced, defined and put to empirical and action-related terms. The new world economic order now tends to privilege the regional as the correlate of global, because of the rise to prominence of globally competitive regional and local industrial high-tech clusters, Techno-Parks and science city. In applying the concept and empirical analysis to twenty developed and emerging knowledge-based nations, it was instructive to note how variable specific regional innovation systems may look. By looking at such variables or dimensions as education enrolment, knowledge transfer between university to industry, trade openness, ICT users, R&D expenditure, high-tech export growth, it is possible to detect more strongly the importance and performance of regional innovation systems. Our research tries to answer the research question as which model or policy should follower regions follow? And find out a more fundamental question is whether valleys and clusters are one of the panaceas for a nation and a region? By addressing this question, this paper contributed to the existing literature in two ways. First, we apply a robust non-parametric unconditional order-m partial frontier approach to identify best practice nations in RIS context. It was argued in the paper that a partial frontier such as order-m approach is more applicable for analyzing regional innovation system framework than traditional FDH (Free Disposable Hull) approach due to the advantage of overcoming outliers or extreme points from the sample. We apply a cross-section approach and use latest dataset from World Development Indicators-2011, World Competitiveness Yearbook-2011 and Penn world table for our analysis. We have found that South Korea, Singapore and Malaysia are the best practice countries among most of the emerging and developed knowledge-based countries from our sample. While doing a policy analysis of these three countries, our study reveals that location does matter for successful regional innovation system. Our findings indicate that investing on Techno-parks, Science city or high-tech clusters certainly generate more employment opportunity, build skilled labor force, well-structured financial systems, encourage venture capital in regional locations, and thus ensure a balanced economic development. By combining the strong policy points of each best practice nations (South Korea, Malaysia and Singapore), policy-makers of follower regions could produce an interesting, profitable yet flexible vision of the role regional innovation systems thought which can play significantly in their economic destiny. Hence, in order to transform ideas from classroom education to practical policy implication, we believe, it is essential to investigate regional innovation system and its applications for future knowledge based generations. In future research, we recommend conditional order-m and α (alpha) frontier analysis to observe the comparison of our sample regions with regions having similar values in an external factor z, e.g. the externality variable. In order to achieve (conditional order-m analysis), the m observations are not drawn randomly but conditional on the external factors. We believe, it is worth looking into how results vary when we put condition on the selection of m in order-m frontier analysis.

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Appendix

1A Technical Aspects of Unconditional Order-m Frontier Analysis:

The main idea of the unconditional *order-m* is simple. For instance, in a multivariate case consider (x_0, y_0) as the inputs and outputs of the unit of interest. (X_1,Y_1),.......,(X_m, Y_m) are the inputs and outputs of *m* randomly drawn units that satisfy $X_i \leq x_0$. $\hat{\lambda}_m(x_0, y_0)$ measures the distance between point y_0 and the order-*m* frontier of Y_1,......, Y_m. It can be written as:

$$\hat{\lambda}_m(x_0, y_0) = \max_{(i=1,\dots\dots,m)} \{\min_{j=1,\dots\dots,q}(\frac{Y_i^j}{y^j})\} \quad (1A)$$

with $Y_i^j(y^j)$ with the *j*th component of Y_i(of y_0 respectively). The order-m efficiency measure of unit (x_0, y_0) is defined as

$$\lambda_m(x_0, y_0) = E[\hat{\lambda}_m(x_0, y_0) \mid X \leq x_0] \quad (2A)$$

The obtained performance measure the radial distance of the unit to the order-m frontier. Note that in any case a unit is at least compared to itself which results in a performance score of one. For an extensive treatment on the conditional and unconditional *order-m* approach see Simar and Wilson (2006).

2A Common Factors that Enable RIS Growth in Best Practice Countries

The most obvious similarity among South Korea, Singapore and Malaysia while becoming high-performing economies of South East Asia are the high proportion of GDP devoted to investment. These economies have relied heavily on foreign direct investment (FDI), which accounted for a high proportion of total capital formation in these

Table 1A Efficiency scores for order-m from FEAR software

Country	Order m=05	Order m=10	Order m=15	Order m=20
Australia	0.93	0.9283	0.88	0.91
China Mainland	1	0.99	1	0.99
Hong Kong	0.97	0.97	0.98	0.98
India	0.88	0.92	0.89	0.89
Indonesia	0.89	0.92	0.9	0.89
Japan	0.96	0.94	0.97	0.98
South Korea	1	1	1	1
Malaysia	1	1	1	1
New Zealand	0.9	0.87	0.9	0.9
Philippines	0.9	0.98	0.9	0.9
Singapore	1	1	1	1
Taiwan	0.97	0.97	0.98	0.98
Thailand	0.98	0.98	0.98	0.98
Denmark	0.9	0.94	0.89	0.87
Finland	0.93	0.94	0.92	0.95
Norway	0.97	0.96	0.96	0.97
Sweden	0.97	0.96	0.96	0.97
Brazil	0.87	0.87	0.87	0.91
Turkey	0.81	0.75	0.76	0.73
Switzerland	1	1	0.99	0.98

Table 2A Different empirical approaches to RISs

Country	Order m=05	Order m=10	Order m=15	Order m=20
Australia	0.93	0.9283	0.88	0.91
China Mainland	1	0.99	1	0.99
Hong Kong	0.97	0.97	0.98	0.98
India	0.88	0.92	0.89	0.89
Indonesia	0.89	0.92	0.9	0.89
Japan	0.96	0.94	0.97	0.98
South Korea	1	1	1	1
Malaysia	1	1	1	1
New Zealand	0.9	0.87	0.9	0.9
Philippines	0.9	0.98	0.9	0.9
Singapore	1	1	1	1
Taiwan	0.97	0.97	0.98	0.98
Thailand	0.98	0.98	0.98	0.98
Denmark	0.9	0.94	0.89	0.87
Finland	0.93	0.94	0.92	0.95
Norway	0.97	0.96	0.96	0.97
Sweden	0.97	0.96	0.96	0.97
Brazil	0.87	0.87	0.87	0.91
Turkey	0.81	0.75	0.76	0.73
Switzerland	1	1	0.99	0.98

economies over the last two decades, and especially from 1986 onward when the revaluation of the yen, the won and the Taiwanese dollar led to a marked acceleration in outward foreign investment flows from North East Asia into other parts of the region. Therefore RIS economists point out that much of the growth in output per worker in South East Asia can be accounted for by growth in capital stock per worker, together with growth in education. Hence, the best practice countries for instance South Korea, Singapore and Malaysia achieved a rapid growth in innovation infrastructure is mainly due to high capital accumulation in early stage of economic development and well educated labor force. Moreover, it argues that South Korea, Singapore and Malaysia all grew fast in national or regional innovation system because their economic managers have got the macroeconomic fundamentals right or where these fundamentals were clearly wrong, governments were prepared to change tack (Rodrik, 1995; Rastin, 2003; Booth, 1998; Afzal & Manni, 2013).

Book Reviews

Race Against the Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy, Erik Brynjolfsson & Andrew McAfee, Digital Frontier Press (2011), 98pages, ISBN: 978-1848440708

Introduction

First, I would like to explain why I selected this book for a book review. The core subject of this book well relates to the reality that we are currently experiencing. We are facing the contemporary dilemma of innovation and lack of jobs. Specifically, the rapid technology innovation (particularly, IT innovation) has contributed a lot to human development but as introduced in this book, it has also taken away many of the existing jobs, simultaneously producing the good and adverse effects. This book tries to solve this dilemma of technology and employment in the American context. However, this is not just an American situation but it could be an important and urgent problem in Korea, also an IT power.

Therefore, this book illustrates well the problems of Korea, which can easily join the advanced countries only when it succeeds in achieving both the acceleration of innovation and the expansion of job creation.

The subject of this book deals with what effects the IT innovation have on the economy, such as jobs, skills, and wage among others. To understand the subject, it is necessary to understand the employment situation of the United States. The employment rate in the U.S. fell into the worst situation since the financial crisis in 2008, but what's more important is that there is no sign of employment recovery even while the economic recovery is going on after the financial crisis in 2008.

In a free labor market like the U.S. market, the employees can freely be dismissed and the employers can easily employ the workers. Accordingly, the employment was recovered in the same scale as the economic recovery. However, an exceptional situation where those phenomena are connected to long-term employment congestion has occurred. Various arguments as to these phenomena have been raised from various academic circles.

These are almost similar with the discussions explaining the employment congestion in Korea. The first argument is the explanation of the temporary employment congestion by the Theory of Business Cycle. Under the Theory of Business Cycle, the employment congestion is regarded as a symptom of business cycle and the prediction of the possibility of economic recovery and employment promotion is possible at the same time. The major contents of the Theory of Business Cycle is that the present employment congestion means that the economy has not sufficiently recovered.

Another argument sees the Post-2008 situation as a stagnation, a possibility of long-term recession. The major phenomenon of the stagnation is that the economic recession and the consumption reduction occur simultaneously but with no price increase, which only shows the optical illusion effect of economic recovery. This phenomenon is connected with the situation that does not accompany the employment recovery. But this argument has a high explanation power only about the long-term economic recession for the past decades rather than the period after the financial crisis in 2008, not having explanation power about the decrease in employment after the financial crisis because the employment situation in the U.S. has so far rapidly recovered, even from the long-term recession.

The last argument is "eschatology of employment", which originated from the book written by Jeremy Rifkin, who tries to explain the present situation through the observation of the process where the technological development after the industrial society replaced human labor. The famous example cited by Jeremy Rifkin is the bank clerk replaced by the ATM machine, which indicates that the technological development reduces the demand for human labor, exacerbating the decrease in employment.

No arguments are completely wrong, nor do they explain all the situations but all the discussions so far (theory of business cycle or stagnation) indicate that the recent slowness in employment recovery, despite the economic recovery, is an important problem in American context, where both economy and employment have rapidly been recovering. This situation can better apply to Korea rather than the Unites States.

This book focuses on how humans can develop hand-in-hand with technology and machines, in the event that the more widely the technological innovation is expanded, the more workers are replaced by the machines(technological innovation), as explained by the 'eschatology of employment' in dilemma puzzle of technological innovation and employment expansion. Above all, this book argues that we have good reason to agonize and discuss these overall phenomena and that it is necessary for us to think about the way how we can develop jointly with the technologies, not fighting (consequently shrinking away from them) against the technologies and machines because we cannot but think that the technological innovation (specifically, digital innovation) has the most important dynamics in current economic development and it can change the direction of labor as a core key of the productivity and growth.

Main Content

This book is composed of five chapters. Chapter 1 deals with the effect of technological innovation on the economy and employment, which was previously explained in the introduction above. The issue of employment and the issue of technological innovation have been separately dealt with as independent issues by many researches so far and were deliberated with a lot of efforts. Their solutions were extracted. However, in this situation where the issue of technological innovation is closely associated with the issue of economy and employment, there were not so many serious researches on the relation between those two issues. While it is true that technological innovation reduces human labor, the new jobs are also created by technological innovation. This book stresses that it is time we should seriously think about the change of labor market by the technological innovation and the labor that leads the technologies.

Chapter 2 asks us whether technological innovation, specifically the development of computers, overpowers the humans. The computers that replace humans and beat the chess champion are frequently introduced in mass media but this book explains that we can find both the bright and dark sides in the computer that replaces humans. For example, this book explains that the distribution and development of computers brought tremendous changes in the business contents, employment, and structure in business organizations. They also brought the change in the type of knowledge delivery such as the ERP system in enterprises that share the knowledge in their organizations. Nevertheless, the author of this book says that there are still many areas where humans have the higher position than the computers. These industries can only be carried out by the persons with the competency of complicated communication and long experience, represented by experienced doctors or veteran lawyers or managers with accumulated marketing ability. The core areas where computers cannot overpower the humans are the areas in need of complicated system awareness or experiences, which are difficult to be automated or the areas in need of problem-solving ability. The author explains about the jobs, where awareness is important, through the expression of "PURE MENTAL JOB". Of course, he also explains that it is true that the phenomenon of job reduction occurs in some of sales and distribution areas as the sales and distribution that use the E-business become brisk. In brief, Chapter 2 stresses that the phenomenon of computer technology replacing the human skills will be more accelerated and it is very important for us to study on the expected effects of this phenomenon on the economy.

Chapter 3 explains in earnest about the catalytic role of technological innovation that determines the success or failure of economic growth and development. As an economic growth, the phenomenon of moderate real income increase can be suggested compared to rapid increase of productivity. The phenomenon of GDP PER PERSON > REAL MEDIAN HOUSEHOLD INCOME is starting to appear, which can be concluded in the difference in growth volume and intensified income gap (growth of upper 20%). The technological innovation has a great effect on the increase of productivity, which shows itself in the form of damage to middle class laborers as well as the inequality of wealth. The insufficient creation of jobs is a more serious problem in this situation of ever increasing population, which comes down to the fierce competition in middle class people, not in upper class people. All technological innovations do not increase the income of all people and even if the wealth increases, the winner and loser always exist. As for the highly skilled and low-skill workers, the routine business of low-skill workers are rapidly replaced with the machines and computers and, on the contrary, the demand for highly skilled workers outstrips the supply. About super stars (core manpower) and ordinary people, the representative markets, where the winner-takes-all phenomenon is expanded, include the music market, software market, drama/movie market, and sports market, and it is the reality that there is a tremendous difference in the annual income of ordinary participants and super stars. In brief, Chapter 3 stresses that the change in 21st century technologies is more rapidly progressing and that the creative destruction in the 21st century actively interferes with the employment decrease, organizational innovation, and the change of company operation system, which is caused by technological innovation. Chapter 3 also clearly states that there can be no doubt that the unemployment due to technological innovation will more widely occur in the job places in the future.

Chapter 4 calls the economic and employment situation discussed so far, which is affected by technological innovation, “DIGITAL ECONOMY”, and premises that the digital economy can increase the productivity and size of the whole pie but it can also produce the economic result that can cause some people to be left behind, it suggests some ways to relieve and overcome this situation First, Chapter 4 stresses the importance of investment in education. This can play the role of improving the quantity and quality of skilled work and decreasing inequality. This can simply start with the increase of the salary of the teachers. Second, this chapter argues that entrepreneurship should be promoted. The business sector should be taught in the overall process of higher education, not just in the elite graduate school of business administration. It is time we cultivate entrepreneurs in a wider class of people. Third, this chapter stresses the investment in national infrastructure that can further expand the investment. The infra improvement can promote the employment as well as the increase in productivity. Fourth, this chapter suggests the improvement of laws, regulations and tax system and the necessity to control employment and dismissal. The flexibility of the labor market will increase in the process of making the above measures endure. In short, Chapter 4 argues that we should develop human capabilities and carry out the activities that surpass the technologies by creating a situation where more people can challenge and more organizations can be compensated.

Chapter 5, where the concluding remarks can be found, stresses that it is important in the present situation to make full use of the technologies and to strengthen the lives of people that use those technologies, as hinted by the subtitle, DIGITAL FRONTIER. Case in point, this chapter explains the case of productivity increase of Indian fishers using digital technology, where the Indian fish middlemen and fishermen could increase productivity and income in the process of cross-checking the catch of fish in real-time basis using the mobile phones given to them, in a situation where the fish price was unstable and the fish distribution market could not sufficiently develop due to the lack of communication network between them. This chapter stresses the importance of people who can derive the economic benefit that use digital technology.

Concluding Remarks

This book deals with the complicated subjects of technological innovation, employment and economic development, suggesting an important insight to us. Although this book stressed the negative effect of technological innovation, it teaches us how well we can live in cooperation with them in this society where the machines and technologies lead us humans.

We can derive again some important issues from this book. As stressed in the main contents of this book, the technological innovation is not disadvantageous to all of us. People in the middle class or the unskilled workers are the most disadvantageous. Are there any alternatives for the general decrease in the number of jobs for these unskilled people in middle class? Is the great expansion of service business responsible for the lack of the number of jobs for unskilled workers caused by the technological innovation? Much of the current job training and employment policy is carried out under the premise of this problem. However, they are showing no significant effect in the creation of the jobs, employment expansion, and increase of income for that class of people. Education is helpful in the long-term perspective but the short-term solutions can include the expansion of businesses that can create many jobs even if they are simple jobs like the service business. The service industry can be considered as the only lever that can support the creation of employment. Accordingly, how we can advance this service business and what effect the service business has on the technological innovation are considered as the important subjects that we should deeply contemplate in future researches. Lastly, I think there may be the cases where we are also the digital frontiers. There is no other country that is as sensitive to technological innovation as Korea and there is also no other country where people change their mobile phones as frequently as Koreans. I think there must be cases wherein we Koreans are digital frontrunners in as many cases as the Americans. What is important is that we should make efforts to reduce the number of neglected digital people by sharing and learning those cases. At this point in time, I think that we should seriously think about the methods and ways to prevent the jobs from being taken away by technology or to prevent income from being reduced by technology.

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Creating Silicon Valley in Europe: Public Policy Towards New Technology Industries, Steven Casper, Oxford University Press (2007), ISBN: 978-0-19-926952-5

Introduction

Steven Casper, the author of Creating Silicon Valley in Europe: Public Policy Towards New Technology Industries (2007), is a Henry E. Riggs Professor of Management and Associate Dean of Faculty Development of KECK Graduate Institute of Applied Life Sciences in California, USA.

During the 1999–2000 academic year, he was invited to participate in a research group at the Netherlands Institute for Advanced Studies (NIAS). At that time and place, the author studied the National Innovation System (NIS) and investigated the interplay between public policy and national institutional frameworks to try to answer whether the “Silicon Valley model” in the U.S. is feasible to the European economy.

The main motivation of the study originated from the appearance of dominating entrepreneurial technology companies in the U.S., such as Microsoft in software, Genentech in biotechnology, and Google on the Internet. After the emergence of these companies, the U.S. technology cluster, such as Silicon Valley, has been recognized as a successful model of innovation. Many governments in developed and developing countries started to construct Silicon Valley-styled innovation clusters at their own country. Many countries, however, did not become as successful as they expected.

Based on an institutional framework, the author compared the performance of the Silicon Valley model adopted in other countries and focused on the biotechnology and software industries, which are the so-called radical innovation sectors." He then identified the main elements that led to the successful establishment of the Silicon Valley model.

The author first introduced the "varieties of capitalism" perspective as the main theoretical framework and then, categorized the market into two different characteristics: Liberal Market Economy (LME) and Coordinated Market Economy (CME).

The Liberal Market Economy encourages the diffusion of each of the key elements associated with Silicon Valley models. It has a financial system that emphasizes the role of venture capital, high-powered incentive structures within firms, and largely deregulated flexible labor markets. The U.S. and UK are well-known major economies organized under the liberal market economy model.

The Coordinated Market Economy, on the other hand, emphasizes long-term employment and large company investments in industrial training. It has a financial system focused more on bank credits than capital market financing and on stakeholder systems than shareholder systems. An important characteristic of stakeholder capitalism is that it pursues relatively long-term or incremental innovation strategies within medium-technology industries. Typical examples are found in engineering, machine tools, automobiles, and specialty chemical industries. In general, German companies and other European economies belong to the CME model.

Employing several case studies of the biotechnology and software industry in the U.S., Germany, and UK, the author argued that the institutional differences and technological characteristics are important elements to establish successful innovation clusters. It could be risky for each government to uptake the Silicon Valley model without the consideration of the institutional and technological features with which each country has relative advantages.

Main Contents

This book is composed of eight chapters. Chapter 1 is an introduction that provides an overall background of the study and a road map of the book. Chapter 2 introduces the varieties of capitalism perspective to develop a theoretical framework that links national institutional structures within LMEs and CMEs to the sustainability of radically innovative companies. The main idea of the analysis is to compare institutional characteristics, such as finance, corporate governance, company law, and labor market organization of the country and link the validity of each element to evaluate the sustainability of firms within CMEs and LMEs.

Chapters 3–5 contain detailed examinations of the biotechnology industry in three countries—the United States, Germany, and the United Kingdom—and a comparison of the performance of those clusters within the institutional framework. The author focuses the comparison on the therapeutics segment that is known as a radically innovative area in the biotechnology industry.

Chapter 3 introduces a successful biotechnology cluster located in San Diego, California, and examines whether biotech firms in the cluster benefit from a comparative institutional advantage of being located within a liberal market economy. The author shows that San Diego biotech firms use venture capital and IPO markets as instruments for high-risk financing, high-powered incentive structures, and flexible labor markets, and argues that the liberal market economy should provide benefits to biotech firms, those that specialize in radically innovative areas.

Chapter 4 describes the biotechnology cluster of Germany and examines why the performance of the cluster is relatively poor even though the German government provides enormous support to stimulate the biotech industry. The author argues that Germany has a long reputation as an "organized" or "coordinated" economy and such characteristics are not suitable for the radically innovative biotechnology industry.

Chapter 5 introduces biotechnology in UK, which is heavily specialized around radically innovative therapeutic research. This country has adopted the key elements of the Silicon Valley model within the liberal market economy. In this chapter, the author evaluates that the UK biotechnology cluster is performed better compared to the German cluster, but is relatively in a poor position compared to the San Diego biotech cluster in the U.S. The author also explains the differences between the role of universities in UK and the U.S. Universities in UK do not have the resources or incentives to fully participate within the marketplace for ideas that surround commercial biotechnology, while the elements explain the different performance between the biotech industries of the U.S. and UK.

Part II of the book, which is composed of Chapters 6–7, suggests alternative pathways by which entrepreneurial technology firms located within the coordinated market economies can become sustainable.

Chapter 6 suggests that one possible strategy for new technology companies is to specialize within the subsectors of new technology industries, which will then demand the creation of company capabilities. Chapter 7 examines whether regional mechanisms could be possible alternatives in organized (or coordinated) economies to support radically innovative companies. The chapter emphasizes that the activities of very large firms, through their presence within a regional economy, could feasibly alter the "normal" patterns of economic coordination to encourage alternative patterns of industrial organization.

The concluding chapter, Chapter 8, summarizes the findings, suggestions, and implications of the research and argues that national institutional frameworks do strongly impact the emergence and sustainability of new technology companies.

Concluding Remarks

The book is motivated by the question of whether the Silicon Valley model could be established well in the European economy. The author argues that the characteristics of national institutional frameworks play an important role in explaining the success of creating the Silicon Valley model. He also suggests that the varieties of capitalism perspective could be a good starting point to predict the performance of an innovation cluster. He is, however, emphasizing that public policy and university capability can also be important complements that can help to explain country competitiveness.

Creating Silicon Valley in Europe provides deeper insight for policymakers in designing innovation clusters and adopting the Silicon Valley model in the country. Its institutional feature is the important elements that explain the success of the Silicon Valley model especially for rapidly innovative industries. The book provides very detailed experiences of each country based upon a consistent analytical framework, which may helps for policy makers to predict the success of innovation cluster. It, however, seems to provide two extreme institutional frameworks and is expected to be able to expand the scope of the analysis into many other mediocre clusters that have mixed institutional characteristics. Such an expansion may enrich the analysis of innovation clusters.

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Science and Technology Trends

International R&D Cooperation in Asia

JAPAN

Hiroshi Nagano[1]

1. Introduction

International collaboration in science and technology is an effective way to boost research activities in collaborating countries. International collaboration specifically attracts attention in recent years because we recognize the clear evidence that international co-authorship produces academic papers whose quotation rates are higher than papers written only by authors within the same country.

International collaboration in research has, however, taken place where the level of research in collaborating countries is almost equal. This is understandable, since collaboration requires complementary partners who can each contribute. Instantly, we faced a rather difficult problem when we considered the possibility of research collaboration with developing countries, in Asia or elsewhere. This is the reason that in the past there were relatively few international collaborations between developed and developing countries, although the importance of such collaboration was stressed in the political arena.

2. Initiative of the Prime Minister's Council

People sometimes ask researchers to be creative. However, policy makers also have to be creative when they consider new programs.

Japan's highest council for science and technology policy, the Council for Science and Technology Policy (CSTP) chaired by the Prime Minister, acknowledged this problem when its expert members published a document named "Toward the Reinforcement of Science and Technology Diplomacy" in April 2007 and proposed the concept of "science and technology diplomacy", initiating cooperation between science & technology and diplomacy. It was a highly creative idea to foster international collaboration. In a nutshell, the CSTP sought the effects of synergy by utilizing science and technology for diplomatic purposes and utilizing diplomacy for the further development of science and technology. CSTP organized a working group focused on this issue and, in May 2008, it finally endorsed an official document also named "Toward the Reinforcement of Science and Technology Diplomacy". It described the need to strengthen science and technology cooperation with developing countries for resolving global issues in the areas of the environment and energy, bioresources, disaster prevention and infectious diseases.

3. Relationship of Science with Diplomacy

Although I wrote that this was a creative idea, the relationship between science and diplomacy has a long tradition. In what is now the United Kingdom, the Royal Society created the post of foreign secretary in 1723, much earlier than the post of Foreign Secretary of the government, which was established in 1782. In the latter part of the twentieth century, science was sometimes utilized by superpowers to maintain their status at times of cold war. When we investigate the

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concept of science diplomacy, we discover that the concept itself is fluid, still searching for a precise definition. In fact, science diplomacy connotes three dimensions;

- Science in Diplomacy: informing foreign policy objectives
- Diplomacy for Science: facilitating international science cooperation
- Science for Diplomacy: using science cooperation to improve international relations between countries

In terms of the relationship between science and diplomacy, there are some interesting expressions by experts in recent years as follows;

"Science diplomacy is not the same as the use of science in diplomacy" and "Science diplomacy is the use of scientific collaborations among nations to address the common problems facing 21st century humanity and to build constructive international partnerships. There are many ways that scientists can contribute to this process" were the words of Nina Fedoroff, Science and Technology Adviser to the US Secretary of State. The former UK Chief Scientific Adviser, John Beddington, once mentioned that "a diplomat is an honest man sent to lie abroad for the good of his country" and "there is a danger of using the uncertainties in science for diplomatic and political ends".

Having recognized the history and these kinds of relevant discussions, CSTP proposed the idea to realize the synergy of science and diplomacy.

4. Arrangements within the Government

In fact, CSTP proposed that the government consider and produce a new framework of international collaboration that sought the linking and collaboration between science and technology policy and foreign policy. Consequently, it led to the collaboration between two governmental agencies which belong to different ministries: on one side, Japan Science and Technology Agency (JST) which is associated with the Ministry of Education, Culture, Sports, Science and Technology (MEXT), providing competitive research funds for science and technology projects, and on the other side, Japan International Cooperation Agency (JICA) which has a long history of working in the field of official development assistance (ODA) for the Ministry of Foreign Affairs (MOFA). This was a unique proposal in Japan, since it is not common to let two agencies under different governmental ministries work together. The idea was that the linking of the budgets from different sources was needed in order to realize research collaboration between developed and developing countries.

5. Launch of a New Program, Collaboration of JST and JICA

Upon receiving the CSTP proposal, the ministries, MEXT and MOFA, including their subsidiaries, JST and JICA, started to negotiate on how to make this proposal concrete, and finally launched the program called SATREPS, which stands for "Science and Technology Research Partnership for Sustainable Development". The presidents of the two entities, Dr. Sadako Ogata of JICA who was the UN High Commissioner in the 1990s and Dr. Koichi Kitazawa of JST, held a signing ceremony in June 2007.

There are three major features of this program.

First, SATREPS facilitates a linkage of totally different sources of funding for the sake of international joint research cooperation between Japan and developing countries. It challenged administrative people in Japan to think out of the box.

Second, SATREPS aims to address global issues with effects that go beyond borders, through projects

Figure 1 Signing ceremony between JST and JICA

that lead to research outcomes of practical benefit to both local and global society. Therefore, it aims not only to do research, but to bring the research outcomes to market, eventually to be produced and sold by the private sector or to be used in society.

Third, SATREPS is engaged in capacity development, working with developing countries to develop human resources for research and development and to develop sustainable research activities, leading to independent research capacity that can address global issues. It can contribute to resolving issues, coordinating networking between researchers and training future human resources in developing countries and also in Japan.

As obvious, the unique character of SATREPS is that it joins and coordinates functions, activities, and capabilities that were once separate, using scientific research potential as a mediator for developmental diplomacy. This is described simply in the SATREPS publicity booklet as, first, the linkage of science and technology with international cooperation, second, the linkage of meeting global needs with meeting local needs, and thirdly, linkage of Japan's capabilities with developing countries' capabilities. That is why "For the Earth, For the next Generation" is used as the attention-grabbing message for SATREPS.

6. Fields of Collaborative Research

Topics that are adopted as SATREPS projects are global issues that affect more than a single country and cannot be resolved without international collaboration. Examples include environment/energy issues, disaster risk reduction, infectious disease control and food security.

The Environment and Energy field encompasses the broad range of global-scale environmental issues and low carbon society/energy. Caused by climate change, growing population. expanding cities, and increasing consumption, there are growing needs, both locally and globally, to pursue research into technology that can resolve environment and energy problems, and to deploy the outcomes of such research. In order to reduce global emissions, it is essential that both developed and developing countries take part in the efforts to achieve a low carbon society.

Natural disasters are a constant danger in Japan, and have resulted in the accumulation of a great deal of knowledge and expertise. In addition to applying this knowledge to disasters and risk reduction in developing countries, collaboration is urgently needed to make further progress in research into earthquake/tsunami early-warning systems and high-precision weather forecasting.

HIV/AIDS, malaria, dengue fever, tuberculosis, highly pathogenic influenza, and other emerging and reemerging infectious diseases can be a major impediment to social and economic development. Efforts to address infectious diseases issues in developing countries can have a direct benefit in protecting the health of individuals worldwide. Collaboration between Japan and developing countries on research in this field contributes to the control of infectious diseases on a global scale.

Sustainable production of food and other bioresources is threatened by problems such as desertification, salinization of agricultural land, and pests, as the global population grows and climates change. In order to continue enjoying the blessings of bioresources, there is a need to facilitate collaborative research that can point the way to sustainable means of production and utilization.

7. Eligible Proposals and the Process Leading to Adoption

For a proposal to be eligible for the SATREPS program, there should already be a good relationship between the Japanese researchers and the developing country researchers. New topics are solicited every year. To file an application, a proposal from the Principal Investigator (PI) of the Japanese side should be submitted to JST, and an official request for ODA technical cooperation from the research institution in the developing country should be submitted to MOFA via the ministry or agency in the developing country responsible for ODA technical cooperation. These documents should be submitted before the common deadline and the content of the proposal should be consistent.

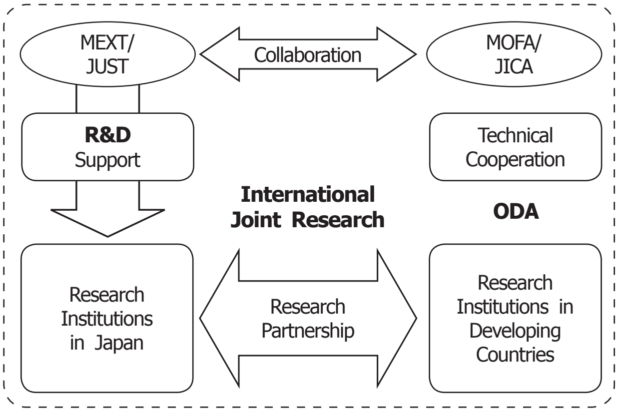

Figure 2 SATREPS Program Structure

In the SATREPS scheme, JST concludes research contracts with research institutions in Japan to support research costs incurred in Japan. In parallel, JICA provides support through its technical cooperation project framework to cover costs in the developing country. Duration of a project is in most cases five years. The annual research funding from JST and JICA for a single project is approximately 100 million JPY (about $ 1m) in total.

8. Human Resource Development Through MEXT Scholarship Program

To assist the SATREPS program, MEXT established a "Global-Issue Section" within its Japanese government scholarship program (university recommendation) for SATREPS projects. The aim of the Global-Issue Section is to develop young researchers with the potential to be future key players in relevant research in their own countries by taking a doctorate at a Japanese institution. Invitation for this Japanese government scholarship program is implemented by MEXT, and the scholarships are budgeted separately from the SATREPS budget. To be eligible for this program, a doctoral degree needs to be received within the term of the SATREPS project.

Since it is critically important to cultivate the next generation of human resources. I hope this MEXT program will be effectively utilized by partners of SATREPS projects.

9. Development of the Program

At the first solicitation for the fiscal year 2008, twelve projects were selected. Six of these projects involved partnerships in Asia: three with Thailand, two with Indonesia, and one with Bhutan. Their topics covered a diversity of the research fields.

After that, additional SATREPS projects have been added to the list, taking up between nine and twenty proposals each year. From 2008 through 2013, a total of 78 projects were adopted. Out of them, 41 projects are with Asian countries, and collaborative topics with African nations are also increasing.

The period of a research project is set for between three and five years, but mostly for five years. However, even at the beginning phase, a SATREPS project should take into account how to continue this project beyond the five years' period to bring its

Table 1 SATREPS projects (FY2008 – FY2013)

Research Areas	Region			FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
	Asia	Africa	Others						
Environment/Energy (Climate Change)	41	20	17	4	4	0	-	-	-
Environment/Energy (Low Carbon Society/Energy)				-	-	4	3	2	1
Environment/Energy (Global Environment Issues)				3	2	4	1	2	3
Bioresources				-	6	5	2	3	1
Natural Disaster Prevention				3	4	2	2	1	2
Infectious Diseases Control				2	4	2	2	1	3
Total				12	20	17	10	9	10

results to the final realization in the market or society. For this reason, stakeholders who will be eventually able to support this realization, such as next phase funding agencies, venture capital, and interested private sector entities, are welcomed to take part in a project through any form of collaboration. In this regard, a hand-over period needs to be incorporated into exit strategy plans. In the figures below, this is marked “Baton Zone”, using the Japanese language term for the exchange zone or passing zone where the baton is passed from runner to runner in a relay race. Figure 3 depicts the exit strategy where the target is a market.

One example is the collaboration with Thailand in the “Innovation on production and automotive utilization of biofuels from non-food biomass” project, which started in 2009, aiming at reducing CO2 emissions with vehicle biofuel made from nonedible vegetable oil. Biofuels are already common automotive fuels in Thailand. The utilization of biofuels in the transportation sector could help mitigate global warming, but because of the risk that production of biofuels derived from grains or vegetable oil will compete with food crops, there is a demand for manufacturing technologies that exploit nonfood sources of biofuel. For this project Waseda University of Japan is cooperating with Thailand, which is becoming the automotive production hub of Asia, to develop production technologies for fuels from Jatropha, an inedible plant. The main project partner is Thailand’s National Science and Technology Development Agency, NSTDA. The Japanese side is conducting engine tests and developing the automotive utilization technologies, as well as estimating CO2 emission reduction benefits through life cycle assessments. Private sector entities in Thailand are already involved in this project. Isuzu Motors Co. in Thailand contributed to the project by providing a car to drive long distances to gather data for assessing usefulness. The Thai national petroleum company is also contributing. Production at pilot plant scale (1 ton/day) is already successfully manufacturing high quality biodiesel from Jatropha oil. It is hoped that a large demonstration plant will be built after approximately ten years’ time.

Figure 4 depicts a different exit strategy for public goods. Here, the target is public dissemination.

This model applies, for instance, to another partnership with Thailand, the “Research and development of therapeutic products against infectious

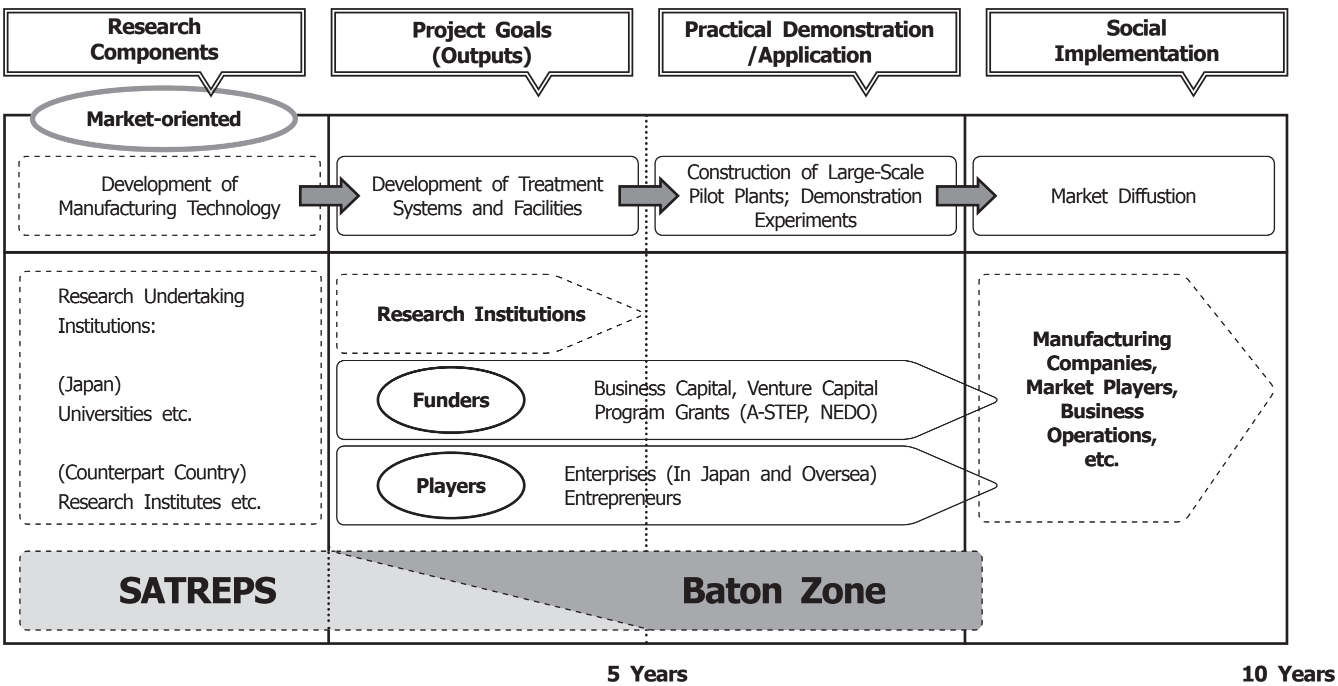

Figure 3 Exit strategy (Target-oriented): Market goods

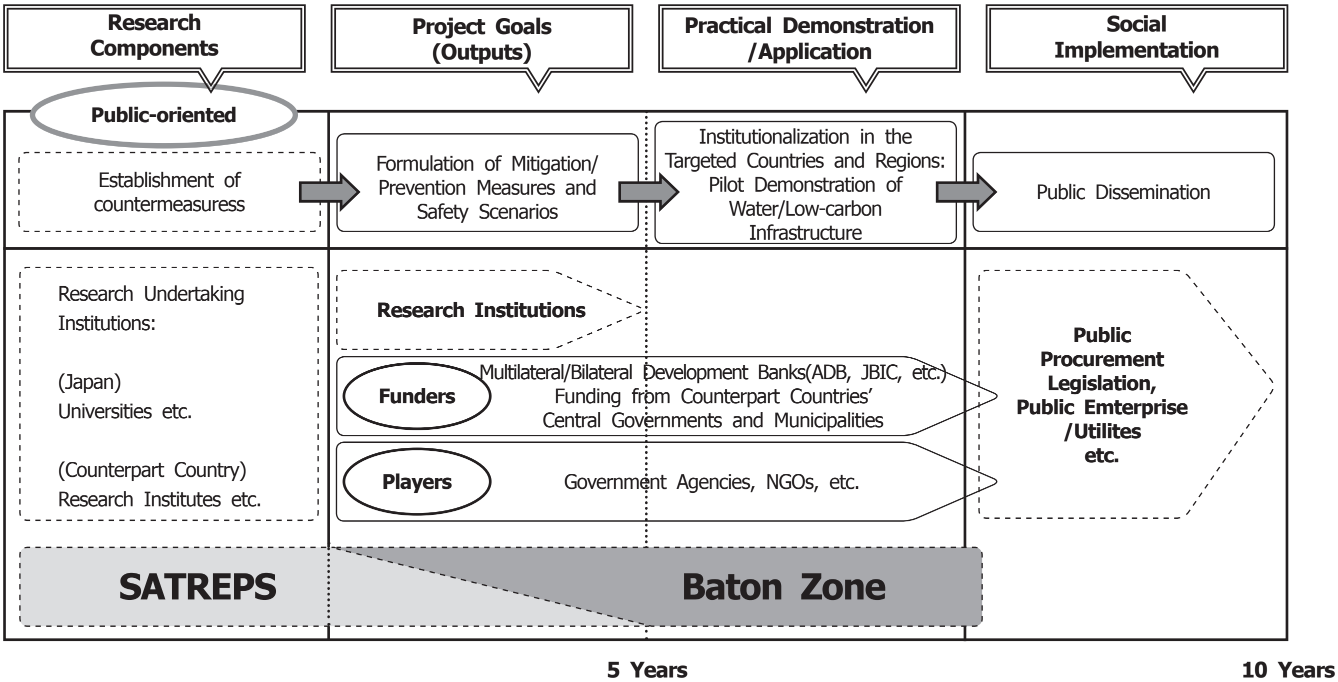

Figure 4 Exit strategy (Target-oriented): Public goods

diseases, especially dengue virus infection" project, aiming at creating drugs effective against the Dengue virus from human beings.

With Indonesia, a good example is "Pilot study for carbon sequestration and monitoring in Gundih area – Central Java Province," a project that was adopted in 2011. The mission here is to resolve CO2 emissions problems associated with natural gas production. This problem can be resolved by creating a system for carbon dioxide capture and storage (CCS) technology in which the CO2 is sequestered underground as a means of directly reducing CO2 emissions. This CCS facility, which might become the first plant in Southeast Asia if successful, is currently under development.

10. International Ramifications

The features of this program were really unique. Consequently, it influenced the US to launch a similar program in 2011, the "Partnerships for Enhanced Engagement in Research (PEER) Science" program. This is a partnership between the U.S. Agency for International Development (USAID) and the National Science Foundation (NSF). The occasion of a panel discussion at the Annual Meeting of the AAAS (American Association for the Advancement of Science) provided a good opportunity to compare the two programs and to benefit from each other's experiences.

Moreover, this topic of a new way of collaboration between developed and developing countries was also raised in the OECD (Organisation for Economic Co-operation and Development) arena. That was at the Global Science Forum (GSF), one sub-committee of the OECD's Committee for Science and Technology Policy. GSF consists of almost all OECD delegates, including Japan and Korea. It takes place twice a year. GSF delegates consist of senior government officials together with people from funding agencies and academia. GSF is operated on a bottom-up system: Topics are raised by member delegates, and if other delegates show their interests in the new proposal, then the topic will be taken up as an agenda item for studying, usually for a two-year term. A topic concerning pursuing collaboration between developed and developing countries was raised by Japan in 2008 and then taken up as a formal topic of OECD GSF, led by Japan and co-chaired by South-Africa and European Union. The topic was "Opportunities, Challenges and Good Practices in International Research Cooperation between Developed and Developing Countries". Its rationale was as follows;

Global issues (e.g., environmental protection, energy security, natural disaster mitigation, preventing and curing infectious diseases, ensuring food security) are increasingly the subject of policy-level deliberations, both nationally and internationally. Cooperation between developed countries and developing countries is of special importance, because developing countries are often the ones most severely affected by global threats, and because they possess much of the expertise, data, and resources that are needed for finding effective solutions.

Concluding the rationale part, the report describes as follows;

The activity focused primarily on cooperative research programs and projects that:

- Combine elements of ODA (targeted at "global issues" such as the UN Millennium Development Goals) with scientific research aimed at discovering new knowledge; and
- Are intended to be true partnerships between developed countries and developing countries, involving significant sharing of responsibilities, activities, resources and outcomes.

Interested delegates offered their data about a total of twenty-nine past or ongoing programs and projects.

The final report of the GSF on this issue was published in April 2011. It enumerates important issues and options, covering the major aspects of collaborative research, notably:

- Achieving an optimal balance between the imperatives of research (bottom-up initiatives, peer review, etc.) with top-down strategic development priorities;
- Developing human capabilities, national science and technology capacity, and expertise in science policy;
- Promoting co-ownership of the outcomes; applying and tranferring results of joint research to local communities or industries in both developed and developing countries and to society in general;
- Evaluating the outcomes using appropriate methodologies and indicators;
- Coordinating and harmonising programs and projects among developed countries and developing countries.

Specifically, this report includes many hints for enhancement of international collaboration with developing countries. For instance, in terms of capacity building, it suggest that a program emphasizing individual capacity building may include:

- Development of individual, as well as institutional, capacities for designing and implementing research programs, including peer review processes, solicitation and communication with researchers
- Development of non-scientific skills that are relevant to research. In some cases, these are particularly important for young scholars in developing countries.
  - Language proficiency, especially English
  - Paper writing (from applications for research grants to publications in scientific journals)
  - Communication with policy makers (e.g., policy briefs)
  - Communication with the general public and the media
  - Personal career development
  - Research management (organisational, financial, personnel, etc.)
- Scholarships (for higher education, including for studying abroad) for students of both developed countries and developing countries)

After having publicized the report on this issue, the GSF still continues the work to seek to refine and expand the earlier findings by taking a detailed look at an important scientific domain, namely, the area of climate change adaptation and biodiversity. Two workshops have already been held in Singapore and in South Africa, and I am looking forward to some constructive recommendations in this regard.

11. Conclusions

The world of the 21st century is changing. The change derives from factors such as globalization, population growth, climate change, environmental degradation, and the quest for better life. Each country is therefore facing new issues nationally and internationally. Asian countries are also facing critical issues, which sometimes can only be solved by collaboration with other countries.

Japan recognized that there were enormous mutual benefits in collaboration with countries in Asia, and outside Asia, in the field of science and technology. The issue here is that we need to devise appropriate tools to exploit them. The new way of collaboration was a clever idea, utilizing the linkage between science and technology and development aid. From our experience since 2008, we have seen that "SATREPS" is operating successfully. This new program also had an impact on the new program in the U.S. and in discussion at the OECD level.

People are often inclined to think within the box. Social systems are usually structured rigidly and are not easy to break it down. However, the world's financial and even human resources are limited. People in the government or funding agencies need to be clever and create brilliant new systems or improve current systems to pursue more social benefits for the globe through creative collaboration among nations, especially between countries in Asia. I am confident that we are clever, and convinced that we will be able to do this.

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KOREA

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1. Introduction

It is not too much to say that R&D investments in the Asian region began in the 1980s in most cases except for Japan. Beginning with cooperation with advanced countries in scientific technology, such as the U.S. National Science Fund (NSF), R&D cooperation in the Asian region has been made mainly through research fund support institutions.

R&D cooperation has been made through the Japan Society for the Promotion of Science (JSPS) and the Japan Science and Technology Agency (JST) in the case of Japan, through the China Scientific Technology Promotion Fund in the case of China, through the Indian National Science Academy (INSA) in the case of India, and through the Australian Research Council (ARC) in the case of Australia.

R&D cooperation in Asia began in the 1980s insignificantly and active cooperation among three countries, mainly Korea, China, and Japan, began in the 1990s. Accordingly, total research funds by country have been steadily increasing in Korea and China.

Beginning with cooperation between Korea and Japan out of the three countries, mainly Korea, China, and Japan, cooperation has been expanded to include cooperation between Korea-China, Korea-India, and Korea-Australia in order of precedence. The forms of cooperation in the early stage were mainly international joint researches with research funds amounting to approximately KRW 20 million per task, international joint seminars with research funds amounting to approximately KRW 10 million per task, and scientist exchange projects with research funds amounting to approximately KRW 5 million per task.

Table 1 Present states of total research funds by country

(unit: USD)

Country	2006	2007	2008	2009	2010	2011
USA	353,328	380,088	406,258	405,072	408,657	415,193
EU	253,885	270,904	294,208	298,421	305,834	320,456
Germany	70,108	74,016	81,971	82,361	86,280	93,055
Russia	22,856	26,554	30,058	34,158	33,425	35,045
Korea	35,293	40,723	43,906	46,729	52,844	59,890
China	86,619	102,323	120,743	154,025	178,168	208,172

Cooperation with Japan was made centering on Korea-Japan Basic Science Exchange Committee that began exchanges in 1990 based on the memorandum of cooperation exchanged between KOSEF and JSPS in April 1979. Thereafter, Korea-China Basic Science Exchange Committee was established in May 1995 and cooperation projects have been implemented centering on the basic science exchange committee.

2. Cooperation in the Asian Region: Began Centering on Korea, China, and Japan

Cooperation between Korea-Japan and Korea-China cooperation has been made evenly in all areas of scientific technology excluding humanities and social science. In particular, mainly basic science projects have been selected and supported. For example, cooperation with Japan has been mainly made in the area of cutting-edge scientific technologies, such as electricity and electronics, material engineering, and biotechnology centering on Korean scientists who studied in Japan.

Some of the Korea-Japan cooperation projects include doctorate thesis programs, international joint researches, international joint seminars, scientist exchange programs, JSP FelloJapanship Program, Winter Institute Program, among others. Currently, cooperation projects, such as international joint researches and international joint seminars are progressing actively.

Whereas international cooperation between USA and Japan was the most active in the 1980s, countries of cooperation began to be diversified in the 2000s to include Germany, Sweden, and China and cooperation with European countries was expanded and reinforced. In addition, special cooperation projects were made between Korea and Germany, Korea and Sweden, Korea and USA, Korea and China, and Korea and Japan. Here,

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Table 2 Present states of R&D funds to the GDP by country

(unit: %)

Country	2006	2007	2008	2009	2010	2011
Israel	4.51	4.86	4.77	4.49	4.34	4.38
Finland	3.48	3.47	3.70	3.94	3.90	3.78
Sweden	3.68	3.40	3.70	3.60	3.39	3.37
Germany	2.54	2.53	2.69	2.82	2.80	2.88
USA	2.65	2.72	2.86	2.91	2.83	2.77
Korea	3.01	3.21	3.36	3.56	3.74	4.03
China	1.39	1.40	1.47	1.70	1.76	1.84

the two countries jointly invested a certain amount of money to implement cooperation.

The ratios of R&D funds to the GDP of Korea and China have been steadily increasing as much as those of advanced countries in the Americas and Europe. The ratio began to steadily increase from 3% in the case of Korea and 1% in the case of China.

2.1 Implementation of Cooperation Projects Through the Basic Science Exchange Committee

In the early 1990s, cooperation with China was mainly implemented through projects for developing countries, such as training Chinese scientists in Korea, visiting projects including scientific technician exchanges, and training Chinese graduate school students in Korea. Based on such cooperation, international joint research cooperation began in the areas that are the common interests of Korea-China, such as the environment, ocean, among others.

Cooperation with China was centered on natural science and basic areas at the beginning but has gradually included the areas of cutting-edge science, such as electricity/electronics, life science, among others, and the scale of projects has been evolving from simple visiting research and international joint research to large multidisciplinary international joint research. China has been recently asking to prepare large research funds that fit its economic development and enlarge cooperation between China and Korea but mainly medium/small-sized tasks are supported until now because of budget situations in Korea.

In particular, unlike other countries in the Americas or Europe, in the case of Japan and China, considering the importance of meetings, which is highly relevant in the Asian region, tasks were selected and supported through Korea-Japan and Korea-China's basic science exchange committees. Each country temporarily selected tasks in the country and final tasks were selected through coordination of opinions in meetings held once a year. Each basic science exchange committee was mainly composed of 7–8 university professors who represented academic fields.

Although many cooperation projects with Japan have been implemented through the basic science exchange committee thus far, the two countries agreed to abolish the basic science exchange committee in 2012. Therefore, no basic science exchange committee with Japan exists now and cooperation is implemented with the China Natural Fund Committee only.

As for the cooperation with Japan, in addition to joint research and joint seminars, projects, such as doctorate thesis programs, have been operated. Currently, 20 joint research tasks and 10 joint seminars are supported every year for the cooperation with Japan and the largest number of international cooperation projects are implemented with Japan along with Germany, USA, France, Sweden, and China.

Doctorate thesis programs are those in which Korean graduate school students are registered in schools in Japan and the students make contact with Japanese thesis directors during vacations to submit theses and receive doctorate diplomas. Because Korean students studying in Japan have increased, new tasks will not be selected anymore from 2014 when five currently supported tasks will be completed.

3. Present State of International Cooperation Implemented Among Korea, China, and Japan

3.1 Present State of Cooperation between Korea National Research Fund (NRF)-Japan Society for the Promotion of Science (JSPS)

For the cooperation with Japan in the 1990s, the early stage of cooperation was mostly centered with Korean scientists' visiting research in Japan based on the principle of mutual support for research expenses

Table 3 Present states of cooperation by country

Year \ Project name		-99	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Cooperative research(new)		140	32	32	32	32	36	36	30	33	31	30	30	21	20	20	555
International joint seminar		79	13	11	13	13	13	13	8	11	11	11	11	10	10	10	237
Scientist exchange	Invitation	229	3	4	4	12	8	9	2	-	-	-	-	-	-	-	271
	Dispatch	584	29	27	28	34	28	17	14	17	5	5	5	1	-	-	794
Doctorate thesis(new)		47	4	8	5	4	6	6	6	3	2	2	2	1	-	-	96
Core University Program		3	1	1	-	1	1	-	-	-	-	-	-	-	-	-	7
Asian Core Program		-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	2
JSPS Fellowship		-	-	-	-	-	-	10	8	5	1	2	2	6	6	6	46

because many scientists wanted research with Japan given that the country maintained international standards in electronics, life science, and chemistry at that time. Currently, projects at equal footing are mainly implemented, such as international joint research and international joint seminars.

A distinctive project among Japanese projects, which is different from projects of other countries, is JSPS Fellowship in which Japan Society for the Promotion of Science (JSPS) supports all airfares and staying expenses of invited scientists. This project has been selecting 5–6 scientists per year and showing high competition rates until now. Projects with Japan have been implemented through the Korea-Japan Basic Science Exchange Committee established in 1990 but this committee was abolished in 2012.

Cooperation projects have been implemented most diversely and frequently with Japan among countries in the Asian region. However, cooperation with China has been expanded and reinforced since 2007.

3.1.1 Introduction of Korea-Japan Basic Science Exchange Committee: Abolished in 2012

Based on an agreement between the governments for basic science promotion in the two countries, mainly Korea and Japan, Korea Science and Engineering Foundation (KOSEF) and Japan Society for the Promotion of Science (JSPS) concluded a memorandum of understanding (MOU) for cooperation in the establishment of the Korea-Japan Basic Science Exchange Committee (1990.12.14.) and the committee was composed of seven branches of study; mathematics/physics, chemistry/materials, biology, information/mechatronics, the earth/the universe, medicine, humanities, and social science, and has been operated thereafter.

Mainly aiming at adjusting cooperation projects in the area of basic science between Korea and Japan and the discovery of new cooperation projects between the two countries, committee meetings have been held every year during 1990–2012 alternately in Korea and Japan.

3.1.2 Overview of the A-HORCs Meeting (Korea, China, and Japan Research Support Institution Head Meeting)

As cooperation among the three countries, mainly Korea, China, and Japan, was reinforced and the necessity of cooperation with each other was required further, Japan Society for the Promotion of Science proposed annual meetings of the heads of research support institutions of individual countries in 2003 to promote cooperation in scientific technology among the three countries. A committee was then organized with the heads of institutions in Korea (Korea Research Fund, NRF), Japan (Japan Society for the Promotion of Science, JSPS), China (National Natural Science Foundation of China, NSFC).

This committee aims to explain the contents and direction of the implementation of cooperation projects of research support institutions in Korea, China, and Japan and to share the results through subject presentations every year. It has been supporting tasks for constructing networks among researchers, such as

Table 4 The history of A-HORCS meeting

Division	Date held	Subject of presentation	Place
1st	2003.11.05 07	Policy for Science and Technology in Korea	Tokyo, Japan
2nd	2004.12.02 04	Policy for S&T Human Resource Development in each of the Three Countries	Shanghai, China
3rd	2005.11.21 24	Project Evaluation System	Gyeongju, Korea
4th	2006.11.06 09	KOSEF's Role in Korea's S&T	Beppu, Fukuoka, Japan
5th	2007.11.04 08	Measures for Efficient Korea/China/Japan Research Fund Management	Hainan, China
6th	2008.11.05 08	Recent Changes of S&T Policy	Jeju, Korea
7th	2009.11.05 07	Policies on International Cooperation	Hiroshima, Japan
8th	2010.09.15 18	Next 5-year perspective of Research Councils in S&T	Xian, China
9th	2011.09.25 28	S&T Policy for Enhancing Green Innovation	Daejon, Korea
10th	2012.09.18 20	Policies for Enhancing Basic Research in Korea	Sendai, Japan

※ 11th, 2013.09.26–29, held in Chengdu, China

scientist exchanges and joint seminars, by organizing research teams centering on research-based institutions in the three countries, mainly Korea, Japan and China, through A3 Foresight Program. A-HORCs Meetings has been held 10 times as of now.

3.2 Korea Research Fund (NRF)-National Natural Science Foundation of China (NSFC) Cooperation Project

Korea National Research Fund (NRF)-National Natural Science Foundation of China (NSFC) concluded a memorandum of understanding for cooperation in 1992 and have been supporting approximately 12 tasks of cooperative research and international joint seminars every year. On reviewing the records of support by project, it can be seen that the numbers of projects that were small at 5-7 per year until 2000 increased from 2004.

3.2.1 Korea-China Basic Science Exchange Committee

To implement scientific technology cooperation projects in the area of basic science between Korea and China more systematically to pursue scientific technology development in the two countries and activate basic research exchanges between the two countries, a memorandum of understanding for cooperation in the establishment of the Basic Science Exchange Committee was concluded during a meeting between scientific technology ministers of the two countries ('95.10, Beijing) and the committee meetings have been held every year from October 1995 until now in China and Korea in turn.

Major duties of this committee are the discovery of cooperative tasks between the two countries in the area of basic science, such as drawing areas of scientific technology of joint interests of Korea and China and selection of joint research projects and joint seminars of Korea-China in the area of basic science (unique projects of the research fund). In addition, this committee has been holding Northeast Asian symposiums with participation of the three countries, mainly Korea, China, and Japan.

The Korea-China Basic Science Exchange Committee has been operated with seven members selected from seven areas; mathematics/physics, chemistry, life science, material science, information

Table 5 NSF-NSFC cooperation records by project

Division	'92 - '99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	Total
Cooperative research	27	7	5	5	15	25	27	25	24	25	25	19	21	22	22	294
Joint seminar	50	9	13	12	13	8	12	14	14	12	13	11	12	10	10	213

science, the earth/the universe, and management science.

3.3 Present States of Asian HORCS (Asian Heads of Research Councils)

3.3.1 Background of Establishment and Role

Because scientific technology R&D cooperation was implemented centering on Korea, China, and Japan during 1980–2000, this council was established for annual meetings of the heads of research support institutions of 10 countries from 2007 in order to promote scientific technology cooperation among research support institutions referring to cooperation among Korea, China, and Japan. The participating institutions include all major research fund support institutions in Asia including 10 institutions, mainly the Korea National Research Fund (NRF), Japan Society for the Promotion of Science (JSPS), National Natural Science Foundation of China (NSFC), Indonesian Institute of Sciences (LIPI), National Research Council of Thailand (NRCT), Vietnam Academy of Scientific Technology (VAST), Department of Science and Technology of Philippines (DOST), University of Malaysia (VCC), India Department of Scientific Technology (DST), and Singapore Agency for Scientific Technology and Research (ASTAR). The record of meetings held thus far is as follows:

3.4 Japan Society for the Promotion of Science (JSPS)

3.4.1 Nature of the Institution

This is an institution that forms scientific research funds for Japanese scientific research foundations, pays funds for researcher cultivation, promotes international exchanges for science, and implements other projects for science promotion, which is an independent administrative corporation under the umbrella of the Japan Ministry of Education, Culture, Sports, Science, and Technology. As of 2012, the budget of this institution is approximately JPY 323.4 billion and the number of personnel is approximately 140.

3.4.2 Major Projects

International academic exchange-related projects implemented by this institution include two country exchange projects, joint research and seminar, researcher exchanges, Asia academic seminars, international chemistry research cooperation project (ICC program), international joint research education partnership program (PIRE program), multilateral international research cooperation project (G8 Research Councils Initiative), A3 Foresight Program, and international academic support. Scientific research fund formation projects include specially implemented research, new rising research, base research, challenge research, research activity start support, among others.

In addition, this institution implements cutting-edge research and development support program (FIRST program), state-of-the-art and next-generation research and development support program (NEXT program), state-of-the-art research base project, special researcher project/overseas special researcher project, global COE (Center Of Excellence) program, among others.

Major projects of the institution include fostering of young researchers, international science cooperation promotion, science research fund support, support for

Table 6 The history of Asian HORCS

Year	Place	Subject
2008	Tokyo, Japan	Recent Changes in S&T System and New Policy Initiatives in Korea
2009	Seoul, Korea	Human Resources Development
2010	Kuala Lumpur, Malaysia	National Disaster Management Lessons Learnt & Shared Best Practices
2011	Bangalore, India	Nurturing Centers of Excellence
2012	Beijing, China	Evaluation of Science Funding & Quality of Science
2013	Bali, Indonesia	Strengthening of Policy on Innovation Support System in Asia

science cooperation between the academy and the industry, and information collection and sharing for science research activities. The entire budget of this institution was KRW 3,850 billion as of 2010.

3.4.3 Manpower Composition

The personnel consists of officers, 96 staff members in 3 departments, and 116 PMs who are outside staff members in the scientific system research center working as full-time workers or part-time workers (212 in total). Some of the personnel are officials dispatched from the Japan Ministry of Education, Culture, Sports, Science, and Technology and universities who are to go back after a certain period of time.

The scientific system research center consists of 9 branches including humanities and is exclusively in charge of academic assessment. Its organization is composed of 1 chief, 2 vice chiefs, senior program managers, and program managers.

3.4.4 Major Projects

This institution implements science research subsidy projects that support for up to five years aiming at the development of creative and pioneering research in all areas and global CEO programs that provide JPY 50–500 million for up to five years. In addition, this institution also implements graduate school education reform programs and other graduate school education reform programs that support students in their doctorate courses.

This institution also implements international exchanges, international joint research, and international joint seminars that support research funds to researchers in other countries in order to form international research team networks with many foreign countries.

3.5 National Natural Science Foundation of China (NSFC)

3.5.1 Establishment

This institution was established in 1986 as a dedicated basic and applied research support institution as part of Chinese scientific technology systems based on a proposal by 89 members of Chinese Academy of Science and has been implementing not only support for basic research but also scientific technology manpower cultivation programs and scientific technology-related international cooperation projects.

3.5.2 Major Functions

Based on national scientific technology development policies, this institution provides funds to basic research projects and some applied research projects. Main activities are utilized as a support for basic and applied research, setting standards for basic and applied research support projects, research task evaluation / selection / support, policy advice for important issues in national basic and applied research policies, support for specialized science groups designated by the government, adjustment and presentation of directions of scientific technology-related program decisions of the groups, linkage with basic research support institutions in foreign countries, and support for the implementation of international cooperation projects.

3.5.3 Organization/Budget/Mumber of Personnel

The organization consists of seven departments, six divisions, and two offices divided by specialized area. The number of personnel is 188 and the budget was KRW 1,800 billion as of 2010.

3.5.4 Area of Support

This institution mainly supports natural science and basic science, such as mathematics/physics, chemistry, life science, earth science, engineering material science, and information science.

3.5.5 Research Support Project

The general programs of the institution include leading projects, important projects, and national, excellent, and rising scientist funds that account for at least 50% of the entire budget. There are also youth science fund projects and international cooperation

Table 7 Present state of budgets of major research fund support institutions

no.	Name of institution	Budget amount	Remark
4	Japan Society for the Promotion of Science (JSPS)	KRW 3,855.9 billion	as of 2010 (JPY 276 billion * KRW 13.97)
5	German Research Association (DFG)	KRW 3,526.5 billion	as of 2010 (EUR 2,327.2 million * KRW 1,515.37)
6	Korea National Research Fund (NRF)	KRW 3,364 billion	as of 2011
7	National Natural Science Foundation of China (NSFC)	KRW 1,794 billion	as of 2010 (RMB 10,400 million * KRW 172.5)
8	Japan Scientific Technology Agency (JST)	KRW 1,560.6 billion	as of 2010 (JPY 111,712 million * KRW 13.97)
13	Australia Research Council (ARC)	KRW 864.7 billion	as of 2010 (AUD 743.226 million * KRW 1,163.44)

programs in addition to general programs.

3.6 Present state of budgets of major research fund support institutions

The budgets of Japan Society for the Promotion of Science and Korea National Natural Research Fund are similarly exceeding KRW 3,000 billion but the budget of National Natural Science Foundation of China is still around 1/2 of that of Korea or Japan although it has been increasing sharply recently. Other countries, such as Thailand, Vietnam, and India, are much inferior compared to Korea, China, and Japan in the area of research fund support.

Because of the active international R&D cooperation among Korea, China, and Japan over the last 20 years and steady increases in the amounts of R&D funds, IMD national competitiveness and the rankings of paper publishing by country are similar.

Table 8 IMD national scientific technology competitiveness rankings (2008–2012)

(Unit: ranking, %)

Country	National competitiveness					Science competitiveness					Technology competitiveness				
	08	09	10	11	12	08	09	10	11	12	08	09	10	11	12
USA	1	1	3	1	2	1	1	1	1	1	1	1	1	2	2
Japan	22	17	27	26	27	2	2	2	2	2	16	16	23	26	24
Korea	31	27	23	22	22	5	3	4	5	5	14	14	18	14	14
Germany	16	13	16	10	9	3	4	3	3	3	6	7	16	13	13
France	25	28	24	29	29	12	11	15	15	12	19	20	20	21	18
China	17	20	18	19	23	10	6	10	10	8	32	21	22	20	26

Source: Swiss International Management Development Agency (IMD), World Competitiveness Yearbook 2012

Table 9 Present state of paper publication of top ten countries in the number of papers (2009–2010)

(unit : case, %)

Country	2009			2010			Increase/decrease rate of the number of papers (compared to the previous year)
	Number of papers published	Ranking	Global share ratios	Number of papers published	Ranking	Global share ratios	
USA	341,104	1	22.38%	338,784	1	22.17%	-0.68%
China	127,669	2	8.38%	135,375	2	8.86%	6.04%
UK	92,558	3	6.07%	93,092	3	6.09%	0.58%
Germany	89,503	4	5.87%	88,420	4	5.79%	-1.21%
Japan	78,873	5	5.17%	72,882	5	4.77%	-7.60%
India	40,254	10	2.64%	40,688	10	2.68%	1.62%
Korea	38,647	11	2.54%	39,843	11	2.61%	3.09%

4. Conclusion

International cooperation that began among Korea, China, and Japan in the 1980s has been expanded to include 10 Asian countries since the middle of the 2000s and the forms of projects have been changed from simple scientist exchanges, joint seminars, and small-scaled international joint research in the early stage to multidisciplinary large international joint research.

The areas of cooperation are also gradually moving from the solution of regional environmental problems in countries in the Asian region and basic research areas, such as life science in the past to cutting edge science areas, such as computer and electricity/electronics.

However, cooperation among the 3 countries, mainly Korea, China, and Japan still accounts for approximately 90% of international cooperation in the area of R&D in Asia and cooperation with Thailand, Vietnam, and Indonesia is in the starting stage now. Cooperation with countries that have been excluded thus far is expected to gradually increase 10 years from now.

Recent trends of cooperation are implementing cooperation projects by forming joint funds of a certain amount between two countries, such as Korea and Germany cooperation program, in which each country invests KRW 60 million every year, the Korea-Sweden joint fund project in which each country invests KRW 410 million every year, and Korea-USA special cooperation project in which each country invests KRW 450 million every year.

Among Asian countries, there is the Korea and China basic science program and the Korea, China, and Japan exchange cooperation program. Currently, cooperation that has been mainly made among Korea, China, and Japan has gradually expanded to include other countries, such as Vietnam and Thailand.

As with the EU, its framework program is implemented so that European countries can easily implement cooperation. This is because of the enhancement of economic statuses and scientific technology development in countries in the Asian region, such as Korea, China, Japan, and India. In addition, on the strength of the geographical and cultural traditions commonly recognized by countries in the Asian region, cooperation among Asian countries is expected to be reinforced through meetings such as A-HORCs or Asian HORCs.

In addition, if common plans for effective measures to cultivate young scientists and open access to disclose research results are made through discussions among countries in the GRC (Global Research Council), which is a regional meeting of research fund support institutions in Asian countries scheduled in November 2013, barriers between countries will be removed further and cooperation in the Asian region will be expanded and reinforced.