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Empirical Analysis of the Competitiveness of Energy Technology for Major Countries Using the Paper and Patent Index

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Abstract

The purpose of this study is to identify the indicators needed to analyze the competitiveness of major countries' energy technologies and to conduct empirical analysis accordingly. In this paper, nine measurement variables were derived as an index centered on patents and papers for energy technology competitiveness analysis. For each of the nine set measurement variables, the index for each of the major energy technologies (photovoltaics, fuel cells, and secondary batteries) was calculated, compared, and analyzed for each of the eight major countries.

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1. Introduction

Energy technology is emerging as an optimal alternative to sustainable development, addressing climate change and energy issues. As a result, the number of investments in energy technology development has increased, and various domestic and foreign actors have been promoting energy technology development in various forms, and the need for efficiency improvement and competitiveness of energy technology development is increasing. In order to enhance competitiveness of energy technology through strengthening energy technology capacity, accurate diagnosis and evaluation of energy technology innovation capacity level by country is necessary. A variety of qualitative and quantitative methods for comparing and evaluating technological competitiveness among countries have been proposed.

In this paper, we set up indicators centering on patents and papers, and analyzed the competitiveness of energy technologies by major countries. To do this, nine measurement variables in the field of papers and patents were

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identified as an index for analyzing the competitiveness of energy technology, and empirical analysis was conducted on photovoltaics, fuel cells and secondary batteries of 8 major countries.

2. How to Analyze Energy Technology Competitiveness and Set Indicators

2.1. Analysis method of energy technology competitiveness

The competitiveness of energy technology was divided into five stages (index identification, statistics and basic data collection, standardization of indicators, missing values processing, comprehensive index derivation and analysis).

step 1 (index identification) Identification of the three major categories that conceptually constitute the competitiveness of energy technology and the nine sub-categories that can be measured.

step 2 (statistics and basic data collection) Using proven sources that are internationally reliable and cross-national comparable, such as OECD.

step 3 (standardization of indicators) Applying the rescaling method to evaluate the measurement units or indicators with different distributions on the same standard.

step 4 (missing values processing) For the data processing, missing data was deleted and a simple average was applied.

step 5 (comprehensive index derivation and analysis) Derivation of composite index composed of total 9 indicators, and analysis of technical competitiveness.

2.2. Setting indicators

The indicators for the competitiveness analysis of energy technology were classified into three latent factors and nine measurement variables. The latent factor was split into 3 criteria – innovativeness, technicality, and marketability. Innovativeness indicates academic creativity, technicality indicates technical leading, and marketability indicates market potential. Next, each criterion was divided into characteristic factors in the measurement variables. The detailed characteristics in the measurement variables consist of 9 factors: Number of Papers (NP), Paper Intensity Index (PII), Paper Citation Index (PCI), Number of Patent Application (NPA), Number of Patent Registration (NPR), Patent Impact Index (PII_n), Market Securing Index (MSI), Concentration Ratio (CR₄), and Herfindahl-Herschman Index (HHI) (Table 1 and Fig 1).

Table 1. The analysis index structure for assessing energy technology competitiveness.

latent factor	Measurement Variables	Definition & Formula
1. Innovativeness	1-1. Number of Papers (NP)	· Number of papers registered in SCOPUS
	1-2. Paper Intensity Index (PII)	· An analysis index indicating on which technical field a certain country concentrates technology innovation activities relatively more than other countries. · $PII = (\text{Number of papers on a specific technology in a certain country} / \text{Total number of papers on a specific technology}) \div (\text{Total number of papers in a certain country} / \text{Total number of papers})$
	1-3. Paper Citation Index (PCI)	· An analysis index helping compare quality level of papers in a certain country on a specific technical field with other countries. · $PCI = (\text{Paper citation counts on a specific technology in a certain country}) \div (\text{Total paper citation counts on a specific technology})$
2. Technicality	2-1. Number of Patent Application (NPA)	· The sum of patent application numbers in KIPO, USPTO, JPO, EPO
	2-2. Number of Patent Registration (NPR)	· The sum of patent registration numbers in KIPO, USPTO, JPO, EPO
	2-3. Patent Impact Index (PII _n)	· An analysis index helping compare quality level of a specific technology in a certain country with other countries. · $PII_n = \{(\text{Number of cited patents of a certain country's technology} / \text{Number of patent application of a certain country's technology})\} \div \{(\text{Total number of cited patents} / \text{Total number of patent applications})\}$
3. Marketability	3-1. Market Securing Index (MSI)	· An index helping determine market securement through patents. · $MSI = (\text{Average number of families of an applicant's nation}) \div (\text{A total of average number of families})$
	3-2. Concentrate Ratio (CR ₄)	· The sum of the market share of the top four firms; A state of market competition inducing the application of a new technology.
	3-3. Herfindahl-Herschman Index (HHI)	· Evaluate market competitiveness through the extent of market concentration. · $HHI = \sum_{i=1}^n S_i^2$ (Si = Number of patent applications of the n-th applicant / Total number

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