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ANALYZING EFFICIENCY OF INTELLECTUAL PROPERTY-INTENSIVE INDUSTRIES OF OECD COUNTRIES

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Abstract. *This study aims to measure the extent of the efficiency of IP-intensive industries of OECD countries and derive meaningful insights for improving the efficiency by exploring the causal relationships between input and output factors that affect the efficiency. These insights can be used to establish strategic directions for increasing the national IP competitiveness. Therefore, this study can contribute to drawing strategic action plans for strengthening the IP-intensive industries from a national perspective.*
Keywords: Intellectual property-intensive industry, Data envelopment analysis, Path analysis model, Efficiency analysis

1. **Introduction.** Intellectual Property (IP) naturally generated from the knowledge-based activities of human beings has been recognized as a mainstream factor to secure national competitiveness [1]. Under this recognition, various studies have tried to analyze the features of IP-intensive industries from a national perspective. 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 and then analyzed the contributions of the IP-intensive industries to the U.S. economy [2]. The European Patent Office (EPO) has also figured out how IP rights can contribute to economic performance in the EU [3]. These studies had emphasized the importance of IP-intensive industries in terms of economic influences. Despite the importance of IP-intensive industries, there have been few studies to analyze the efficiency of these industries and to identify critical factors to increase the efficiency. Therefore, this study aims to measure the level of IP competitiveness of OECD countries and to facilitate establishing action plans to strengthen the industrial competitiveness by analyzing the efficiency of IP-intensive industries. To do that, this study first measures the level of IP competitiveness of OECD countries by using Data Envelopment Analysis (DEA) and then explores the causal relationships between input and output factors that affect the efficiency by incorporating path analysis. This study contributes to drawing strategic plans for increasing the national IP competitiveness in that it investigates the causal relationships between input and output factors that affect the efficiency of IP-intensive industries. The rest of this paper is organized as follows. Section 2 reviews the related works on measuring the efficiency of IP-intensive industries and Section 3 describes the overall research framework. Section 4 shows the results of our study and Section 5 concludes the paper and discusses future research directions.

2. **Groundwork.** Data Envelopment Analysis (DEA), a representative of the non-parametric methods, has been generally used to assess the relative efficiency of Decision Making Units (DMUs) by comparing the measured values of input and output parameters [4]. DMUs are regarded as entities responsible for producing outputs from inputs [5]. Charnes, Cooper and Rhodes [4] proposed a Charnes, Cooper and Rhodes (CCR) model which assumes Constant Returns to Scale (CRS) and Banker, Charnes and Cooper [6] presented a Banker, Charnes and Cooper (BCC) model based on the assumption of Variable Returns to Scale (VRS) by extending CCR.

By using DEA, many researchers have attempted to evaluate the efficiency of IP-intensive activities. Co and Chew [7] analyzed the degree of efficiency of R&D activities which are core factors in IP competitiveness. Kocher et al. [8] examined the changes in R&D productivity by using R&D expenditure and the number of academic papers. Wu et al. [9] figured out how the expenditure on R&D employment can cause changes in IP stock. These studies have only focused on assessing the current status of IP-intensive industries with the measurement of R&D efficiency. However, it is more necessary to discuss how to improve the efficiency by deriving meaningful insights from the analysis. Therefore, this study tries to not only measure the relative efficiency of IP-intensive industries of OECD countries but also facilitate establishing strategic plans to enhance the current efficiency. To do that, this study uses path analysis model which calculates the direct and indirect influences between variables and then extracts core factors in those relationships [10]. The path analysis model investigates the paths of independent variables' effect on a dependent variable from the complex multiple correlations [10]. Therefore, this study aims to examine the efficiency of IP-intensive industries by using DEA and then draw meaningful insights for establishing strategic action plans to improve the efficiency by applying path analysis model.

3. **Research Framework.** A procedural framework of this study consists of 3 steps as shown in Figure 1: 1) defining appropriate DMUs, input and output variables, 2) measuring the efficiency of IP-intensive industries by using DEA and 3) analyzing the effect between variables to address how to improve the efficiency.

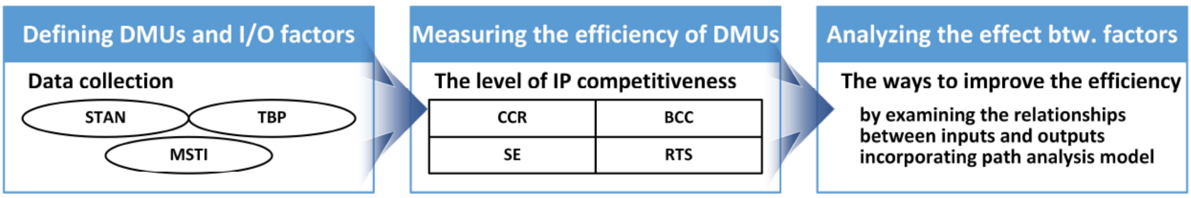

Figure 1. Research framework

We focus on the IP-intensive industries of OECD countries so we choose OECD countries as DMUs with considering the usability of data related to the input and output variables. 27 countries are eventually selected for DMUs. Based on the deep discussion of the literature about the efficiency of IP activities, we set gross domestic expenditure on R&D, R&D personnel and expenditures in IP-intensive industries as input variables and technology balance of payments, production and value-added in IP-intensive industries as output variables (Table 1).

In line with these variables, we collected data from the OECD STAN (STructural ANalysis), Main Science and Technology Indicators (MSTI) and TBP (Technology Balance of Payments) database during 2009 and 2011. To analyze the production efficiency using DEA, the time lag from inputs to outputs should be considered. Many researchers had generally assumed that two years are acceptable [11]. Following this generally accepted

Table 1. Input and output variables

	Variable	Data source
Input	*Gross expenditure on R&D*	*OECD MSTI*
	R&D personnel in IP-intensive industries	*OECD STAN*
	R&D expenditures in IP-intensive industries	*OECD STAN*
Output	*TBP: Receipts*	*OECD TBP*
	Production in IP-intensive industries	*OECD STAN*
	Value-added in IP-intensive industries	*OECD STAN*

assumption, we had adopted two years as the time lag from inputs to outputs when calculating the efficiency of IP-intensive industries. This study wholly depends on the OECD database, but it does not provide enough data for most of OECD countries after the year 2012. Therefore, we had decided to basically use the output data of 2011. It means that this study may not reflect the latest trends of IP-intensive industries. However, we had thought that it is more important to incorporate more countries' data into our analysis rather than using the recent data of the small number of countries.

The target of this study is not the entire industries of OECD countries but the IP-intensive industries so the data should be only limited to the relative industries. Therefore, we filtered the collected data in accordance with the definition of IP-intensive industries made by the U.S department of commerce. The IP-intensive industries were defined as the industry classes that intensively use the protection offered by patents, trademarks and copyrights. However, the IP-intensive industries are defined using the North American Industry Classification System (NAICS) and the OECD database provides the statistical data based on the International Standard Industrial Classification (ISIC). Therefore, we carried out matching process by incorporating a concordance table between ISIC rev. 4 and NAICS 2012 presented by the United Nations Statistics Division.

4. **Results and Discussion.** Table 2 shows the measured efficiency of IP-intensive industries of DMUs after applying DEA. 5 DMUs including Belgium, Estonia, Korea, Mexico and Slovak Republic show the highest degree of efficiency. Japan shows relatively low efficiency in CCR model but the highest one in BCC model. It can be construed that Japan is technically efficient but scale inefficient due to its large size of the scale of IP-intensive industries. This point can be captured by exploring the Scale Efficiency (SE) since it can be obtained by dividing CCR score by BCC score. The SE means a DMU operates at smaller scale compared to others but generates the same output [12]. Returns To Scale (RTS) indicates the behavior of returns in outputs of DMUs resulting from proportionate changes in all inputs [13]. The RTS can be identified as increasing (IRS), decreasing (DRS), or constant (CRS) [13]. If changes in outputs are greater than the changes in inputs, the production system can be considered that it exhibits the IRS. In case of the IRS, it may be expected that the production efficiency can be improved by increasing the size of the scale. If changes in outputs are smaller than the changes in inputs, the production system can be thought that it reveals the DRS. In case of the DRS, it is necessary to adjust the size of the scale to improve the production efficiency. Most of DMUs are classified into the DRS, but only Slovenia shows the result of the IRS. Therefore, to improve the efficiency of IP-intensive industries of Slovenia, it is required to expand the size of its industries by focusing on the input factors.

These results only show the current status of efficiency of IP-intensive industries. Although the BCC model can generate the benchmark targets for inefficient DMUs, they are limited to each DMU and cannot explain the causal relationships between inputs and outputs. Therefore, this study explores the way to improve the efficiency by examining

Table 2. Results of applying DEA

DMU	*Austria*	*Belgium*	*Canada*	*Czech Republic*	*Denmark*	*Estonia*	*Finland*	*France*	*Germany*
CCR	*0.384*	*1*	*0.747*	*0.487*	*0.391*	*1*	*0.383*	*0.469*	*0.455*
BCC	*0.521*	*1*	*0.892*	*0.715*	*0.618*	*1*	*0.568*	*0.936*	*1*
SE	*0.737*	*1*	*0.837*	*0.681*	*0.633*	*1*	*0.674*	*0.501*	*0.455*
RTS	*DRS*	–	*DRS*	*DRS*	*DRS*	–	*DRS*	*DRS*	*DRS*
DMU	*Hungary*	*Ireland*	*Italy*	*Japan*	*Korea*	*Mexico*	*Netherlands*	*New Zealand*	*Norway*
CCR	*0.260*	*0.039*	*0.364*	*0.413*	*1*	*1*	*0.219*	*0.354*	*0.342*
BCC	*0.538*	*0.130*	*0.594*	*1*	*1*	*1*	*0.893*	*0.369*	*0.436*
SE	*0.483*	*0.302*	*0.614*	*0.413*	*1*	*1*	*0.245*	*0.960*	*0.785*
RTS	*DRS*	*DRS*	*DRS*	*DRS*	–	–	*DRS*	*DRS*	*DRS*
DMU	*Poland*	*Portugal*	*Slovak Republic*	*Slovenia*	*Spain*	*Sweden*	*Switzerland*	*United Kingdom*	*United States*
CCR	*0.379*	*0.486*	*1*	*0.872*	*0.240*	*0.333*	*0.319*	*0.233*	*0.556*
BCC	*0.426*	*0.499*	*1*	*1*	*0.510*	*0.607*	*0.948*	*0.654*	*1*
SE	*0.891*	*0.975*	*1*	*0.872*	*0.472*	*0.549*	*0.336*	*0.356*	*0.556*
RTS	*DRS*	*DRS*	–	*IRS*	*DRS*	*DRS*	*DRS*	*DRS*	*DRS*

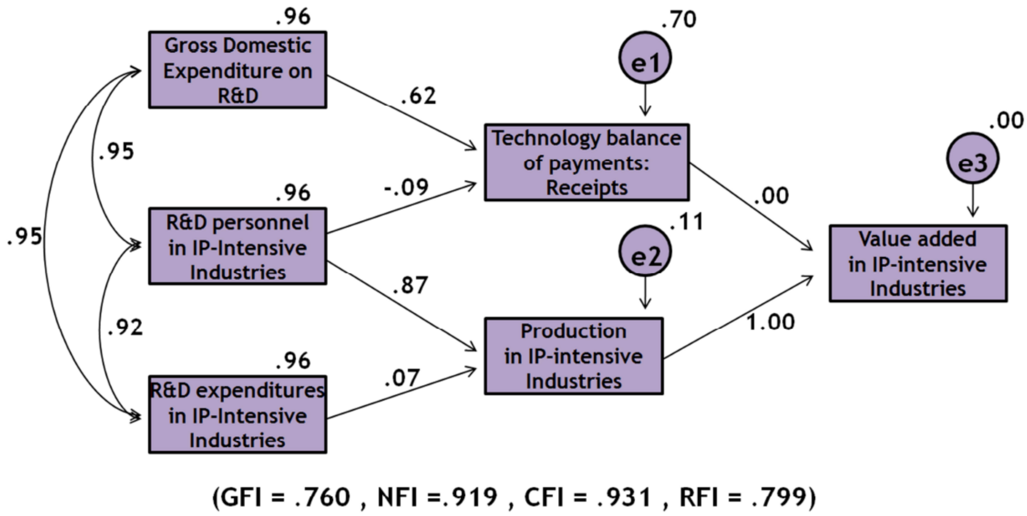

Figure 2. Results of applying path analysis model

the relationships between inputs and outputs incorporating path analysis model. Figure 2 shows the results of applying path analysis model.

The most influential factor for the technology balance of payments is the gross domestic expenditure on R&D. The R&D personnel in IP-intensive industries are the most important factor for the production in IP-intensive industries. Moreover, the value-added in IP-intensive industries is highly dependent on the production in IP-intensive industries. From the results of applying path analysis model, we can generate meaningful insights to improve the efficiency of IP-intensive industries by producing more outputs on the same inputs. First, OECD countries should establish strategic plans to expand investment on R&D to increase the extent of the export of technologies. Second, they have to devise plans to employ more R&D employees in IP-intensive industries to extend the volumes of the gross domestic production. Finally, they have to seek strategic ways to create more value-added by enlarging the amount of the gross domestic production. It can be a good example to give the tax benefit to IP-intensive companies who invest a large amount of money into R&D activities or hire relatively many R&D workers.

This study measures the extent of the efficiency of IP-intensive industries of OECD countries and derives meaningful insights for improving the efficiency by synthetically applying DEA and path analysis model. They are independently used but their results are explicitly connected. It means that the influential relationships between factors derived from applying the path analysis model will be equally construed by all the countries but we can present different ways to different groups of countries to improve the efficiency of their IP-intensive industries since we have already identified the RTS of each country. They basically need different approaches to improve the level of efficiency. Therefore, it can be a strength regarding results of applying DEA as well as our contribution. In case of the IRS, how to increase the size of the scale is an important issue so the relevant countries should select some input factors that have a large effect on the output factors and then make an effort to increase the extent of those inputs. In case of the DRS, it should be addressed how to adjust the size of the scale so the relevant countries should select some input factors that have a little effect on the output factors and then try to adjust the extent of those inputs.

5. **Conclusions.** This study aims to measure the extent of the efficiency of IP-intensive industries of OECD countries by applying DEA and then derive meaningful insights for improving the efficiency by incorporating path analysis model. It can contribute to drawing strategic action plans for increasing the national IP competitiveness in that it investigates the causal relationships between input and output factors that affect the efficiency of IP-intensive industries. Despite the contribution, further challenges still remain. First, to generalize the results of this study to the whole countries, it is necessary to expand the range of analysis by collecting more countries' industrial data. Second, we had collected data from the OECD database during 2009 and 2011. To reflect the latest industrial trends, it is required to acquire more recent data and incorporate them into the efficiency analysis.

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