Triple Helix-based Institutional Analysis for Regional Innovation: Comparison of South Korea and Taiwan's Science Parks

Sunyoung Yun[1], Joosung Lee[1*]

Abstract
Since the global economic crisis in 2008, the necessity of reorganizing national and regional innovation systems has risen in macro perspectives. In particular, the regional innovation system is beneficial to understand the network among national economic constituents such as government and industries. Therefore, this paper examines the regional innovation system and its applications to Korea and Taiwan's science parks. Etzkowitz and Leydesdorff (2000) suggested that in a knowledge-based economy, knowledge sharing and interaction among system participants are key sources of innovation. The Triple Helix model of university-industry-government helps to understand the regional knowledge creation, utilization, and technology transfer effectiveness (Etzkowitz et al., 2007).
This research aims to diagnose the regional innovation institutions' roles and relations and to define the characteristics of the Asian science parks' innovation models. Therefore, we first quantitatively measured the two regional university-industry-government network density and structure of collaborative knowledge generation. Secondly, we qualitatively analyzed regional innovation participants' roles of knowledge, consensus, and innovation creation suggested by Triple Helix model. Finally, this result brings regional innovation policy through the comparison of Taiwan's Hsinchu Science Park and South Korea's Daedeok Innopolis. This study is meaningful in that it presents an analysis on regional innovation institutions as micro units of Triple Helix qualitatively and quantitatively. This case study also provides regional innovation policy implications for designing other developing countries' regional innovation system.

Keywords: Triple Helix, South Korea's Daedeok Innopolis, Taiwan's Hsinchu Science Park, Innovation Systems Network

1. Introduction

As innovation has become a key driver of economic growth, it is important not only for corporations but also for countries, regions, and industries. Since the global economic crisis in 2008, reorganizing national, regional and industrial innovation has become more important as there is more discussion on reorganizing innovation systems. Regional innovation systems in particular are at the center of focus (Cooke, 1996), based on the perspective that in order to ensure national competitiveness in the current situation where markets around the world are opening up to allow the transfer and sharing of resources with anyone anywhere, regions must develop competencies that differentiate themselves from others (Porter, 1998). However, according to a report titled "The Global Competitiveness Report 2011-2012" by the World Economic Forum, despite the importance of regional innovation, Korea ranked 28th out of 42 countries in

[1] Graduate School of Innovation & Technology Management, Korea Advanced Institute of Science and Technology(KAIST), #2101, N5, 291 Daehakro, Yuseong-gu, Daejeon, 305-701, Republic of Korea
*Corresponding author. E-mail: jooslee@kaist.ac.kr

terms of its state of cluster development.

This study performs empirical and comparative analyses based on the research question that differences in the level of interaction and roles of innovation participants in regional clusters represent differences in level of competitiveness. Empirical analysis was conducted on Korea's Daedeok Innopolis and Taiwan's Hsinchu Science Park, both of which were established in the period between 1970 and 1980 through government initiatives, and are representative regional innovation clusters of their respective countries. Taiwan is an appropriate subject for comparative since it ranks first in the World Economic Forum's State of Cluster Development Ranking. In addition, the Triple Helix model emphasizes the need for a cooperative university-industry-government (UIG) relationship in order to achieve innovation, and it is a reliable model that has been used by many researchers to analyze regional innovation (de Castro et al., 2000; Ughetto, 2007; Etzkowitz & Dzisah, 2008; Frykfors & Jönsson, 2010; Smith & Bagchi-Sen, 2010). Therefore, in order allow for a objective comparison of the regions, the Triple Helix model was applied as the theoretical standard. Also, in consideration of the fact that existing case studies applying the Triple Helix model provide macro analyses and qualitative analyses at best, this study aims to conduct qualitative and quantitative analyses of the cooperative relationship between UIG from a micro perspective.

Therefore, the purpose of this study is to first, identify the differences in the roles of innovation participants in Daedeok and Hsinchu via a qualitative analysis of the roles of innovation participants based on the triple helix model. Second, this study aims to compare the tendencies of cooperative relations of regional innovation participants in Daedeok and Hsinchu through quantitative and visual analyses. Third, this study proposes future regional innovation policies for South Korea's Daedeok Innopolis based on analysis of the roles and structures of institutions within the regional innovation system. This has significance in an academic sense that it provides a quantitative and visual description of the triple helix structure, and in a practical sense that it provides information on the specific roles of innovation participants as well as policy implications for developing nations that are seeking to newly create or modify their regional innovation systems.

2. Related Studies

2.1 Triple Helix Model

2.1.1 Role of UIG Institutions

In the course of knowledge-based economic development, innovation is not created by a single entity, but by many entities. Accordingly, not only companies, knowledge creators such as but universities and government research institutes have emerged as key innovation participants (Etzkowitz, 2002). In addition, a new approach for regional innovation in which innovation participants eliminate hierarchical and bureaucratic structures and cross boundaries to establish and develop new relations (Lee et al., 2010). In other words, regional innovation cannot be achieved by strengthening the individual competencies of regional innovation participants. it can be achieved when regional innovation participants form a single regional innovation system in which they maintain mutually dependent relations as suppliers, consumers, collaborators, and competitors.

The Triple Helix model suggested by Etzkowitz and Leydesdorff (2000) is a model that incorporates changes in centers and the relations of innovation participants. The Triple Helix model was devised an a conceptual tool for analyzing the roles of UIG necessary to achieve innovation. Innovation occurs when multiple entities interact in the creation, utilization, and transfer of knowledge, and the key of this model is that it displays the complex interactions between UIG entities that occur in this process through the movement of a triple helix (Etzkowitz & Leydesdorff, 2000). While emphasizing mutual interaction between innovation participants, Etzkowitz (2002), in reference to the specific roles of regional innovation participants based on science and technology, argued the need for innovation participants to create knowledge space, consensus space, and innovation space, and claimed that regional innovation based on knowledge can be achieved only when the three spaces function effectively.

First, knowledge space creation emphasizes cooperation between innovation participants in R&D activities to improve the regional environment. To realize growth of the regional economy through science, innovation participants can establish the foundations for development of new technologies by concentrating science and technology projects and businesses. Second, consensus space creation refers to creation of a space for connecting the knowledge provided by the knowledge space with creation of socioeconomic value. Consensus space is where innovation participants that possess human resources from different organizations and academic backgrounds gather together to share vision, strategies, and ideas. Third, innovation space creation is the role of innovation participants in which they infrastructure such as startup incubation, venture capital, legal and accounting services to realize the established goals. Innovation participants can achieve success by establishing cooperative relationships to create these three spaces. Therefore, this study seeks to conduct an empirical analysis of the roles assumed by UIG innovation participants in creating these three spaces for regional innovation based on science and technology

2.1.2 Cooperative Structure of UIG Institutions

The Triple Helix model allows for the analysis of the relationship structures of innovation participants. It generally classifies the relationship between UIG into three separate models (Etzkowitz & Dzisah, 2008). The first is the static model in which the government plays the leading role among the three participants by coordinating the relationship between the key innovation participants and providing the resources to execute new initiatives and projects (Lee et al., 2010). University and industry operate via specialized organizations that vertically connected to the government (Etzkowitz, 2008). While this type of model impedes autonomy by a certain degree due to the fact that the government supervises industry and university, but because it allows for the possibility of strong leadership, setting of clear goals, possibility of using key resources from the part of the government, it can be seen frequently in the case of developing nations seeking to cultivate technology intensive industries. The role of the innovation participants increase and they affect regional development as educational institutions and companies grow under the lead of the government.

Second, there is the *laissez-faire* model in which innovation participants maintain clear boundaries and exist independently without engaging in organic relationships. In this model, the functions performed by the innovation participants are limited to industry's production, government's regulation, and university's basic research, and each participant does not expand its function into that of another participant or assume multiple roles. In the *laissez-faire* model, there is a limit to how much innovative competency each participant can secure due to the change in the social environment for open innovation.

Third, there is the normative model where innovation participants maintain horizontal networks and each organization has an overlapping interface at its boundary. In this model, innovation entites expand and share their functions with other participants due to changes in the social and economic environment. As UIG interaction increases, a cooperative ecology model is established.

According to Etzkowitz (2008), in order to solve complex social problems and achieve economic results, the normative model in which innovation participants maintain horizontal cooperative relationships is the ideal model. This study, by assuming the overlap of roles as cooperation, seeks to identify the cooperative structure based on joint R&D. While existing studies assessed the degree of cooperation between innovation participants by investigating co-authorship (Park et al., 2005, Leydesdorff & Sun, 2009, Park & Leydesdorff, 2010), this study aims to calculate the density of the network between innovation participants by using co-patents, a key indicator of science and technology knowledge as criteria. Network density refers to the strength of connections between participants in a network. It is suitable for identifying cooperative relationships based on the fact that it shows the number of relationships between innovation participants in the network. It also provides a visual description of the entities leading the cooperative relationships, allowing for identification of key innovation participants from a macro perspective.

2.2 Regional Innovation Policies

Innovation policies are policies that can affect the development of technology and type of innovation. They include R&D policies, technology policies, infrastructure policies, regional (industrial complex) cultivation policies, and education policies (Science & Technology Policy Institutes, 2005). While science and technology policies focus on facilitating the cultivation of basic science as a public goods, innovation policies not only consider factors that influence the spread of technology from the supply perspective, but factors from the demand perspective such as technology purchases by public agencies (Edquist & Hommen, 1999). In other words, the role of innovation policies include organizing, enhancing or supplementing existing factors to enable innovation to occur within the nation, industries, and companies and to ensure that innovation activities can lead to market performance and economic development.

The innovation system approach is one of the most widely applied approaches in studies on innovation policies. The comprehensive concept of the innovation system model is applied in many science policies based on the fact that innovation does not occur sequentially or gradually, but rather through mutual interaction between innovation participants and systemic interactions that incorporate dynamic processes (Woolthuis et al., 2005). As society becomes ever complex and rapidly changing, many different theories related to policies that affect industrial development are also being developed, and the current approach to policy establishment is to combine the many theories and analyses rather than focusing on a specific perspective (Bauer et al., 2012). The innovation system is appropriate for modern policy making, which, in regards to technology development, requires a more comprehensive view as well as perspectives from different angles, in that it leads innovation, and places importance on the agencies, organizations, and innovation participating in innovation policy decision making. Within the innovation system, an organizational ecology of the innovation participants is formed, and activities for change and evolution of the system such as production, knowledge accumulation and dispersion, education and training, technology development, establishment of regulations are carried out together (Kuhlmann et al., 2010). Therefore, innovation policies focus on improving the system to facilitate the establishment of network relations between agencies/organizations within the organizational ecology (OECD, 1999). This study aims to analyze the roles and relationships of innovation participants within the regional innovation system and make policy proposals for regional innovation.

3. Method of Analysis and Data Collection

Qualitative and quantitative analyses were conducted in order to identify the roles and relationships of innovation participants within a regional innovation system. Qualitative analysis consisted of expert interviews[1)] on the roles of knowledge creation, consensus creation, and innovation creation suggested by Etzkowitz (2002) as the key roles of innovation participants for realizing science and technology-based regional innovation, and a comparative analysis of Taiwan and Korea's science parks based on additional material. Comparative analysis is a suitable method when numerous variable interact at the same time (Skocpol, 1976), and it is also suitable for this study since the entities in the triple helix are affected by many different variables. In addition, comparative analysis of differing innovation systems of difference

1) Hsinchu Science Park : 2011, November 16~17. 5 people depth-interviews (Hsinchu Science Council 2, National Tsing Hua University Professors 1, National Chengchi University 1), Daedeok Innopolis : 2011, December 7~8. 4 people depth-interviews (KAIST 2, Government Research Institutes in Daedeok Innopolis

regions and countries is suitable for this study, which seeks to propose innovation policies in that it is the most powerful method for persuading and enlightening policy makers (Bergek et al., 2005).

For quantitative analysis, this study conducted a triple helix analysis of the cooperative relations of innovation participants of Korea and Taiwan's science parks by selecting innovation participants that represent each region and conducting a network analysis of the selected innovation participants by using co-patents as an index of cooperation. While existing triple helix studies measured the strength of cooperation based on the amount of information with co-authorship as the knowledge index, this study examined co-patenting is a link in the network (Tel Wal & Boschma, 2009) by quantifying the density of cooperative relationships and producing a visual description of the network structure.

Representative innovation participants were selected through interviews with officials at Daedeok Innopolis and Hsinchu Science Park, and IT industry selected as the regions' representative industries. Next, government research institutes and universities in the regional cluster that represented the selected industries were selected, while representative companies were selected among the IT companies registered in the regional cluster based on 2010 sales figures and the existence of USPTO patents (see Table 1). The co-patenting applications registered in USPTO between January 1, 2007 to December 31, 2011 were drawn upon by using the Thomson Innovation database to selected subjects (Thomson, 2012). When screening the patent data, if it turned out another subject within science park, another subject' patents were searched or if it was not, the subject were drawn by relation symmetric metrics. After selection of the target entities, co-patent networks were analyzed using the UNICET 6.0 software package.

4. Empirical Analysis of Daedeok Innopolis and Hsinchu Science Park

4.1 Triple Helix Role Analysis of Innovation Entities

4.1.1 Roles of Innovation Entities at Daedeok Innopolis

- **Role of government**

In 1970, the Korean government, realizing that science and technology will play a key role in the country's economic growth, sought to foster science and technology at a government level. In 1973, the Daedeok Science Park was established and the necessary infrastructure was built, and by 1978, the relocation of research institutes was in full swing (Shin, 2000). In the mid 1990s, the government sought to transform the complex into a technology cluster that emphasizes UIG networks consisting of research institutes in the Daedeok Science Park, nearby universities and venture companies, and regional government. In 1999, the government revised the Act on Management of the Daedeok Science Park to establish the legal foundation for its shift from a R&D and education complex into a high-tech industrial complex. The government takes the initiative in setting the directions for Daedeok Innopolis' growth, changing the complex's name in 2000 to Daedeok Valley to signify its ambition to become a new silicon valley, and later in 2005 to Daedeok Innopolis (Kang, 2006). The government has invested over KRW 30 trillion into the Daedeok Innopolis over the past 30 years, and since 2005, it has sought to transform the complex from an R&D center into an innovation cluster that

Table 1 Selected representative U-I-G entities

UIG	Daedeok Innopolis	Hsinchu Science Park
University	Korea Advanced Institute of Science & Technology (KAIST), Chungnam National University	National Chiao Tung University, National Tsing Hua University
Companies	Silicon Works, Lightlon	TSMC, AU Optronics
Government Research Institute	Electronics and Telecommunications Research Institute (ETRI), Korea Institute of Science and Technology Information	Industrial Technology Research Institute (ITRI), National Chip Implementation Center

possesses industrial functions (Lim, 2010). In regards to R&D, while outside R&D funding fell from 70% in 2006 and 2007 to approximately 40% in 2009, dependency on external sources for R&D funding still remains high (Daedeok Innopolis, 2012). This shows that the government continues to play a leading role in determining the financial and strategic direction of Daedeok Innopolis.

The central and regional governments have exerted efforts to transform Daedeok Innopolis into an innovation cluster, but cooperative UIG relations necessary for creating innovation in the region have yet to be formed. The government has increased support for UIG gatherings to facilitate the establishment of business-centered networks, providing assistance for regular forum, symposium, and group exchange activities. The government has also established 'INNO-Cafes' to facilitate communication and the exchange of knowledge between universities, companies, and research institutes. 'INNO-Cafes', which are venues for UIG networking, have increased in numbers from 24 in 2004 to 150 in 2008. To establish global networks in addition to domestic networks, in 2010, Daedeok Innopolis hosted the International Association of Science Parks (IASP) World Conference. In order for the Daedeok cluster to be revitalized, it must transform from a cluster centered around research institutes and universities which are passive about creating economic effects into one that is led by companies. Only when research institutes and universities play roles in cooperative activities that are centered around companies can an actual revitalization be expected (Chung et al., 2007).

In the case of Daedeok Innopolis, the government assumes the lead role as a regional innovation participant, from providing funding for creating innovation space to creating consensus space.

• Role of industry

As of 2009, there are approximately 1,000 companies at Daedeok Innopolis generating a total of KRW 12 trillion in sales. Their combined compound annual growth rate from 2005 to 2009 was about 48%. However, sales of each company is expected at about KRW 12 billion, so most of the companies are SMEs. A look at the distribution of the companies that relocate to Daedeok Innopolis each year by business area shows IT companies about 39% and bio technology and other technology development support companies taking up about 11% (Daedeok Innopolis, 2012). The political direction for commercialization has been provided since Daedeok Innopolis began its transformation from an R&D based cluster into an innovation cluster with industrial functions, but in reality, Daedeok Innopolis has no specialized areas, and companies focusing on IT, BT, NT, ST, ET, CT, and convergence technologies are spread out within the complex. Because a core industry has not been designated and there is no industrial infrastructure, Daedeok currently lacks the environment for specialized industries to cluster. In addition, the companies within the complex lack competitiveness, and therefore are unable to lead joint projects or form cooperative relationships with research institutes and universities. As a result, the companies withing Daedeok Innopolis contribute little to knowledge creation, and do not play significant roles in providing strategic direction and creating consensus. While there are some research institutes belonging to major Korean companies, most belong to their respective head offices and do not engage in independent research to create profits through technology development. Therefore, the companies within Daedeok are found to play minor roles in innovation space creation.

• Role of university

Daedeok Innopolis began from the need to expand the size of the research complex established around the Korea Advanced Institute of Science and Technology. KAIST and Chungnam University became the major universities in Daedeok Innopolis, while industrial universities such as Mokwon University and Korea Polytechnics were established nearby. Since 2005, universities are operating business incubation centers to commercialize R&D, but because their histories are short, have yet to produce any significant results.

KAIST which is a key entity of Daedeok Innopolis, ranked 27th in the areas of Engineering and IT in the

2011 QS World University Rankings (Topuniversity, 2011). While it is notable that KAIST is Korea's premier R&D focused university that competes with other world-class universities, the school has not achieved any success in terms of commercialization. Since 2006, KAIST has been operating a technology commercialization center and business incubation center under KAIST I-U Cooperation Foundation. As of 2010, about 100 companies are located within the centers. While these companies have generated KRW 2.1 billion in profit through 2,100 technology transfer projects, this figure is small considering that universities in the US such as MIT generate billions of dollars each year through technology transfers.

In sum, universities within Daedeok Innopolis are the key creators of knowledge space as well as the creators of innovation space for commercialization of knowledge, but do not play the role of creators of consensus space that cultivate strategic industries.

4.3.2 Roles of Innovation Entities at Hsinchu Science Park

• **Role of government**

The Taiwanese government, inspired by Silicon Valley in California, established the Hsinchu Science Park in 1980. Soon after its establishment, after which high quality personnel began to flow into Hsinchu, and the area grew into a center for IT industries (Tung, 2001). To encourage the influx of personnel required for Hsinchu Science Park's growth into an industrial cluster, the government provided direct financial assistance, handing out tax benefits to companies that moved in and reducing taxes when employees working at companies within the complex sold shares of their own company. The government also built infrastructure such as housing facilities and international schools to attract high quality human resources.

In addition, the government made direct investments in technology development and commercialization through the ITRI research institute. The Taiwanese government actively participated in cultivating industry for the following reasons. First, Taiwan's industrial infrastructure was too weak for the private sector to make large investments in R&D or production facilities, and awareness of the need for R&D investment was weak. Second, because private companies lacked the ability to adopt advanced technologies from overseas, it was necessary for the government to directly cultivate the human resources to transfer technology (Hongwu, 2006). In consideration of such conditions, the government played the role of consensus creator, sending ITRI employees to technological conferences and trade shows to learn the latest technologies and while designating key industries for technology development and transfer. In short, the Taiwanese government assumed the roles of knowledge space creator and consensus space creator through government research institutes.

ITRI's role as a innovation space creator led to the spin off of global companies such as TSMC, UMC, and VIS. ITRI focused on operating incubation labs and fostering human resources for transferring technology to companies. Since 1996, ITRI has operated an open lab for technology commercialization projects. A total of 311 companies have participated in the open lab and over 165 startups have been cultivated through over NT$ 59 billion (approximately KRW 2.4 trillion) in paid in capital. Among the cultivated startups, 15 have grown into listed companies. In sum, ITRI directly creates knowledge space while establishing innovation space.

• **Role of industry**

As of 2010, Hsinchu Science Park is home to 449 companies which generate approximately KRW 45 trillion in sales. Their combined compound annual growth rate from 2005 to 2010 was about 3.7% (Hsinchu Science Park, 2012). Average sales of each company is estimated at KRW 100 billion, which is 6.5 times more than companies in Daedeok Innopolis. Sales contribution by business area was IT (foundry, DRAM manufacture) companies 67.5%, followed by photoelectronic companies, and LCD companies.

Hsinchu Science Park was bestowed with the political direction of cultivating IT industry at the time the regional cluster was established. It developed the world's first ‘dedicated foundry’ business model.

TSMC, which is currently the global number one dedicated foundry company, acquired technology at the time of its foundation through a strategic partnership with Philips. The company, by opening up information on its production processes except for those related to its core competencies and providing state-of-the-art technology at low cost to domestic and foreign fabless design companies in the region, also played a leading role in creating knowledge space and consensus space (Willy et al., 2009).

Because foundry companies require high capital investment in the early stages of business, the government had large shares in them, and this made them more open to cooperation with fabless companies. Such industrial structure allowed an ideal level of specialization. TSMC continues to play a key role in consensus space creation by seeking to establish an open innovation platform based on the idea that dedicated foundries must maintain cooperative relationships with other participants in the system semiconductor industry. In sum, while companies in Hsinchu Science Park played knowledge creation roles at first through cooperation with the government, they are currently cooperating with companies, government agencies, and universities as leaders of consensus space creation.

- **Role of university**

The National Tsing Hua University (NTHU) and National Chiao Tung University (NCTU) are the major universities in Hsinchu Science Park, while there are a total of 9 universities in the vicinity. The number of students enrolled in the universities are approximately 10,000. Personnel exchange between the universities within the Hsinchu Science Park and research institutes and industrial facilities within the complex is frequent. In the case of a precision equipment center located within the complex, 16 of its 19 doctorate degree holders graduated from NTHU (Shin, 2000). The universities in Hsinchu Science Park are a key source of human resources for the companies and government research institute in the complex.

Universities and the National Science Council, a government agency, are attempting to reach consensus on establishing a regional innovation system. NTHU and the National Science Council, through the "Pilot Study on the Research Park Development" project, plan to establish a regional innovation ecology centered around R&D within Hsinchu Science Park. Aside from seeking strategic consensus, to enable continuous innovation, NTHU and the National Science Council operate the "Strengthening the foundation Enhancement Program" for training companies within the complex on innovation.

In addition, universities and companies within Hsinchu Science Park cooperate mainly through venture startup programs based on joint research in science and technology. Companies within Hsinchu Science Park such as MediaTek, Novatek, and Delta Electronics co-established a Joint Research Center with NTHU, and TSMC, through the "Joint Development Program", provides continuous assistance to NTHU faculty and students in conducting industry-related research. NCTU also has a shining of example of a university spinoff; Acer Inc. Acer Inc. was founded by an electronics major at NCTU, and has since grown into a leading LCD manufacturer. It provides infrastructure for the ITRI/NHTU to enable continuous research and development under university and research institute cooperation. As a result, since its establishment in 1998, the NTHU Center has produced 101 incubated companies. Among these companies, 8 have given IPOs, and they have contributed a approximately NT$ 50.0 billion (US$ 1,600 million) in creating innovation space. In sum, universities within Hsinchu Science Park can be seen as entities that create consensus space and innovation space.

4.3.3 Role of Innovation Participants and Result of Comparative Analysis

Table 2 is the result of analysis based on interviews with personnel in charge of Daedeok Innopolis and Hsinchu Science Park and experts on the roles played by universities, companies, and government research institutes in Daedeok Innopolis and Hsinchu Science Park as innovation participants from the early days up until now in the areas of knowledge, consensus, and

Table 2 Comparison of U-I-G roles in science parks

Triple Helix Space	Daedeok Innopolis' UIG Roles	Hsinchu Science Park's UIG Roles
Knowledge Space	• Creation of knowledge centered on IT technology is led by government research institutions and universities • Existence of a wide range of knowledge based on basic science, rather than research areas focusing on industry, making sharing and exchange difficult	• Universities, industry, and government research institutes create knowledge through cooperative networks • Industry-connected knowledge is created through U-I and G-I networks
Consensus Space	• Government research institutions seeks to find UIG point of consensus, but wide range of research areas and industries exist • Regional SMEs that lack resources or competency, and are therefore inadequate to play roles as consensual innovation participants	• Government research institutes actively hosts gatherings of domestic and overseas experts, and enabled the reaching of consensus on Hsinchu Science Park's and the world's first dedicated foundry business model • Reached inter-industry consensus by using foundry companies as the network platform within the semiconductor industry
Innovation Space	• Government research institutes and universities operate business incubation centers, but there are no innovation participants to create global companies • Technology transfer is being sought, but currently still in the initial infrastructure operating stage	• Government research institutes operates research institute incubation center and enables commercialization through direct spin-off • Global companies developed from university business incubation centers
General role of triple helix innovation entities	• Government research institutes has led the knowledge, consensus, and innovation space since the formation of the regional cluster	• Government research institutes led the knowledge, consensus, and innovation space at the time of the formation of the regional cluster, but now each innovation participants creates knowledge, consensus, and innovation space

innovation creation.

While at Daedeok Innopolis, the government has and continues to lead the creation of knowledge, consensus, and innovation since the development of the cluster, at Hsinchu Science Park, the government led the knowledge, consensus, and innovation space in the Park's early days, but since the IT (foundry, fabless) became the main industry of the cluster, universities, industry, and government institutes play certain roles in knowledge, consensus, and innovation creation, and the roles are shared.

4.2 UIG Relations of Triple Helix

The Triple Helix model suggests that innovation gains momentum under cooperative UIG relations (Etzkowitz, 2008). Because the subjects of analysis are science parks, this study seeks to determine the degree of UIG cooperation and which participant plays a leading role in cooperating by examining tendencies for joint research and development. Patents, because they are a surrogate index of knowledge creation, may be applied as the results or products. Therefore, this study conducted a network analysis of co-patents as a means to identify the degree of cooperation in UIG relations.

4.2.1 UIG Cooperative Relations in Daedeok Innopolis

Analysis showed the network density of the 22 entities that had co-patents with Daedeok Innopolis to be 0.4221. When the participants of the co-patent applications where categorized into university, companies, and government research institutes, universities and government research institutes were found to be playing key roles in cooperative co-patent development, the ratio of participation in co-patents being 47.60% for universities and 33.80% for government research institutes (see Table 3).

In addition, as shown in the network analysis results in Figure 1, the intensity of cooperation among entities within the network was not high and the networks of each entity were not diverse, except for in the case of ETRI and KAIST. Such results can seen to be in the same context with a previous study which found that entities within the Daedeok Innopolis

Table 3 Daedeok Innopolis co-patenting participation(2007-2011)

Categories	Number of UIG Entities	Co-patenting Relations Ratio[2)]
University	6 entities	47.60%
Companies	11 entities	18.60%
Government Research Institutes	5 entities	33.80%

did not display much of the characteristics of a horizontal cooperative network among different groups and that the level of cooperation was weak due to the fact that research institutes competed to ensure information security rather than to establish a culture of information sharing, and that Daedeok Innopolis consists of an exclusive network in which relations were mostly maintained by the originating entities of ETRI, KAIST, and Chungnam University or through social gatherings based on personal acquaintance (Lim, 2010).

In addition, the weak network density can be attributed to the lack of synergy from the concentration of research institutes which are unrelated in research areas or which are not functionally connected. That was a result of forceful demands from the central government to government and private research institutes to relocate to the cluster (Shin, 2000).

One challenge that Daedeok Innopolis must solve is the economic results (Lim, 2010). ETRI located in Daedeok Innopolis ranked first at the '2011 Innovation Anchor Scorecard' in terms of US patents, and KAIST

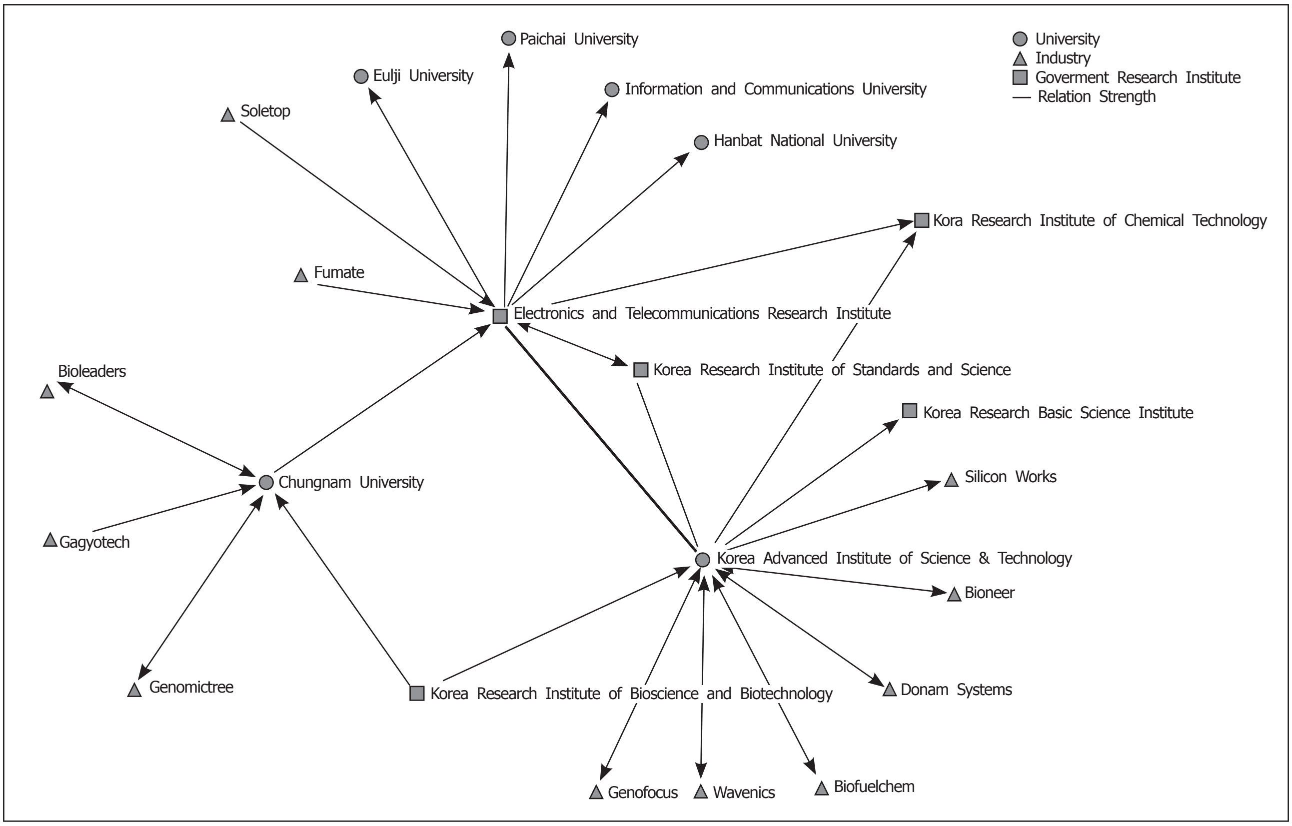

Figure 1 UIG relations in Daedeok Innopolis

2) The Co-patenting Relations Ratio= The number of each entity's co-patenting / The number of total analyzed sample entities' co-patenting(UIG)

too displayed notable research performance after 40 years since its establishment by ranking 27th in the Engineering and IT sector of the 2011 QS World University Rankings. However, Daedeok Innopolis has yet to cultivate a global corporation that can represent it. This can also be seen in this study's analysis of UIG relations in Daedeok Innopolis. There are hardly any interactions between companies in the network, while the network centering around universities and government research institutes and the lack of connections between companies in the network show a relationship structure in which innovation participants are unable to achieve economic results.

4.2.2 UIG Cooperative Relations in Hsinchu Science Park

Analysis of cooperative relations between universities, industries, and government research institutes showed the network density of the 24 universities, IT companies, and government research institutes within the Hsinchu Science Park to be 1.4438, higher than that of the Daedeok Innopolis. When the participants of the co-patent applications where categorized into university, companies, and government research institutes, companies and government research institutes were found to be playing key roles in cooperative co-patent development, the ratio of participation in co-patents being 57.20% for companies and 39.40% for government research institutes (see Table 4).

A closer look at the entities playing major role in co-authorship shows ITRI at the center of companies and research institutes in the LCD and semiconductor industries (see Figure 2). Another difference of Hsinchu Science Park from Daedeok Innopolis is the high network density of companies, government research institutes, and universities in the LCD and semiconductor industries. In addition, at Hsinchu Science Park, fabless companies are engaging in co-patent development with foundry companies such as TSMC and UMC, showing that cooperative R&D is being carried out as specialization occurs even among companies. TSMC and UMC are global companies located within Hsinchu Science Park. Both were initially spun off from government research institutions but both currently interact with other companies than government research institutes. For example, TSMC provides design services for a wide range of products from 0.5 micron to 28 nanometer chips and Silicon proven IP to SoC services, and provides technical support to a global clientele located in Europe, China, Japan, and Korea through a strong partnership with Global Unichips designed for mutual prosperity (Gartner, 2011). This corresponds with the replies of experts who were interviewed that companies in Hsinchu Science Park have outgrown the support of government research institutes and are now independent entities that create consensus spaces with other industrial entities, government research institutes, and universities.

Table 4 2007-2011 Hsinchu Science Park co-patenting participation

Categories	Number of UIG Entities	Co-patenting Relations Ratio
University	2 entities	3.40%
Companies	17 entities	57.20%
Government Research Institutes	5 entities	39.40%

Hsinchu Science Park, unlike Daedeok Innopolis, displays strong U-I-G relations in specific industries as well as the formation of specialized business ecosystems in specific industries.

5. Conclusion and Regional Innovation Policy Proposals

As in the assertion made by Etzkowitz (2002), it is important for innovation participants from university, industry, and government to play the role of creating knowledge space, consensus space, and innovation space, as it is important for innovation participants to develop co-evolving relationships. During Hsinchu Science Park's early days, the government played the role of the creator of knowledge, consensus, and innovation space and led the rapid growth of the IT industry. However, after the regional industry's growth stabilized, the innovation participants divided the roles. The government concentrated on its role of creating

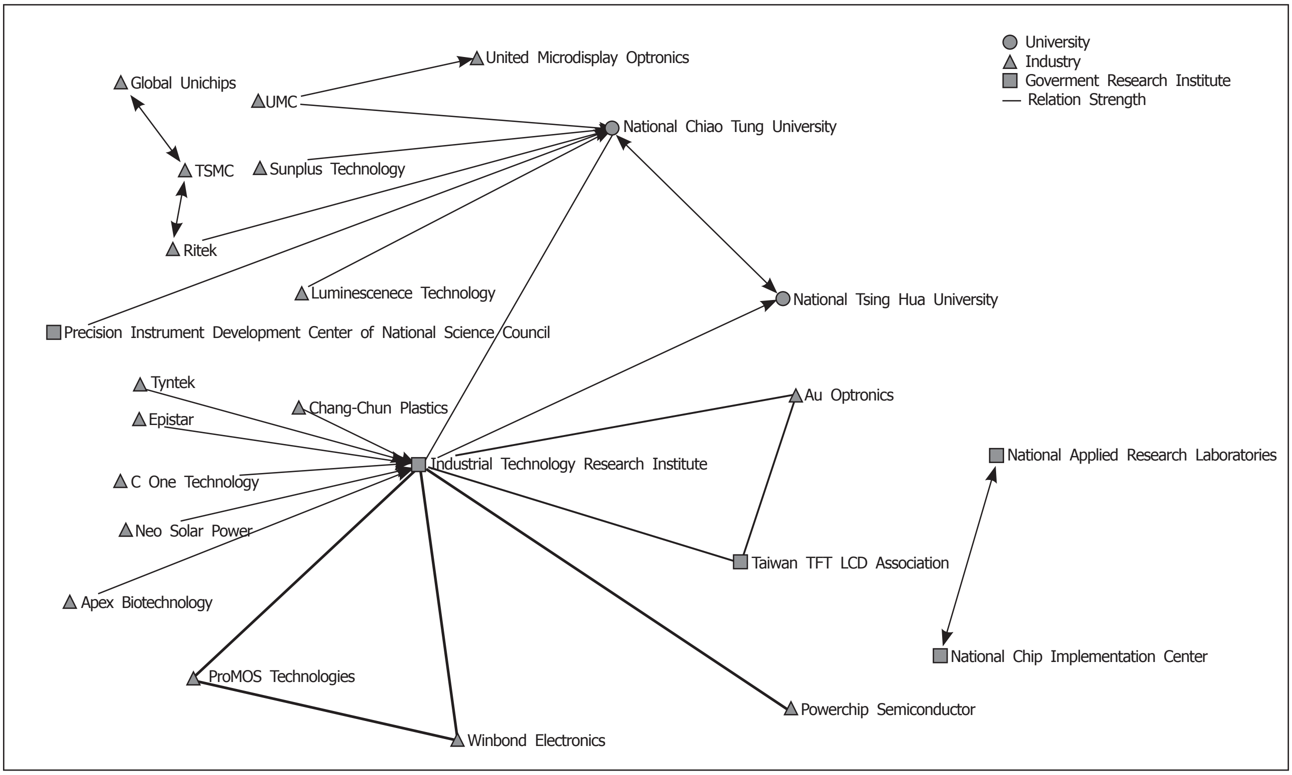

Figure 2 U-I-G relations in Hsinchu Science Park

knowledge space, while companies and universities began to take the lead in creating consensus and innovations space. In contrast, in the case of Daedeok Innopolis, the government continues to lead the creation of knowledge, consensus, and innovation space since the establishment of the cluster up until now. This is probably the result of the fact that Daedeok Innopolis was initially established as a cluster for research on basic sciences.

While Taiwan's Hsinchu Science Park possesses the consensus and innovation infrastructure for the knowledge and business models necessary to foster the target industry, Korea's Daedeok Innopolis still does not have a specialized target industry and remains as a concentration of basic science companies.

In addition, as seen in the network analysis on cooperation among innovation participants, cooperation is still done mostly between government research institutes and universities at Daedeok Innopolis, and the network density is low. On the other hand, Hsinchu Science Park is more active toward cooperative relations than Daedeok Innopolis. In order for Daedeok Innopolis, which remains as a government-initiated cluster focusing on basic sciences, to achieve economic innovation through successful commercialization of technology.

There must be a change in the roles of innovation participants and the cooperative relations. To this end, this study proposes the following policies for regional innovation of Daedeok Innopolis.

First, in order to establish a sound regional innovation structure, the government must identify the region's core competencies and then select industries to focus on and implement policies to concentrate on those industries. Daedeok Innopolis' innovation participants have been making independent efforts to strengthen competency, but such efforts have failed to lead to economic achievements. Therefore, it is important to focus on cultivating a selected number of target industries so that a virtuous cycle of technology development, commercialization, innovation creation, and profit realization within the region can be established. The New England Council is one good example of such a political consensus space. In the 1920s, universities in New England such as MIT and Harvard possessed knowledge in economically promising areas of research. Karl Compton, the then president of MIT, proposed the utilization of the competitive advantage of the region's academic infrastructure and the systematic creation of new companies based on science and technology (Etzkowitz, 2002). To achieve this, industry, government, and university leaders developed the region into a consensus space by gathering together to analyze and develop new ideas. In the same manner, government research institutes in Daedeok Innopolis, where research is spread out in many areas, can enable concentrated research and development by seeking consensus and establishing a strategic direction for industry development.

Second, at Daedeok Innopolis, creation of knowledge based on technology development is encouraged. The problem lies in the fact that such knowledge is not commercialized. Therefore, it is important for, universities and government research institutes, which currently possess superior research abilities, to become creators of knowledge and innovation. This study proposes the implementation of policies that encourage university startups as a measure to facilitate this. Located in Daedeok Innopolis is KAIST, which is a world leader in Engineering and IT, and talents from such schools should develop commercializing technology and establishing innovation infrastructure as basic competencies. Hong and Kim (2008) pointed out that venture startups that originate from Korean universities tend to focus on manufacturing, an area which the industrial infrastructure is well established, while there are few startups that target new business areas. Therefore, universities, the region's core creator of knowledge, must foster venture startups that focus on new growth drivers such as BT, NT, and CT, and because research on a wide range of areas are being carried in Daedeok Innopolis, regional innovation policies based on university startups are expected to be successful.

Third, Daedeok Innopolis is mostly populated by SMEs which focus mostly on research and development and lack the commercialization abilities. Therefore, policies to facilitate the establishment of commercialization infrastructure are required. One good example of commercialization infrastructure establishment is the American Research and Development Corporation (ARD). ARD is the US' first venture capital firm in US and was established in 1946 as a result of cooperation between universities (MIT, Harvard), financial institutions, and the government. It contributed to the development of regional industries by providing venture startups with consulting services in financing as well as technology and business (Etzkowitz, 2008). Once the growth of companies is led by the creation of innovation space, just as in the case of Taiwan's Hsinchu Science Park, networks centered around companies are formed, and it will be possible to establish a venture ecology where universities and research institutes enjoy mutual growth.

This study conducted a empirical analysis of the network structure and roles of participants of regional innovation by applying the Triple Helix model. In contrast to the fact that existing case studies applying the Triple Helix model focus on macro perspectives, this study selected representative innovation participants and conducted a comparative analysis of their roles and relations from a micro perspective. This study has significance in that it provides empirical analysis from both qualitative and quantitative perspectives, and in that there is little literature on comparative studies on the roles of innovation participants suggested by Etzokowitz (2002). However, because the purpose of this study was to conduct a comparative study of the two regions, the tendencies of some of the network relationships of representative innovation participants were analyzed while the relationship between network structure, the central entity of the network, and regional innovation performance was not examined. Therefore, future studies will require network analysis of triple helix innovation participants for examining the relationship between network structure, the central entity of the network, and regional innovation performance or innovation participant performance. In addition, the methods utilized in this study are useful to decision makers and researchers of developing nations in the fact that they can be used empirically according to the development stage of their country's regional clusters. Based on the fact that innovation is create by an organic network rather than a single entity, the empirical analysis in this study may be of practical use in establishing a direction for policies as it can be used to analyze the desired roles and relationships of each innovation entities.

References

Bauer, J., Lang, A., & Schneider, V. (2012). Innovation policy and governance in high-tech industries. Verlag; Berlin; Heidelberg: Springer.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmarki, S., & Rickne, A. (2005). Analyzing the dynamics and functionality of sectoral innovation systems: A manual. DRUID Conference, June: 27-29.

Chung, E. D., Yang, Y. S., & Park, J. C. (2007). A study for firm-centered clustering to rejuvenate industrial cluster: A case study of Daedock high-up program [In Korean]. Korean Industrial Economic Association, 20(4), 1359-1380.

Cooke, P. (1996). The new wave of regional innovation networks: Analysis, characteristics and strategy. Small Business Economics, 8(2), 159-171.

Daedeok Innopolis (2012). Cluster statistics overview. Daejeon: Daedeok Innopolis. Retrieved from http://dd.innopolis.or.kr.

de Castro, E. A., Rodrigues, C., Esteves, C., & da Rosa Pires A. (2000). The Triple Helix model as a motor for the creative use of telematics. Research Policy, 29, 193-203.

Edquist, C., & Hommen, L. (1999). Systems of innovation: Theory and policy from the demand side. Technology in Society, 21, 63-79.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From national system and "Mode 2" to a triple helix of university-industry-government relation. Research Policy, 29, 109-123.

Etzkowitz, H. (2002). The triple helix of university-industry-government implications for policy and evaluation. SiSTER, Working Paper 2002.11, 1-18.

Etzkowitz, H., Dzisah, J., Ranga, M., & Zhou, C. (2007). The Triple Helix model of innovation: University-industry-government interaction. Tech Monitor, Jan-Feb, 14-23.

Etzkowitz, H. (2008). The Triple Helix of university-industry-government in action. London: Routledge.

Etzkowitz, H., & Dzisah, J. (2008). The triple helix of innovation: Towards a university led development strategy for Africa. African Technology Development Forum Journal, 4(2), 3-11.

Freeman, L. C. (1979). Centrality in social networks conceptual clarification. Social Networks, 1, 215-239.

Frykfors, C. O., & Jönsson, H. (2010). Reframing the multilevel triple helix in a regional innovation system: A case of systemic foresight and regimes in renewal of Skåne's food industry. Technology Analysis & Strategic Management, 22(7), 819-829.

Hong, S. M., & Kim, K. S. (2008). An analysis of university originated venture business in Korea its political perspective: Focused on the comparison with Japan. The Journal of Entrepreneurship and Venture Studies, 11(4), 141-161.

Hongwu, S. O. (2006). Agency problem, institutions, and technology policy: Explaining Taiwan's semiconductor industry development. Research Policy, 35, 1314-1328.

Hsinchu Science Park (2012). Cluster Statistics Yearly Report. Hsinchu City: Hsinchu Science Park. Retrieved from http://www.sipa.gov.tw/english.

Kang, H. S. (2006). The study on the roles of national laboratories in the regional innovation systems: Comparative studies between Daedok Science Park in Korea and some European experiences [In Korean]. Journal of the Korean Association of Regional Geographers, 12(1), 108-123.

Kuhlmann, S., Shapira, P., & Smits, R. E. (2010). The theory and practice of innovation policy: An international research handbook. Cheltenham: Edward Elgar.

Lee, C. W., Lee, J. H., & Park, K. S. (2010). An inquiry into the triple helix as a new regional innovation mode l [In Korean]. Journal of the Economic Geographical Society of Korea, 13(3), 335-353.

Leydesdorff, L., & Sun, Y. (2009). National and international dimensions of the triple helix in Japan: University-industry-government versus international coauthorship relations. Journal of the American Society for Information Science and Technology, 60(4), 778-788.

Lim, H. (2010). Good governance of the new industrial policy in Korea : Promotion strategy of regional economic growth and the Daedeok Innopolis [In Korean]. The Institute of East and West Studies at Yonsei University, 22(1), 77-113.

OECD (1999). Managing national innovation systems, New York, Cambridge: Cambridge University Press.

Park, H. W., Hong, H. D., & Leydesdorff, L. (2005). A comparison of the knowledge-based innovation systems in the economies of South Korea and the Netherlands using triple helix indicators. Scientometrics, 65(1), 3-27.

Park, H. W., & Leydesdorff, L. (2010). Longitudinal trends in networks of university-industry-government relations in South Korea: The role of programmatic incentives. Research Policy, 39, 640-649.

Porter, M. E. (1998). Clusters and the new economics of competition. Boston: Harvard Businesses Review.

QS (2011). QS World University Rankings 2011. Sydney: University of New South Wales. Retrieved from http://www.topuniversities.com/world-university-rankings/qs-world-university-rankings-2011

Science & Technology Policy Institutes (2005). Formulation of a comprehensive policy framework: Applied to Finnish and Korean national innovation policies [In Korean]. Seoul: Science & Technology Policy Institutes.

Shin, D. H. (2000). Networks of high technology venture Firms in Daejeon, Korea [In Korean]. Journal of the Korean Regional Development Association, 12(1), 1-15.

Skocpol, T. (1976). Comparative studies in society and history, Cambridge: Cambridge University Press.

Smith, H. L., & Bagchi-Sen, S. (2010). Triple helix and regional development: a perspective from Oxfordshire in the UK. Technology Analysis & Strategic Management, 22(7), 805-818.

Ter Wal A. L. J., & Boschma R. A. (2009). Applying social network analysis in economic geogrphy: Framing some key analytic issues. Annals Regional Science, 43, 749-756.

Thomson (2012), Patents for Daedeok Science Park and Hsinchu Science Park, Retrieved May 18- May 30, 2012, from Thomson patent database.

Tung, A. C. (2001). Taiwan's semiconductor industry: What the State did and did not. Review of Development Economics, 5(2), 266-288.

Ughetto, E. (2007). Foresight as a triple helix of industry, university, and government relations. Foresight, 9(5), 14-22.

Wang, J., & Teng, A. (2011). Competitive landscape: Top fabless semiconductor companies, Taiwan, 2011. Stamford. CT: Gartner, Inc. Retrieved from http://www.gartner.com/technology/ site-index.jsp.

Willy, S., Chen-fu, C., Chintay, S., & Jack, C. (2009). The TSMC way: Meeting customer needs at Taiwan semiconductor manufacturing co. Boston: Harvard Business School.

Woolthuis. R. K., Lankhuizen, M., & Gilsing, V. (2005). A system failure framework for innovation policy design. Technovation, 25, 609-619.

World Economic Forum (2011). The Global Competitiveness Report 2011-2012. Retrieved from https://www3.weforum.org/docs/WEF_GCR_Report_2011-12.pdf.