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The Effect of Integration on the Change of Technological Knowledge Structure: Based on the German Reunification

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Abstract

The Effect of integration on the change of technological knowledge structure: based on the German reunification

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The reunification of Germany is often regarded as a miracle of the 20th century but this miracle ended up politically. After reunification, Germany went through an unexpected deep recession despite the expectation of fast convergence and economic prosperity. To elucidate the reason for the tardy and stagnant convergence, previous economic studies have focused on the reallocation of input factors such as capital accumulation and labor thinning, the observation of the convergence phenomenon and misguided monetary policy. From a national innovation system (NIS) view, they have failed to adopt a systemic approach considering the interaction between societal change and the role of technology. Investigation of the change in the technological knowledge

structure would be a good starting point to understand the effect of economic integration on Germany.

In this study, the technology structures were constructed by a technology network using EPO patent data. I then figured out the competitive technologies of a country and considered the interaction among technologies via knowledge spillover and the movement of agents after reunification. The topologies of technology structure, relative degree of technology concentration and technological distance/similarity were examined for GDR, FRG and Germany. The analysis results showed that the technology structure of Germany covered that of FRG. A difference existed in the relative degree of development but the distribution of hub technologies were similar among the three countries. This might have had potential to enable the absorptive capability of GDR to adopt advanced technologies of FRG. The frictionless integration of technology would have been possible if German policy on science and technology had stimulated investing in GDR's R&D system in areas in which GDR had superiority (e.g., chemical sector). But the technology system, institution and researchers of GDR collapsed due to the impetuous process of organizational integration and unilateral absorption to FRG after reunification.

German reunification does not provide solutions but rather leaves questions and challenges for Korea in the case of unification of the Korean Peninsula. A substantial period of time must be taken to consider the relatively developed technology and highly trained human resources in the North; otherwise, Korea could miss an opportunity to achieve technological integration of the Korean Peninsula. German reunification urges

Korea to be ready and prepare a strategy in advance that draws on the lessons in reunification in Germany.

Keywords: Economic integration, Technological knowledge structure, Network Analysis, Unification

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Chapter 1. Introduction

It has been 25 years since the fall of the Berlin Wall. The collapse of the Communist government came without bloodshed or violence. The people of the German Democratic Republic (GDR) took part in peaceful mass demonstrations against the regime of the GDR and these movements led to the fall of the Berlin Wall on November 9, 1989 and of the GDR. After only one year, Germany was reunified. In terms of the political unification of the two countries, it was a miracle. But this did not lead to another miracle like Wirtschaftswunder (German for "economic miracle"), which took place in West Germany after World War II. Because reunification was an unexpected occurrence, Germany did not have enough time to prepare appropriately. At most events, reunification seemed to be successful. Eastern Germans could recover their own sovereignty and political liberty, be assured of receiving social insurance, enjoy improved living standards, move without restriction, and so on. When compared to the former Eastern economic situation, the eastern economy has made tremendous progress since reunification (Wiesenthal, 2003). However some inevitable failures arose from economic problems, especially unemployment.

Shortly before the reunification, an obvious economic power gap existed between the two countries. The population of West Germany was about 64 million and that of East Germany was 27% that of the West. The per capita GDP of West Germany was $20,540 and the East 33% of that. After reunification, since 1990, the Germany government has made tremendous investments to restore East Germany, resulting in flourishing landscapes in former East Germany areas. After several years, the wage, productivity, competitiveness and unemployment rate of the East converged to that of the West and the East seemed to be about to catch up to the West. But the convergence process has come to a halt since 1996. Despite the remarkable restoration, East Germany still lags behind West Germany. For example, GDP per capita of the former East increased to 66% of that of the West, but no more convergence occurred. To explain this slowdown in the East's catching up with the West, most previous studies have focused on the reallocation of input factors in the former Eastern area – labor thinning and capital deepening. Some gave attention to monetary policy and the German central bank setting the official exchange rate at 1:1. But the black market exchange rate was estimated to be one to three or one to four, reflecting the economic reality (Blum, 2011; Paus, 1998). All these changes after reunification caused a distorted labor market, mistaken investment decisions on capital, unemployment and low productivity in East Germany (Burda, 2008; Hansen, 2000; Smolny, 2010; Snower & Merkl, 2006).

Collier and Siebert (1991) expected to see positive progress in living standards and productivity within 4~5 years after reunification. The impact of newly introduced capital accumulation and the market economy on economic behavior should have brought rapid and positive growth as all Germans expected. Although high investment per capita was made in the former East Germany area, most investment has been concentrated on building construction rather than equipment. As a result, a lack of infrastructure has led to slow progress in technology and affected labor productivity and competitiveness (Sinn, 2002).

There is a need to elaborate on the economic circumstances which accompanied the sudden reunification since existing studies are not sufficiently complete. They missed the accumulation of technological knowledge, which is the real economic growth engine.

Since knowledge is a major contributor to productivity and economic growth (Adams, 1990), German reunification could be an important driving force for growth through knowledge spillovers in the process of development (Holod & Reed, 2004). It is widely accepted that economic and technological development are closely related. For East Germany, which was distanced from the West, reunification was a perfect opportunity for growth. Notably in the catching-up process, the technological gap between the frontiers and late comers, or leaders and followers, is the key determinant of growth (Bernard & Jones, 1996a; Jan Fagerberg, 1987; Kumar & Russell, 2002; Keun Lee, 2005). In the reunification of Germany, in a more general sense, the integration of the two units enables commodities, financial capital and technological knowledge to migrate freely without migration costs (Sinn, 2000). When two countries are geographically close to each other, share a common language and have a similar technological specialization, they are more likely to collaborate and catch up faster (Griffith, Redding, & Simpson, 2009; Guellec & van Pottelsberghe de la Potterie, 2001). With broadened resources, and geographical and political advantages, all conditions surrounding East German after unification were favorable for technological catching up. From these points of view, it is worth analyzing the effect of German reunification on technological change to understand the progress of development and convergence.

In this study, instead of capital accumulation and labor race, the change of technological knowledge structure of East Germany, West Germany and a reunified Germany are to be analyzed. As emphasized in NIS theory for studying the technology structure of a country, how technologies interact with other technologies in the process of development and the role of policy matter in this problem. By constructing the technology structure by network analysis, one can figure out the competitive technologies of a country and how they affect each other via knowledge spillover. Without considering the contemporary surroundings, these studies would be in vain. Comparison of technology structures, investigation of the change in technological similarity, as well as how technology policy has affected the growth potential are also important and to be stressed. Research on German policies will provide conceivable lessons to Korea, which is preparing for unification in the Korean peninsula.

This thesis is organized as follows. The next section reviews the literature on the previous economic approaches explaining the reunification of Germany, importance of technology on economic growth, the conditions arising from integration and the concept of a national innovation system and network analysis to illustrate the role of technology. Then follows an explanation of the methodology used in this paper, results and discussions of empirical analysis, and finally the implications of this study will be deliberated.

Chapter 2. Literature Review

2.1 German Reunification and Economic Integration

The fall of Berlin Wall on November 9 1989 was a decisive step toward the collapse of communism in Easter Europe and toward the reunification of Germany. Since reunification, Germany has poured enormous money to reconstruct the former East Germany area. Alexander Fisher who was Managing Director of the German Institute for Economic Research in Berlin (DIW) pointed out that total €2.1 trillion was spent. This amount is comparable to Germany' GDP in 2009, €2.4 trillion. Policy makers and economists could not foresee how expensive the cost for reunification would be, let alone theses expense, but they rather expected that East Germany would grow fast and catch up the living standard, productivity, and major economic progress of the West within 5 to 10 years (Collier & Siebert, 1991; Hallett & Ma, 1994).

In 1989, the population of the West Germany was about 64 million and that of the East was 27% of the West and West Germany's per capita GDP was $20,540 and the East was one third of that. As East Germany had the world's tenth-largest economy in 1980s and was the most stable economy within the Soviet Bloc, smooth transition from a centrally planned economy to a market economy was expected despite of significant gap between East and West Germany. These initial conditions compelled the former East to catch up the higher productivity growth path of the West, favored expensive fiscal policy and boosted intensive investment in the former East region. Directly after the reunification, real GDP of the East, production and employment rate were broke down. Before long, however, the resurrection and fast growth of the East astonished the whole world (Smolny, 2010). Figures proved that the Eastern economy were on the brink of overcoming its weakness and catching up the Western economy. However, the rapid convergence came to halt after 1996 - the gap of labor productivity, nominal wage and GDP per capita (Burda, 2008). The unemployment rate of the East almost doubled from 1991 to 2004 and sunk to 10.7 % in 2012 which is the lowest level within 20 years but still twice of the West. Until German government reformed 'Agenda 2010' coming into effect on Jan 1st 2005 to resurrect the German economic, Germany went through economic recession for years after unification.

Economists and policy makers took the phenomenological approach to the stagnation of convergence problems, such as the empirical investigation based on annual indices performed on nominal wages, nominal labor productivities and unemployment or convergence stagnation. Studies with indices of economic variables and policy of finance or labor analyzed that while unofficial exchange rate was 3 to 4 East Marks for 1 Deutsche Mark before integration, adoption of 1 to 1 exchange rate was equivalent to more than 300 % real appreciation (Blum, 2011; Paus, 1998). Due to the mistaken policy without consideration of realistic productivity difference between two Germanys or spontaneous adjustment, the wage in the former East was pressured to keep high with generous unemployment support(Snower & Merkl, 2006). The unemployed in the East received massive social transfer that more than 50 % of the transfers are spent for pension or social security and only 12 % for infrastructure expense(KINU, 2011; H.-W. Sinn, 2002). There was labor race from the East to the West due to higher wage in the West resulting the higher unemployment in the East(Hansen, 2000). M.C. Burda (2008) focused on deep change of industrial structure of the East Germany accompanied by both capital deepening and labor thinning in the East and why labor market did not function properly. Researchers tried to analyze the possible and realistic economic convergence path for East Germany based on monetary union, fiscal transfers and labor migration. And they expected the equalization of two German per capita would take about 50 years (Hallett & Ma, 1994; Scheufele & Ludwig, 2009). Even though capital intensity of the East was higher than the West, labor productivity and employment rate of the East still lagged far behind the West German level and seemed to lose a driving force to catchup.

2.2 Determinants for Economic Growth

2.2.1 National Innovation System and Economic Growth

According to Freeman, Lundvall was the first man who used the expression of 'National Innovation System (NIS)' but it was Fridrich List who introduced the concept of NIS for the first time (Chris Freeman, 1995). In his paper, 'The National System of Political Economy (List, 1841)', to explain how Germany caught up and overtook England, List emphasized 2 factors. One is the accumulation of knowledge is the growth engine for economic growth and the other is the systemic interaction among science, technology and skill (C. Freeman, 1995). There are standard reference of NIS edited by Nelson (1993), Lundvall(1992) and Edquist (1997) gave their own definition of NIS and shared the importance of institutions, interactive process involving many actors at micro level and the role of government in keeping the system appropriate (Soete, Verspagen, & Weel, 2009). After introduction of NIS theory, researchers examined the source of innovative capacity of a nation such as country-level R&D intensity or public policy (Furman, Porter, & Stern, 2002). Lundvall set borders of NIS in two steps, a core and a wider setting around the core. The core of the innovation system is the firms in interaction with other firms and firms with the knowledge infrastructure. Wider setting includes almost every fields – the national education systems, labor markets, financial markets, intellectual property rights, competition in product markets and welfare regimes and so on (Lundvall, 2007). Recently among many factors, the role of agents – individuals as well as firms- are getting importance in knowledge base economy. The interactions among the agents involved in technology development are as important as investments in research and development (OECD, 1997). The important elements of knowledge are embodied in the minds and bodies of agents (Lundvall, 2007). Accepting the contention of Abramovitz and Johnson that social capability to absorb the advanced knowledge is important in development (Abramovitz, 1986; Temple & Johnson, 1998), it is individuals who play the most important role under the innovation system.

Another source for innovation can be found in diversity. Many scholars stressed that establishing members of a firm of a society with diverse set of actors would reduce the risk of redundancy and increase the chance to create the relative novelty of the knowledge (Phelps, Wadhwa, Yoo, & Simon, 2010; Salavisa, Sousa, & Fontes, 2012) . In consequence, diversity of knowledge structures would facilitate the innovative process (Cohen & Levinthal, 1990). These studies on the effect of diversity on innovation are in accordance with the contentions of pioneers of the NIS. Edquist explained that the mechanisms introducing novelties in the system is creation or generation of diversity (Edquist & Hommen, 1999). Freeman also asserted the importance of policy to encourage originality and diversity (Chris Freeman, 1995).

2.2.2 Role of technology in economic growth

Economic research over several decades have focused on a tendency for economic long-run growth paths, world's economic convergence and income inequality across the nations. As prosperity is not all about the increase in a nation's gross domestic product (GDP) growth, welfare or happiness index should be considered too (Aghion & Howitt, 2009). But still, economic growth is what mainly determines the material well-being and today's living condition of billions of people over the world. This is perhaps the most compelling reason why many economists have sought for the determinants of economic convergence. In exogenous growth model, economy cannot grow in the long-run without technological progress (Solow, 1956). On the other hand, endogenous growth model explains long-run growth via physical and capital accumulation (Romer, 1986). But the former neoclassical model explains cross-country convergence while the latter cannot. In general, technology and capital are the main source of the growth, some empirical and theoretical studies tried to discriminate the effect of technology change and capital deepening on growth and convergence (Kumar & Russell, 2002; Pigliaru, 2003).

Technology is not the almighty thus requires careful approach but it is quite indisputable that technology really matters for the growth. In today's world, a substantial share of economy refers to knowledge-intensive goods and service where technology is major source of competitiveness. So analysis of technology could be the first step to describe and understand the economic performance of a country. Empirically, jan Fagerberg confirmed that there exists a close relationship between the level of economic development and the level of technological development. For analysis he measured GDP per capita and R&D or patent statistics respectively (Jan Fagerberg, 1987), meaning that technology gap does matter. Besides mentioned above, many papers in an amazing number stress the importance of technology in economic growth. Difference in technologies across the countries and the technological changes were found to be matched to the evolution of the cross-country distribution of labor productivity (Bernard & Jones, 1996b; Kumar & Russell, 2002). Thanks to a new wave of interest in economics of technological change, now technology is universally acknowledged as the driving force of development and growth (Liso, 2006). Not only for the upper middle- and high income countries but for the lower middle- and low-income countries where trying to catch up the frontier countries, technology reveals to be important consistently(K Lee & Kim, 2009).

2.2.3 Integration Effect in Germany after Reunification

In perspective of NIS, technological catch up or technological development is the key success factor for the economic growth and the increase in diversity of actors fosters the innovative process of a country. The situation of Germany faced after reunification was miserable as far as the gap between two Germanys were concerned, but also promising for the East to catch up the West, in the view of NIS. East Germany had ideal conditions for technological catching up which was accompanied by economic integration. The gap itself would not guarantee the catching up of technology or the economic prosperity always. However, there are investigations proving that integration has positive effect on economic growth (Andersen, Haldrup, Sørensen, Bentolila, & Srensen, 2000; Wu, 2000). Surmising on the example of China that Wu (2000) analyzed, regional integration of Taiwan, Hong Kong, Guangdong and Fujian was one of good examples of positive integration-effect in terms of growth and productivity performance. In addition to Wu, Andersen et al. conducted studies on the effect of integration in EU. He found out that closer international integration made the transfer of technological knowledge easier, gradually leading to technological catchup (Andersen et al., 2000). Fagerberg and Verspagen (1996) suggested that technological knowledge spillover be an important source of growth with example of EU regions. And Paci & Pigliaru (1999) gave further confirmation on the significance of integration as major component of growth in the empirical study of European regions.

German reunification enabled commodities, financial capital and technological knowledge to migrate freely without migration costs (H. Sinn, 2000). This reminds us that the endogenous economists emphasize the importance of opening up (Aghion & Howitt, 2009). Integration has the same effect of opening up, inducing knowledge spillovers from more advanced to less advanced and from the richer to the poorer. From a standpoint of spillover, East Germany again, had favorable conditions for catching up – resource availability, broadened markets, geographical accessibility and even political advantages. Literature have pointed that geographic proximity and sharing the common language favor the fast technological catching up which shows consistency with productivity catch up (Funke & Niebuhr, 2005; Griffith et al., 2009; Guellec & van Pottelsberghe de la Potterie, 2001).

The preceding reviews show that the East Germany after the reunification had advantageous conditions for technological development and increase in diversity. Despite of many economic figures staying faltering, staggering and losing the driving force of convergence, the reunified Germany had enough potential for growth in view of technology development.

2.3 Technological knowledge structure

2.3.1 Indicators of Technology

Nowadays, it is widely recognized that knowledge is a major contributor to economic growth, directly affecting the productivity. Accurate understanding of technology is critical for both policy makers at country or sector level and managers at firm level. However, the reliable measurement for the status of one country's technology is still ambiguous in some measure (Pigliaru, 2003). Quoting a passage from de la Fuente's paper which Pigliaru also referenced in his paper (2003), de la Fuente(1997) asserted as following; "The catch-up hypothesis has received considerable attention in studies in the historical and growth accounting tradition but there are few econometric studies in the convergence literature dealing with it, probably because it is difficult to come up with a reliable index of technical efficiency."

There have been many attempts to figure out the levels of technological development depending on the purpose of the studies. First, at firm level, the challenge for measurement of technological level aims at evaluating one firm's technological capability as a potential source of innovation. (Schoenecker & Swanson, 2002). Swanson (2002) reviewed several indicators of technological level and definitions of them. According to their paper, the most common indicators can be classified into three categories; financial measures, patent statistics or statistics of new products introduced. Average R&D spending, ratio of R&D expenditure to sales (R&D intensity) are the comprehensible method to estimate firm's technology activities or technology competitive strategy. Simply, counting the number of patents or the frequency of citation is another way to measure the different dimension of one firm's technology - the scale and the quality.

These two indicators can be regarded as technology input and output measurement for each. Second, concerning at the country level, neoclassical theory regareded that the level of technology primarily depends on the relation between labor and capital, which is represented as R&D expenditure in paper of Schoenecker and Swanson. Third, the technology gap theorists relate the technological level of a country to the level of innovation using patent statistics as proxy for technology level. If one aims to analyze technology level with the result of technology, new product introduction related measure is the most appropriate and popular (Becheikh, Landry, & Amara, 2006; Schoenecker & Swanson, 2002). Judging from the indicators shown above, relating technology level to capital – R&D expenditure, plain patent statistics or the new products are not appropriate for the evaluation of technology catch up.

2.3.2 Analysis of technological knowledge

There are many emerging measures for technological knowledge according to the necessity for designing and evaluating technological policy, comparing the relative situation of countries and assessing their areas of strength and weakness (OECD, 2002). As competition in science and technology innovation among nations becomes more intense, evaluation and judgment of technological capacity is also getting important to improve country’s competition and assess the relative technological competitiveness (I. Cho, 2012; Watts & Porter, 1997). Hence, a number of studies have identified the technology structure of a country (Malerba & Orsenigo, 1996; Shin & Park, 2007). As industrial structure plays an important role as the main policy target and as an effective mechanism to diffuse technology rapidly and effectively (M.-S. Kim & Park, 2009), it can be inferred that technology structure would play the similar role in the same manner.

The research of structure and life cycle on the co-evolution of technology, industry structure and the technological trajectories might back up this (Karvonen & Kässi, 2013).

As index of technological level, many researchers have used patent data. Cho (2012) used patent data to evaluate the technological level and to identify the technological status among countries. Fagerberg (1987) calculated the indexes of technological level for 25 countries based on patent statistics and found the relation between the technological development and the economic growth. Patent documents are an essential source for technical and commercial knowledge about technology process and it helps identify general technology trend covering all sectors of technology (M.-S. Kim & Kim, 2012). Among many indicators, patent has many information researchers can be inferred and can work on (e.g., co-words, co-classification, citation analysis, mapping, etc). Since patents are major result of R&D, patentee argues the essential features of his study through claim including boundaries of property rights he wants to protect, so patents has the core knowledge represented in the result of research or embedded in actors (Lanjouw & Schankerman, 2001). Research concerning the patents can represent the origin and core features of technology. Hence patents have been used for analyzing competitive, technology trend and competitive position assessment (Daim, Rueda, Martin, & Gerdsri, 2006). Especially, constructing technology structure using these patent data can be expected to elaborate the fields of technological specialization of a country (Leydesdorff, 2008). In many cases, patents, particularly the technology classification are the most appropriate and the only reliable source for examining how technologies behave over time and for identifying cross-fertilization between technological fields, etc.(Dibiaggio & Nesta, 2005; OECD, 2009)

Co-classification is known to be an effective way for a potential indicator of technology linkage (OECD, 1994). OECD Patent Manual says that as one and the same patent may be classified onto several different technology fields that classification code can be a proof of linkage between such fields. The criteria for technological knowledge structure should be considered before constructing. The structure should involve all technology fields and contain all information about path of development over period. It should be able to show how all technologies are connected and related as one technology can affect the development of others (Choi, Kim, & Park, 2007a). And the patent technology code is suitable for tracking and characterizing technological changes, defining technology space and identifying distinct technological capabilities (Strumsky, Lobo, & van der Leeuw, 2012). Moreover, the technological structure represented by a network can include the main characteristic of technology 'technology flows' (*spillover*), as the main function of network is the flow or distribution of information. Recent researchers revealed that particular way the knowledge structures are organized not only influence the innovation performance of actors' but also plays important role in creation, combination and diffusion of new knowledge globally (Balland, Suire, & Vicente, 2013; Cowan, Jonard, & Özman, 2003; Ozman, 2009). After all, on the assumption that technological network is the most effective to create and disseminate knowledge, it is the appropriate method with the aim of identifying the core technology and competitiveness for the better innovations (H. Lee, Kim, Cho, & Park, 2009; Shin & Park, 2010).

2.4 Social Network Analysis

2.4.1 Network Analysis in Innovation Study

In the social networks studies, it depends on the actor's position within a network whether she would take maximized gain or what social role is expected for her (S. Borgatti, 2003). Bogatti explains the actor's position in the network in terms of a desirable abstract pattern of links. Then one can locate her position in a network whether occupying central positions or being unconnected to others. In the last decade social network analysis has grown considerably and spanned to all of the social sciences and even other fields (S. P. Borgatti & Halgin, 2011). The innovation studies should include the process of creating new social relation between actors and generating novel knowledge, to investigate the role of agents engaging in innovation or to identify the position of actors in the network (Coleman, Katz, & Menzel, 1966; Obstfeld, 2005). It is important to get one's position in a network because it considerably affects the innovation performance (Burt, 1993; Lilien & Mallapragada, 2014). In other words, the influence of agents in a network affects considerably in innovative performance. Therefore change in the composition of agents in a network, like introducing new and inhomogeneous actors in a network would bring alteration. Change of agent will make connections and diversity of knowledge be diversified and this will be recombined with the existing knowledge, raising creative and innovative activity (Burt, 1993; Granovetter, 1973; Hargadon, 2002).

2.4.2 Characterizing the Network

Borgatti and Halgin (2011) defined the network that it consists of a set of actors (or nodes) along with a set of ties (or edges or links) of a specified type (such as friendship) that link them each other. The nodes occupy positions within the structure which the pattern of ties in a network yield. Most of network analysis deal with characterizing network structures and node positions (S. P. Borgatti & Halgin, 2011). Centrality is one of the most studied concept and a fundamental concept in network analysis. Measures of centrality summarize a node's involvement or contribution to the cohesiveness of the network (S. P. Borgatti & Everett, 2006). Centrality identifies which nodes are more central than others. Freeman (1978) tried to answer the question of what centrality is. He provided three main centralities (degree, betweenness and closeness) in binary network. For example in a star shaped network, the center node attains the maximum values of three centralities. This position has the maximum possible degree, is maximally close to all other nodes and falls on the shortest path between the largest possible numbers of other nodes (Freeman, 1978). Closeness centrality was defined as the inverse sum of the shortest path from the focal node to all other nodes. Borgatti(2005) pointed that this closeness concept should be restricted to certain processes without disconnected components thus have limitation for application. Betweenness is defined as the share of times that node *k* lies on the shortest path, when a certain node *i* needs a node *k* in order to reach a node *j* via the geodesic path (Freeman, 1987). It can be applied to networks with disconnected nodes but large proportion of nodes will not connect other 2 nodes in the shortest path, receiving the betweenness centrality value, zero (Opsahl, Agneessens, & Skvoretz, 2010). The last measure of centrality is degree. It counts number of adjacencies for a node. This simple measure can explain the important index of a node's potential relating activities with other nodes. When a node is defined as one of the technology class, then the degree centrality of this node can identify which technology is important or plays an influential role in technology network. The larger value indicates that the node is more centralized in inflow or outflow of knowledge (M.-S. Kim & Park, 2009).

2.5 Research Question and Research Model

Since1948 Korea has stayed divided between communist North Korea and capitalist South Korea. No one in Korea can exclude any possibility of unification of Korean Peninsula whether it comes all of a sudden or step by step. Political integration could not guarantee the economic integration as shown in previous section. Among many critical determinants of economic growth, technological knowledge plays important role in this knowledge-based economy. Instead of investigating the accumulation of capital, accumulation of knowledge would do matter for the substantial potential for economic growth. Questions to be answered in this study is whether the technological integration was successful as economic integration after reunification of Germany and the role of policy on technology after reunification.

So here in this study, what change the reunification of Germany had brought to the technology of East and West Germany was to be clarified. Also to get de facto implication and lessons for Korea, the policy on technology or R&D was investigated and assessed. This study is eagerly anticipated to alter the importance of technological integration after unification and of proper preparation for policy when possible.

To investigate the technological integration after reunification of Germany, it is necessary to check whether the technological R&D resources from two Germany were utilized properly and whether two countries' technologies were in harmony after reunification. Reflecting the characteristics of technology that are developed by giving and receiving the influence by other technologies, network analysis is most appropriate method to represent the competitiveness of a country. Hence using the technological network, the consolidation of two countries' technologies is tested in this study.

Chapter 3. Empirical Analysis

3.1 Data

In order to identify the technological structure of a country, Worldwide Patent Statistical Database version 5.0 released by European Patent Office (EPO) on October 14, 2013 were used. According to the *Global Patent Data Coverage*, published by EPO on July 2011, this database covers information of patents over 90 countries, including titles of patents, names of applicants and inventors, addresses of them and references. Patents of East and West Germany applied during the period 1980 to 1990, and patents of reunified Germany from 1990 to 2010 were collected. The country code for East Germany was *DD* and the code for West and the reunified Germany was *DE*. Patent data with country code *DE* was classified according to the filing date of patents. Since this study aims to reveal how the integration affected on the change of technological knowledge, the time window should be adequate enough to cover time lag of spillover and adjustment time after reunification of Germany. It is known that time for knowledge spreading out is not limited and effects of spillover on economic variables take years (Verspagen & De Loo, 1999). After reunification, there was restructure process of the former East German research system and reallocation of both researchers and institutions. Therefore to take enough consideration of effects caused by the reunification and of changes arising from the reallocation of resources of R&D, the objective data from 1980 to 2010 were set to be analyzed.

3.2 Measurement

3.2.1 Classification of Patent

To provide an internationally common classification of patens, the International Patent Classification (IPC) system was designated by the Strasbourg Agreement in 1971 and entered in force on October 7, 1975. IPC may precede the classification symbols on patents and facilitate retrieval of patents by intellectual property offices and other users, in order to evaluate the inventive step or non-obviousness of technical disclosure (WIPO, 2014).

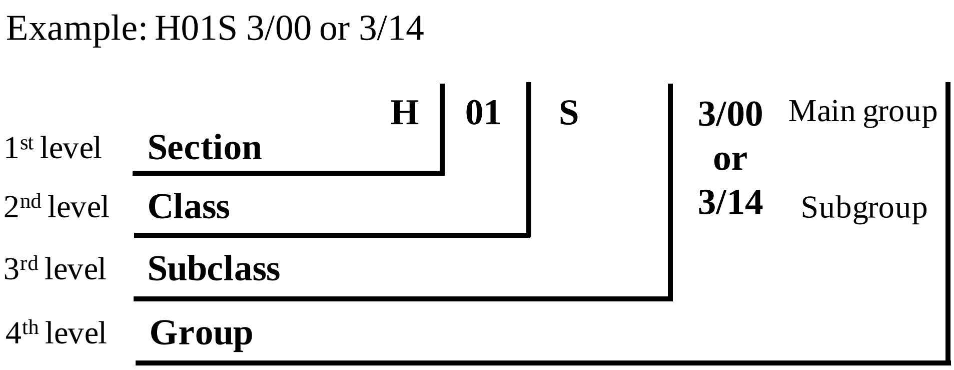


Figure 1. Hierarchical structure of International Patent Classification

Figure.1 shows the complete classification symbol with the combined symbols of section, class, subclass and main group or subgroup. Section is the highest level of IPC hierarchy. Patents are classified into eight sections regarding to technological fields. Each section is represented by the capital letters A through H and each section is entitled as following: A- Human necessities, B- Preforming operations; Transporting, C- Chemistry;

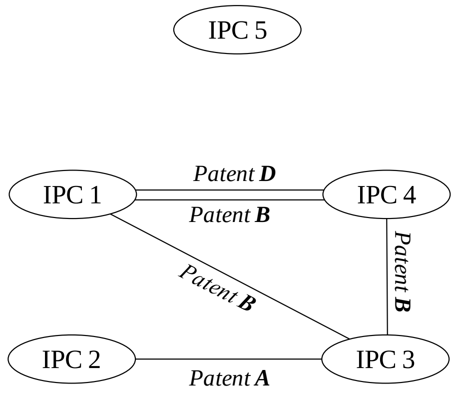
Metallurgy, D- Textile; Paper, E- Fixed constructions, F- Mechanical engineering; Lighting; Heating; Weapons; Blasting, G- Physics, H- Electricity. The second level, class symbol consists of two-digit number. For example, H01 means basic electric elements. Each class comprises one or more subclasses and this third level of classification is symbolized by capital letter, indicating as precisely as possible the content of the subclass. H01S means devices stimulated emission. Each subclass is broken down into subdivisions referred to as groups and each group symbol consists of two numbers separated by the slash, for example H01S 3/00 represents lasers.

3.2.2 Technological Knowledge Network

To facilitate the use of patent as building blocks for the technological knowledge structure, some terms should be clearly understood. Since more than one IPC code can be assigned to one patent document and most patents belong to more than one class (Fleming & Sorenson, 2001) , one can assume that the frequency by which two IPC codes are jointly assigned to the same patent document can be interpreted as a sign of the strength of the knowledge relationship (Breschi, Lissoni, & Malerba, 2003). Letting one IPC code to denote the node and links to represent the connection between the nodes, the technological knowledge structure can be constructed by the nodes and links as technology network. Figure.2 (a) describes the IPC codes of each patent and (b) shows the connection between IPC codes. IPC code 2 and 3 is linked by Patent A. Patent B with three IPC codes 1, 3, and 4 makes 3 links between IPC code 1 and 3, 1 and 4, and 3 and 4. Figure.2 (c) shows the part of EPO patent data used for analysis in this thesis. Patent with application ID 9185006 has 2 IPC codes C03B 37/00 and C03B 37/08, so there is one link. Application ID 9185017 patent is assigned to four IPC codes and these codes make total 6 links in technology network. Patent C has one IPC code, IPC 5. Figure.2 (a), (b) illustrate that IPC 5 is isolated with no link and (c) shows that patent 9185016 has only one IPC code E21D 21/00 hence it is isolated and has no link in network constructed in this example.

Patent **A**		IPC 2	IPC 3		
Patent **B**	IPC 1		IPC 3	IPC 4	
Patent **C**					IPC 5
Patent **D**	IPC 1			IPC 4	

(a) Patents with multiple IPC codes



(b) Network linked by IPC co-occurrence

Application ID	IPC-1	IPC-2	Total Number	Application Filing Date
9185006	C03B 37/00	C03B 37/08	2	1980-01-02
9185016	E21D 21/00	<NA>	1	1980-01-03
9185017	A61P 29/00	C07D 233/42	4	1980-01-03
9185017	A61P 29/00	A61K 31/425	4	1980-01-03
9185017	C07D 233/42	C07D 513/04	4	1980-01-03
9185017	A61P 29/00	C07D 513/04	4	1980-01-03
9185017	A61K 31/425	C07D 513/04	4	1980-01-03
9185017	A61K 31/425	C07D 233/42	4	1980-01-03

(c) Construction of database for co-occurrence

Figure 2. Example of technology network

3.2.3 Analysis of Centrality

Before investigating the change of technological structure, overall knowledge structure of each country need to be illuminated. To clarify the topology of technological knowledge structure represented by technology network, the connectivity and the property of network should be examined. Over years, a great many measures of centrality have been proposed to figure out the position of a node in a network. In his paper, Freeman provided several measures of centrality and some are introduced here for technology network analysis(Freeman, 1978). One of well-known measure is betweenness centrality. Calculating this centrality of node k begins at counting the number of geodesic paths that node *i* needs node *k* in order to get node *j* via the shortest path. Freeman (1987) defined betweenness centrality $C_B(k)$ as

$$C_B(k) = \sum_{i}^{n} \sum_{j}^{n} b_{ij}(k)\,, whre\ i < j, i \neq j \neq k$$

where n is the number of nodes in a network. Let $g_{ij}(k)$ the number of geodesic linking i and j that contains$k$. Then the probability, $b_{ij}(k)$ that node k falls on a randomly selected geodesic linking *i* and *j* can be written as

$$b_{ij}(k) = \frac{g_{ij}(k)}{g_{ij}}$$

For the comparison of centralities among countries, the effect of network size should be considered and eliminated as number of pairs of nodes increase as the size of network increases. The betweenness centrality can be normalized by the possible maximum number of pairs of any two nodes in the network except the node *i* which the betweenness centrality is to be calculated. Then the normalized betweenness centrality for weighted graph is defined as the following (M.-S. Kim & Park, 2009).

$$C'_B(k) = \frac{C_B(k)}{(g-1)(g-2)/2}$$

The graph size was denoted as g.

There is also degree centrality $C_D(i)$ which is defined as the number of nodes connected to node i, implying how deeply the node *i* is embedded in a network. Degree centrality assumes that $C_D(i)$ is large if node *i* is adjacent to a large number of other nodes or in direct contacts with others, and small if node *i* tends to be cut off from direct contacts. For example in Figure.2 (b), degree centrality of the node of IPC 5 is zero ($C_D(IPC\ 5) = 0$) as it is totally isolated from connection in the network. In general, degree centrality is the basic indicator as the first step in analyzing network.

Albert et al used degree distribution to obtain the topology of network in the web and confirmed that large network followed a power law and showed scale-free nature of the link distribution (Albert, Jeong, & Barabasi, 1999). Freeman's (1978) centralities have limitation that he considered only binary network, not the global structure of network. Technology network should be a weighted network and be defined as the sum of the weights attached to the links that are connected to a node (Opsahl et al., 2010). So in technology network analysis using co-occurrence of IPC codes in patents, degree centrality for weighted networks is applied. And this labels the node strength according to the definition of Opsahl et al (2010). This measure is formalized as follows:

$$C_D^w(i) = \sum_{j}^{N} w_{ij}$$

where is w_{ij} a weighted adjacency of a link between node *i* and *j*, in which $w_{ij} = 0$ if node i has no connection to others. The degree centrality also needs consideration of the network size and normalizing by the maximum number of neighbors that a node can have in a network:

$$C'^{w}_{D}(i) = \frac{\sum_{j}^{N} w_{ij}}{g-1}, where\ i \neq j \neq k$$

Albert et al. (1999) constructed degree distribution ($P(C_D^w)$) of the network, representing the relation between the degree centrality and the frequency of the node with certain degree. Once degree distribution follows the power law as in the study of Albert et al., then it is referred as scale free network. In this distribution fluctuation in high degree area is inevitable because the frequency of that area is low. But this fluctuation makes it difficult to recognize the important information that a network has, e.g. scale free property. Newman(2004) resolved this problem by introducing cumulative degree distribution $P(C_{D>}^w)$. Instead of plotting simple histogram, it plots the sum of frequency or probability that the degree has a value greater than or equal to a certain degree. While degree distribution decreases by a power function and has linear relation with degree in log-log scale with exponent γ ($\log P(C_D^w) \sim -\gamma \cdot \log C_D^w$), Newman (2004) demonstrated that cumulative degree distribution also follows a power law but with a different exponent, $\gamma - 1$. Hence, $\log P(C_{D>}^w) \sim -(\gamma - 1) \cdot \log C_D^w$.

3.2.3 Centrality Map and Technological distance

The position of each technology is assigned by the centralities and it can be transferred in centrality map of which the space is spanned by two centralities. In accordance with the studies of Albert et al, (1999), Everard and Henry (2002), Kim, Cho and Kim (2012), the positions of the technology network were represented. In general, the map are divided into four areas and named as hub, core, bridge and peripheral. A node in high degree and high betweenness centrality is referred as hub and this node closely connects other nodes in the entire network. A node in core part with high degree and low betweenness is positioning at the center of the network but not able to relate other nodes. A node in bridge area has low degree but high betweenness centrality and tends to connect other nodes.

Technological distance or technological proximity is the result of knowledge links and learning processes which could be conventionally considered either unintended or intended (Breschi et al., 2003). It can refer to the distance of firms, industries and countries in terms of their technological focus or profiles (Stellner, 2014). According to the Stellner's definition of technological distance, it represents distance between countries as the length of technological space between two countries.

There are many methods to calculate the technological distances(Engelsman & Raan, 1994; Griliches, 1984; Jaffe, 1986). Grilichers regarded the patent data as useful tool for positioning firms in technology space. As classification of patent is technology based rather than product market based, IPC classification of firm's patent portfolio is a good measure of technology development of a firm or a country (Jaffe, 1986). Rosenkopf and Almeida (2003) suggested the very simple way to use the Euclidean distance to measure the technological distance between firm pairs. Using patents, technological classes were tabulated and the Euclidean distances were calculated between these patent class vectors for each pair of firms (Rosenkopf & Almeida, 2003). This study compared each technology sector the square difference of the patent class vectors of each pair. Therefore the higher values of distance denotes lower similarity. The centrality map and the technological distance are the way to represent the technology competency of a country and the relative difference in degree of development, to measure the similarity of countries, the joint of these two methods are introduced here. Instead of using the patent vectors of firm pairs, the technological coordination of a country is used. Then the Euclidean distances between each technological sectors are measured according to the coordination of technology defined by degree and betweenness centralities.

Chapter 4. Analysis Result

4.1 Descriptive Statistics

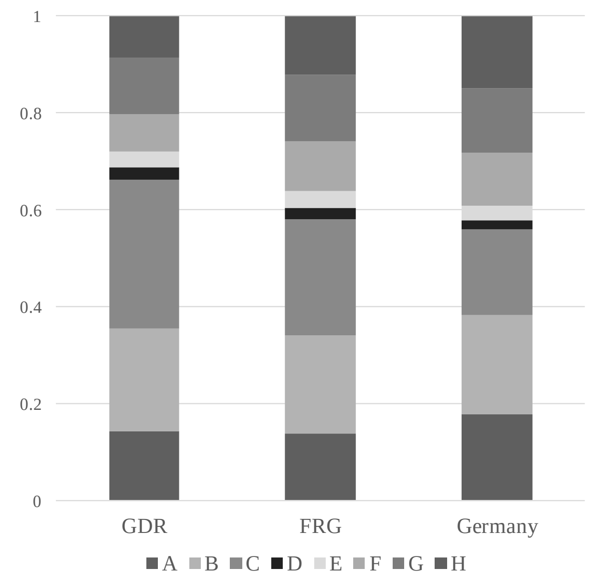
Hereinafter East Germany and West Germany before reunification are referred to as GDR (German Democratic Republic) and FRG (Federal Republic of Germany), respectively. Germany or DE (Deutschland) represent the Germany after reunification on October 3, 1990. EPO patent data of GDR within period from January 1, 1980 to October 2, 1990 were extracted by the country code, DD. Patent with country code DE were extracted and divided according to the filing date of patent, Jan 1, 1980-Oct 2,1990 for FRG and Oct 3, 1990 – Dec31 2010 for Germany.

Numbers of all patents data of GDR, FRG and Germany with valid filing date information were 113,549, 927,971 and 2,574,003 respectively. When patent data with undefined IPC codes are excluded data set become 107,727, 898,084 and 2,470,669. Since it requires patent data should include at least two IPC codes to build technological knowledge structure, so patents with uni-IPC should be eliminated from data set. The numbers of patent data for technological knowledge structure analysis of each country are 38,740, 624,190 and 1,854,501. These patent data set were applied to establish the technology networks of GDR, FRG and Germany. As technology of a country varies, the number of IPC codes or the number of nodes and the number of links revealed to be different. Table 1 summarizes the characteristics of technology network of three countries- the number of nodes and links, average length of the shortest path and network diameter which is defined as the largest geodesic distance between any pair of nodes in the network. Number of nodes can be understood as the size of a network.

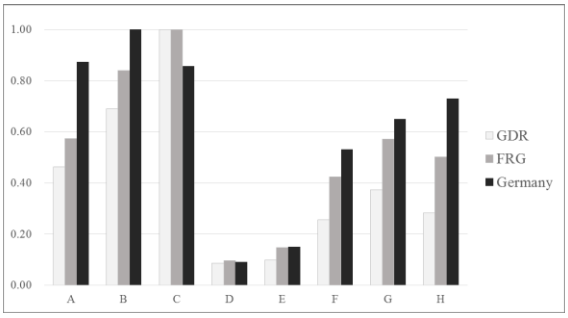
Table 1. Measures of Network

	Number of Nodes	Number of links	Average Path Length	Network Diameter
GDR	29,186	521,465	5.24	19
FRG	60,220	8,393,710	3.45	11
Germany	61,286	20,535,342	3.22	10

To represent a network of patents, as one patent must have at least two IPC codes, but there are quite many patents with only one IPC code. Especially for GDR, among 107,272 total patents, 68,531 patents have uni-IPC code which is almost 64% of all patents. Therefore, simple counting can give information of the overall development of technology sectors without any loss. Therefore simple analysis of number of patents was investigated to understand the competence of technological field before investigating the technology structure of each country. Brief comparison of number of patents which were applied from each country can help get the basic outline down for the technology development. Despite of few limitations mentioned above, the number of patent application have been used for a tool to analyze the competitiveness of technology development and capability (Choi, Kim, & Park, 2007b; Choi & Park, 2009; Lim & Sanidas, 2011). All patents from GDR, FRG and DE were classified into 3-digit class level of IPC code, and sums of patent number for each class were calculated. According to WIPO, there are 129 classes in IPC and number of classes for GDR is 120, 122 for FRG and 123 for DE.



(a) Degree of Concentration by Number of patents



(b) Normalized number of patents at section level

Figure 3. Comparison of Total Number of Patents

Figure 3 shows the comparison of normalized number of patents at section level. It gives a hint for how each technology field had been developed similarly between countries and the relative concentration of technology section in GDR, FRG and DE, at generic level. Comparison of the normalized number of classes each country help figuring out degree of relative development or degree of concentration of technology in each country. Figure 3 (a) shows that in GDR, patent filing was highly concentrated on section

C (chemical). The portion of section *B* (performing operations, transporting) varies little across countries, around 20 %. Section *D* (textile, paper) and *E* (fixed construction) are most undeveloped sections in all countries. Section *H* (electricity) grows in portion in sequence of GDR, FRG and Germany. But one should not jump in to the conclusion that all sectors except *D* and *E*, are equally developed in Germany. The distribution of the number of patent in technology class level, the technology classes with high frequency is highly skewed and concentrated on certain sectors. This is represented in Appendix Figure 1 and will be explained by in terms of centrality in network analysis. Figure 3 is just a brief presentation at the highest level.

4.2 Topology of technology network

Using the IPC codes of patents which are assigned more than two IPC codes, technological knowledge structure was constructed. Figure. 4 describes the cumulative distribution of degree centralities of GDR, FRG and Germany in log-log scale. In this graph, x-axis expresses the degree centrality and y-axis does the frequency of the degree centralities larger than a certain value. By ordinary least square (OLS) analysis, all three cumulative distribution showed linearity with the slope of -1.195, -1.136 and – 1.004 respectively, thus they follow power law with exponent 2.195, 2.136 and 2.004 for each. Although graph appeared horizontally in the low degree centrality area, it was test with 1 % significance probability and R squared value were 0.944, 0.936 and 0.95 for GDR, FRG and Germany, respectively. There do exist the difference in absolute amount of patents or the node and linkage, but the technology network have the same topology. The power-law property of technology networks of three countries indicate that the probability of finding technology with a large number of links is significant and that node is the technology hub with highly connected to other technologies. It is well known that typically there are nodes with low degree centrality and a small number of nodes with high degree centrality, often following a power-law distribution (Girvan & Newman, 2002).

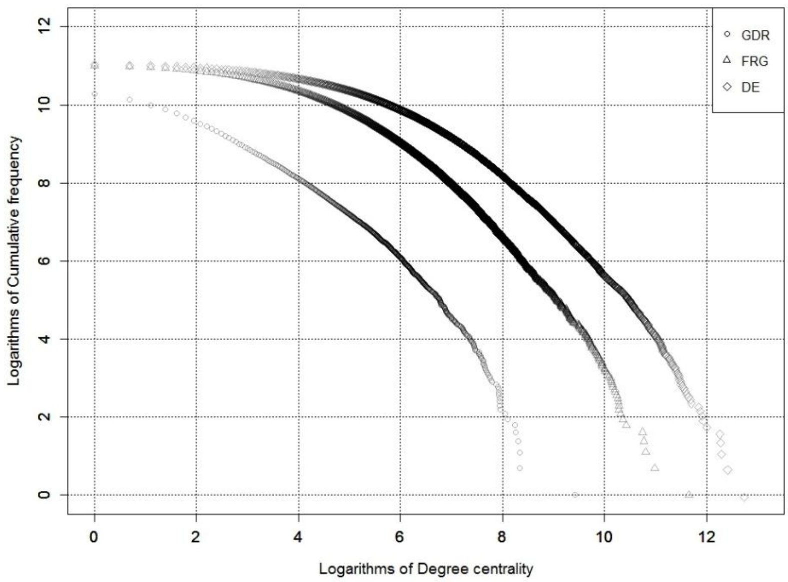


Figure 4. Cumulative degree distribution of GDR, FRG and DE

4.3 The relative degree of development

The cumulative degree distribution was derived at the 4th level of IPC, to get a hint for the most highly linked technology of each country, the sum of normalized weighted degree centrality was calculated at the 2nd class level. This 3-digit top 10 technologies of each country according to the score of degree centrality are listed in Appendix Table 1. Direct comparison of the each technological classes of GDR, FRG and Germany is not appropriate due to the difference in network size among three countries. For example, the technology class with value around 2.3 ranked 3rd in GDR, 23rd in FRG and 50th in Germany. And in the case of the total number of patents including the uni-IPC code patents, the number of 8th largest technology class of GDR, H 08 is comparable the median of FRG. So by ranking the technology classes within a country, the relative degrees of technology development for each technology class were compared. The relative degree of technology sector development can show how science and technology R&D resource and the following results were allocated within a country. Also it enables the relative competence of each country. Figure 5 shows the comparison of ranking between (a) GDR and FRG, (b) GDR and Germany and (c) FRG and Germany. The 45 degree line is to monitor the relevance of competitiveness between two countries. Figure 5 (a) and (b) show dispersed distribution, meaning that the relative degree of development between GDR and FRG, and between GDR and Germany are quite different compared to Figure 5 (c). But as it was confirmed from Figure 3 (b) above, concentration of technology development does not vary with the countries. For instance, nine of top ten technology class are the same in Figure 5 (a). The points close to the origin depict the top technology class and it shows dense gathering around the 45 degree line. According to Figure 5 (c), the technology network of FRG and Germany considerably fall into line.

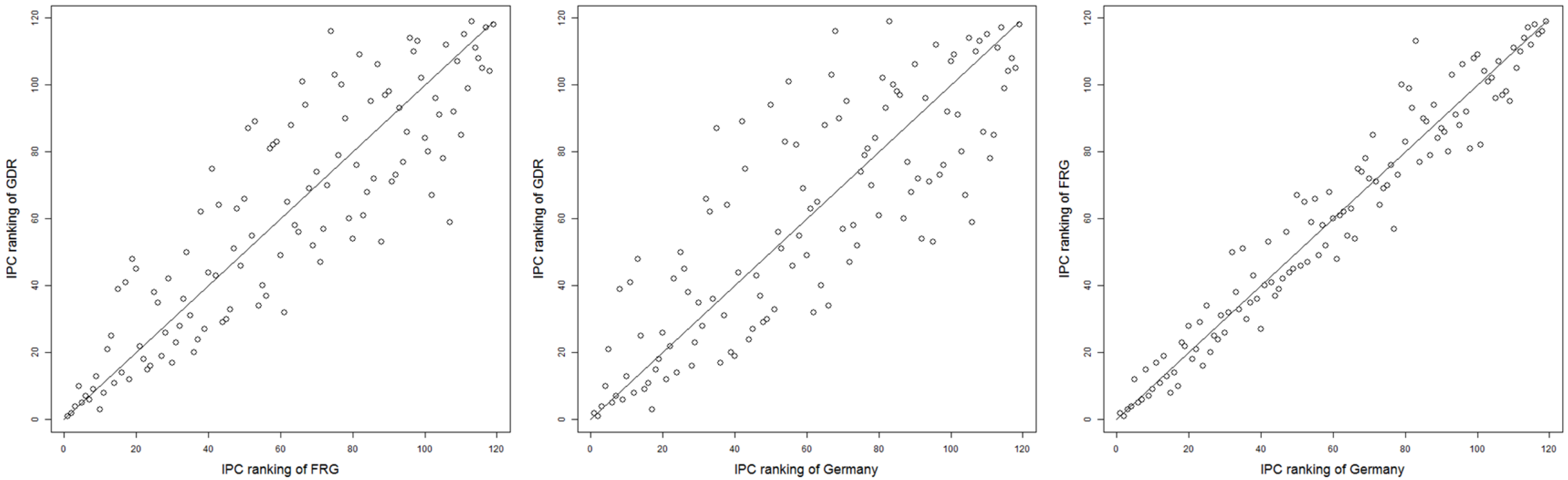


Figure 5. Ranking by Degree Centrality

The technology class ranking of FRG and Germany and the overlap of mainly developed technology classes, the technology structure of reunified Germany turned out to follow that of FRG. Figure 6 is a duplicate of Figure 5 (c). In Figure 6, all points of technological class were classified into 3 types to analyze the effect that GDR had on the change of the technology structure of Germany after reunification. Each type explains the pattern of change in technology class ranking between FRG and Germany, and between GDR and FRG.

Figure 7 shows the explanation of each type. Technology A is type 1, technology E is type 2 and technology C is type 3.In case of decrease of FRG's ranking after reunification, the classes with higher ranking in FRG and lower ranking in Germany are classified as type 3. Among the classes with lower ranking in FRG and higher ranking in Germany, the technologies which ranked higher in GDR than FRG are identified as type 1 and those which ranked lower in GDR are rebelled as type 2. By definition of types, technology class grouped as type 3 locate under the 45 degree line in Figure 6. Type 1 would have positively affected on the development of technology structure after reunification, since most of relative degree development of technology classes are hovering around the level of that of FRG. For example A43 ranked 77, 94 and 88 in GDR, FRG and Germany in sequence. As A43 ranks higher in Germany than in FRG and higher in GDR than in FRG, it should be classified as type 1. The result of comparison in Figure 6 confirms that no technology which are highly connected to other technologies or located in the center of the technology network belongs to type 1. Those categorized as type 1 are scattered at middle- and low- rank and these are listed in the Appendix table 2. Overall, technology structure of Germany followed the way of FRG and GDR affected little on it.

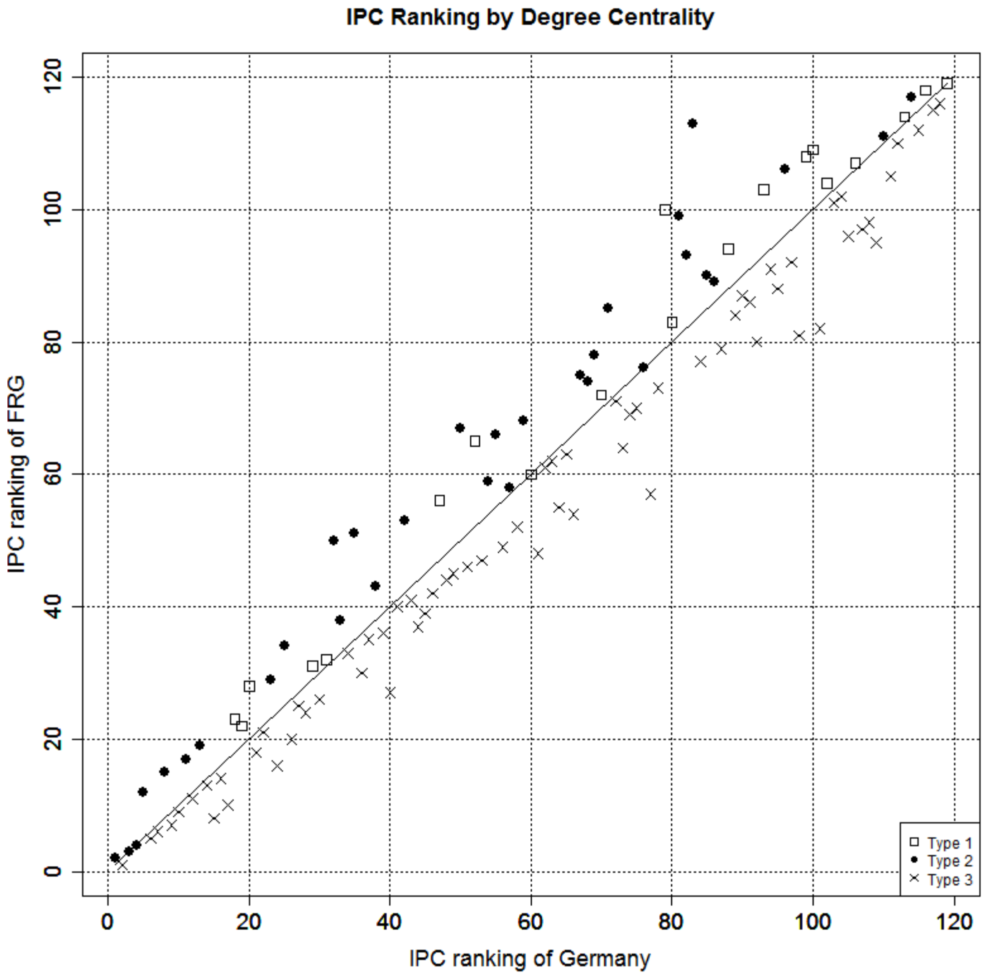


Figure 6. Relative Change in Ranking between FRG and Germany

Rank	GDR	FRG	Germany
1	A	C	E
2	B	E	A
3	C	D	C
4	D	A	B
5	E	B	D

Figure 7. Example of technology type

4.4 Technology Similarity

The result of comparing the relative development of each country revealed that the knowledge network of Germany resembled FRG. Then one can question how similar technological structures are. Using both betweenness and degree centralities, the location of a technology class is defined more precisely within the technology network. Figure 8 illuminates the position of a node represented on the centrality map which is spanned by betweenness and degree centralities. Two centralities of all countries were calculated by the normalized centralities. This will eliminate the network size effect and enable to compare the position of nodes of different countries at the centrality map.

As mentioned in the previous chapter, there are small number of node with high betweenness and high degree centrality, hence most nodes have low centralities. Due to the difference in the order of magnitude, the linear scaled centrality map cannot represent all features of two centralities, therefore the centrality map was measured on the logarithmic scale. The degree centrality and the betweenness centrality has the positive relation for all countries. Every countries have hub technologies with high degree and high betweenness centralities which is identified in accordance with the result of tests for power law of the cumulative degree distribution. Black circle stands for GDR, green triangle for FRG and purple diamond for Germany. In spite of the difference in the total number of patents, the number of nodes, or the graph size, the groups of nodes belonging to FRG and DE looks close. But the technology classes ranked by degree and betweenness centrality are significantly overlapped as shown in Appendix Table 1.

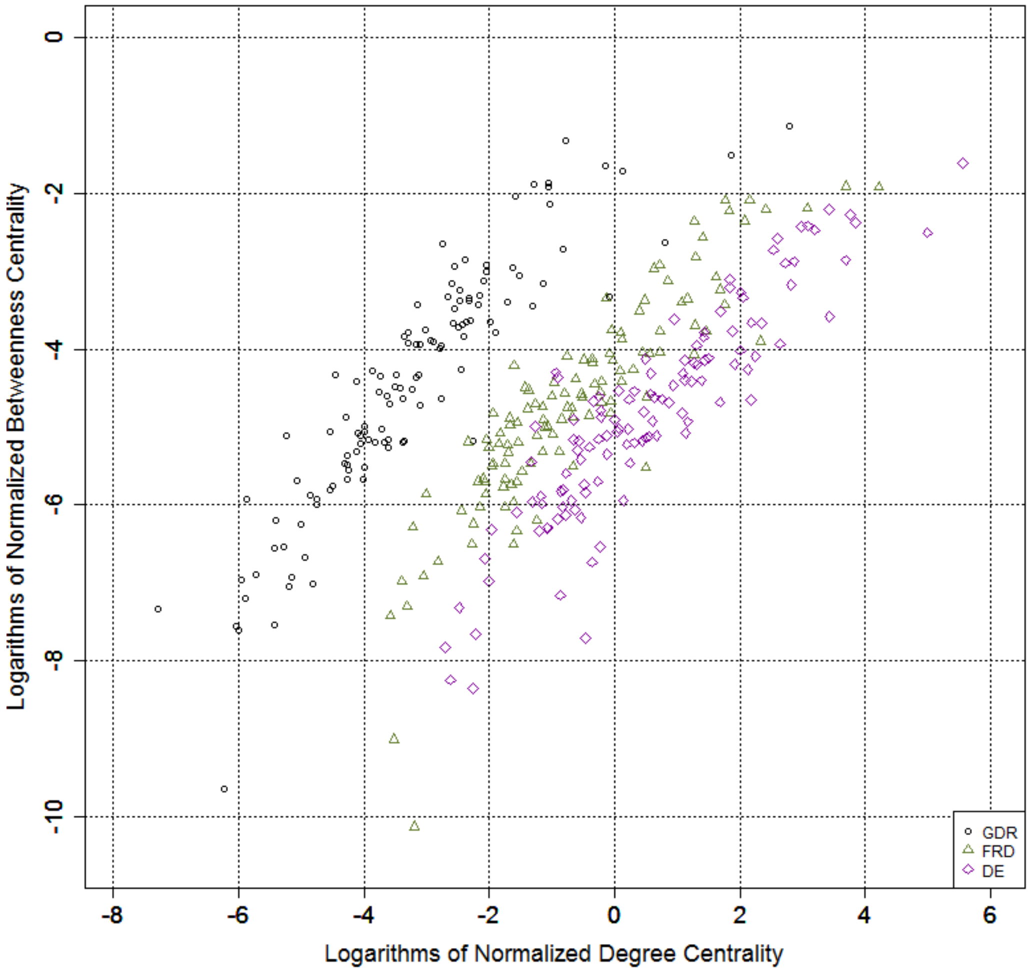


Figure 8. Centrality Map

Figure 9 illustrate the Euclidean distance of each technology class at 3 digit IPC code, between pairs of countries in logarithmic scale. The average Euclidean distance between GDR and FRG is 2.86 and between FRG and Germany is 1.23. The average distance between GDR and Germany is 4.03 and this value is approximately the sum of GDR-FRG and FRG-Germany distance. Except one class, *C40*, FRG-Germany distances over all classes show constant.

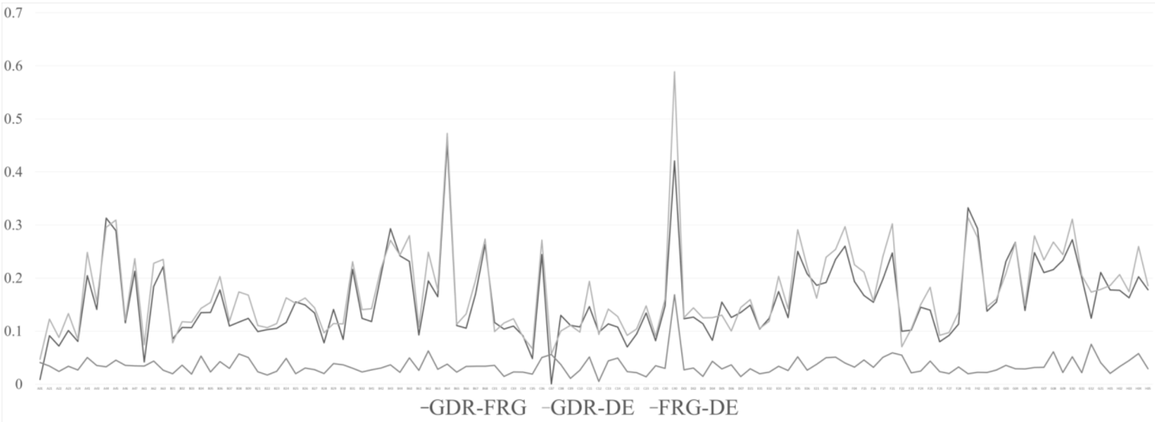


Figure 9. Technological Distance

So far, three analysis are conducted to clarify the effect of integration on the change of technological knowledge structure. These three are the analysis of topology of technology structure, comparison of relative degree of technology class development and technology similarity. The former two are measured by degree centrality and the last one is based on degree and betweenness centralities. All results show consistency that first, the technology structure topology of three countries are the similar and technology structures of FRG and Germany coincide considerably, suggesting that the technology structure of Germany after reunification followed that of FRG. Second, the relative concentration and development of technology measured by number of patents at technology class level, the degree and the betweenness centralities imply that although there are difference in relative precedence, most developed areas in three countries are quite similar.

Chapter 5. Discussion

5.1 The Change in Technological Knowledge Structure

The empirical analysis results show that the technological knowledge structure of Germany followed that of the Federal Republic of Germany (FRG) and the most developed technology classes rarely changed. To reveal the relation of the technology structure between FRG and Germany, the top 200 applicants of the two countries were investigated. The scale-free property of the technology structure of the three countries can be applied not only to the distribution of cumulative degree centrality but also to the relation between the applicant and number of patents filed by the applicants. Few applicants filed a lot of patents and the distribution of the number of patents per applicant is highly skewed. In other words, it means that highly ranked applicants could exert their influence in determining the technological knowledge structure of one country. There were 124 foreign firms in FRG within the top 200 applicants and 121 in Germany, and most of the foreign firms overlapped. This might explain the similarity of technology structure before and after the reunification. These foreign firms can affect the technological knowledge structure of Germany via knowledge spillover. While selection bias might exist, foreign technology in developed countries has a positive effect on spillover and stimulates the growth of total factor productivity (TFP), as well as in developing countries (Lipsey, 2004; Liu, Siler, Wang, & Wei, 2000; Manca, 2010; Pack & Saggi, 1997). The higher the capability and competitiveness host countries have, the more positive effect the multinational corporations have (Blomstrom & Kokko, 1998).

The volume of GDR's trade with FRG could affect the overlap of relatively concentrated technology classes between GDR and FRG. For FRG, the share of trade with GDR was slight, 1.5 %, and the percentage of workers who were involved in trade with GDR was 0.03% of the working population. But for GDR, FRG was the second largest trading partner followed by the Soviet Union, taking a 36~50 % share of foreign trade. The economic interchange with FRG was significantly important and FRG was an important channel to secure funds and the advanced technology[1]. From the positon of the firms and researchers in the former East, they had the opportunity to catch up to the more developed technology of the former West, if the technology structure and competency were comparable (L. Kim, 1980). In terms of technology distance, researchers have recognized the inversed U-shape relation between the technology distance and performance after integration (assimilation or M&A) (Ahuja & Katila, 2001; Raesfeld, Geurts, Jansen, Boshuizen, & Luttge, 2012). As far as learning opportunities and absorptive capacity are concerned, the more similar the knowledge structure, the better the chance of having a positive impact on performance (Cohen, Goto, Nagata, Nelson, & Walsh, 2002; Cohen & Levinthal, 1990). But sometimes, appropriate dissimilarity appears to help explore the novel opportunities for learning (Gilsing, Nooteboom, Vanhaverbeke, Duysters, & van den Oord, 2008). The analysis investigated above in this thesis would not be adequate to judge whether the technology distance between GDR and

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[1] http://www.dailynk.com/korean/read.php?cataId=nk03201&num=103605 (Accessed on November 28th, 2014)

Germany was appropriately close to maximize the absorptive capacity of GDR or not. But it gives a clue that there was reduced hindrance or constraints caused by difficulty in communicating or a lack of understanding, because the absorptive capacity of an organization often depends on the frictionless transfer of knowledge within the members of an organization (Østergaard, Timmermans, & Kristinsson, 2011; Symeou, 2012).

5.2 German Policy on Technology after Reunification

It is generally accepted that a larger technological and productivity gap are favorable for a faster catch-up rate (Abramovitz, 1986). One thing that cannot be overlooked is that despite the favorable conditions for technological catch up, East Germany cannot converge rapidly without effort. The East should have made sufficient efforts first, to raise its own ability to absorb and adopt the technology; and second, to invest in R&D activities to increase the incidence of technology spillover (Kinoshita, 2001). In a way, '*Catch up*' is not a word that expresses the economic convergence of the East and the West. Rather, it can be understood to embrace all processes in the resurrection of Germany after reunification. As already stressed in this paper, with the 'tearing down of the Wall', all the conditions GDR faced were quite favorable for the former East to catch up to the West. But while technologically lagging behind, the catch up would never be guaranteed since the development or restoration process is not a spontaneous or immediate process. Empirical studies have shown that integration favors faster convergence for those who lag behind, but they also emphasize the limitation of their findings and that "more detailed analysis of economic, social and institutional structure should be carried out." This implies that the overall societal situation, especially policy on technology, should be considered too (Jan Fagerberg, 1987; Manca, 2010).

This study answered the question of how the reunification of Germany affected the change in the technological knowledge structure and the question of how effective the technological integration was. The result is that the GDR did not significantly affect Germany after the reunification and Germany covered the structure of FRG. It seemed that the GDR exerted little influence, but an additional explanation is demanded. One basis is the policy that Germany adopted after reunification. Most statistics described in this paragraph were borrowed from Meske's study (1993). After reunification, the enterprises of the East went through privatization and public technology institutions and universities were rearranged in accordance with the Western system. As a result, the number of private and public research institutions were reduced and many R&D researchers in the former East lost their jobs or they moved to the West. On the other hand, many scientists from the West had the chance to move to the East and be promoted to managerial positions. The 86,000 eastern researchers in 1989 were reduced to 31,997 in 1993 (Meske, 1993). This led to loss of R&D in the East's human resources and a chance to maximize the effect of introducing new actors into the West as Germany covered the structure of FRG. Meske (1993) evaluated that the policy was not wrong in a methodological sense but what brought problems was one-sided absorption. The East demanded the unilateral transformation of the structure. This supports that Germany lost the potential for technological integration by utilizing the absorptive capability of the East's researchers, and hence the GDR's ability to show its competence after reunification was limited.

Another basis to explain the failure of technological integration can be found in the number of patents per 100,000 residents in 2005 (Appendix Figure. 2). Patents are concentrated on the former West states and the five new states of Germany ranked bottom (Lessenich & Nullmeier, 2006). And according to the data issued by The Federal Statistical Office of Germany, 28.5% of the total patents of Germany in 2007 were from Baden, which is located in the southwest and once part of West Germany. It is a widespread practice in literature to assign patents to regions on the basis of applicants' addresses when the assessment of knowledge impact on growth at the local level of aggregation or the geography of collective processes of knowledge creation is at stake (Marrocu, Paci, & Usai, 2013; Maurseth & Verspagen, 2002; Quatraro, 2010). Comparing the number of patents backs up the argument that technological convergence failed until recent years.

5.3 Implication to Korea

Germany was divided into two for 41 years. It's been more than 65 years since division of Korea into South and North. Compared to the situation of Germany, inter-Korean international exchange is extremely trivial. German civilians could apply for visiting their family or friends in the other Germany and could cross the border, but it is impossible in Korea. Most traffic is blocked except the channel through government or non-profit relief organizations. This long severance has created a great difference not only in economics but in ideology, social values and culture. To avoid the integration shock Germany suffered decades ago (Burda, 2008), Korea should prepare a gradual process of unification and avoid imitating the quick integration of Germany. The key words of the current administration of South Korea are the trustpolitik and normalization of the interrelationship between the North and the South. For example, by moving forward with the policy of internationalization of the Kaesong industrial complex, the Korean government tried to accumulate the experience of citizen diplomacy. Once North Korea make efforts towards denuclearization on the Korean Peninsula, Park's government is preparing for the gradual increase of inter-Korean exchange through the so-called "Vision Korea" project. In this reconstruction infrastructure project, a program for technological inter cooperation is also considered (B. Cho, 2013; KINU, 2013; Park, 2013). Technology not only plays an important role as a growth engine but also sometimes plays a role in international relations. One can hear on the news that the U.S. or E.U. have toughened technological sanctions against countries where they want to apply pressure[2] in the case of the Ukrainian crisis. Technologies especially like information and communication technology do have impacts on international affairs (McCarthy, 2014; Weiss, 2005). Thus, technology can act as a buffer or an intermediary between two countries before and after unification.

Unlike foreign countries' economic or technological sanction policies, Korea can utilize technology as a reconciler in inter-Korean relations from now on. Although

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[2] http://www.washingtonpost.com/politics/us-eu-toughen-russian-sanctions-to-pressure-putin/2014/09/12/515b80ce-3a98-11e4-8601-97ba88884ffd_story.html (Assessed on

reliable statistics on the North are not available, with the assumption that there is an inextricable link between technology and industry (Bhalla, 1985; Messerschmitt & Szyperski, 2005; Østergaard, 2009), the industry structure of the North has been studied. About 50 % was concentrated on mining and mining manufacturing and it is assumed that most people would be involved in the mining sector and that mining-related technologies must have developed. North Koreans seldom apply patents or publish articles in international journals (KOSIS, 2012). For successful technological integration on the Korean peninsula, it is a must to comprehend the relatively developed technology in North Korea and what kind of technology highly trained human resources are most involved in, no matter how long it would take. Otherwise, Korea will miss an opportunity for technological integration, just as Germany did. German reunification cannot be the solution to follow but rather provides a challenge to Korea in the case of unification of the Korean Peninsula. By increasing and extending the exchange of human resources and technology between the South and the North, the two Koreas should develop solid and interactive international relations to understand the necessity of cooperation.

5.4 Limitation

This study contributes to shedding light on the reunification of Germany by applying a novel approach through analyzing the integration of the technological knowledge structure. But this study has some limitations. Investigation of regional technology convergence can directly give empirical proof of the relation between technology development and economic convergence and growth, but due to a lack of an adequate number of patents filed from the former Eastern area, it was not feasible. The patents filed in Germany after reunification were sorted into the Eastern and Western regions manually according to their address information but the obtained data on the East was not enough to construct the technology structure. This was revealed by the statistics on the number of patents per resident. This also made it impossible to trace the effect of introducing new agents into the technology innovation of West Germany. As the technological knowledge structure of Germany was similar to that of FRG, GDR could be regarded as being absorbed or incorporated into FRG. Further, FRG gained new agents and this could have affected the innovation system of Germany. But most Eastern researchers stopped filing patents before reunification and most of the Eastern applicant-based information was unavailable. These results were found while investigating the EPO patent data. Researches mentioned above left as limitation of this study.

For further study, it would be worth relating the technology structure and the industrial structure to confirm the connection between technology, industry and economic growth. This might help in studying North Korea because the disclosed data of the North are very limited but the industrial structure is known at least. Thus, one can estimate the technology structure or technological competency of the North through developing more cooperative relations.

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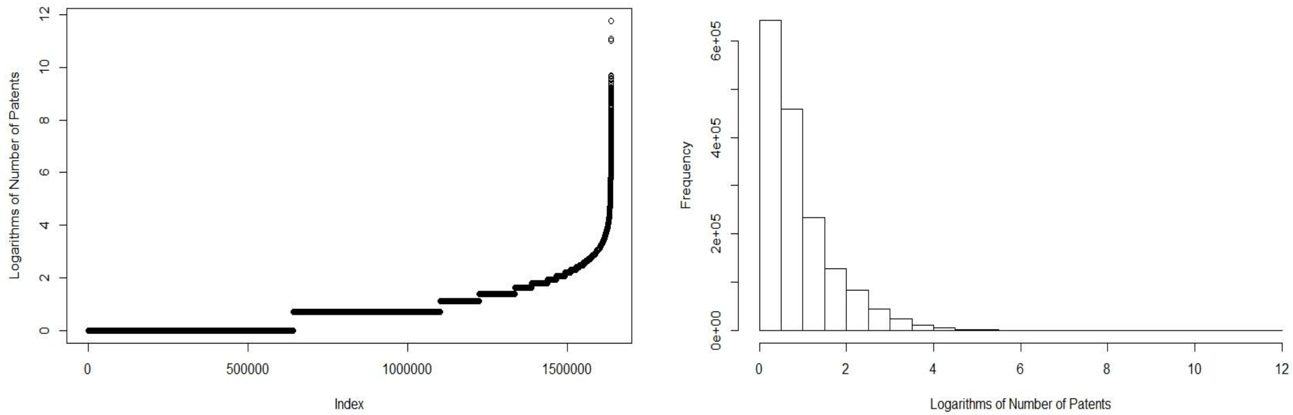
Appendix



(a) Distribution of Number of Patents in log-scale (b) Histogram of Number of Patents in log-scale

A. Figure 1 Distribution of Number of Patents per applicants in Germany after unification

A. Table 1 Main technology of Germany; before and after reunification

(a) By Number of patent

Rank	GDR	FRG	Germany
1	C07	C07	A61
2	A61	A61	H01
3	G01	H01	C07
4	A01	C08	H04
5	H01	G01	G01
6	C08	F16	B60
7	B01	B65	C08
8	B23	B01	F16
9	B65	H04	B65
10	F16	B60	G06

(b) By Degree Centrality

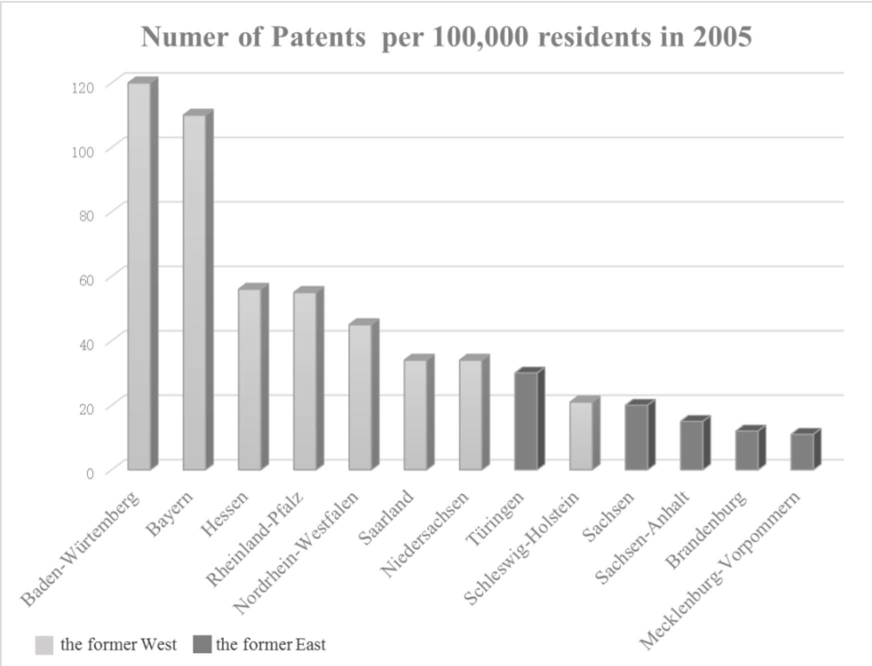
Rank	GDR	FRG	Germany
1	C07	C07	A61
2	A61	A61	C07
3	A01	C08	C08
4	C08	H01	H04
5	C12	C12	H01
6	B01	G01	C12
7	G01	B01	G01
8	C09	B29	B01
9	B29	F16	B60
10	H01	A01	G11

(c) By Betweeness Centrality

Rank	GDR	FRG	Germany
1	C07	A61	A61
2	G01	C07	G01
3	A61	G01	H01
4	B01	F16	C08
5	C08	C08	B01
6	H01	H01	F16
7	F16	B29	B60
8	B65	B01	C07
9	B23	F02	B29
10	B29	B65	B65

A. Table 2. Technology Classes Grouped as type 1 in Figure 6

Type 1	Rank	Description
A23	15	Foods or Foodstuffs
B41	18	Printing, Lining Machines
B32	23	Layered products
C11	26	Oils, waxes, detergents, candles
C23	28	Coating metallic material
D04	37	Braiding, knitting, trimmings
F28	49	Heaet Exchange in general
B24	56	Griding, Polishing
B66	57	Hoisting, Lifting
C05	59	Fertilisers
A21	61	Baking
A43	77	Footwear
B08	84	Cleaning
D02	91	Yars,
B09	92	Disposal of solid waste
E03	96	Water Supply
C13	104	Sugar Industry
F17	107	Storing or Distribution gases
B06	111	Generating or Transmitting Mechamical Vibration
B68	118	Saddlery



A. Figure 2. Number of patents per residents

초록

독일의 통일은 20세기의 기적으로 일컬어지지만 이는 정치적인 기적에 머물렀다는 한계가 있다. 독일은 통일 후의 빠른 경제적 수렴 현상과 발전을 기대했으나 예상치 못한 깊은 침체기를 겪어야만 했다. 경제학계는 정체된 수렴 현상을 설명하기 위해 자본 축적이나 노동 인구 감소와 같은 생산 요소의 재분배, 수렴 현상 분석 혹은 잘못된 통화정책 등에 대해 연구해왔다. 국가 혁신 시스템 관점에서 볼 때, 이러한 선행 연구는 사회적 변화와 기술의 역할 사이의 상호 작용에 대한 시스템적인 접근을 간과하고 있다. 독일의 경제적 통합이 야기한 영향력을 알아보기 위해 통일 전후 기술 지식 구조의 변화를 알아본다.

본 연구에서는 연결망 이론을 통해 EPO 특허 자료를 바탕으로 통일 전의 동독, 서독 그리고 통일 독일 세 국가에서 출원된 특허의 기술분야를 분석하였다. 기술 연결망은 한 국가의 기술 경쟁력, 지식 전이를 통한 기술 간의 상호작용, 통일 후 인력의 이동에 의한 영향을 분석을 위한 적합한 도구이다. 지식체계의 연결 중심성과 매개중심성을 측정함으로써 기술 구조의 위상, 상대적 기술 집중도 및 기술적 유사도를 조사하였다. 연구 결과는 통일을 전후하여 독일 지식 체계의 구조는 크게 변하지 않았음을 보인다. 그러나 통일 후의 독일은 핵심 기술 분야 및 기술의 유사도가 서독의 기술 구조와 매우 유사해 동독의 기술 영향력이 통일 후의 독일에 크게 영향을 미치지 못하였음을

보인다.

독일의 통일이 분단된 한국에게 이후 통일 시의 기술적 통합을 위한 해답을 주지는 못하지만 한국은 독일의 기술 정책을 타산지석 삼아 다가오는 통일 한국을 대비할 필요가 있음을 시사한다.

주요어: 경제적 통합, 기술 지식 구조, 네트워크 분석, 통일

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