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The Effects of Patent and Paper Technological Competitiveness on Delphi Survey's Technological Level: A Concentration on Base Software Computing

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Abstract

Objectives: Major countries have promoted Research and Development (R&D) policies on a governmental level with a global move to preoccupy the market that arises from this technological progress. **Methods/Statistical Analysis:** Concentrating on the base software computing technology, this study proposes a practical method of evaluating a nation's technological level. It does so by testing whether a nation's technological competitiveness using patent and paper statistics as measures of a nation's R&D productivity and influence of scientific technology significantly affects the technological level of a nation that is measured based on the subjective answers of experts. **Findings:** In this study, an empirical analysis was performed to verify whether patent and paper technological competitiveness, patent technological competitiveness and paper technological competitiveness, respectively, of the base software computing technology present a significant effect on the Delphi Survey's value. The results of the analysis are as follows. First, patent technological competitiveness has a significantly positive effect on Delphi Survey's value. Second, paper technological competitiveness has significantly positive effect on Delphi Survey's value. In conclusion, the study's technological competitiveness value from patent and paper evaluation indicators has a significant effect on the technological level measured by experts. This indicates that the evaluation method for technological competitiveness using indicators from patents and papers as products of R&D to measure productivity and the influence of science and technology can be exploited for an objective measurement of the national technological level. **Improvements/Applications:** Therefore, through additional research with various industries applied, the practicality of the national technological level evaluation is expected to appear.

Keywords: Paper Competitiveness, Paper Indicator, Patent Indicator, Software Computing, Technological Level

1. Introduction

Due to developments in the recent mobile computing environment, it became possible to easily access networks in outdoor settings using a mobile PC and process a massive amount of data. Additionally, cloud computing environments have been built, which allows users to easily share data without installing the necessary software on one's computer by connecting to the internet using an IT device. Moreover, due to the emergence of massive data-generating platforms such as IoT and the advent of big data technology, the realization of a system that was considered impossible becomes possible, causing the development of artificial intelligence to accelerate. With this acceleration of the global movement toward the base software computing technology, major countries carry forward R&D policies on a governmental level[1,2]. These countries have established and enforced R&D investment strategies in order to raise the investment efficiency and effectiveness of the enormous budget on R&D that has

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been deployed into the base software computing technology. Therefore, it is fairly important to evaluate the national technological level regarding base software computing technology, which can be measured either by the Delphi Survey, a subjective method that relies on experts' opinion or by the patent and paper technological level evaluation method, an objective method that depends on the statistical data of patent and paper as products of R&D[3–5]. This paper calculates the patent and paper technological competitiveness for each country using the relevant statistical data of the base software computing technology. It also tests if this competitiveness has a significant effect on the technological level measured by the Delphi Survey. The paper is organized as follows. Section 2 presents a literature review of the technological level evaluation as well as the patent and paper technological competitiveness evaluation method. Section 3 demonstrates the research model which examines the correlation of the significance between the patent and paper technological competitiveness and technological level from the Delphi Survey. Section 4 illustrates the result from the empirical analysis that analyzes the influence of the patent and paper technological competitiveness on the Delphi Survey's technological level. Finally, conclusions are given in Section 5.

2. Theoretical Background

2.1 Technological Level Evaluation

Since the country's competitiveness in the future depends on scientific technology, many indicators have been widely researched to measure changes in scientific technology capabilities over decades. As a result, the indicators have also been used to predict national technological level, assess market environments and improve national technological level[6]. However, thus far, no standardized technological level evaluation methods have been proposed. The existed methodologies include expert interviews, surveys and the Delphi method[7]. The technological level evaluation compares various technologies of multiple agents (i.e. industries and firms). The national technological level can be defined in many ways including "the capability to effectively utilize technological knowledge in investment, production and innovation" in "the level of accumulation of technology relating to industrial production" in and "the quantitative depiction of functional ability for technological purposes, divided into functional and technological parameters" in[8]. Also, the technological level is defined as the "measured value of the performance of a specific technology at a specific point in time"[9].

2.2 Patent Evaluation Indicators

A patent indicator is a tool that analyzes the technological attributes from both microeconomic and macroeconomic perspectives. It also explains the factors that support the national innovative system and traces the extent of the spread of knowledge among states, industries, technology fields and enterprises. Furthermore, the indicator is applied to measure the product of research and development as well as the structural and development levels of a specific technology or industry; finally, it is the most reasonable means of measuring or evaluating technological improvement[10]. The patent indicator is one that measures the information extracted from bibliographic data in the relevant document; in other words, it measures the innovativeness and technological value of a patent based on its application, family, citation frequency, as well as triad and US registered patent families. Patent evaluation indicator evaluates the patent technological competitiveness based on PAI, PII, PMI and PCI as shown in Table 1.

Table 1. Patent evaluation indicators

Variable	Definition
PAI	Patent Application (PA) of nation i in Technological Field (TF) F → PA_{iF}/PA for all competitors in F (technology share based on PA)
PII	PA_{iF}/i's total PA
PMI	Size of Patent Family (PF) and share of patents for triad (US, JP, EPO) PA_{ik}
PCI	Average citation frequency of PA_{ik}:PC_{iF}

2.3 Paper Evaluation Indicators

Paper information provides a quantitative assessment concerning human kind's level of progress including science and technology[11]. Paper index is being studied by a number of researchers as a tool that analyzes a research project's performance level. Quantitative or qualitative statistics of papers can be commonly used to comprehend the current state of scientific and technological cooperation and competitions among nations[12,13]. Patent indicators generally consist of a Bibliometric Activity Index (BAI) that evaluates the quantitative aspect of a paper and a Bibliometric Citation Index (BCI) that evaluates the qualitative aspect. BAI and BCI can be used as indicators to measure R&D productivity and the influence of science and technology[14]. Paper evaluation indicators are also shown in Table 2 with BAI and BCI, the two indices that measure both the quantitative and qualitative sides of a paper.

Table 2. Paper evaluation indicators

Variable	Definition
BAI Bibliometric Activity Index	Paper Numbers (PN) of nation i in Technological Field (TF) F → PN_{iF}/PN for all competitors in F (technology share based on PN)
BCI Bibliometric Activity Index	Average citation frequency of PA_{ik}:PC_{iF}

2.4 Patent and Paper Technological Competitiveness Evaluation Models

The technological level evaluation models can be classified as non-quantitative models (i.e. Delphi technique) and quantitative models (i.e. patent and paper indicators). The non-quantitative models uses expert opinions, whereas, the quantitative models use patent and paper competitiveness values. We use the patent AIMC model. The AIMC model includes four indexes to measure patent technological competitiveness: The Patent Activity Index (PAI), Patent Intensity Index (PII), Patent Market power Index (PMI) and Patent Citation Index (PCI). The equation for solving the AIMC model is as follows:

$$\text{Patent AIMC} = W \times P' = (W1 \times PAI) + (W2 \times PII) + (W3 \times PMI) + (W4 \times PCI),$$

Where W_1, W_2, W_3 and W_4 are weighted values.

We also use the paper AC model. The AC model includes two paper indexes to measure paper technological competitiveness: The Bibliometric Activity Index (BAI) and Bibliometric Citation Index (BCI). The equation for solving the AC model is as follows:

$$\text{Paper AC} = TB' = (T1 \times BAI) + (T2 \times BCI)$$

3. Study Design

3.1 The Study Model

Figure 1 shows the study model. This study validates whether patent and a paper technological competitiveness influences the Delphi Survey's technological level. If the validation shows the existence of any influence, then a new model for evaluating technological level is proposed.

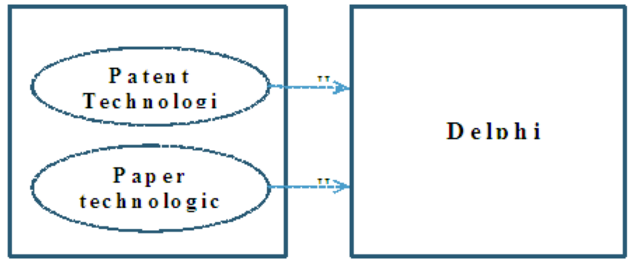

Figure 1. The study model.

3.2 Hypothesis Setting

3.2.1 Patent Technological Competitiveness

Patent technological competitiveness measures the value of competitiveness using the four patent evaluation indicators (PAI, PII, PMI and PCI). Patent technological competitiveness has a significant influence on the national technological level. Thus, the following hypothesis H1 is formulated.

- **H1:** Patent technological competitiveness has a positive effect on Delphi Survey's national technological level.

3.2.2 Paper Technological Competitiveness

Paper technological competitiveness measures the value of competitiveness using the two paper evaluation indicators (BAI and BCI). Paper technological competitiveness has a significant influence on national technological level. Thus, the next hypothesis H2 is as follows:

- **H2:** Paper technological competitiveness has a positive effect on Delphi Survey's technological level.

3.3 The Study Process

This study follows the following four stages. First, the technology structures of ICT sector are classified and search keywords are identified. Then, patent and paper data are gathered. Based on these patent and paper data, the patent and paper technological competitiveness are calculated. Lastly, to analyze the influence of the patent and paper technological competitiveness on Delphi

Survey's technological level, a multiple regression analysis is performed.

4. Empirical Analysis

4.1 Technology Tree

The evaluation technologies are illustrated in Table 3. The technology tree of the base software computing technologies follows the one used by experts in universities, industries, and research institutions under the Korean Ministry of Science.

Table 3. Technology tree

Base software computing	Mobile computing
	Big data platform
	Computing system
	High performance computing
	Artificial Intelligence (AI) perceptual computing
	Cloud computing

4.2 Patent Data Analysis

Patent data were extracted through keyword searches according to the technology classifications in Table 4. They were based on patents with filing disclosure dates between January 1, 2000 and December 31, 2014, as disclosed by the patent offices of the Republic of Korea, the United States, Japan and Europe. As shown in Table 4, a total number of 97,564 patents were filed in the 12 countries in the 14 years from 2000 to 2014 on the related technologies with families numbering 422,440 and citations at 262,416.

Table 4. Patent statics in smart service and information protection

Statistical item	patent application number	patent family number	patent citation number (USPTO)	Total
NL	1,617	9,680	1,364	12,661
TW	1,109	2,891	1,602	5,602
DE	3,552	16,890	5,106	25,548
US	43,824	198,466	173,151	415,441
SW	1,186	7,420	1,250	9,856
UK	1,226	6,864	1,959	10,049
IT	290	1,515	243	2,048
JP	28,062	109,648	54,715	192,425
CN	4,454	13,622	1,853	19,929
FR	2,930	16,755	3,206	22,891
FI	1,160	6,624	1,694	9,478
KR	8,154	32,065	16,273	56,492
Total	97,564	422,440	262,416	782,420

NL, stands for the Netherlands; **TW**, Taiwan; **DE**, Germany; **UK**, United Kingdom; **IT**, Italy; **FR**, France; **FI**, Finland; **CN**, China; **JP**, Japan; **KR**, Republic of Korea; **SW**, Sweden; and **US**, the United States.

4.3 Paper Data Analysis

Paper data were extracted through keyword searches according to the technology tree in Table 3. As shown in Table 5, the analysis covers the papers registered in the SCOPUS database during the past 15 years, between January 1, 2000 and December 31, 2014. The evaluation of paper indicators was conducted based on the number of paper registration and citations in the five countries. As illustrated in Table 5, during the past 15 years between 2000 and 2014, the total publications number of the 12 countries with the registered papers is 66,997 with citations totaling 840,990.

Table 5. Paper statistics in smart service and information protection

Statistical items	Paper numbers	Paper citation numbers	Total
NL	1,126	19,603	20,729
TW	2,476	16,058	18,534
DE	4,520	58,326	62,846
US	21942	438,635	46,0577
SW	802	14,275	15,077
UK	5,225	118,755	123,980
IT	2,775	28,628	31,403
JP	4,414	34,962	39,376
CN	17,213	53,801	71,014
FR	2,709	37,026	39,735
FI	610	6,068	6,678
KR	3,185	14,853	18,038
Total	66,997	840,990	907,987

4.4 Weights for Patent and Paper Evaluation Indicators

As shown in Table 6, to evaluate the national technological levels, the weighted values are derived through the AHP method.

Table 6. Weights for the patent AIMC model

Patent indicators	Weight	Paper indicators	Weight
PAI	0.253	BAI	0.454
PII	0.201		
PMI	0.304	BCI	0.546
PCI	0.242		
Total	1.000		1.000

4.5 Patent and Paper Evaluation Indicators

Based on the 97,564 applications, 422,440 families, 262,416 citations, 66,997 published papers and 840,990 paper citations from 47 subsectors in the base software computing technologies sectors from 2000 to 2014, four patent indicators and two paper indicators were calculated on all technologies sectors (i.e. 51 subsectors). The all calculated patent and paper indicators were transformed into square roots. The technological levels of the 12 countries were then evaluated on the transformed data. The patent technological competitiveness (Patent_TC) is obtained by the following equation:

$$\mathbf{Patent_{TC}} = \mathbf{W} \times \mathbf{P}' = (\mathbf{W1} \times \mathbf{PAI}) + (\mathbf{W2} \times \mathbf{PII}) + (\mathbf{W3} \times \mathbf{PMI}) + (\mathbf{W4} \times \mathbf{PCI}),$$

where W_1, W_2, W_3, and W_4 are weighted values.

Additionally, the values of the Paper Technological Competitiveness (Paper_TC) are obtained by the following equation:

$$\mathbf{Paper_{TC}} = \mathbf{TB}' = (\mathbf{T1} \times \mathbf{BAI}) + (\mathbf{T2} \times \mathbf{BCI})$$

The TLE values are the results of a 2015 Delphi Survey, which was carried out by experts in the universities, industries, and research institutions under the IITP Table 7.

4.6 Multiple Regression Analysis

Multiple regression analysis was performed to evaluate if the patent and paper technological competitiveness, Patent_TC and Paper_TC, respectively, of the base software computing technology have a significant effect on the Delphi Survey's TLE value. In order to perform the multiple regression analysis, autocorrelation of the Delphi Survey's TLE value and multi co linearity of the Patent_TC and Paper_TC as independent variables were reviewed. The Durbin-Watson index was used to test for auto-correlation of the dependent variable, which turned out to be 1.411 with respect to the estimated Delphi Survey's TLE value. This makes the TLE value closer to 2 and far from 0 or 4; therefore, it is independent and not auto-correlated. The VIF (Variance Inflation Factor) was used to determine multi-collinearity among the independent variables. The VIF values of all independent variables were less than 10, which makes the data suitable for regression analysis.

Table 7. TLE among nations

Nation	PAI	PII	PMI	PCI	BAI	BCI	Patent_ TC	Paper_ TC	Delphi Survey's TLE
NL	0.02	0.16	0.28	0.15	0.04	0.09	61.46	45.46	80.37
TW	0.02	0.17	0.21	0.09	0.07	0.10	47.89	50.38	80.61
DE	0.05	0.20	0.32	0.18	0.10	0.17	75.12	59,24	80.37
US	0.18	0.22	0.31	026	0.20	0.47	96.42	99.10	99.03
SW	0.03	0.18	0.31	0.11	0.04	0.08	63.18	43.72	67.27
UK	0.03	0.20	0.33	0.15	0.09	0.22	71.26	62.68	80.40
IT	0.01	0.16	0.26	0.11	0.07	0.12	53.30	52.17	82.39
JP	0.10	0.17	0.28	0.19	0.09	0.12	74.53	52.78	81.36
CN	0.05	0.18	0.26	0.09	0.19	0.19	59.46	70.44	69.93
FR	0.04	0.19	0.33	0.15	0.07	0.11	71.57	49.14	80.55
FI	0.03	0.21	0.31	0.17	0.04	0.05	71.09	40.86	72.20
KR	0.06	0.20	0.28	0.15	0.08	0.10	69.82	51.96	73.53

Table 8. Regression analysis results

Dependent variable	Independent variable	B	SE	β	t	p	VIF
DS_TLE	Constant	40.241	3.501		11.495	.000	
	Patent_TC	.415	.054	.615	7.742	.000*	1.425
	Paper_TC	.140	.040	.277	3.485	.001*	1.425
	R2 = .641, Modified R2 = .632, Regression df = 2, Residual df = 81 F = 72.323 P = .000 Durbin-Watson = 1.411						

* p< 0.05

Delphi Survey's TLE stands for Delphi Survey's Technological Level Evaluation; Patent_**TC**, Patent Technological Competitiveness; and Paper_TC, Paper Technological Competitiveness.

The results of the multiple regression analysis are as follows. Patent_TC (p<.05) shows a significant effect on the Delphi Survey's TLE. As Patent_TC gets higher, B (0.415), the Delphi Survey's TLE also becomes higher; likewise, as Paper_TC gets higher, the Delphi Survey's TLE becomes higher. The explanatory power of these independent variables in explaining the dependent variable, Delphi Survey's TLE, is 63.2% Table 8.

4.7 Hypothesis Validation

The hypothesis test results are presented in Table 9.

Hypothesis 1 was selected because the Patent_TC has a standardized regression coefficient of 0.615, which shows a significantly positive effect.

Hypothesis 2 was selected because the Paper_TC has a standardized regression coefficient of 0.277, which also shows a significantly positive effect.

Table 9. Hypothesis test results

Hypothesis	**H 1**	**H 2**
	Patent_TC	**Paper_TC**
DS_TLE	B = .615, p = .000*	B = .277, p = .001*
Support	Yes	Yes

* p< 0.05

DS_TLE is Delphi Survey's Technological Level Evaluation.

5. Conclusions and Implications

In this study, an empirical analysis was performed to verify whether patent and paper technological competitiveness, Patent_TC and Paper_TC, respectively, of the base software computing technology present a significant effect on the Delphi Survey's TLE value. The results of the analysis are as follows. First, Patent_TC has a significantly positive effect on Delphi Survey's TLE value. Second, Paper_TC has significantly positive effect on Delphi Survey's TLE value. In conclusion, the study's technological competitiveness value from patent and paper evaluation indicators has a significant effect on the technological level measured by experts. This indicates that the evaluation method for technological competitiveness using indicators from patents and papers as products of R&D to measure productivity and the influence of science and technology can be exploited for an objective measurement of the national technological level. Therefore, through additional research with various industries applied, the practicality of the national technological level evaluation is expected to appear.

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