ICIC Express Letters
Part B: Applications
Volume **7**, Number **10**, October **2016**

ICIC International ©2016 ISSN 2185-2766
pp. 2241–2246

ANALYZING EFFICIENCY OF IP-INTENSIVE INDUSTRIES: THE CASE OF KOREA

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Received March 2016; accepted June 2016

Abstract. *This study aims to measure the efficiency of Korean industries and compare the efficiency between IP-intensive industries and non-IP-intensive industries in Korea using Propensity Score Matching (PSM) and Data Envelopment Analysis (DEA). To select appropriate Decision Making Units, we use PSM prior to applying DEA. We first measure the extent of the efficiency of IP- and non-IP-intensive industries and then check whether there are statistical differences between them applying Mann-Whiteny U test. As a result, it reveals that the IP-intensive industries show relatively higher efficiency than the non-IP-intensive industries. According to the result, we suggest that Korea government has to establish relative strategies that make full use of high-efficiency of IP-intensive industries to strengthen the national competitiveness.*
Keywords: Intellectual Property-intensive industry, Efficiency analysis, Propensity score matching, Data Envelopment Analysis

1. **Introduction.** Intellectual Property (IP), like any other form of conventional forms of property, is an asset. The owner has the right to prevent the unauthorized use or sale of the property. Some common types of IP Rights (IPR) are trademarks, copyrights, patents, industrial design rights that are protected by law [1]. IP has been recognized as a mainstream factor to secure national competitiveness as we can easily see from the patent battle between global firms [2]. The U.S. Department of Commerce has defined IP-intensive industries by identifying which industry classes intensively use the protection offered by patents, trademarks, and copyrights [3].

Because of emphasizing the importance of IP-intensive industries, in many countries including U.S., Korea and EU, various studies have tried to research the characteristics of IP-intensive industries from a national perspective. The European Patent Office (EPO) has figured out how IP rights can contribute to economic performance in the EU [4]. Korea Institute of Intellectual Property (KIIP) has analyzed the economical ripple effect of IP-intensive industries in Korea using variables like export, value added, sales and labour cost [5]. The U.S. Department of Commerce has also researched the contributions of the IP-intensive industries to the U.S. economy using Gross Domestic Product (GDP), export and wage [3]. Previous studies have mainly emphasized the importance of IP as an intangible asset so they only focused on the economical perspective. In spite of the importance of IP-intensive industries, there are few studies to compare the efficiency between IP-intensive industries and non-IP-intensive industries from an industrial perspective.

Accordingly, this study aims to measure and compare the efficiency of Korean IP- and non-IP-intensive industries from an industrial perspective by using Data Envelopment Analysis (DEA) that measures efficiency of Decision Making Units (DMUs) such as countries, companies and industries in this study. Especially, we use Propensity Score Matching (PSM) prior to using DEA to select appropriate DMUs for DEA. The strong point of PSM method is considering only one score that is calculated by using a number of characteristics at the same time instead of various variables, so we use PSM to select DMUs. To analyze Korean industries, first, we measure the efficiency of selected DMUs and then, we compare the efficiency of Korean industries between IP-intensive industries and non-IP-intensive industries. The contribution of this study is that this study will help establish the government-wide investment strategies of Korea.

The remainder of this paper is organized as follows. Section 2 provides a brief introduction of DEA, PSM and reviews the previous related studies. The overall research framework is in Section 3. The approach is then illustrated in Section 4. The paper ends with conclusions and directions for future research in Section 5.

2. **Groundwork.** Efficiency can be simply defined as the ratio of output to input. DEA, a representative of the non-parametric methods, has been generally used to find the values of the relative efficiency of DMUs (such as industries in the case of this study) by comparing the measured value of input and output parameters [6]. CCR model, the first DEA model, proposed by Charnes, Cooper and Rhodes, assumes Constant Returns to Scale (CRS) [7]. Banker, Charnes and Cooper propose BCC model, which allows Variable Returns to Scale (VRS), and was extended from CCR model [8]. DEA results are CCR score, BCC score, and Scale Efficiency (SE) that can be obtained by CCR/BCC and Return to Scale (RTS). Returns to Scale (RTS) consists of Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). There are Increasing to Scale (IRS) and Decreasing Returns to Scale (DRS) in VRS [9]. If DMU is given an efficiency score of '1', it is considered to be efficient; an efficiency score less than '1' indicates inefficiency because, efficiency score is between 0 and 1 [10].

We consider selection bias, with regard to a non-randomized sample. To solve selection bias, Rosenbaum and Rubin [11] introduced PSM methodology that can control the selective problem that might under or over estimate the effect of the treatment factor. Advantage of PSM is the identification of matching pairs that have a relatively small difference in propensity score. We consider only one score instead of various variables because the score is calculated by using a number of characteristics or variables at the same time, using PSM [12].

Many researchers have attempted to analyze the efficiency of IP-intensive activities by using DEA, as shown in Table 1. Heng and Ding [13] compared R&D efficiency of global firms such as GE, Samsung and Haier Group using the variables such as employment and R&D expenditure and sales. Kocher et al. [14] analyzed the changes in R&D productivity by using R&D expenditure and the number of academic papers. Wu et al. [15] researched R&D efficiency analysis between companies, on how the expenditure on R&D employment can cause changes in IP stock using the R&D employees, operation cost, R&D expenditures as input and sales, intellectual capital stocks as output variables. Renula [16] studied R&D productivity as efficiency of manufacturing industries of Malaysia applying DEA using labour, value added, capital stock and workers. Many researchers mainly have studied briskly from a national perspective and an entrepreneurial perspective, but there are a few studies in the matter of industrial perspective comparing efficiency between industries of the same country. Therefore, this study tries to not only

Table 1. Previous studies relating IP-intensive activities

No.	Researchers	Research Objective
1	Heng and Ding [13]	Comparative analysis of R&D efficiency between global firms
2	Kocher et al. [14]	Analyzing R&D productivity in OECD countries
3	Wu et al. [15]	Research of R&D efficiency between companies
4	Renula [16]	Measuring R&D productivity of manufacturing industries

measure the efficiency of industries but also compare the efficiency between IP-intensive industries and non-IP-intensive industries.

3. **Research Framework.** The research framework for measuring and comparing the efficiency of IP- and non-IP-intensive industries is shown in Figure 1. This study consists of 3 steps: 1) defining input and output variables and data collection, 2) measuring and matching the propensity score for defining DMUs and, 3) analyzing the efficiency of DMUs by using DEA and comparing the efficiency between IP-intensive-industries and non-IP-intensive industries.

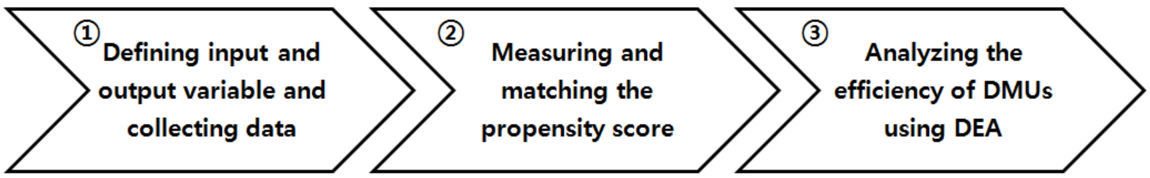

Figure 1. Research framework of this study

4. Results and Discussions.

4.1. **Defining variables and collecting data.** The objective of this study is measuring and comparing efficiency between IP-intensive industries and non-IP-intensive industries of Korean industries, so we choose input and output variables first at all steps. We consider the usability of input and output variables data related to the industrial level, and one of the important working in using PSM, DEA methodologies.

We deal with industry level, R&D expenditure, value-added and labour cost in industry of 2010 for PSM. Background variables are summarized in Table 2. Labour cost, R&D expenditure and value-added have relationship with industry R&D efficiency, so we make division 3-levels as high, medium and low level, thereby processing industry data/total industries data and we used industry level among variables, and industry level classified as four types was suggested by OECD based on the ISIC rev.3.

To apply DEA, we used 2 input data in 2008 (R&D expenditure, Labour cost) and 2 output data in 2010 (Production, Value-added) for comparing the efficiency between IP-intensive industries and non-IP-intensive industries in Korea. Table 3 shows input and output variables for DEA.

We collected data for this research from OECD STAN (STructural ANalysis) database concerning the Korean industries. We changed industry code from NAICS code to ISIC rev.4 because U.S. Department of Commerce defined IP-intensive industries as the industry classes that intensively use the protection offered by patents, trademarks and copyrights using the NAICS code but OECD STAN provides the ISIC code.

Table 2. Background variables for PSM

Variable	Description	Previous studies
Industry Level	high, medium-high, medium-low, low	[12]
R&D Exp	high, medium, low	[13-15]
VALU	high, medium, low	[5,13]
LABR	high, medium, low	[5,16]

Table 3. Input and output variables for DEA

	Variable	Data source	Previous studies
Input	labour costs	OECD STAN	[5,16]
	R&D expenditures	OECD STAN	[13-15]
Output	production	OECD STAN	[13,15]
	value-added	OECD STAN	[5,13]

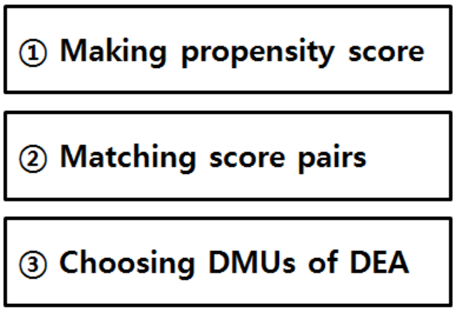

Figure 2. Process of defining DMUs

4.2. **Measuring and matching the propensity score.** For defining DMUs of DEA, we use PSM methodology. This step consists of 3 small stages. First, we make score of PSM using variables defined preceding step of research framework. Second stage is matching the pair of propensity score between IP-intensive industry and non-IP-intensive industry and third stage is defining DMUs by selecting pairs of nearest propensity score gap between IP-intensive industries and non-IP-intensive industries. Figure 2 shows process for defining DMUs.

This research creates groups of similar IP-intensive industries and non-IP intensive industries based on the propensity score calculated by the probit model, so we make propensity score using background variables about each industry. Next, we match score pairs between IP-intensive industries and non-IP-intensive industries. From that, we gain 24 pairs of propensity score between IP- and non-IP-intensive industries. Finally, we choose 10 pairs from the 24 pairs using nearest score gap. As a result of applying the PSM methodology, we acquire 20 industries that will be used as DMUs of DEA when measuring and comparing the efficiency of IP-intensive industries and non-IP-intensive industries.

4.3. **Measuring and comparing the efficiency of DMUs by using DEA.** To measure and compare the efficiency of IP-intensive industries and non-IP-intensive industries, we use 20 DMUs defined preceding step, simultaneously, when applying DEA. The results of DEA consist of descriptive statistics quantity of BCC score and the number of most efficiency industry in Table 4.

The objective of this study is comparing the efficiency between IP-intensive industries and non-IP-intensive industries. Therefore, we force on not comparing the efficiency between each industry of 20 industries, but comparing two-group industries, IP-intensive

Table 4. Efficiency of IP-intensive industries and non-IP intensive industries

	Mean	Std. Dev	Min.	Max.	BCC = 1
IP-intensive industries	0.888	0.214	0.497	1	7
non-IP-intensive industries	0.596	0.309	0.135	1	2

Table 5. Results of the Mann-Whiteny U test

	N	Mean rank	Sum of rank
IP-intensive industries	10	13.3	133
non-IP-intensive industries	10	7.7	77

Mann-Whiteny's U = 22.0, Z = −2.219, p = 0.035**

Level of statistical significance. ** = 5%

industries and non-IP-intensive industries. This study uses actual data, so we deal with BCC score, not CCR score because BCC model allows VRS that means the variable's pure efficiency.

First, from the view point of BCC score, IP-intensive industries have average BCC score 0.888, and that result means efficiency of IP-intensive industries average BCC score is high, because score of result of DEA is between 0 and 1. The BCC score of non-IP-industries is average 0.596, and that result is less than average BCC score of IP-intensive industries. Second, from the view point of the number of the most efficient industries (BCC score = 1), IP-intensive industries have 7 most efficient industries, but non-IP-intensive industries have 2 industries. Finally, we find the statistical difference of efficiency between IP-intensive industries and non-IP intensive industries by analyzing Mann-Whiteny U test. Table 5 shows results of the Mann-Whiteny U test.

From the result of DEA analysis, efficiency of IP-intensive industries is relatively higher than efficiency of non-IP-intensive industries. To make full use of efficiency of IP-intensive industries, it can be a good example to create more profits from national perspective, and Korea government supports the IP-intensive industries more than non-Ip-intensive industries by making supporting strategy such as giving tax benefit and giving government grants for the encouragement of R&D. In that case, companies of IP-intensive industry will produce more profit and more jobs.

5. **Conclusions.** This study aims at not only measuring the efficiency of Korean industries but also comparing efficiency between IP-intensive industries and non-IP-intensive industries by using DEA. Furthermore, we use PSM methodology for choosing DMUs of DEA to measure the efficiency of Korean industries. We checked difference of efficiency between IP-intensive industries and non-IP-intensive industries of Korean industries. In addition, we found the statistical difference of result of DEA by analyzing Mann-Whiteny U test and we suggested some supporting strategies for using efficiency of IP-intensive industries. Nevertheless, this study has limitation. We forced on checking recent trends of efficiency of Korea industries and comparing IP-intensive industries and non-IP-intensive industries, so, we used only the latest 3 years data (from 2008 to 2010) of OECD in this study. However, if we use long-term data, we will get different results of research and we will be able to check overall change of efficiency of Korean industries. Moreover, if we use different input and output factors, we can find any other valuable results in the future.

Acknowledgment. This work was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (NRF-2014R1A1A1005317).

REFERENCES

[1] D. K. Sharma, Intellectual Property and the need to protect IT, *Indian Journal of Scientific Research*, vol.9, no.1, pp.84-87, 2014.
[2] S. Graham and S. Vishnubhakat, Of smart phone wars and software patents, *The Journal of Economic Perspectives*, vol.27, no.1, pp.67-85, 2013.
[3] U.S. Department of Commerce, *Intellectual Property and the U.S. Economy: Industries in Focus*, U.S. Department of Commerce, 2012.
[4] European Patent Office, *Intellectual Property Rights Intensive Industries: Contribution to Economic Performance and Employment in the European Union*, European Patent Office, 2013.
[5] Korea Institute of Intellectual Property, *Studies on Intellectual Property – Economical Ripple Effect of IP-intensive Industry*, Korea Institute of Intellectual Property, Seoul, 2014.
[6] K. Choi and J. Ahn, Measuring the efficiency of universities in Korea using DEA and clustering approach, *ICIC Express Letters, Part B: Applications*, vol.5, no.6, pp.1673-1679, 2014.
[7] A. Charnes, W. W. Cooper and E. Rhodes, Measuring the efficiency of decision making units, *European Journal of Operational Research*, vol.2, no.6, pp.429-444, 1978.
[8] R. D. Banker, A. Charnes and W. W. Cooper, Some models for estimating technical and scale inefficiencies in data envelopment analysis, *Management Science*, vol.30, no.9, pp.1078-1092, 1984.
[9] S. Choi, S. Shin, D. Choi and W. Seo, Analyzing efficiency of intellectual property-intensive industries of OECD countries, *ICIC Express Letters*, vol.10, no.5, pp.1207-1212, 2016.
[10] J. Park, H. Bea and S. Lim, A DEA-based method of stepwise benchmark target selection with preference, direction and similarity criteria, *International Journal of Innovative Computing, Information and Control*, vol.8, no.8, pp.5821-5834, 2012.
[11] P. R. Rosenbaum and D. B. Rubin, The central role of the propensity score in observational studies for causal effects, *Biometrika*, vol.70, no.1, pp.41-55, 1983.
[12] D. Chun, Y. Chung, C. Woo, H. Seo and H. Ko, Labor union effects on innovation and commercialization productivity: An integrated propensity score matching and two-stage data envelopment analysis, *Sustainability*, vol.7, no.5, pp.5120-5138, 2010.
[13] C. Heng and Y. Y. Ding, A DEA study on R&D efficiency: Compare with most famous transnational corporations in PRC, USA and South Korea, *International Conference on E-Business and E-Government*, pp.2351-2354, 2010.
[14] M. G. Kocher, M. Luptacik and M. Sutter, Measuring productivity of research in economics: A cross-country study using DEA, *Socio-Economic Planning Sciences*, vol.40, no.4, pp.314-332, 2006.
[15] W. Y. Wu, H. J. Tsai, K. Y. Cheng and M. Lai, Assessment of intellectual capital management in Taiwanese IC design companies: Using DEA and the Malmquist productivity index, *R&D Management*, vol.36, no.5, pp.531-545, 2006.
[16] M. Renula, A DEA approach to understanding the productivity growth of Malaysia's manufacturing industries, *Asia Pacific Journal of Management*, vol.19, no.4, pp.587-600, 2002.