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Transformation of Sectoral Innovation Pattern : Evidence from Korea*

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Abstract

Purpose – This work tries to analyze the transformation of sectoral innovation pattern as time goes by to enhance the understanding on sectoral innovative activities, particularly considering the change of the nature of knowledge, and the trend of convergence.

Research design, data, and methodology – This work tries to identify main factors, which determine the output of technological innovation through the econometric analysis, utilizing the result of *Korean Innovation Survey* and find a stylized fact on the change of the innovation pattern.

Result – As a result of estimation, some major elements show different effects for two discrete years, 2002 and 2010; in chemical industry the open information source and neutral basic research become more important with the appropriation mechanism such as patents, and in machinery industry, the importance of internal information has been getting decreased with rising importance of customers.

Conclusion – This work presents that some elements show different effects for two discrete years. Among three major elements, the source of information and appropriation mechanism shows different features for both industries. This means that we should explicit consider the changing nature of innovative environment, which leads to and heavily influence whether the innovative activity would be effective or not when we design innovation strategy and innovation policy.

Keywords: Transformation, Technological Innovative Pattern, Sectoral Difference, Industry, Korean Innovation Survey

JEL Classification Code: O3, M1.

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1. Introduction

One of historical research themes of innovation studies is the pattern of innovation by sectors since the seminal work by K. Pavitt in 1984, particularly in the field of innovation initiated and led by firms. This theme on sectoral pattern of innovation has tried to explore the difference on how innovations are achieved by sectors and which elements influence innovation by sectors, with the aim of understanding the major innovation mainly led by firms, the essential innovative agent in capitalist economy.

As such, the discussion on sectoral innovation pattern (Pavitt, 1984; Tidd & Bessant, 2009; Malerba & Orsenigo, 1996; Breschi et al., 2000; Park, 2019) has contributed to the understanding on the phenomenon of technological innovation by highlighting the difference of sectoral patterns based on the differential nature of knowledge. However, it has some limitations. Particularly it implicitly assumes that the pattern is fixed and time-invariant; thereby its analysis has remained as a static one. This aspect can make explanation sectoral innovation under changing environment including nature of knowledge limited.

Generally innovative pattern is not fixed. It can be changed. Main drivers can be the change of knowledge led by new paradigm and new discovery in knowledge domain, and at the same time the change of nature of demand can also generate the change of innovative pattern. As similar, Malerba (2006) is trying to understand the relationship between innovation and the evolution of industries. However, it remains at conceptual level by theoretical reasoning. To our knowledge, the necessity comprising the issue of dynamic aspects has not been effectively addressed.

Based on this background, the research question can be set as follows as a partial effort to addressing the issue, particularly from the point of empirical analysis. What are common and what are different in terms of effective elements of innovative pattern as time goes by? This question is relating to identifying the effective elements and its change by time.

This work tries to analyze the transformation of sectoral innovation pattern as time goes by in order to enhance the understanding on sectoral innovative activities, particularly considering the change of the nature of knowledge, and the trend of convergence. *Korean Innovation Survey (KIS)* done for a decade can be useful for analyzing the dynamic change of sectoral innovation pattern. To this aim, we try to identify main factors which determine the output of technological innovation through the econometric analysis utilizing the result of *Korean Innovation Survey* and find a stylized fact on the change of the innovation pattern.

2. Theoretical consideration

Sectoral differences in terms of the technological innovative pattern have been major research theme since K. Pavitt′s work. Pavitt (1984) analyzed the characteristics of technological innovative pattern differing by sectors utilizing the database of the major technology developed in the UK. It found the source of technological innovation, generation and utilization of innovation, firm size and organization, and appropriation, and some common patterns. It called these as innovative patterns and identified 4 types of sectors (supplier-dominated, scale-intensive, science-based, specialized supplier), which was extended with another type (information intensive sector) later.

Since this work, further conceptual works have been done by various scholars. Theoretically typical work is the formulation of sectoral innovation system (SIS) focusing on the characteristics of underlying knowledge of technological innovation, in particular its differential nature. These works study the main constituents such as technological opportunity, cumulativeness, appropriability, and the nature of knowledge base, and their relationship (Malerba & Orsenigo, 1996; Breschi et al, 2000), considering the characteristics of knowledge. And diverse empirical works have been done (Freel, 2003; Souitaris, 2002; Castellacci, 2008; Malerba, 2004; Kim, 2004, 2006; Song, 2000; Park, 2003; Peneder, 2010; Leiponen & Drejer, 2007; de Jong & Marsili, 2006; Park, 2019).

However, they have some limitations. They implicitly assume that the pattern is fixed and time-invariant and does not explicitly consider the changing nature due to changing knowledge base and changing nature of demand. Therefore, their analysis has remained as a static one and can function as one of obstacles to understand innovation by sector as it is.

In trying to overcome this limitation and to be dynamic analysis, analysis on sectoral difference should bear in mind the transformation of innovative pattern by time. Malerba (2006) and de Poel (2003) have a similar approach. According to Malerba (2006), research has to include the analysis of demand in terms of competent consumers and innovative users, the examination of the role of knowledge in terms of the knowledge base of industries and the study on the dynamics of collaborations in innovation and R&D networks. It argues that two elements generating the

transformation are the change of knowledge led by new paradigm and new discovery in knowledge domain, and at the same time the change of nature of demand can also generate the change of innovative pattern.

The nature of demand, that is the characteristics of market, the preferences of consumers, market differentiation and segmentation, and the size and growth of demand affect innovative efforts and therefore technical change in diverse ways. And another factor is user involvement in innovation.

It is known that a given knowledge base defines the nature of the problems firms have to solve, affects the division of innovative labor in an industry and influences market structure. And in a dynamic fashion, the knowledge base itself changes as an effect of the behavior of firms and of technological change, a process that future research has to take into full account (Malerba, 2006).

Similarly, De Poel (2003) analyzes the transformation of technological regimes. Particularly it analyzes how the transformation of technological regimes is enabled and constrained by sectoral patterns of innovation. Four innovation patterns are distinguished: the supplier-dependent, the user-driven, the mission-oriented and the R&D-dependent innovation pattern. It shows that there are distinct differences between how these four innovation patterns enable and constrain the transformation of technological regimes and in the degree to which they do so. In addition, innovation patterns sometimes enable the development and acceptance of innovations that radically deviate from existing regimes and may help to transform such regimes.

Based on previous work, we try to analyze the transformation of sectoral innovative pattern empirically. It can complement the conceptual work trying to comprehend the dynamic process and understand the differential nature of late-comer countries such as South Korea.

3. Methodology

This work extends the work of Park (2019) which is trying to identify the major factors which can exert an effective influence on actual innovation output, utilizing the result of Korean Innovation Survey. Therefore, this work utilizes the methodology of Park (2019), which estimate the effect of each innovation related elements on the innovation output for one year. However, this work extends the dataset by two different years. It is because this work focus on the difference between two discrete years for comprehending the transformation for that period. Comparing elements for two years need some matching between the dataset for 2002 and that for 2010, because the questionnaires in each year are not exactly same (the details can be seen in result tables).

Following Park (2019), the differential pattern of technological innovation by sectors can be identified by the way of estimating which factors is effective by industry in term of innovative performance. Major influential elements on innovative performance can be set based on the discussion in Pavitt (1984): source of innovation, the innovative organization, appropriation.

The source of innovation can consist of source of information itself, acquisition of technology embedding information, and cooperative activities exchanging information. Each sector may feature different effective determinants in terms of each element. Pavitt (1984) argued that in case of supplier dominated sector, the supplier is very important source for effective technological innovation; in case of science based sector, the internal R&D and advanced research institute such as universities is very important source; in case of scale intensive sector the internal experience and skill is the most importance source of technological innovation; in specialized supplier sector the internal skill building and the relationship with customers is important. These three sources of innovation can be effective only for proper source for each sector.

The source of information consists of 24 channels in *Korean Innovation survey*. (1) Private research institutes, (2) Universities, (3) Public research institutes, (4) Non-profit organizations (Trade associations, Chamber of commerce & industry etc.), (5) Affiliated companies, (6) Competitors in the same industry, (7) Firms in related industry, (8) Suppliers (raw materials/S.W.), (9) Suppliers (machinery /facilities) (10) Clients (11) Business service firms (technical, law, accounting, consulting etc.) (12) Employees (13) Informal networks among CEOs or CTOs, (14) Patent information, (15) Conferences (16) Journals and magazines, (17) Fairs and exhibitions (18) Newspapers, TVs (19) The Internet, (20) Procurement Dept., (21) Marketing Dept., (22) Research Dept., (23) Development Dept., (24) Production Dept. Acquisition of technology and cooperative activities can be done with as follows. (1) Affiliated companies, (2) Competitors in the same industry, (3) Firms in related industry, (4) Clients, (5) Business service firms (technical, law, accounting, consulting etc.), (6) Suppliers (raw materials/components/S.W.), (7) Private research institutes, (8) Universities, (9) Public research institutes, (10) Non-profit organizations (Trade associations, Chamber of commerce & industry etc.)

Innovative organization can consist of firm size, the share of highly educated employees, the share of (formal) job training, and the form of R&D organization. For innovative organization, the access to and acquisition of the

knowledge can be important. The share of highly educated employees and the share of job training can signal the possibility of the access to scientific and explicit knowledge and acquisition of explicit knowledge respectively. With the form of R&D organization we can understand the internal relationship, and the importance and power given to that organization within their companies. Independent organization can explore deeply into technical knowledge independently, but other form of R&D organization can acquire non-technical knowledge such as customer and market, and production on a relatively fragile base.

Pavitt argued that the access to and acquisition of explicit knowledge is important for science-based sector, compared to other types of sectors. Meanwhile, in other sectors the non-technical knowledge and tacit knowledge can gain higher importance.

Lastly, appropriation mechanism can consist of one for product innovation and one for process innovation. Actually, this mechanism can be captured by the company′s attitude toward utilizing patent for appropriation mechanism, which can be influenced by recognition that the distinction between explicit knowledge and tacit knowledge is important. The appropriation mechanisms comprise formal mechanisms (1-4) and informational mechanisms (5-7) as follows in Korea Innovation Survey; (1) Patents, (2) Utility Model (3) Industrial Design, (4) Trademarks, (5) Secrecy, (6) Complexity of design, (7) Lead-time advantage on competitors. And the survey divides the appropriation mechanism for product innovation and that of process innovation.

Table 1 shows the innovation pattern and its elements as follows

Table 1: The Innovative Pattern and its Elements

Innovation pattern	Elements
Source of innovation	Source of information
	Acquisition of technology
	Cooperative activities
Innovative organization	Firm size
	The share of highly educated employees
	The share of job training
	Form of R&D organization
Appropriation mechanism	Appropriation mechanism for product innovation
	Appropriation mechanism for process innovation

Considering the amount of data and the availability of statistical analysis it is inevitable that we limit our analysis to major typical industries, that is, chemical industry, machinery industry. Each industry is captured by two-digit SIC cords. Their full titles are: Manufacture of Chemicals and Chemical Products (24 industry), Manufacture of Other Machinery and Equipment (29 industry) according to Korean Standard industry classification. With this industry we investigate the difference between year 2002 and year 2010.

The equation for estimation is set as follows, as is Park (2019). The innovative output is set as dependent variable, and major factor which is regard as having possibility of influencing the innovative output as independent variables and the innovative effort whose proxy is R&D intensity and firm size is set as control variables. The share of sales of new products due to innovation is utilized for the proxy of the innovative output and independent factors are set as with Table 1, considering the Pavitt′s work and the questionnaire and its response of Korean innovation survey.

3. Findings

Contrary to our expectations, all the elements have not shown different feature by time. One of the reasons can be that the time span from 2002 to 2010 is not sufficiently enough for any change to take place. Otherwise some elements

can be heavily influenced by the nature of path dependency specific for that specific industry. Only some elements show difference by time, such as resource for innovation, cooperation partner, and the appropriation mechanisms. Findings by each industry can be summarized as follows.

3.1 Chemical industry (24 industry)

For chemical industry, the importance of information source has changed. In 2002, the entity along the value chain has effective importance, but in 2010 their effectiveness does not exist. In 2010 the conference which is usually open type and enables close dialogue with technical expert is much more important for innovation.

Table 2: The Significant Elements in Information Source for Innovative Output

Information source (2002)	2002	2010	Information source (2010)
procurement		positive	internal
sales	negative		
research	positive		
development	positive		
engineering			
production			
CEO			
affiliated company			affiliated company
competitor			competitor
material supplier	negative		supplier
machinery supplier			
customer	positive		customer
consulting firm			
hiring person			newly hired person
joint venture			
university			university
public research institute			public institute
institute for testing			
association		negative	external association
association for research			
private research institute			private service firm
patent information			
technical meeting		positive	conference
technical magazine			technical journal
exhibition			
public media			
internet	negative		

Note: vacant cell shows no statically meaningful results.

In relation to partners for cooperation, in 2002, the affiliated company and competitor which have casual relation with innovator have importance. However, in 2010, the public institute is shown to be significant element for innovative output.

Table 3: The Significant Elements in Cooperation Partner for Innovative Output

Cooperation partner (2002)	2002	2010	Cooperation partner (2010)
affiliated company	positive		affiliated company
competitor	positive		competitor
material supplier			supplier
machinery supplier			
customer			customer
consulting firm			private service firm
hiring person			
joint venture			
university			university
public research institute	positive	positive	public institute
institute for testing			
association	positive		
association for research	negative		
private research institute	positive		

Note: vacant cell shows no statically meaningful results.

For appropriation mechanism, the interesting finding is the effect of secrecy in case of product innovation. In 2002, the mechanism of secrecy has a positive effect, but in 2010, their effect is not significant. At the same time, complex design has a negative effect. In case of process innovation, the mechanism of market preemption also has lost their effectiveness. This trend can hint at the higher effect of patent protection.

Table 4: The Significant Elements in Appropriation Mechanism for Product Innovation for Innovative Output

Appropriation mechanism (2002)	2002	2010	Appropriation mechanism (2010)
intellectual property	positive	positive	patent
		positive	utility model
			design rights
			trademark
secrecy	positive		secrecy
complex design		negative	complex design
market preemption	positive	positive	market preemption

Note: data of year 2002 does not give detail information on each intellectual property and vacant cell shows no statically meaningful results

Table 5: The significant elements in appropriation mechanism for process innovation for innovative output

Appropriation mechanism (2002)	2002	2010	Appropriation mechanism (2010)
intellectual property		positive	patent
			utility model
		negative	design rights

			trademark
secrecy	positive		secrecy
complex design			complex design
market preemption	positive		market preemption

Note: data of year 2002 does not give detail information on each intellectual property and vacant cell shows no statically meaningful results

3.2 Machinery industry (29 industry)

In machinery industry, the internal source of information is effective elements in 2002. But it does not hold in 2010. In 2010, the university and the open-type conference has emerged as a significant source of information.

Table 6: The Significant Elements in Information Source for Innovative Output

Information source (2002)	2002	2010	Information source (2010)
procurement			Internal
sales			
research			
development	positive		
engineering	positive		
production			
CEO			
affiliated company			affiliated company
competitor	negative		Competitor
material supplier			Supplier
machinery supplier			
customer			Customer
consulting firm			
hiring person			newly hired person
joint venture			
university		positive	University
public research institute		negative	public institute
institute for testing	negative		
association			external association
association for research			
private research institute	positive	positive	private service firm
patent information	positive		
technical meeting		positive	Conference
technical magazine			technical journal
exhibition			
public media			
internet			

Note: vacant cells do not show any statically meaningful results

For cooperation partners, typical finding is that customers can be effective partners, contrary to the situation in 2002.

Table 7: The Significant Elements in Cooperation Partner for Innovative Output

Cooperation partner (2002)	2002	2010	Cooperation partner (2002)
affiliated company			affiliated company
competitor	positive	positive	competitor
material supplier			supplier
machinery supplier			
customer		positive	customer
consulting firm			private service firm
hiring person	positive		
joint venture	positive		
university			university
public research institute		negative	public institute
institute for testing	positive		
association	negative		
association for research			
private research institute	positive		

Note: vacant cells do not show any statically meaningful results

With relation to appropriation mechanism, the interesting fact is the changed effect of intellectual property. In 2002 these elements show significant effect, but in 2010 they do not show any significant effect.

Table 8: The Significant Elements in Appropriation Mechanism for Product Innovation for Innovative Output

Appropriation mechanism (2002)	2002	2010	Appropriation mechanism (2010)
intellectual property	positive		patent
			utility model
			design rights
			trademark
secrecy	positive	positive	secrecy
complex design			complex design
market preemption	positive	positive	market preemption

Note: data of year 2002 does not give detail information on each intellectual property and vacant cell shows no statically meaningful results

Table 9: The Significant Elements in Appropriation Mechanism for Process Innovation for Innovative Output

Appropriation mechanism (2002)	2002	2010	Appropriation mechanism (2010)
intellectual property	positive		patent
			utility model
			design rights
			trademark

secrecy	positive	positive	secrecy
complex design			complex design
market preemption	positive	positive	market preemption

Note: data of year 2002 does not give detail information on each intellectual property and vacant cell shows no statically meaningful results

4 Concluding remarks

The discussion on sectoral innovative pattern implicitly assume that the pattern is fixed and time-invariant and does not explicitly consider the changing nature due to changing knowledge base and changing nature of demand. As such it has limitations as a useful tool for comprehending present innovation phenomenon. As with the conceptual work trying to comprehend the dynamic process, we tried to analyze the transformation of sectoral innovation pattern as time goes by in order to enhance the understanding on sectoral innovative activities, particularly considering the change of the nature of knowledge, and the trend of convergence.

Korean Innovation Survey (KIS) done for a decade can be utilized for analyzing the dynamic change of sectoral innovation pattern. We tried to identify main factors which determine the output of technological innovation through the econometric analysis utilizing the result of *Korean Innovation Survey* and find a stylized fact on the change of the innovation pattern. This work extends the work of Park (2019) which is trying to identify the major factors which can exert an effective influence on actual innovation output, utilizing the result of *Korean Innovation Survey*. Therefore, this work utilizes the methodology of Park (2019). However, this work extends the dataset by two different years. It is because this work focus on the difference between two discrete years for comprehending the transformation for that period.

The differential pattern of technological innovation by sectors can be identified by the way of estimating which factors is effective by industry in term of innovative performance. Major influential elements on innovative performance can be set based on the discussion in Pavitt (1984): source of innovation, the innovative organization, appropriation. Considering the amount of data and availability of statistical analysis it is inevitable that we limit our analysis to major typical industries, that is, chemical industry, machinery industry. With this industry we investigated the difference between year 2002 and year 2010.

As a result, we can find some difference as follows. For chemical industry, the importance of information source has changed; while in 2002, the entity along the value chain has effective importance, in 2010 their effectiveness does not exist; in 2010 the conference is much more important for innovation. In relation to partners for cooperation, while the affiliated company and competitor which have casual relation with innovator have importance in 2002, the public institute is shown to be significant element for innovative output in 2010. For appropriation mechanism, the interesting finding is the effect of secrecy in case of product innovation; while the mechanism of secrecy has a positive effect in 2002, their effect is not significant in 2010. In case of process innovation, the mechanism of market preemption also has lost their effectiveness. This trend can hint at the higher effect of patent protection. Generally, in chemical industry the open information source and neutral basic research become more important with the appropriation mechanism such as patents.

In machinery industry, while the internal source of information is effective elements in 2002, it does not hold in 2010. For cooperation partners, customers can be effective partners in 2010, contrary to the situation in 2002. With relation to appropriation mechanism, the interesting fact is the changed effect of intellectual property; while these elements show significant effect in 2002, they do not show any significant effect in 2010. In machinery industry, the importance of internal information has been getting decreased with rising importance of customers.

According to analysis, we come to know that some elements show different effects for two discrete years. Particularly among three major elements, the source of information and appropriation mechanism shows different features for both industries. This means that we should explicit consider the changing nature of innovative environment, which leads to and heavily influence whether the innovative activity would be effective or not. This work can give an important element to consider for policy maker and corporate officer when they try to make their innovation policy and innovation strategy effective.

This seminal empirical work can contribute in that it can complement the conceptual work by making discussion changing more plentiful and giving empirical evidences to them and help understanding the differential nature of late-comer countries such as South Korea contrary to industrial countries like UK and European countries. However, we still have a long way to go. This work does not cover all industries because of the limitedness of relevant data. At the

same time focusing on identifying the changing elements render this work neglecting the rationale behind the changing. We just present a steppingstone for research in the future. The rationale behind the changing innovative pattern is still at the poor level and should be combined with actual history of each industry in specific countries.

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