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A new intellectual property metric for standardization activities

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ABSTRACT

This study formulates a method to measure the effects of standardization to assist in evaluating innovation and R&D policies. Its main purpose is to examine standardization activities within R&D organizations. This allows for a more appropriate policy evaluation framework than examining such activities within standard development organizations does. The study also redefines the conventional notion of intellectual property (IP) normatively and introduces the term "integrated IP" to reflect our new concept of joining IP and standardization activities. Our new concept captures the "fuzzy" impact of standardization on R&D to improve innovation management. The study presents a vector equation expressing the new IP definition and uses it to model revenues arising from a standard-essential patent for strategic IP management with standardization. The model indicates the importance of patents commercially required for product differentiation for the purpose of innovation with standards.

1. Introduction

As R&D policy evaluation relating to technology standards is still in the exploratory phase (Tassey, 2003), a method and concept for management of innovation and standardization is developed in this study. This study presents a new intellectual property metric. The study analyzes its nature and application to R&D and innovation policies. Moreover, the study normatively redefines the conventional notion of intellectual property. A key new concept—integrated intellectual property (integrated IP)—is a comprehensive form for addressing intellectual property and standardization.

As the first contribution, the proposed model analyzes how the fusion between patents and standards affects innovation, and the model is described in vector equation form. This study analyzes industrial sectors according to how strongly patents and standards are related. It models revenue in a manner applicable to individual projects through which the merits and shortcomings of the standard-essential patent (SEP) formation are discussed and reveals the "SEP paradox," which means SEPs are not necessarily the most revenue generating condition and can be an obstacle to innovation when standards are involved. The conception of a "negative patent," which expresses the relative effect between patents and standards, is also presented in the model. The second contribution of this study is to focus on standardization within R&D organizations rather than within standard development organizations (SDOs).

The policy evaluation methodology for standardization is thought to have an established framework. In reality, that is not the case. For instance, data for limited types of output factors (e.g., the current number of *de jure* standards) are available (International Organization for Standardization, 2006). However, data for such inputs as financial and human resources have not yet been provided nor has a suitable measurement method been determined. Nevertheless, standards now require special attention in policy analysis. For example, projects funded by the Japanese government are required to report standardization achievements so as to evaluate R&D outcomes. R&D projects within Japan's Ministry of Economy, Trade and Industry usually run for three years, and final achievements, including standardization results, are evaluated. At the New Energy and Industrial Technology Development Organization, a Japanese government-funded R&D body, evaluation of R&D achievements also includes standardization results. At both organizations, however, the scope of evaluation remains limited to such outputs as the number of proposed standards.

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The EU initiated a policy program for demand-side innovation in the 2000s, and assessment of the impact of standardization is now a major element in policy review (Edler et al., 2012). However, impact assessment remains limited to such qualitative questions as “Are EU standards becoming international standards?” (Edler et al., 2012).

The methodology for assessing the impact of standards is not necessarily well developed in the US despite efforts spanning recent decades (Tassey, 2003). R&D evaluations by the National Institute of Standards and Technology include estimations of how research impacts standards (Edler et al., 2012). However, the relationship between R&D as an input factor and standardization as an output factor has not been discussed persuasively from a quantitative standpoint.

This study analyzes data from *The Survey of Intellectual Property-Related Activities* by the Japan Patent Office. It finds that the correlation of standardization activities with patent applications is high, up to half the correlation of R&D activities in Japan's electric machinery industry for 2008–2010. This finding implies that standardization exerts a significant impact on resource allocation.

2. Literature review

This section describes our methodological approach in this largely undeveloped area of research.

2.1. Basic data resources

Standardization activities relating to IP seem to be of primary importance for innovation in an organization (Tamura, 2010). In addition, the standardization activities relating to IP avoid data noise relating to management standards and recognitions that are not necessarily directly related to R&D and innovation (e.g., ISO management system standards).

Hence, this study focuses on:

i) Standardization activities in organizations or institutions where R&D is actually conducted rather than those in SDOs where R&D is not performed.
ii) Standardization activities that occur as part of IP-related activities, as opposed to all standardization activities within an organization.

We draw upon raw data from the *Survey of Intellectual Property-Related Activities* for fiscal years 2008–2010. The Japan Patent Office has published this survey annually since 2002 to facilitate creation of effective IP policy.

Gathering data requires clear definitions for each metric. “Standard” and “standardization” have assorted meanings. Stango (2004) defines standards as “specifications that determine the compatibility of different products.” However, this definition focuses only on outputs of standardization activities for products or services. Definitions for inputs such as the quantity of labor are also necessary. Therefore, we use eight definitions specified in the Japan Patent Office Survey (2008, 2009, 2010) (Appendix B): (1) standardization-related activities (SA), (2) personnel engaged in standardization-related activities (SA personnel), (3) IP-related standardization activities (IPRSA), (4) personnel engaged in IP-related standardization activities (IPRSA personnel), (5) IP-related activities (IPA), (6) personnel engaged in IP-related activities (IPA personnel), (7) R&D activities and (8) R&D personnel.

2.2. Data of standardization

Policy evaluation of standardization is still not fully carried out because data on standards, R&D, and IP are not gathered by the same entities, namely, R&D organizations. Previously, data concerning standardization were gathered only for external organizations such as SDOs. Thus, no statistical analysis of factors within R&D organizations exists. The Organization for Economic Co-operation and Development (OECD), the administrative forum for science and innovation policy, has not yet fully studied the standardization issue in the Frascati Manual, which delineates practices for surveying R&D and collecting data (OECD, 2002; Tamura, 2013). Furthermore, a large share of related research focuses narrowly on the activities of SDOs, such as the International Organization for Standardization (ISO) and the International Telecommunication Union. The important point is that SDOs are not engaged in R&D but in drafting standard-related documents among country representatives. This is one obstacle to viewing direct relations between R&D and standardization. A second hindrance to data measurement is that links between personal contributions and standardization activities are difficult to determine because ownership of standards is undefined. However, patent law clearly specifies that the inventor is the owner of a patent.

2.3. Standardization and innovativeness

2.3.1. R&D and standardization activities

According to Blind (2002), R&D expenditures correlate negatively with the number of standards generated by SDOs. However, this research did not directly measure SA within R&D organizations or corporations; measures are from standard documents generated in SDOs. Presumably, findings about the nature of standards are indeterminate because previous research focuses mainly on activities outside of R&D organizations (Gandal et al., 2007). One reason SDOs are studied is that the number of participants in SDO activities from corporate and other entities conducting R&D is easily monitored. To answer the questions of why and how standardization activities are important for R&D capability, research into SA conducted within the R&D organization itself is essential.

Standardization activities are conventionally understood from the viewpoint of knowledge spillover from R&D. Non-R&D-intensive corporations are conventionally regarded as standardization-oriented and can overcome inadequate R&D capability by gaining knowledge from SDO activities. It is also noted that for less R&D-intensive industries, standards are important for growth, as seen in macroeconomic EU data during the 1990s (Blind and Jungmittag, 2008). However, interviews with Japanese R&D researchers found that, with regard to innovation, standards have greater impact on industrial sectors than R&D research does (Tamura and Matsuda, 2008). This result apparently contradicts the explanation that leading R&D-intensive corporations avoid standardization activities for fear of spillover of trade secrets (Blind, 2006).

2.3.2. Standards and innovation

Standards can affect economic efficiency positively and negatively (Tassey, 2000). As for the negative effect of standards, it has been shown that historical events are more important than an economic perspective, and standards can produce “lock-in effects” (Arthur, 1989). Thus, obsolete technology can hinder the formation of potentially superior new standards (Farrell and Saloner, 1985).

In the US semiconductor industry, however, standards create entrepreneurial opportunities by dis-integrating vertically integrated incumbents (Funk and Luo, 2015). In addition, the US electric machinery industry exhibits a significantly positive correlation between the number of participants in an SDO (American National Standards Institute) and the number of patents granted (Gandal et al., 2007). This finding implies that participation in an SDO benefits the conceptual formation of patents. Further, a public research institute in Germany examined relationships between (1) participation in SDO activities and publication of academic papers and (2) participation in SDOs and patent application, and it found that researchers' publications in applied and industry-oriented journals relate significantly and positively to their participation in SDOs (Zi and Blind, 2015). At the same time, patent applications exert a significantly negative marginal effect on their participation in SDO activities, which can be attributed to protection of patent-related information (Zi and Blind, 2015). These two cases imply a paradox: researchers who did apply for a patent were unlikely to have participated in SDOs, but those likely to apply for patents probably do participate in SDOs (Gandal et al., 2007; Zi and Blind, 2015). This paradox implies the need to enforce policies to protect trade secrets among participants in SDOs (Tamura, 2015).

Three types of standards relate to the timing of standardization with regard to innovation and market expansion: (1) anticipatory standards, (2) enabling standards and (3) responsive standards (Egyedi and Sherif, 2010). Anticipatory standards apply to entirely new services and seek to resolve expected interoperability problems accompanying the production of prototypes. Enabling standards seek to reduce production costs in parallel with market growth. Responsive standards seek to improve efficiencies or reduce market uncertainties for auxiliary products and services. These three types are supposed to occur sequentially. Transitions to newer technologies occur after the market for a prevailing technology is saturated, (Egyedi and Sherif, 2010; Jakobs et al., 2001; Sherif, 2001). Repetition of the sequence generates sequential innovation.

2.4. Standardization and intellectual property rights

In terms of innovation, standards have played a separate and independent role for a long time as an innovation factor. However, recent changes in technology development have altered the conventional ideas because of the rapid development of information technologies. The number of patents essential to technological standards has risen rapidly (Simcoe, 2005). These are standard-essential patents (SEPs). Their licensing must conform to fair, reasonable, and non-discriminatory (FRAND) conditions. Thus, they are double-edged. Inventors can set royalty ratios freely by licensing patents, but FRAND terms restrict royalty ratio, which inventors can charge (Lopez-Berzosa and Gawer, 2014). If permissible royalties are insufficient to recover investment, corporations hesitate to invest in R&D.

Another problematic issue regarding FRAND is "reverse hold up," if licensees of SEPs pay no royalties (Pohlmann and Blind, 2014). In addition, SEPs and FRAND are vague concepts, and legal uncertainties remain (Simcoe, 2006). Hence, FRAND status needs further clarification (Pohlmann and Blind, 2014). This problem is inferred by an EU Commission survey that asked inventors their reasons for obtaining an SEP. The answer "securing freedom to operate/market entry" ranked 4 on a five-point scale of escalating importance, indicating respondents considered SEPs "important" for securing market entry. However, the aim of "generating licensing revenue" scored about 2.7 on the survey, and the result implies respondents regarded SEPs between "unimportant" and "neutral" as sources of revenue through FRAND licensing (Pohlmann and Blind, 2014). These results highlight why relations between standardization and intellectual property rights are relevant, important, and complex.

2.5. Analytical framework for management of innovation with standardization

We use the number of patent applications as the indicator of innovation achievement through standardization. We assume that the number of patent applications and corporate innovativeness have the positive relationship described by Cefis and Orsenigo (2001). The literature generally assumes patented inventions correlate positively with R&D expenses. Acs and Audresch (1989) show patents are a reasonably reliable measure of innovation and correlate positively with R&D expenditures.

Some patents reflect incremental innovation and others radical innovation. Radical innovation does not necessarily arise only through basic research, and incremental innovation does not necessarily originate only from applied and developmental research. That is, basic research and developmental research may produce radical or incremental innovation, and both can lead to patent applications covering radical and incremental innovations. This means that the output of R&D with respect to type of innovation largely depends on R&D strategy. Previous accumulated research concerning how patents affect innovation does not categorize individual patents as incremental or radical innovations, and it uses the number of patents as one integrated metric in empirical analysis (Trajtenberg, 1990). One reason for this is that patent application forms do not mention whether innovations are radical or incremental.

Following Acs and Audresch (1989), we do not distinguish between types of R&D activities. Data from Japan's Ministry of Education, Culture, Sports, Science and Technology (2009) attribute 40% of total R&D expenses in Japanese industry to R&D personnel overhead. Therefore, the number of R&D personnel is an appropriate proxy for R&D activities because R&D expenses relate positively to the number of R&D personnel.

3. Hypotheses

3.1. Relationships between R&D, standardization and patents

Acs and Audresch (1989) regard the number of patent applications as a good indicator of innovation. We use it as the variable indicating the positive degree of innovation. This analytical approach should suitably measure the effect of standardization on innovation.

Previous research adopts two perspectives about the relationship between patent applications and standardization. Gandal et al. (2007) state that participation in standard formation affects innovation positively, but they investigate the standard-related activities that occur exclusively in SDOs that are external to corporations. Hence, their conclusions do not elucidate whether the same relationships prevail within R&D organizations or institutions. The second perspective is that R&D-oriented corporations are patent-oriented and not standardization-oriented because they do not obtain any useful information from standardization activities (Blind, 2006). This argument implies the effect of standard-related activity on patent applications is weak or negative.

Extensive drafting and administration of patent applications governs relationships between patent applications with IP-related activities. Applications will relate positively to IP-related activities. As for the R&D activities, they are assumed to correlate positively with applications because patents are the output of R&D.

Hypothesis 1 follows from the discussion above.

Hypothesis 1: In the case of internal organizational activity between 2008 and 2010, standardization activities correlate weakly or negatively with patent applications, whereas IP-related activities and R&D activities correlate positively with patent applications.

We examine this hypothesis by evaluating correlations between patent applications and (1) IPA, (2) IPRSA instead of SA and

(3) R&D activities, respectively, over the examined years. If Hypothesis 1 is confirmed, the conventional perspective of standardization is supported empirically. If not, the nature of standardization must be understood differently.

3.2. *Differences between years*

To verify the robustness of the analytical result, we determine whether correlation coefficients across 2008–2010 display a relative order.

Hypothesis 2: Over the period studied, three correlation coefficients (1) between IP-related activities and patent applications, (2) between standardization activities and patent applications and (3) between R&D activities and patent applications exhibit a relative order.

3.3. *For cross-sector comparison*

The electric machinery industry is believed to be strongly affected by standardization. Hence, one way to clarify specific characteristics of standardization is to compare differences among industries (specifically, between electric machinery and other industries). The effect of standardization on the electric machinery industry will become more apparent by comparing the types of industries. With regard to innovation management, results will suggest which industries need more standardization activities and which require fewer.

Hypothesis 3: Three correlation coefficients (1) between IP-related activities and patent applications, (2) between standardization activities and patent applications and (3) between R&D activities and patent applications are higher in the electric machinery industry than those correlation coefficients in other industries.

4. Method

The Pearson's correlation coefficients we obtained are comparable because the dimensions and units of input (i.e., the number of personnel) are identical.

4.1. *Hypothesis examination*

We explore the relationships of patent applications with (1) IPA, (2) SA and (3) R&D activities by using (1) the number of IPA personnel as a proxy for IPA, (2) the number of IPRSA personnel as a proxy for SA and (3) the number of R&D personnel as a proxy for R&D activities. Those SA comprise IPRSA and non-IPRSA. It is preferable to use the number of SA personnel to evaluate the effects of SA. However, we used the number of IPRSA personnel because the extent of SA in organizations cannot be obtained directly from the *Survey of Intellectual Property-Related Activities*. Fig. 1 illustrates relationships among these factors.

The category *other industries* depicted here indicates all Japanese industries excluding electric machinery. Correlations were assessed by *t*-tests with significance set at $p=0.05$, $p=0.01$, and $p=0.001$. All calculations were performed using Microsoft Excel 2010 and STATA statistical analysis tools.

4.2. *Dataset construction*

Our datasets capture all industries, Japan's electric machinery industry, and other industries using raw data from the *Survey of Intellectual Property-Related Activities* for 2008–2010 in accordance with practices in previous research (Tamura, 2010) (Appendix C).

4.3. *Descriptive statistics*

Table 1 shows summary statistics, including arithmetic means and other statistics.

Among standardization-related indicators, one corporation in Japan's electric machinery industry employed nearly twice as many IPRSA personnel as the mean number for other industries. This result supports our classification of Japan's electric machinery industry as standardization-oriented and other industries as not standardization-oriented.

Japan's electric machinery industry submitted two to nearly three times the mean number of patent applications as other Japanese industries during 2008–2010 and employed double the mean number of IPA personnel employed in other industries. It employed one to one-and-a-half times as many R&D personnel as other industries during 2008–2010.

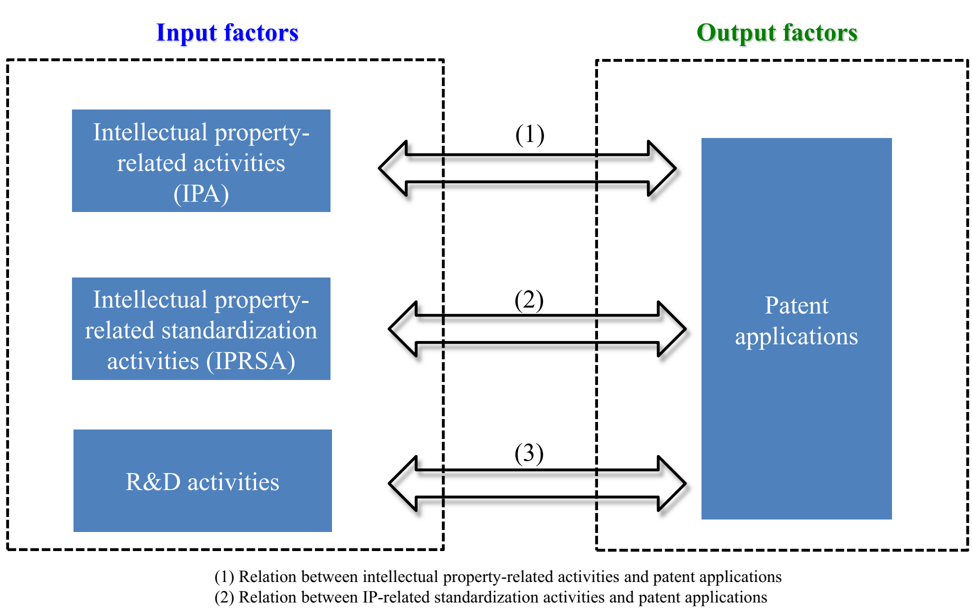

Fig. 1. Relations between input and output factors.

Table 1
Summary statistics for input and output factors: all industries, the electric machinery industry and other industries in Japan for the period 2008–2010.

		2008			2009			2010		
		All industries	Electric machinery industry	Other industries	All industries	Electric machinery industry	Other industries	All industries	Electric machinery industry	Other industries
	Observations (Total number of survey responses)	2143 (3375)	319	1824	1974 (3841)	294	1680	2039 (3555)	273	1766
Patent applications	Mean	84.324	172.296	68.939	81.799	152.616	69.407	70.165	158.034	56.582
	Standard deviation	410.263	600.586	365.044	399.165	597.894	360.445	321.982	561.291	264.156
	Variance	168315.9	360703.7	133257.5	159332.9	322504.1	129921.2	103673	315048	69778.3
	Range	10767	7432	10767	10281	7120	10281	6970	6657	6970
IPA personnel (FTE)	Mean	6.089	11.459	5.150	6.007	9.965	5.315	5.889	11.758	4.981
	Standard deviation	17.771	36.778	11.366	16.799	31.528	12.447	17.635	38.541	11.137
	Variance	315.8	1352.6	129.1	282.2	994.0	154.9	311.0	1485.4	124.0
	Range	360	360	174	329.9	329.9	239.9	412	412	191
IPRSA personnel (FTE)	Mean	0.858	1.309	0.779	0.881	1.395	0.791	0.804	1.336	0.721
	Standard deviation	3.741	7.750	2.435	3.959	8.273	2.534	3.906	8.577	2.495
	Variance	14.0	60.0	5.9	15.6	68.4	6.4	15.2	73.5	6.2
	Range	121	121	36	124	124	38	132	132	43
R&D personnel (FTE)	Mean	260.110	283.851	255.958	242.468	247.860	241.524	249.926	314.890	239.884
	Standard deviation	1032.484	1007.989	1036.924	787.700	545.911	822.865	923.866	1171.188	879.436
	Variance	1066023	1016041	1075211	620472.7	298019.8	677107	853530	1371682	773408.7
	Range	23000	15900	23000	16094	5000	16094	20082	17600	20082

FTE: Full-time equivalent.

5. Results

The calculated correlation coefficients appear in Table 2 for all industries, in Table 3 for Japan's electric machinery industry (standardization-oriented), and in Table 4 for other industries (not standardization-oriented). Fig. 2 shows the trend of Pearson correlation coefficients over the examined period.

6. Discussion

Our findings contradict the conventional wisdom that high-technology and R&D-intensive corporations are more patent-oriented and less standardization-oriented (Blind, 2006). In fact, Japan's high-technology industry appears to have been more standardization-oriented during the period studied. It is notable that our metric of the standardization factor is not the conventional standardization activities studied previously but a new metric that specifically measures standardization related to intellectual property. This difference in the scope of standardization metrics likely explains the result observed.

6.1. Hypothesis validation

6.1.1. Hypothesis 1

Hypothesis 1 that IP-related activities and R&D activities correlate positively with patent applications is supported for all years observed. However, the expectation that standardization activities correlate weakly or negatively with patent applications is not supported: all industries and other industries evidence positive and near-zero correlations, whereas the correlation for the electric machinery industry is stable and positive. These results contradict the previous explanation that firms with little R&D expertise will be more involved in standardization activities and those with

Table 2
Correlations between patent applications, intellectual property-related activities and intellectual property-related standardization activities and R&D in all industries in Japan.

		I. Patent applications	II. IPA personnel		III. IPRSA personnel		IV. R&D personnel	
IV. R&D personnel	2008						1	
	2009						1	
	2010						1	
III. IPRSA personnel	2008				1		0.1889***	
	2009				1		0.1391***	
	2010				1		0.1486***	
II. IPA personnel	2008		1		0.3547***		0.5137***	
	2009		1		0.2889***		0.5043***	
	2010		1		0.3102***		0.5497***	
I. Patent applications	2008	1	0.7705***	(1)	0.1986***	(2)	0.4774***	(3)
	2009	1	0.8205***		0.1785***		0.5622***	
	2010	1	0.8000***		0.1934***		0.4981***	

Note: (1), (2) and (3) correspond to correlations (1), (2) and (3), respectively, in Fig. 1. (1), (2) and (3) are the relationships between the input and output factors.
p-value: *** Significant at 0.1%.

Table 3
Correlations between patent applications, intellectual property-related activities and intellectual property-related standardization activities and R&D in the electric machinery industry in Japan.

		I. Patent applications	II. IPA personnel		III. IPRSA personnel		IV. R&D personnel	
IV. R&D personnel	2008						1	
	2009						1	
	2010						1	
III. IPRSA personnel	2008				1		0.3578***	
	2009				1		0.3380***	
	2010				1		0.2663***	
II. IPA personnel	2008		1		0.4088***		0.7901***	
	2009		1		0.3247***		0.7781***	
	2010		1		0.3291***		0.8126***	
I. Patent applications	2008	1	0.8987***	(1)	0.3085***	(2)	0.5892***	(3)
	2009	1	0.9431***		0.3092***		0.7566***	
	2010	1	0.8565***		0.2834***		0.5558***	

Note: (1), (2) and (3) correspond to correlations (1), (2) and (3), respectively, in Fig. 1. (1), (2) and (3) are the relationships between the input and output factors.
p-value: *** Significant at 0.1%.

Table 4
Correlations between patent applications, intellectual property-related activities and intellectual property-related standardization activities and R&D in other industries in Japan.

		I. Patent applications	II.IPA personnel		III.IPRSA personnel		IV.R&D personnel	
IV.R&D personnel	2008						1	
	2009						1	
	2010						1	
III.IPRSA personnel	2008				1		0.1457***	
	2009				1		0.1165***	
	2010				1		0.0915***	
II.IPA personnel	2008		1		0.2488***		0.5039***	
	2009		1		0.2340***		0.5370***	
	2010		1		0.2643***		0.4718***	
I. Patent applications	2008	1	0.7328***	(1)	0.1121***	(2)	0.4623***	(3)
	2009	1	0.7714***		0.0773***		0.5620***	
	2010	1	0.7809***		0.0945***		0.4897***	

Note: (1), (2) and (3) correspond to correlations (1), (2) and (3), respectively, in Fig. 1. (1),(2) and (3) are the relationships between the input and output factors.
p-value: *** Significant at 0.1%.

more expertise will avoid such activities (Blind, 2006).

The sign of the metrics for the electric machinery industry is expected to be negative, but it is positive and fairly large instead. The coefficient for the number of IPRSA personnel as a proxy for SA implies that the amount of SA relates positively to corporate innovativeness. Consequently, the relationship between standardization and innovativeness is positive. This tendency is the same for 2008, 2009 and 2010.

6.1.2. Hypothesis 2

Results support Hypothesis 2. For Japan's electric machinery industry in 2010, correlation coefficients (1) between IPA and patent applications, (2) between IPRSA and patent applications, and (3) between R&D activities and patent applications observe this relative order: (1) IPA and patent applications > (3) R&D activities and patent applications > (2) IPRSA and patent applications. The relative relationship is identical for 2008 and 2009.

6.1.3. Hypothesis 3

Results support Hypothesis 3. Other industries show lower correlation coefficients than the electric machinery industry does. The 2010 coefficient between IPA personnel and patent applications for the electric machinery industry (0.85) exceeded that for all industries (0.80) and other industries (0.78). The electric machinery industry's coefficient was the highest. This tendency is the same in other two coefficients in 2010. The relative relationship is identical in 2008 and 2009.

6.2. Theoretical explanation

Our results require explanation from a new angle. This section discusses and redefines normatively the definition of “intellectual property”. In addition, the vector equations are presented to support the redefinition and we explore the structure of anticipated revenues obtained from the equation's model.

6.2.1. Concept and definitions

This study suggests that separate treatment of IP and standardization explains why the effect of standardization on R&D has been found too ambiguous to explain and why standards are thought to be formulated on the basis of historical events rather than technological superiority (Arthur, 1989).

We propose combining IP and standards in one metric that reflects the mixture between them. This proposal departs from conventional notions surrounding these issues because previous research focused exclusively on effects from either IP or standardization and discussed each separately. Our expanded conception unifies IP and standardization in a two-dimensional space with IP

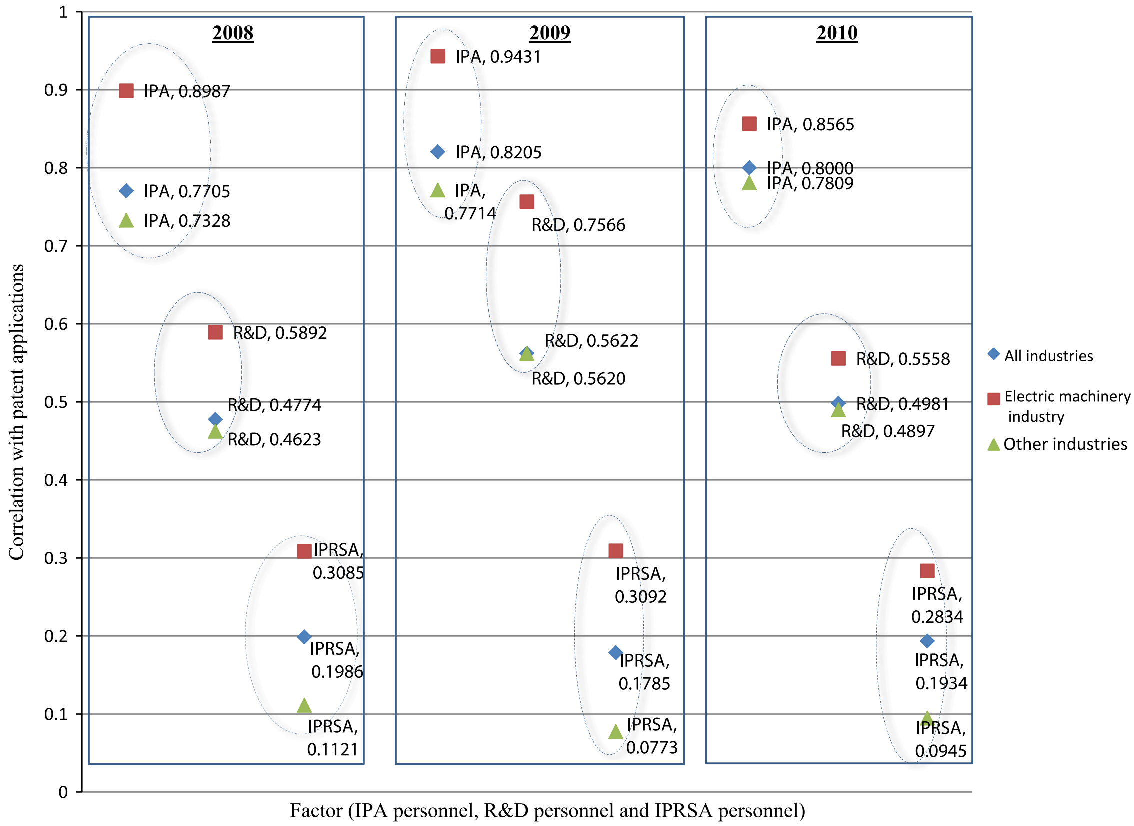

Fig. 2. Correlation with patent applications of the factors IPA personnel, R&D personnel and IPRSA personnel for all industries, the electric machinery industry and other industries for the period 2008–2010.

and standardization levels as a basis. We call the proposed conception as "integrated IP activities." If standardization activity is zero, our metric will reflect only IP activity; if IP activity is zero, the value will reflect only standardization activity.

In this new context, "intellectual property" should be redefined normatively because its previous usage referred only to patents or patenting activities. That usage is related to the idea, arising in the 1990s, that patents can be seen as a kind of intangible assets called "intellectual property" in contrast with the notion of conventional property such as tangible assets. For decades, redefining "intellectual property" has been unnecessary because the role of standardization has been relatively small and its role in IP has been negligible. However, the integration of the two elements has proceeded rapidly since the 2000s. Now the notion of IP needs to be reconstructed, and numerical expressions and equations for that reconstructed notion need formulation.

Our proposed normative definition features two clauses:

i) *The term "integrated intellectual property" or "integrated IP" encompasses all activities relating to intellectual resources, including patents and standardization.*
ii) *The term "patent-related intellectual property" or "patent IP" refers to activities relating exclusively to patents or patenting, except standardization activities.*

6.2.2. Mathematical expression of the new definition: two-dimensional spatial expression

Using the definition above, we construct the two-dimensional structure in coordinate space in Fig. 3.

a) Definition of integrated IP vector

$$\overrightarrow{integrated\ \ IP} = \overrightarrow{patent\ \ IP} + \overrightarrow{standardization}, \qquad (1)$$

where $\overrightarrow{integrated\ \ IP}$: *the vector of integrated IP,*

$\overrightarrow{patent\ \ IP}$: *the vector of patent IP,*

$\overrightarrow{standardization}$: *the vector of standardization*

i) When $\overrightarrow{patent\ \ IP} = \vec{0}$,

$\overrightarrow{integrated\ \ IP} = \overrightarrow{standardization}$ (i. e., *standardization activities*)

ii) When $\overrightarrow{standardization} = \vec{0}$,

$\overrightarrow{integrated\ \ IP} = \overrightarrow{patent\ \ IP}$ (i. e., *patent IP activities*)

b) Integration level
The angle between the patent IP and standardization vectors is introduced as angle θ, which can be interpreted as the level of integration between the two factors. Thus, θ is defined as "the integration level." As Fig. 4 indicates, the length of integrated IP changes with the angle of θ.
The level of integration for a given angle θ can be defined as

$$Integration\ \ level\ \ \theta := \cos^{-1}\left(\frac{\overrightarrow{patent\ \ IP} \bullet \overrightarrow{standardization}}{\left|\overrightarrow{patent\ \ IP}\right| \left|\overrightarrow{standardization}\right|} \right). \qquad (2)$$

(Detailed derivation appears in Appendix D.)

In this, $\overrightarrow{patent\ IP} \cdot \overrightarrow{standardization}$ is the inner product between the patent IP vector and the standardization vector.

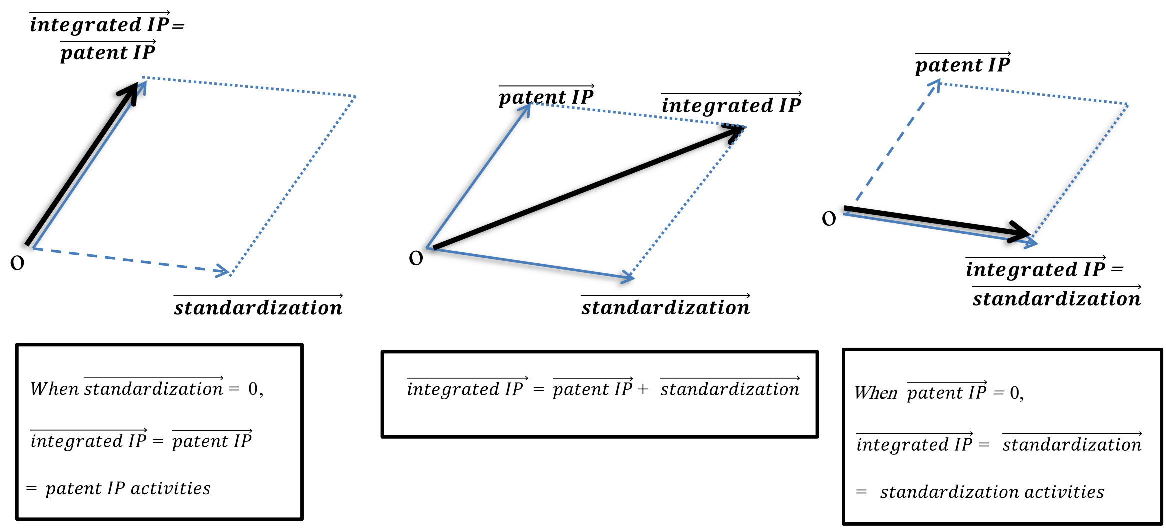

Fig. 3. Two-dimensional graph of patent IP and standardization.

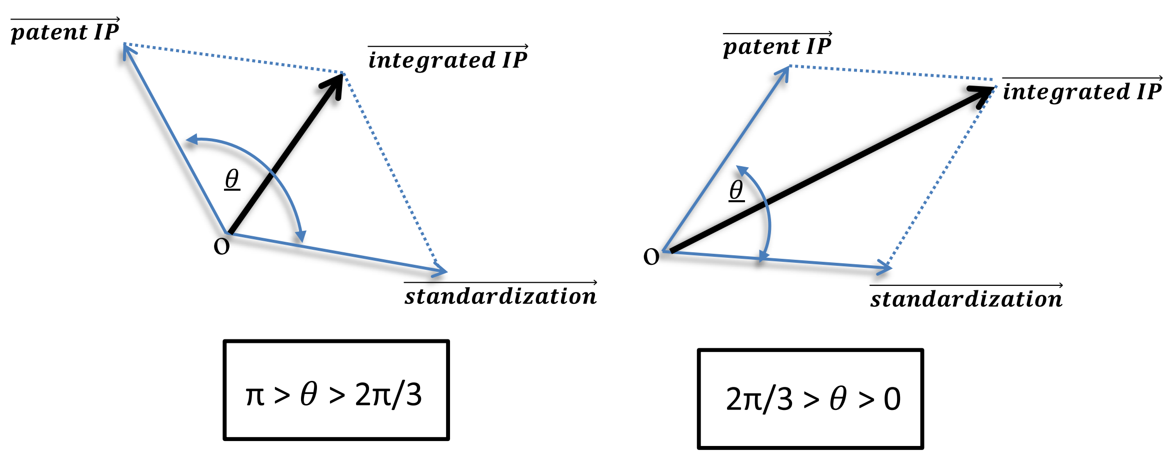

Fig. 4. Effect of angle of two vectors (patent IP and standardization) on the magnitude of integrated IP.

c) Magnitude of integrated IP vector

The magnitude of IP is defined as the Euclidean magnitude of integrated IP. The quantity usefully explains the influence of integrated IP on innovation.

$$\text{magnitude of integrated IP vector} = \left|\overrightarrow{\text{integrated IP}}\right| = \sqrt{2 + 2\cos(\theta)} \quad (3)$$

(When $\left|\overrightarrow{\text{patent IP}}\right|$ and $\left|\overrightarrow{\text{standardization}}\right|$ are each set as 1.)
(Detailed derivation appears in Appendix D.)

When $\pi > \theta > 2\pi/3$, the magnitude of the integrated IP vector becomes smaller than that of the patent IP vector. In this area, the magnitude of the integrated vector declines below 1 when the patent IP and standardization vectors have a common magnitude of 1. This implies a subtractive effect between the two vectors.

$$\text{magnitude of integrated IP vector} = \left|\overrightarrow{\text{integrated IP}}\right| < \left|\overrightarrow{\text{patent IP}}\right| = 1$$

In particular, when $\theta = \pi$, the standardization vectors offset the patent IP vectors. This condition indicates that the technology for which patents are sought has been standardized and cannot be patented unconditionally. In this situation, the standard hinders the patentability of the technology and acts as a "negative patent."

On the other hand, when $2\pi/3 > \theta > 0$, the magnitude of the integrated IP vector exceeds 1 even if the patent IP and standardization vectors have a magnitude of 1. The magnitude of the integrated IP vector exceeds that of the patent IP vector alone because effects between the two vectors are additive.

$$\text{magnitude of integrated IP vector} = \left|\overrightarrow{\text{integrated IP}}\right| > \left|\overrightarrow{\text{patent IP}}\right| = 1$$

This model can be expanded beyond an analysis of industrial sectors to identify SEPs on the basis of individual products. When $\theta = 0$, the coincidence of $\overrightarrow{\text{patent IP}}$ and $\overrightarrow{\text{standardization}}$ implies that the patent is an SEP by definition.

For SEPs,

$$\text{magnitude of integrated IP vector} = \left|\overrightarrow{\text{integrated IP}}\right| = \sqrt{2 + 2\cos(0)} = 2 \quad (4)$$

(When $\left|\overrightarrow{\text{patent IP}}\right|$ and $\left|\overrightarrow{\text{standardization}}\right|$ are each set as 1.)

6.2.3. Industrial sector basis model

The important finding in Fig. 4 is that the value of angle θ should correspond to macro changes affecting industrial sectors. Further, this angle is the cause of the "fuzziness" observed in the evaluation of standardization. In standardization-oriented

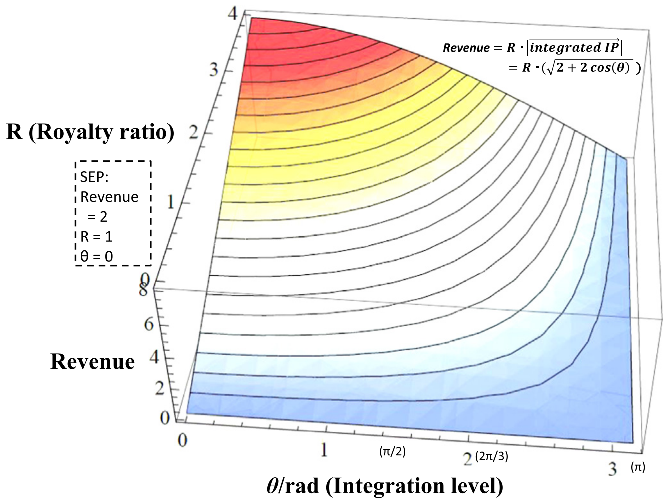

Fig. 5. 3D graph of the relation among Revenue, R (Royalty ratio) and θ.

industrial sectors like electric machinery, the angle θ is much smaller and the effects of patent IP and standardization activities are additive, creating synergy. The magnitude of integrated IP will be greater in such industries. In contrast, when the angle θ exceeds $2\pi/3$, the joint effect of the two factors is subtractive and offsetting. In such industries, the interaction between patent IP and standardization is one of opposition, and magnitudes decrease. Such industries are presumably non-ICT industries, and in the past their situation generally indicated $\theta > 2\pi/3$.

Using the angle θ, our new concept makes it possible to resolve scholarly discrepancies about how standards affect R&D and innovation (Arthur, 1989; Blind and Jungmittag, 2008; David, 1985; Gandal et al., 2007). As for temporal changes in level of integration, the value of angle θ should diminish over time because many new products increasingly require networking functions such as the Internet of Things. Standardization-related activities are increasingly necessary when designing products in nearly all industries.

6.2.4. Individual project basis model

Alongside macro analysis of industrial sectors, our conception can be used to analyze individual projects. The angle between the patent and the related standard embodies the relationship within projects. Our model implies the existence of integrated IP in which θ is not zero. This type of integrated IP is the combination of (a) standards and (b) patents required for product differentiation. Such a patent is not technologically essential and is not an SEP. Patents commercially required for product differentiation are formed at the periphery of standardized technology. They are important because their royalty rates need not meet FRAND conditions, whereas they must in the case of SEPs (i.e., when $\theta=0$). Therefore, non-SEP conditions governing patents commercially required for product differentiation present a strategic option for enhancing royalties.

6.2.5. Revenue model

The following model analyzes the effect of θ on revenue. Revenue obtained from integrated IP is proportional to the product of the patent royalty rate and the magnitude of integrated IP. This is because the magnitude of integrated IP is assumed to be a good proxy for related sales and production quantities.

$$Revenue = R\cdot\left|\overrightarrow{integrated\ \ IP}\right|, \quad (5)$$

where $\left|\overrightarrow{integrated\ \ IP}\right|$: *the magnitude of integrated IP,*

R: royalty rate of the patent.

For comparison, royalty rate R for SEPs, which must meet FRAND conditions, is set to a common value of 1 as the base (e.g., $R=1$ and $\theta=0$).

In addition, $\left|\overrightarrow{patent\ \ IP}\right|$ and $\left|\overrightarrow{standardization}\right|$ are set as 1.

According to θ, revenue is mainly categorized into two cases from Eqs. (3), (4), and (5):

$$i)\theta=0\ \ Revenue\,(SEP)=R\cdot\left|\overrightarrow{integrated\ \ IP}\right|=1\cdot\sqrt{2+2\cos(0)}=2;$$

$$ii)\theta>0\ \ Revenue\,(nonSEP)=R\cdot\left|\overrightarrow{integrated\ \ IP}\right|=R\cdot(\sqrt{2+2\cos(\theta)}).$$

The formula is plotted in Figs. 5 and 6. In Fig. 6, the horizontal axis indicates integration level θ, and the vertical axis indicates royalty rate R. The contour lines show the anticipated revenue. When $(R, \theta)=(1, 0)$ on the chart, an SEP is indicated, and the contour line indicates 2. For SEPs, royalty rate R is fixed by FRAND.

The crucial point is that SEPs might not provide inventors the most revenue because FRAND conditions restrict royalty ratios. If anticipated royalties are less than anticipated, inventors may cease R&D. This structure hinders innovation creation.

a) Region where the value of the revenue contour line is larger than 2

In this area, revenue exceeds the SEP case. In Fig. 6, when θ is mainly under $\pi/2$, revenue exceeds 2 (the value obtained under SEP conditions), even when R is small (between 1 and 2) or similar to that in the SEP case. This suggests that the formation of integrated IP distinct from SEPs can generate more revenue. In this region, the magnitude of the combination of patents and standards can be smaller than under SEP conditions. However, a high royalty rate can produce higher revenue.

Under SEP conditions, where $\theta=0$, FRAND conditions fix $R=1$. Hence, revenue cannot be increased by raising R. This constraint may hinder innovation if inventors expect low royalty payments. If SEP conditions can be avoided, the patent holder can earn more revenue than possible under SEP conditions by obtaining patents commercially required for product differentiation. Generally, SEPs seem to garner more revenue, although this model and Figs. 5 and 6 show that this is not always true. We suggest that this contradictory result can be understood as the “SEP paradox” or “FRAND paradox.” At present, where patents and standards merge, the

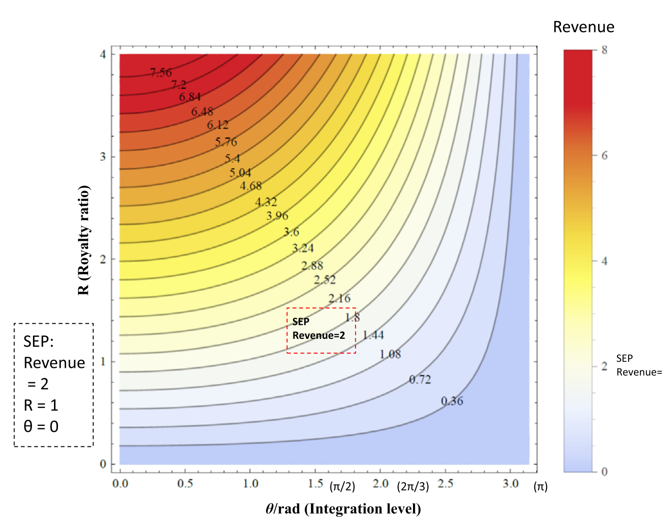

Fig. 6. Contour heat map of revenue.

strategic decision to form an SEP is important for managing innovation.

b) Region where the value of the revenue contour line is smaller than 2

In the area of Fig. 6 where θ markedly exceeds $\pi/2$, revenue is below 2, and revenue from integrated IP is less than that from SEP royalties. In this region, even with $R=3$ (which is threefold the value allowed for an SEP (i.e., $R=1$)), revenue is below 2 obtained under SEP conditions. A high royalty rate does not improve revenue in this region. The opposite effect appears between patents and standardization, and this area is unsuitable for revenue-seeking. Using standards integrated in this area seems unimportant for innovation.

6.3. Theoretical and managerial implications

6.3.1. Theoretical perspective

Our new conception of intellectual property explains standards and patents in the integrated format and, for the first time, explains the difference between an SEP and non-SEP in the theoretical manner. Moreover, the connection between IP and standardization is shown possible by measuring internal activities in the same entities. Our approach makes it possible to connect standardization to R&D within R&D entities.

6.3.2. Managerial perspective

This study's primary practical implication is that data related to standardization in R&D entities are collectable and usable in analyzing and assessing policies statistically. Data accumulated could be used as the quantum of labor input in cost-benefit analysis of R&D management and innovation policy. Labor and production labor are input metrics in cost-benefit analysis employed by the National Institute of Standards and Technology (Tassey, 2003).

7. Limitations and further research

Data for conventional standardization activities are presently unavailable. Therefore, we could offer no comparative empirical analysis between IP-related standardization activities and conventional standardization activities. Future studies could do so once data are available.

In addition, current data are not presented in time series. Therefore, our analyses are not longitudinal and the average influence of standards on innovation is shown in this study. Receipt of further data, especially panel data, will allow study of dynamic relationships between the standardization and innovation processes.

8. Conclusion

This empirical study has shed new light on the relationship between R&D and standardization activities within R&D organizations rather than within SDOs external to R&D organizations. Its results indicate, first, that patent applications correlate significantly and positively with IP-related standardization activities. Second, standardization-oriented industries (Japan's electric machinery industry) have higher correlations than non-standardization-oriented industries (other industries examined). Third, these observations apply across multiple years (2008–2010). These results imply that standardization activities in R&D organizations may encourage innovation in high-technology industries.

In addition, this study normatively redefined conventional notions of intellectual property and introduced the concept of integrated IP to treat IP and standardization activities integrally. We have provided a vector equation to document our redefinition as in Eq. (1).

Finally, this study presented the SEP paradox, which suggests that SEP formation is not always useful for improving innovation with standardization. Our model also conceptualizes the negative patent to explain the situation when the standard hinders the patentability of a technology. This negative patent helps to explain relations between standards and patents more comprehensively.

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Appendix A.

Nomenclature

FRAND Fair, Reasonable, And Non-Discriminatory
FTE Full-Time Equivalent
ICT Information and Communications Technology
IP Intellectual Property
IPA IP-related Activities
IPA personnel Personnel engaged in IP-related Activities
IPRSA IP-Related Standardization Activities
IPRSA personnel Personnel engaged in IP-Related Standardization Activities
SA Standardization-related Activities
SA personnel Personnel engaged in Standardization-related Activities
SDO Standard Development Organization
SEP Standard Essential Patent

Appendix B.

See Table B1

Appendix C.

See Table C1

Appendix D. Derivations of equations

$$\cos(\theta)=\frac{\overrightarrow{patent\ \ IP}\bullet\overrightarrow{standardization}}{\left|\overrightarrow{patent\ \ IP}\right|\left|\overrightarrow{standardization}\right|} \tag{A.1}$$

Hence,

$$Integration\ \ level:\ \theta=\cos^{-1}\left(\frac{\overrightarrow{patent\ \ IP}\bullet\overrightarrow{standardization}}{\left|\overrightarrow{patent\ \ IP}\right|\left|\overrightarrow{standardization}\right|}\right)$$

Table B1
Definitions of terms.

Term	Nomenclature	Definition		
(1) Standardization-related activities	SA	i) Formation of standards or amendments to a certain technology among multiple relevant parties (formation and amendment refer to the simplification and unification of technical specifications, measurement and inspection methods, and technological terms or symbols)	ii) Negotiations for the drafting of technology standards by international or domestic committees	iii) Management and support of standards
(2) Personnel engaged in standardization-related activities	SA personnel	Individuals who engage in SA		
(3) IP-related standardization activities	IPRSA	i) Research of patents for related standards, the evaluation of licensing negotiations for essential patents, draft preparation and submission of patent statements in relation to standardization, responses to patent infringement claims relating to technology standards, and standard-related planning, management, research, evaluation, and other related activities	ii) Proposal of standards, the standard deliberation process, and domestic and international standard-related negotiation	iii) Support activities for standardization, such as education, public promotion, accounting, general affairs and others
(4) Personnel engaged in IP-related standardization activities	IPRSA personnel	Individuals who engage in IPRSA		
(5) IP-related activities	IPA	i) Acquisition, maintenance or mining of industrial patents, the management of IP, and the evaluation of IP rights, negotiations of license agreements, transactions and dispute settlements of IP rights	ii) Support activities such as planning, investigation, education, accounting, general affairs and others	
(6) Personnel engaged in IP-related activities	IPA personnel	Individuals who engage in IPA		
(7) R&D activities	–	i) Thinking about, considering, and collecting information, materials, and test samples, and experimenting, inspecting, analyzing, and reporting of results in research centers and research departments	ii) Preparing, designing, fabricating, and assessing pilot plants and prototype models in manufacturing sites such as factories	iii) General administrative and accounting work to support all such activities
(8) R&D personnel	–	Individuals who engage in R&D activities		

Table C1
Outline of the Survey of Intellectual Property-Related Activities and the data preparation procedure for this study.

1. Outline	(1)Purpose	This survey, which has been published annually by the Japan Patent Office since 2002, obtains data on individuals, companies, universities, and research institutes to facilitate effective intellectual property policymaking in Japan. The response rate for the survey is at about 50%; for example, of the 6372 eligible participants surveyed in 2010, the Japan Patent Office received a total of 3555 responses, for a response rate of 55.8%.
	(2)Counting method	The survey determined the numbers of (i) IPA personnel, (ii) IPRSA personnel, and (iii) R&D personnel on a full-time equivalent (FTE) basis rather than using a headcount. Although headcount and FTE can both be used to measure the number of personnel engaged in a specific activity, the Frascati Manual of the OECD recommends FTE for counting researchers and scientists (OECD, 2002).
2. Data preparation procedure for this study		(1) Data concerning individuals other than those working in organizations were removed from the dataset because the aim of this study is to examine effects within organizations. (2) Only complete data including all four factors (patent applications, IPA personnel, IPRSA personnel, and R&D personnel) were included in the dataset. Observations with incomplete data were disregarded. (3) Data were removed from the dataset if the number of IPRSA personnel was larger than the number of IPA personnel because such data are likely the result of completion error by survey respondents.

$$magnitude\ of\ integrated\ IP\ vector = \left|\overrightarrow{integrated\ IP}\right| \tag{A.2}$$

$$= \left\{ \left|\overrightarrow{patent\ \ IP}\right|^2 + \left|\overrightarrow{standardization}\right|^2 - 2\left|\overrightarrow{patent\ \ IP}\right|\left|\overrightarrow{standardization}\right| \cos(\pi - \theta) \right\}^{\frac{1}{2}}$$

(∵ Law of cosines)

$$= \left\{ \left|\overrightarrow{patent\ \ IP}\right|^2 + \left|\overrightarrow{standardization}\right|^2 + 2\left|\overrightarrow{patent\ \ IP}\right|\left|\overrightarrow{standardization}\right| \cos(\theta) \right\}^{\frac{1}{2}}$$

(When $\left|\overrightarrow{patent\ \ IP}\right|$ and $\left|\overrightarrow{standardization}\right|$ are each set as 1.)

$$= \sqrt{2 + 2\cos(\theta)}$$

References

Acs, Z.J., Audresch, D.B., 1989. Patents as a measure of innovative activity. Kyklos 42 (2), 171–180.
Arthur, W.B., 1989. Competing technologies, increasing returns, and lock-in by historical events. Econ. J. 99, 116–131.
Blind, K., 2002. Driving forces for standardization at standardization development organizations. Appl. Econ. 34, 1985–1998.
Blind, K., 2006. Explanatory factors for participation in formal standardization process: empirical evidence at firm level. Econ. Innov. New Technol. 15 (2), 157–170.
Blind, K., Jungmittag, A., 2008. The impact of patents and standards on macroeconomic growth: a panel approach covering four countries and 12 sectors. J. Product. Anal. 29, 51–60.
Cefis, E., Orsenigo, L., 2001. The persistence of innovative activities: a cross-countries and cross-sectors comparative analysis. Res. Policy 30, 1139–1158.
David, P.A., 1985. Clio and the economics of QWERTY. Am. Econ. Rev. 75 (2), 332–339.
Edler, J., Georghiou, L., Blind, K., Uyarra, E., 2012. Evaluating the demand side: new challenges for evaluation. Res. Eval. 21, 33–47.
Egyedi, T.M., Sherif, M.H., 2010. Standards dynamics through an innovation lens: next-generation ethernet networks. IEEE Commun. Mag. 48 (10), 166–171.
Farrell, J., Saloner, G., 1985. Standardization, compatibility and innovation. RAND J. Econ. 16 (1), 70–83.
Funk, J.L., Luo, J., 2015. Open standards, vertical disintegration and entrepreneurial opportunities: How vertically-specialized firms entered the U.S. semiconductor industry. Technovation 45–46, 52–62. http://dx.doi.org/10.1016/j.technovation.2015.07.00.
Gandal, N., Gantman, N., Genesove, D., 2007. Intellectual property and standardization committee participation in the US modem industry. In: Greenstein, S., Stango, V. (Eds.), Standards and Public Policy. Cambridge University Press, New York, pp. 208–230.
International Organization for Standardization, 2006, ISO Members 2006. ISO, Geneva.
Jakobs, K., Procter, R., Williams, R., 2001. Standardisation, innovation and implementation of information technology. Comput. Netw. Age Glob. 57, 201–217.
Japan Patent Office, 2008, Results of the Survey of Intellectual Property-Related Activities 2007. Japan Patent Office, Tokyo (in Japanese).
Japan Patent Office, 2009, Results of the Survey of Intellectual Property-Related Activities 2008. Japan Patent Office, Tokyo (in Japanese).
Japan Patent Office, 2010, Results of the Survey of Intellectual Property-Related Activities 2009. Japan Patent Office, Tokyo (in Japanese).
Lopez-Berzosa, D., Gawer, A., 2014. Innovation policy within private collectives: evidence on 3GPP's regulation mechanisms to facilitate collective innovation. Technovation 34, 734–745.
Ministry of Education, Culture, Sports, Science and Technology, 2009. Monbukagaku toukei youran [Statistical Abstract]. Ministry of Education, Culture, Sports, Science and Technology, Tokyo, in Japanese.
OECD, 2002. Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development. OECD, Paris.
Pohlmann, T., Blind, K., 2014. The interplay of patents and standards for information and communication technologies. Prax. Informationsverarbeitung Kommun. 37 (3), 189–195.
Sherif, M.H., 2001. A framework for standardization in telecommunications and information technology. IEEE Commun. Mag. 39 (4), 94–100.
Simcoe, T., 2005. Explaining the increase in intellectual property disclosure. In: Bolin, S. (Ed.), The Standards Edge: Golden Mean. Bolin Communications, Ann Arbor.
Simcoe, T., 2006. Open standards and intellectual property rights. In: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), Open Innovation: Researching A New Paradigm. Oxford University Press, New York.
Stango, V., 2004. The Economics of Standards Wars. Rev. Netw. Econ. 3, 1–19.
Tamura, S., 2010, Correlation between Standardization and innovation from the viewpoint of intellectual property activities: electric machine industry and all organizations in Japan. In: Proceedings of the Conference of Portland International Conference on Management of Engineering and Technology 10 (PICMET10), IEEE Explore database.
Tamura, S., 2013. Generic definition of standardization and the correlation between innovation and standardization in corporate intellectual property activities. Sci. Public Policy 40, 143–156.
Tamura, S., 2015. Who participates in de jure standard setting in Japan? The analysis of participation costs and benefits. Innov.: Manag. Policy Pract. 17 (3), 400–415.
Tamura, S., Matsuda, H., 2008. Policy action for strategic international standardization (Kokusai Hyoujun Senryaku ni Kakawaru Seisakuteki Torikumi). J. Jpn. Soc. Precis. Eng. 74 (1), 12–15 (in Japanese).
Tassey, G., 2000. Standardization in technology-based markets. Res. Policy 29, 587–602.
Tassey, G., 2003. Method for Assessing the Economic Impacts of Government R&D. National Institute of Standards & Technology, Gaithersburg.
Trajtenberg, M., 1990. A penny for your quotes: patent citations and the value of innovation. RAND J. Econ. 20, 172–187.
Zi, K., Blind, K., 2015. Researchers' participation in standardisation: a case study from a public research institute in Germany. J. Technol. Transf. 40 (2), 346–360.