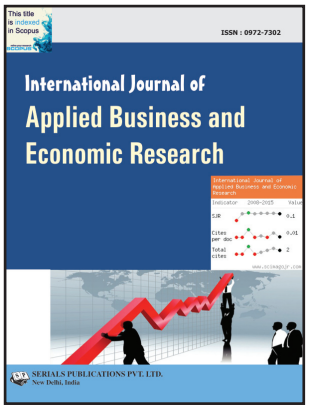

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Classification of Technology-Leading Countries According to fsQCA Calibration Methodology

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ABSTRACT

Indicators for technology innovation have been researched and discussed dynamically by international organizations and the academia but, unfortunately, the researches or discussions about the degree or typology of technology innovation have not been seriously made by any domestic or international institutes. If we categorize or measure the degree of membership of a technology or a nation, we can provide appropriate policies depending on the degree or situation. In the paper, a new methodology for calibration—fuzzy set calibration introduced by Charles C Ragin—was introduced. The paper suggests that new methodology for the typology and measurement can provide the appropriate and necessary policies.

Keywords: Fuzzy-set Calibration, Technology Innovation, IT Leading Countries, fsQCA.

1. INTRODUCTION

There is ongoing discussion about various research methodologies to explain and theorize social phenomenon with more objective and scientific methods. The two most representative methodological approaches are case-oriented qualitative research method description (Wiles et. al., 2010) and variable-oriented quantitative research method description (Botyarov, 2015).

Due to the differences in methodologies, the two methods are regarded different from each other. Also it is true that it has progressed in different ways. However, the selection of these methodologies generally is in the difference between abundance and lack of cases, thus the consequence of difference in methodology is in the matter of large N and small N (Goldthrope, 1997). Also in the content, it is true that both are used in a complementary manner. For example, even in the data analysis of quantitative research, the results can be interpreted when any qualitative description is given.

When methodology is decided upon according to the number of cases, research progresses using case-focused qualitative research method if there are few cases. If there are many cases such as 50 or over, variable-oriented quantitative research method will be conducted (Ragin, 1987: Yin, 1994; Ragin, 2000; Choi, 2009).

However, when there are 20 to 30 cases, there is a problem in deciding which it did to conduct the research with. In relation to this, Charles Ragin (2008) suggested a methodology called fsQCA. This methodology presents a comparative methodological approach using 20 to 30 cases. Specifically, the fsQCA basic methodology by Charles Ragin converts existing scores into aggregate scores based on mathematical logic converting the existing sequence numbering into aggregate relationship. Thus, it has a basic logic that converts sequence relation to aggregate relation. This is called calibration (Ragin, 2008).

When figuring out the results of a certain phenomenon in an aggregate relationship, there is a problem that it is difficult to evaluate the problem of significance before testing. However, in social science, as far as development and progress of theory are concerned, new typology also has an important meaning. The study aims to suggest new typology in social phenomenon where it is thought that this new typology by aggregate relationship is appropriate.

2. STRENGTH CATEGORIZATION METHODOLOGY BY TECHNOLOGY INNOVATION AND TECHNOLOGY SECTOR

The Limitations in Current Methodology

Currently, methods to categorize strength by technology innovation and technology sector have not been appropriately presented. It can be said that the fundamental reason is the pluralism, flex ability, and difficulties in predicting in the phenomenon of innovation. In recent state-of-the-art technology development, the ramification of the technology is large and unlike the past, it is becoming more difficult to measure innovation.

It is difficult to categorize the areas of the technology sector and evaluate the ranking just with a statistical index of the current innovation index (Kim and Jung, 2003). Fuzzy-set theory first designed by Zadeh (1965) is an expanded form of traditional set theory and, recently, its application is being attempted by Charles Ragin (2008) and Jon Kvist (2007).

Using this approach, this study aims to find multiple conjunctural casual relationships. Second, it seeks to present any other useful methodology. Thus, it is using the advantage of representing partial membership, which is a characteristic of fuzzy set. After this, the differences in kind and degree can be simultaneously evaluated (Choi, 2009).

As such, it suggests an appropriate methodology for the classification and typology of a certain phenomenon on fsQCA methodology. Thus, rather than ranking under the basic structure of comparison, basic hypothesis of aggregation relationship is set and classification is attempted on comparative variables in a certain aggregate relationship. It can be said that this methodology presents a highly useful meaning in areas where classification on social phenomenon is necessary.

Calibration

Here, the study will further explain calibration as introduced by Ragin (2008). It can be said that the most important factor in fuzzy set analysis is calibration. For example, it is an essential problem to decide in which domain questions such as "Can something that has a degree of conditions (membership) be included in the set categorized as democratic system?" and "What degree is in a complete relational intrusion or in 75% level?" will be included.

This calibration is a natural and daily research procedure in natural sciences such as chemistry and physics. For example, in case of 20°C, normal people can generally recognize this experientially. Thus, this temperature is a certain degree between 0 and 100. Most social scientists are satisfied with calibrated measurements; however, without calibration, we may be able to know that a certain liquid is warmer than another, but we cannot know if two experiment subjects are cold or hot. This can be seen in the same context as the social scientist not being able to know which nation is more democratic.

This calibration is especially important when a certain condition set acts as a factor deciding other conditions or a total condition. For example, deciding the number of patents that indicate a strong software nation can be seen in the same context as using it differently than other standards. What is important here is that according to the standard the researcher calibrates, the application of the result value can change.

Because of this, it is crucial for the researcher to acquire knowledge about corresponding field and validity, such as social phenomenon, to acquire validity of calibration. Finally, the standard of the categorization must be consistent "agreed upon standards (Ragin, 2008)."

3. FUZZY-SET CALIBRATION APPLICATION

Categorization Standard

The study aims to categorize leading countries by technology sector, post catch-up countries, developing countries, and underdeveloped countries based on innovation evaluation by countries based on patent analysis results in the 2006 OECD report (Khan and Dernis, 2006). This will be done using the calibration method in fsQCA. This is the most fundamental stage in the corresponding methodology.

The subjects of analysis for patent analysis of comparison subjects were, first, (without technology classification) patents, information communication-related technology, biotechnology, and software technology registered on EPO, USPTO, and JPO which are patent organizations by country. In the related database, data of a total of 50 countries were presented but when there were no patents by a certain technology sector or there were significantly low numbers, it was excluded from comparison subjects.

According to this, 39 countries were selected as comparison subjects. First, categorization standard was established using SPSS frequency analysis to establish the standard of categorization. Second, set scores according to fsQCA software were given. Here, the software logic representing membership score is as follows (Lee, 2012).

$$\text{Degree of membership} = \exp(\text{log odds}) / \{1 + \exp(\text{log odds})\}$$

This classification standard can be appropriately used for general patent technology, information communication-related fields, and bad technology. However, in case of software technology, due to classification standards by frequency analysis, it is difficult to categorize other technology fields identically. In software technology, compared to other industries, large impact can be made with small investment as it has a strong "winner-take-all" effect where the corresponding technology is applied to all as the corresponding technology reaches standardization.

In addition, "ideal type" analysis was attempted for the analysis of leading nations by technology sector. Through this, the categorization of leading nations with the technology sector was attempted. Thus, the categories of four technologies—conventional technology, information communication-related technology, software technology, and biotechnology—were created. Excluding software technology, categorization was conducted among leading technology countries, post catch up countries, developing countries, and underdeveloped countries according to the categorization standard through frequency analysis.

In making a separate categorization standard on software technology, researcher knowledge about the corresponding field will play an important role. Thus, because it is a key point in suggesting categorization standard in calibration through fsQCA methodology, there is a basic premise that the researcher should have adequate knowledge of the corresponding field.

In this study, unlike frequency analysis method and other technology areas, countries with more than 700 software patent technologies were categorized as the starting point of a software leading nation. In this case, the included countries were the United States, Japan, and Germany whereas other countries corresponded to nations with clear differences in the number of patents in the corresponding field.

In this case, the corresponding nation is France and in case of France, the reality is that there are no companies that have strengths in the software field. In case of the United States, it corresponds to a nation that has strong software companies such as Microsoft that has most of the market share for computer operating systems, Apple that is first-place in smartphone operating systems, and Google which is the leading Internet search engine company.

In case of Japan which is the second-place patent nation, it dominates the global game industry with Nintendo and Sony. Lastly, in case of Germany, centering on a company called SAP, it has the premier corporate total solution provision company. Objectivity must be presented on these categorization standards to acquire rationality on the categorization standards.

Also it must be possible to have reasonable interpretation through appropriate evaluation of the results. The study attempted analysis focusing on the classification of leading nations by technology sector. However, it can be evaluated that the nations within technology sectors based on this analysis is also possible (Lee, 2012).

Table 40.1
Calibration Results by Technology Sector : OECD Countries

cou	*TRAD*	*ICT*	*BIO*	*SOFT*	*traf*[1]	*ictf*	*biof*	*softf(1)*[2]	*softf(2)*[3]
AUS	367	295	100	75	0.53	0.44	0.86	0.68	0.1
AUT	282	278	35	29	0.32	0.38	0.12	0.11	0.02

cou	*TRAD*	*ICT*	*BIO*	*SOFT*	*traf*[1]	*ictf*	*biof*	*softf(1)*[2]	*softf(2)*[3]
BEL	397	326	67	44	0.57	0.51	0.58	0.32	0.04
CAN	661	683	136	141	0.84	0.8	0.97	0.95	0.5
DEN	216	220	99	33	0.18	0.2	0.85	0.15	0.02
FIN	594	708	25	137	0.79	0.81	0.06	0.95	0.47
FRA	2447	2308	271	359	1	1	1	1	0.76
GER	7271	5290	797	732	1	1	1	1	0.96
IRE	60	91	7	18	0.03	0.03	0.02	0.05	0.01
ITA	840	691	78	73	0.93	0.8	0.69	0.67	0.09
JAP	13195	8571	813	1101	1	1	1	1	0.99
KOR	630	1259	54	134	0.82	0.97	0.38	0.94	0.45
NET	966	1681	149	234	0.96	0.99	0.98	1	0.62
NEW	41	40	22	10	0.03	0.02	0.05	0.02	0.01
NOR	106	114	28	20	0.06	0.06	0.07	0.06	0.02
POL	9	15	5	4	0.02	0.01	0.01	0.01	0.01
SPA	120	179	42	16	0.07	0.12	0.19	0.04	0.01
SWE	896	596	93	111	0.95	0.74	0.81	0.88	0.27
SWI	924	616	103	72	0.95	0.76	0.87	0.66	0.09
UK	2045	1824	330	305	1	1	1	1	0.71
US	18324	11070	2342	2605	1	1	1	1	1

Source: Lee, 2012

Table 40.2
Calibration Results by Technology Sector : non-OECD Countries

cou	*TRAD*	*ICT*	*BIO*	*SOFT*	*traf*[1]	*ictf*	*biof*	*softf(1)*[2]	*softf(2)*[3]
BRA	36	21	11	3	0.03	0.01	0.02	0.01	0.01
CHI	144	248	49	27	0.09	0.28	0.3	0.1	0.02
TAI	102	164	21	44	0.05	0.1	0.04	0.32	0.04
IND	78	68	28	16	0.04	0.02	0.07	0.04	0.01
ISR	328	326	73	63	0.44	0.51	0.64	0.59	0.07
RUS	59	46	14	5	0.03	0.02	0.03	0.02	0.01
SIN	85	120	10	28	0.05	0.05	0.02	0.11	0.02

Source: Lee, 2012

1. Based on each number of patents by technology field, it is converted into a fuzzy score.
2. Calibration is done on the responding analysis according to the same standards of other technology fields.
3. Corresponding analysis is calibrated according to standards different from other technology fields. Thus, S/W company, which is first-place in the world, is categorized as subject. This is a standard setting considering the "winner-take-all" phenomenon based on standardization in S/W technology. In fact, Microsoft is responsible for 90% of the global OS market share and MS is also responsible for 70% of Web browser market share.

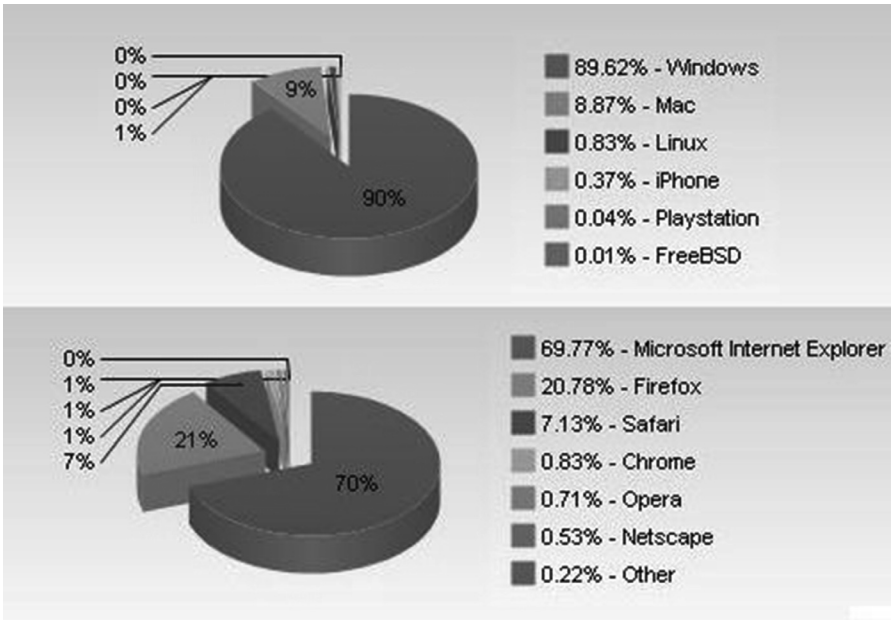

Figure 40.1: Global Market Shares of OS and Internet browser (2009)
Source: **Net Market Share (http://marketshare.hitslink.com)**

Analysis of the Results

First, calibration was conducted on the standard of number of patent technologies by country, and fuzzy-scores were given. As a result, nations that corresponded to commercial common sense or external data such as objective economic indicators like GDP were mapped as leading technology nations.

However, when all technologies were analyzed using identical standards (thus, "frequency analysis"), a result that was rather difficult to understand was derived in ideal type categorization on trad, ICT, and SOFT fields. Thus, in case of Korea, it was categorized into leading S/W technology nation. For this, the study based on experiential knowledge and based on the United States, Japan, and Germany which have undisputed global premier companies in the software technology sector, additional calibration was attempted by increasing the figures on the number of patent data.

Figure 40.2: Companies Selected as the Categorization Standards

4. DISCUSSION

Objective and detailed aces on these categorization standards can progress in other research dimensions additionally in a long-term perspective. However, this study concludes with presentation of data of attempting new categorization rather than objective validity. The result of reclassification according to the standards shows significant results. Thus, Korea could be classified as a leading software technology nation and a vulnerable software technology nation..

Also, excluding countries such as France and the United Kingdom, all countries were categorized as vulnerable software technology nations. As a result, useful research data that can be accepted in experiential social phenomenon were presented.

Through these standards, it can be inferred that ample knowledge of the corresponding field and researchers, and scientific proof through objective data can act as a significantly important factor in conducting fsQCA analysis. Thus, in this area, a bridging role of quantitative method and qualitative method can be presented.

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