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The Dynamics and Determinants of De Jure Standards: Evidence from the electronic and electrical engineering industries (Revised)

TAMURA Suguru
RIETI

Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

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The Dynamics and Determinants of De jure Standards: Evidence from the electronic and electrical engineering industries

Suguru TAMURA
RIETI (Research Institute of Economy, Trade and Industry)

Abstract

This study evaluates the time intervals over which standards should be reviewed as a function of the standards' dynamics. Determining the optimum interval over which to review standards facilitates the creation of new product markets. Data for this study (about 15,000 active or withdrawn de jure standards) were collected and analyzed, which resulted in several findings. First, the effective time interval over which standards should be reviewed differ as a function of the technological field in which the standard is used. Second, a standard's type (particularly design and symbol standards) also significantly affects the effective time interval for a standard's review. Third, the types of review (e.g., amendment) are significantly associated with the standards' effective terms. These findings allow for the validation of a mathematical model that explains the dynamics of the standard's value. This model allows for an analysis of the relationship between a standard's value and the type of review to which it should be subjected. The model features a critical value that uniformly explains de facto standards and de jure standards in terms of the standards' dynamics.

Keywords: De jure standard, Effective term, Type of standard, Type of review, Dynamics
JEL: O30, O31, O34, L15.

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1. Introduction

In this study, I explore the dynamics of standards by investigating their effective terms. More specifically, I evaluate Japanese de jure standards. By investigating these standards, I seek to identify the factors that influence their effective terms, thereby facilitating the optimization the manner in which they are managed. Although there are a number of ways to investigate de jure standards, I am most interested in exploring how three factors influence a standard's effective term: (1) the technological category in which the standard is applied, (2) the type of the standard, and (3) the type of review. As such, in this study, I discuss the model and how it illustrates the relationship between a standards' value and these three factors. In the model, I introduce the notion of η (a threshold figure) and $\eta V(0)$ (a critical value), both of which are related to the value of standards. These values help to uniformly explain de facto standards and de jure standards in terms of the standards' dynamics.

Standards can be generally classified into one of two categories—de facto standards and de jure standards. Whereas de facto standards are formulated through market mechanisms and competition, de jure standards (e.g., Japanese Industrial Standards [JIS]) are typically determined through the activities of public standards development organizations [1]. Briefly speaking, the de facto standard is determined in the market as a result of enterprise competition. As a result, there are no adequate records related to de facto standards' effective start and end dates. In contrast, the JIS maintains chronological records associated with de jure standards [2]. The existence of these records facilitates the analysis of the dynamics of de jure standards using the JIS data. For the purposes of this study, I define a standard's "effective term" as the difference between 2014 (or the year of withdrawal if a standard has been withdrawn) and the year it was established. This calculation results in a metric I use as the dependent variable in the econometric analysis.

De jure standards are reviewed after a certain period of use [2]. Standards couched in the JIS, for example, are reviewed every five years. Reviews are executed per a rules-based process initiated by a user's request and can take several forms, including withdrawal, replacement, amendment, and confirmation[1]. A "withdrawal" refers to a review that results in the termination of an active standard; a "replacement" concerns a review in which a standard changes its name or contents, or splits into other standards; an "amendment" relates to the modification of an existing standard; and a "confirmation" leaves a standard in its current form with no change. As I am interested in evaluating changes to standards, I use three variables related to the type of review in the econometric analysis: whether a standard is withdrawn (WITH), amended (AMEND), or replaced/split (REP) or not.

"Type of standard" refers to the subject matter about which a standard is oriented. Generally, standards dictate rules related to a product's characteristics (i.e., production standards) or the use of certain measurement metrics (i.e., measurement standards). Other standards, however, dictate rules associated with industrial design (e.g., products and graphic symbols) [3]. For the purposes of the analysis, I have classified these standards as "design and symbol" standards. As such, I have categorized JIS standards into one of three categories based on their different types: production standards, measurement standards, and design and symbol standards.

In addition to the aforementioned factors, this study also evaluates standards based on whether they are international in scope (i.e., "international reference"), or serve a legislative purpose (i.e., "legislative usage").

To evaluate the factors outlined above using a functional model, I assume the functional relationship between these variables to be represented as:

$$\textit{Effective term of standard} = f\,(\textit{technological category, type of standards, type of review, international reference, legislative usage}), \quad f'(\cdot)>0 \qquad (1)$$

[1] This statement discusses the system of de jure standards. There is no systematic review period for de facto standards. The timing of technological update, which I consider a review, is generally decided in market competition.

Using this functional model, I empirically estimate the magnitude of the factors that influence the effective term of standards governed by the JIS. I estimate this model via an OLS method with a sample of 15,127 observations of current and past standards. This analysis produced several novel findings. First, the marginal effects of the aforementioned factors on a standard's effective term differ among industrial categories. This finding suggests that optimizing the review interval of de jure standards requires an evaluation of the technological category in which a standard is typically applied. Second, the results indicate that a standard's type affects its effective term. More specifically, the effective terms of "design and symbol" standards significantly differ from the effective terms of standards of other types.

2. Literature Review and Hypothesis Formation

2.1 De jure Standards in Japan

For the purposes of this study, I collected standard's data (as of 2014) from the JIS's e-JISC database[2]. The JIS summarizes the de jure standards utilized by firms in Japan. De jure standards differ from de facto standards in that de jure standards are developed in public and are handled by a public agency [4]. Owing to the transparency associated with de jure standards, each standard has a clear starting date. This allows for a calculation of each standard's term of effectiveness.

2.2 Availability of Data on Standards

Data regarding the effective terms of standards are generally not well prepared. One reason for the poor preparation of data on standards is the OECD's lack of a viable statistical framework for collecting data on standards ([5][6]). This is a significant shortcoming, given the degree to which data are collected from a variety of resources to evaluate different societal dynamics [7]. Because of the lack of a statistical framework for evaluating these data, there have been few empirical studies on the dynamics of standards. Of a few studies that do exist, they use bibliographic data from JTC1[3][8] and PERINORM[4][9] to facilitate their analyses.

2.3 Standard and Innovation

Standardization is a natural result of the diffusion, selection, and adoption of technological changes [10]. Given that standardization is not a static process, the effect of a standard on product innovation is dynamic and differs at each stage of a product's life cycle. In this way, standards can be categorized as one of three types: anticipatory standards, enabling standards, and responsive standards [11]. Some researchers contend that these three types of standards occur sequentially (and facilitate product innovation) over the course of a product's life cycle ([9][12][13]).

2.4 Type of Standard

The ways in which types of standards affect innovation is a growing area of research. As this body of research has grown, researchers have concluded that standards serve three functions: information, compatibility, and variety reduction [14]. The information function reduces transaction costs; the compatibility function creates network externalities; and variety reduction builds a critical mass of products [14]. Past scholarship on standards has largely focused on standards for production ([15][16][17]), or standards for measurement and testing [18]. Standards for designs and symbols, however, have not been thoroughly explored ([19][20][21]). This empirical oversight is notable, given that research in some technological fields (e.g., nanotechnology and information technology) has shown that the market success of products in these fields is largely contingent on the development of standards related to designs, symbols, terminology, measurement, and testing methods ([22][23]).

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[2] e-JISC is an electric database maintained by the Japanese government to organize data related to past and current Japanese Industrial Standards.

[3] JTC1 is the joint technical committee associated with ISO and IEC.

[4] PERINORM is the EU's bibliographical database of de jure standards. This database is maintained by SDOs in the EU.

2.5 Dynamics of Standards

Research on the dynamics of standards is relatively new [24]. Empirical and theoretical work on standards has typically focused on costs (e.g., transaction costs and production cost savings), competition (i.e., how to use standards to organize markets), communication and coordination (e.g., agreeing upon technical specifications) [25], or the effect of participating in activities related to standards' development ([20][26][27][28][29]). Researchers that have adopted a macroeconomic perspective have evaluated the role of standards in international trade flows ([18][21]).

Some previous research has quantitatively evaluated the dynamics of international de jure standards. However, this research has used only semi-parametric methods (e.g., Cox survival analysis [9]) and descriptive analysis [8]; thereby, limiting the amount of research on the marginal effects of different factors on a standard's effective term of use. Some researchers have also employed qualitative methods to investigate the dynamic nature of standards. For instance, David [15] and Yamada and Kurokawa [17] surveyed de facto standards using qualitative methods of observation. David [15] evaluated the orientation of letters on keyboards, finding that the QWERTY key arrangement (despite being ergonomically inefficient) has persisted for about 100 years. One reason for the persistence of this standard derives from the "locking-in" of human skill sets.

Yamada and Kurokawa [17] researched the dynamics of 13 de facto standards in the information technology and audiovisual industries in Japan. Specifically, they evaluated standards associated with different storage devices and players, including CDs, DVDs, and VCRs. The longest-lived among these standards was associated with the floppy disk (24 years) and the shortest was associated with the Betamax VCR (3 years). The authors indicated that longer effective terms of de facto standards result in larger profits from those standards. Although Yamada and Kurokawa [17] evaluated standards based on the time when they were established and the time they were withdrawn, there was no verifiable, quantified evidence related to these key dates. Moreover, notably in Japan's audiovisual information industry, de facto standards could be established when market share reached 2% to 3% (e.g., VCR, video discs, and game hardware). This study found that de facto standards are more likely to be established when companies rapidly increase their market share [17]. Table 1 summarizes previous work in this domain.

[Table 1]

2.6 Hypothesis Formation

The literature summarized above suggests a series of interrelated relationships. Figure 1 summarizes these various relationships, and highlights hypotheses that can be tested to evaluate them.

[Figure 1]

2.6.1 The Effect of Technological Category on a Standard's Effective Term

The technological category in which a standard is applied affects that standard's effective term. This is manifest among EU de jure standards, where differences in technological categories have different effects on standards' effective terms [9]. Therefore, I predict:

H1: The technological category in which a standard is developed significantly affects its effective term.

2.6.2 The Effect of a Standard's Type on a Standard's Effective Term

Measurement standards are generally considered more stable than non-measurement standards. This stability is because measurement standards sometimes produce data for legislative purposes. As legislation requires continuity, the standards used in developing legislation must be similarly durable. Despite the intuitiveness of this assertion, empirical research is rarely consistent. In contrast, the emergence of new technologies requires the development of new measurement standards. As such, radical innovation can yield a wealth of new measurement standards. For example, in the case of R&D on nanotechnology (a field in which radical innovation is in continuous progress) new measurement standards are necessary [22]. Given the need to continuously develop new standards in these sectors, standards can be short-lived. Even measurement standards, which are typically stable and have long effective terms, are likely to be replaced in the same way as non-measurement standards.

In addition to measurement standards, this study focuses on standards related to designs and symbols. These standards define the fundamental shapes and images associated with goods and services. As such, these standards tend to have longer effective terms. It therefore follows that:

H2: A standard's type significantly affects its effective term.

2.6.3 The Effect of a Type of Review on a Standard's Effective Term

Finally, I examine the relationship between the reviews to which a standard is subjected and the standard's effective term. A review of the extant literature shows that the technological contents of a standard can be updated by amendment [24]. This suggests that the review of a standard can significantly affect its effective term. To test this possibility, I propose the following hypothesis:

H3: The type of review to which a standard is subjected significantly affects its effective term.

3. Method

3.1 Analytical Framework

For de facto standards, effective terms are positively related to corporate profitability [17]. The more properly a standard is reviewed, the more effectively it is likely to be updated technologically. In sum, identifying the optimum standard's review period increases the technological information in the standard; thereby, making it more versatile.

3.2 Estimation Equation

I used an ordinary least squares method with robust standard errors to estimate the model defined in this section. I used the analytical package STATA to estimate the model. This model is expressed as a linear combination of independent variables. Specifically, the estimation model is expressed as:

$$Effective\ term = \beta X + u \qquad (2)$$

, where β is the coefficient matrix and X is the variable matrix. u is an error term. Table 2 summarizes the variables to populate the model.

[Table 2]

3.3 Variables and Data Preparation

I used the data from the e-JISC, which houses bibliographic data related to standards used in Japan. In total, I collected data on 15,127 active and withdrawn standards.

3.3.1 Technological Category

To construct a variable to represent the technological category in which a standard is situated, I created dummy variables for each of the 19 technological areas[5] identified by the JIS. Each of these technology areas are identified by an alphabetic code (see Appendix A).

3.3.2 Type of Standard

I first categorized standards as being related to either designs and symbols or measurement by

[5] Within the JIS database, technological category is not equivalent to the ISO/IEC's International Classification for Standards (ICS) [3].

evaluating the standards' titles. Titles that include Japanese words related to measurement (e.g., *kensa* [measurement], *shiken* [examination]) were assumed to identify measurement standards. Titles that included Japanese words related to design and symbol (e.g., *kigou* [design or symbol]) were assumed to identify standards related to designs and symbols (see Appendix B). All other standards (i.e., those that did not contain measurement- or design-/symbol-related terms) were categorized as production standards. Similar to technological category, I created dummy variables for each of these standard's types.

3.3.3 Type of Review

I classified the types of reviews to which standards were subjected into one of three categories. These relate to whether a standard was withdrawn (WITH), amended (AMEND), or replaced/split (REP), respectively. Withdrawal indicates that the standard was abolished and no subsequent standard was created. Amendment indicates that a standard has undergone some change that has led it to its current state. Replacement indicates that a standard has been supplanted by a successor, or that another standard has emerged as an offshoot.

4. Results and Discussion

4.1 Descriptive Statistics

Table 3 outlines the descriptive statistics associated with all variables. The dummy variable associated with the type of standards is broken into three types: production standards (p_type), measurement standards (m_type), and design and symbol standards (d_type). Appendix C shows the correlations between the variables.

[Table 3]

4.2 Estimation Results and Discussion

4.2.1 Estimation Results

Table 4 shows the results of the model estimation. To perform the estimation, I set cat1 (civil engineering and architecture) and p_type (production standards) as baselines, since the number of those standards is large. All models include references to international standards and legislative usage as control variables. For all models, the variance inflation factor (VIF) is below 2.00, suggesting that the data are not subjected to perfect multicollinearity. In Model 1, I estimated only the effect of technological category on a standard's effective term. Results of the Model 1 estimation indicate that whereas some technological categories are negatively related to a standard's effective term (e.g., cat3 [electronic and electrical engineering], cat13 [management system], cat16 [medical equipment and safety appliances], and cat18 [information processing]), others are positively related to a standard's effective term (e.g., cat2 [mechanical engineering], cat4 [automotive engineering], and cat5 [railway engineering]). Model 2 includes types of standard and technological category as predictor variables. The results of this estimation show that measurement standards and design and symbol standards have longer effective terms. In Models 3, 4, and 5, I included the AMEND, REP, and WITH variables, respectively, related to the review of standards. These additions showed that the different types of review are all significantly associated with a standard's effective term.

[Table 4]

4.2.2 Hypothesis Validation

Figure 2 provides a visual depiction of the results of the hypothesis tests. The results of the analyses related to Hypothesis 1 do not allow it to be rejected. In the estimation models, the technological category dummies were found to be significantly related to the effective terms of standards applied in those categories. This was particularly true in the mining (cat11) and pulp and paper (cat12) categories. Still, the magnitude of the relationship was weaker in the electronic and electrical engineering (cat3) and management system (cat13) categories. This suggests that the review interval for standards in the mining and pulp and paper industries can be extended to reduce administrative costs; standards in the electronic and electrical engineering and management system sectors can be shortened.

[Figure 2]

I also found cat3 (i.e., standards in the electronic and electrical engineering sector) to be negatively related to the effective term of a standard in Models 1-4. This result was consistent, though marginally significant, in Model 5. This result is consistent with the intuitive understanding that product lifecycles in this sector are shorter than product lifecycles in the baseline sector. This is likely due to the fact that the development of new standards occurs frequently in this sector, where innovation is paramount([11][12][13]). Interestingly, the relationship between standards in the information processing sector (cat18) is significant in Models 1-3, but not Models 4 and 5. Previous research in this domain has produced similar results [9]. The non-significant results in Models 4 and 5 may indicate that information technology has become a General Purpose Technology (GPT) [30], making it unsuitable for categorization in a specific technology category.

Results also provided at least partial support for Hypothesis 2. The coefficient associated with standard's types was significant in Models 2-5. This result is consistent with past work, which has shown, for example, that design and symbol standards are important in the nanotechnology sector in Germany [22]. The results of my analysis indicate that production standards, designs and symbols standards, and measurement standards are in decreasing order in terms of their effective terms. Results indicate that the design and symbol standards have shorter effective terms than production standards. This is not consistent with general understanding related to the effective terms of standards' types. This difference is likely attributable to the fact that the current analysis focuses on de jure standards rather than de facto standards. In contrast to de facto standards, de jure standards often define production goods as intermediate goods. There is little need to change the technical requirements for production goods (e.g., chemical materials). As such, the characteristics of production goods intrinsically delay the time at which the standards become obsolete.

Finally, the results associated with Hypothesis 3 do not allow it to be rejected. The manner in which a standard is reviewed is significantly and positively related to its effective term. More specifically, the results of the estimation indicate that the amendment of a standard has a more substantial influence on the standard's effective term than its replacement. The coefficient associated with amendment is the largest of the three types of reviews (about 22) in Models 3-5. The coefficient associated with replacement is significant in Models 4 and 5. However, the coefficient associated with withdrawal is significant and negative in Model 5. This result implies that technological amendment of standards allows for the accumulation of technologies to a greater degree than replacement. This is likely the case because obsolete technology can typically be replaced.

4.2.3 Model

I propose Equation (3) to estimate the relationship between the value of standards and time[6]. Here, value of standards can be expressed as:

$$V_{cat,\,k}(t) = V_{cat,\,k}(0)\,\frac{e^{\alpha(t+\beta)}}{(1+e^{\alpha(t+\beta)})} \qquad (3)$$

, where *V* refers to the economic value of the standard as public goods when t time has elapsed since the previous review. *V* also represents the benefit provided by a reviewed standard. *cat* represents the technological category in which a standard is applied. k indicates the number of times a standard has been reviewed. t indicates the number of years that have elapsed since the standard was last reviewed, and α and β are constants.

[6] I deduce this model from a theoretical perspective; hence, this study does not include a discussion of the empirical method to measure the value *V*.

I further define t_r as the review interval. Figure 3 shows the relationship between elapsed time t and V (in Case 1, α = -1.5, β= -10; in Case 2, α = -1.5, β = -6). The relationship of t_r to V is indicated in Figure 3. The value of a standard in t_r is denoted as $V(t_r)$. In Equation (3), the constant α defines the declining speed dV/dt and constant β defines the plateau state where V is stable. When β is large, a standard maintains the value $V(0)$ for a relatively longer period of time than when β is small.

[Figure 3]

In Case 1, where the review interval t_r is set at five years, $V_{1,k}(t_r)$ is equal to $V_{1,k}(0)$. In this case, it is better to extend the review period to reduce administrative costs associated with maintaining the standard. In Case 2, however, $V_{2,k}(t_r)$ is less than $V_{2,k}(0)$ when time elapses to the review interval t_r. Therefore, in Case 2, it would be useful to shorten the review interval. Standards related to electronic and electrical engineering (cat3), as well as management system (cat13) are Case 2 standards. Other categories (e.g., mining(cat11), and pulp and paper(cat12)) are Case 1 standards.

If the cost to amend or replace a standard is larger than the benefits obtained by reviewing a standard, the standard will be withdrawn [24]. The value provided by reviewing a standard can be expressed as:

$$\text{Benefit of review} = \text{Value provided by a reviewed standard after k times review} - \text{cost of review at k times} \quad (4)$$

, which can be simplified as:

$$= V_{cat,(k+1)}(0) - C_k \quad (5)$$

The condition of review choice is expressed from Equation (6) as:

$$\text{Benefit of review} = V_{cat,(k+1)}(0) - C_k > 0 \quad (6)$$

Equation (6) specifies a condition in which a standard is not withdrawn. Some standards have been neither amended nor replaced. These still-active standards have large values for β, and contain knowledge that is resistant to obsolescence.

I introduce the notion of the critical review interval t_c, in which the lock-in effect of a standard appears and the value of a standard in t_c is denoted as $V(t_c)$. t_c differs across technological categories and t_r and t_c satisfies the relationship in Equations (7) when a standard can retain the lock-in effect:

$$V(t_r) > V(t_c) = \eta V(0) \quad (7)$$

, where η is the threshold figure and $\eta V(0)$ is the critical value at which a lock-in effect emerges.

Generally, η is high for de facto standards because product or service developers maintain market competitiveness by developing and applying new standards. As such, the review interval is shorter for these firms[7]. In contrast, the η associated with de jure standards need not be high. By introducing those values, it is possible to uniformly explain the de jure standards and the de facto standards in terms of their dynamics.

[7] For discussion, I consider the interval in technological update of de facto standards as a review interval. The timing of technological update of de facto standards is generally decided in market competition.

4.3 Policy Implications

ISO protocols dictate that the maximum time interval that should elapse between standards' reviews is five years [2]. This study suggests the need for a more flexible system by which de jure standards are reviewed. The results of this research are applicable not only to standards housed under JIS, but also de jure standards developed by international standard development organizations. The findings produced here also help to facilitate the process by which de jure standards are reviewed. Given that de jure standards have become essential in the fields of advanced science and technology, it is critical that the review structure is revisited and adjusted.

The analyses presented in this study indicate that the technological categories specified by JIS are not consistent with ICS. To make the management procedures associated with de jure standards more consistent, regional standard development organizations (e.g., JISC) should strive to define their categories in a manner similar to other methodologies (e.g., ICS). Another approach to standardize the system by which international and regional standards are defined is the use of a concordance table[8], which facilitates the exchange of international data to improve management systems.

4.4 Limitation

It is important to note that I used bibliographic data (i.e., titles of standards) of standards to classify them in terms of standards' types. Future research should seek to use more detailed qualitative data to facilitate the classification of standards. Further, I proposed a numerical model of the relationship between the value of standards and time, as in Equation (3). Nevertheless, presently, the model is for theoretical discussion; hence, an empirical methodology for measuring variables such as V is essential for further discussion.

5. Conclusion

Several interesting observations emerged from the analyses presented here. First, I found that the technological category to which a standard applied was significantly related to the standards' effective terms. Second, a standard's type was also found to be significantly related to its effective term. More specifically, the results indicate that design and symbol standards were significantly different from other standard's types with respect to their effective terms. Third, the type of review was significantly associated with a standard's effective term, likely as a function of technological accumulation. Finally, the proposed model illustrates the relationship between a standards' value and the type of review. η and $\eta V(0)$ help explain the de facto standards and the de jure standards in terms of the standards' dynamics.

Appendices:

Appendix A: Technical classifications of JIS [4]

1. Category A: Civil Engineering and Architecture
2. Category B: Mechanical Engineering
3. Category C: Electronic and Electrical Engineering
4. Category D: Automotive Engineering
5. Category E: Railway Engineering
6. Category F: Shipbuilding
7. Category G: Ferrous Materials and Metallurgy
8. Category H: Nonferrous Materials and Metallurgy
9. Category K: Chemical Engineering
10. Category L: Textile Engineering
11. Category M: Mining

[8] A concordance scheme is used to connect the data sets belonging to the different classification system.

12. Category P: Pulp and Paper
13. Category Q: Management System
14. Category R: Ceramics
15. Category S: Domestic Wares
16. Category T: Medical Equipment and Safety Appliances
17. Category W: Aircraft and Aviation
18. Category X: Information Processing
19. Category Z: Miscellaneous

Appendix B: List of design and symbol standards

[Table B.1]

Appendix C: Pearson correlation coefficients

[Table C.1]

Note: The list of design and symbol standards can be downloaded from the RIETI web site: http://www.rieti.go.jp/jp/publications/summary/14080016.html

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Tables and Figures:

Table 1. Summary of previous research and the current study.

		Methodology	Scope				Data source
			De facto or De jure standards	Standard Type Evaluated?	Technological category	Region	
Previous research	David (1985)[16].	Qualitative case study	De facto standards (Active standards)	No	Keyboard arrangements	All countries	Historical observation
	Yamada and Kurokawa (2005) [17].	Qualitative case study	De facto standards (Withdrawn standards)	No	Storage devices and players (e.g., floppy disks, VCRs)	Japan	Newspapers and other financial reports
	Egyedi and Heijen (2008)[8].	Quantitative non-parametric analysis (descriptive statics)	De jure standards	No	Information and telecommunication technology	All countries	JTC1 data base
	Blind (2008)[9].	Quantitative semi-parametric analysis (Cox survival analysis)	De jure standards	Yes	Information technology, and telecommunication products	EU	PERINORM
The current study		Quantitative parametric analysis (robust OLS)	De jure standards (Active and withdrawn standards)	Yes	All JIS technology categories	Japan	e-JISC data base

Table 2. Explanation of variables.

Variable	Notation in analytical results	Explanation	Related hypothesis	Notes
EFFECTIVE TERM	term	*Effective term of standard:* The number of years between the year of a standard's establishment and its withdrawal (inclusive). If the standard had not yet been withdrawn, the number of years between its establishment and 2014.	All	Dependent variable
CAT	cat1, cat2, …, cat18, cat19	*Technological category:* Dummy variables created to represent the technological sector in which the standard is applied.	H1	Independent variable
TOS	p_type, m_type, d_type	*Type of standard:* Dummy variables created to indicate the kind of standard (i.e., production standard, measurement standard, or design and symbol standard).	H2	Independent variable
WITH	withdrawal	*Withdrawal:* Dummy variable for one kind of review. "withdrawal" indicates that a standard had been previously withdrawn.	H3	Independent variable
REP	replacement	*Replacement:* Dummy variable for one kind of review. "replacement" indicates a standard has been supplanted or split into other standards.	H3	Independent variable
AMEND	amendment	*Amendment:* Dummy variable for one kind of review. "amendment" indicates a standard has been changed, but not fundamentally altered.	H3	Independent variable
INTER	international	*International reference:* Dummy variable to indicate whether a standard references another international standard.	All	Independent variable (Control variable)
LEG	legislative	*Legislative usage*: Dummy variable to indicate whether a standard was referenced for legislative usage.	All	Independent variable (Control variable)

Table 3. Descriptive statistics.

	Variable	Observation	Mean	Std.Dev.	Min.	Max.
1	term	15127	28.079	18.479	0	65
2	cat1	15127	0.058	0.233	0	1
3	cat2	15127	0.149	0.356	0	1
4	cat3	15127	0.148	0.355	0	1
5	cat4	15127	0.032	0.176	0	1
6	cat5	15127	0.019	0.135	0	1
7	cat6	15127	0.046	0.209	0	1
8	cat7	15127	0.035	0.185	0	1
9	cat8	15127	0.036	0.188	0	1
10	cat9	15127	0.179	0.384	0	1
11	cat10	15127	0.025	0.156	0	1
12	cat11	15127	0.017	0.130	0	1
13	cat12	15127	0.009	0.095	0	1
14	cat13	15127	0.007	0.081	0	1
15	cat14	15127	0.031	0.172	0	1
16	cat15	15127	0.024	0.153	0	1
17	cat16	15127	0.046	0.209	0	1
18	cat17	15127	0.011	0.102	0	1
19	cat18	15127	0.051	0.221	0	1
20	cat19	15127	0.077	0.267	0	1
21	withdrawal	15127	0.295	0.456	0	1
22	replacement	15127	0.020	0.140	0	1
23	amendment	15127	0.618	0.486	0	1
24	p_type	15127	0.656	0.475	0	1
25	m_type	15127	0.042	0.200	0	1
26	d_type	15127	0.302	0.459	0	1
27	international	15127	0.439	0.496	0	1
28	legislative	15127	0.121	0.327	0	1

Table 4. Estimation results.

	Model 1				Model 2				Model 3				Model 4				Model 5			
	Coefficient	Robust standard error	t-statistic	p-value	Coefficient	Robust standard error	t-statistic	p-value	Coefficient	Robust standard error	t-statistic	p-value	Coefficient	Robust standard error	t-statistic	p-value	Coefficient	Robust standard error	t-statistic	p-value
1.Technological category																				
cat1	baseline				baseline				baseline				baseline				baseline			
cat2	3.484	0.682	5.10	***	1.673	0.691	2.42	*	3.986	0.577	6.91	***	4.428	0.577	7.68	***	4.250	0.574	7.40	***
cat3	-2.583	0.678	-3.81	***	-4.470	0.683	-6.54	***	-1.666	0.583	-2.86	**	-1.154	0.583	-1.98	*	-1.090	0.581	-1.87	+
cat4	8.929	0.966	9.25	***	8.070	0.973	8.29	***	7.544	0.762	9.90	***	7.959	0.762	10.44	***	7.580	0.749	10.13	***
cat5	5.287	1.044	5.06	***	3.549	1.057	3.36	**	2.368	0.865	2.74	**	2.906	0.861	3.38	**	3.050	0.847	3.60	***
cat6	9.716	0.831	11.69	***	6.408	0.845	7.59	***	6.968	0.686	10.16	***	7.521	0.686	10.96	***	7.513	0.675	11.13	***
cat7	6.686	1.143	5.85	***	6.380	1.112	5.74	***	7.185	0.834	8.62	***	7.757	0.834	9.29	***	7.535	0.841	8.96	***
cat8	6.279	0.917	6.85	***	7.459	0.910	8.20	***	5.551	0.757	7.33	***	5.899	0.752	7.84	***	5.659	0.747	7.58	***
cat9	6.739	0.676	9.97	***	6.520	0.671	9.72	***	7.526	0.574	13.11	***	8.032	0.575	13.97	***	8.226	0.572	14.37	***
cat10	8.920	0.991	9.00	***	8.477	0.982	8.63	***	6.036	0.793	7.61	***	6.509	0.790	8.24	***	6.720	0.784	8.58	***
cat11	15.927	1.215	13.11	***	17.285	1.286	13.44	***	13.197	1.018	12.97	***	13.741	1.022	13.45	***	13.848	0.991	13.98	***
cat12	11.736	1.640	7.16	***	13.813	1.680	8.22	***	10.019	1.169	8.57	***	10.005	1.187	8.43	***	10.606	1.161	9.14	***
cat13	-12.186	0.850	-14.33	***	-16.741	0.854	-19.59	***	-8.394	1.071	-7.84	***	-7.798	1.067	-7.31	***	-8.153	1.118	-7.30	***
cat14	3.003	1.105	2.72	**	4.830	1.043	4.63	***	5.570	0.816	6.83	***	6.066	0.815	7.44	***	5.623	0.813	6.92	***
cat15	-0.038	0.986	-0.04		-2.392	0.970	-2.47	**	-1.498	0.844	-1.78	+	-1.138	0.835	-1.36		-0.989	0.812	-1.22	
cat16	-3.274	0.896	-3.66	***	-5.721	0.891	-6.42	***	-0.549	0.741	-0.74		-0.061	0.739	-0.08		-0.064	0.745	-0.09	
cat17	1.372	1.276	1.08		-0.635	1.291	-0.49		5.414	1.052	5.15	***	5.942	1.058	5.62	***	6.013	0.993	6.06	***
cat18	-6.179	0.697	-8.87	***	-10.397	0.718	-14.49	***	-1.591	0.658	-2.42	*	-1.022	0.658	-1.55		-0.867	0.663	-1.31	
cat19	3.262	0.755	4.32	***	2.800	0.774	3.62	***	4.742	0.635	7.46	***	5.227	0.636	8.22	***	5.106	0.633	8.07	***
cons	29.299	0.580	50.48	***	32.772	0.596	54.95	***	14.015	0.540	25.97	***	13.522	0.539	25.07	***	15.253	0.554	27.52	***
2.Type of standard																				
p_type					baseline				baseline				baseline				baseline			
m_type					-8.650	0.324	-26.67	***	-3.570	0.255	-14.00	***	-3.564	0.255	-13.99	***	-4.121	0.259	-15.90	***
d_type					-4.565	0.670	-6.81	***	-1.741	0.552	-3.16	**	-1.659	0.552	-3.00	**	-1.697	0.552	-3.07	***
3.Type of review																				
withdrawal																	-3.425	0.247	-13.84	***
replacement													7.444	0.828	8.99	***	6.397	0.842	7.60	***
amendment									22.524	0.227	99.37	***	22.376	0.227	98.55	***	22.451	0.229	97.89	***
4.Control variables																				
international	yes				yes				yes				yes				yes			
legislative	yes				yes				yes				yes				yes			
R square	0.173				0.212				0.509				0.512				0.517			
F-value	269				302				1059				1020				1014			
Observation	15127				15127				15127				15127				15127			
VIF	1.72				1.68				1.67				1.65				1.64			

*** p<0.001,** p<0.01,* p<0.05, + p<0.1

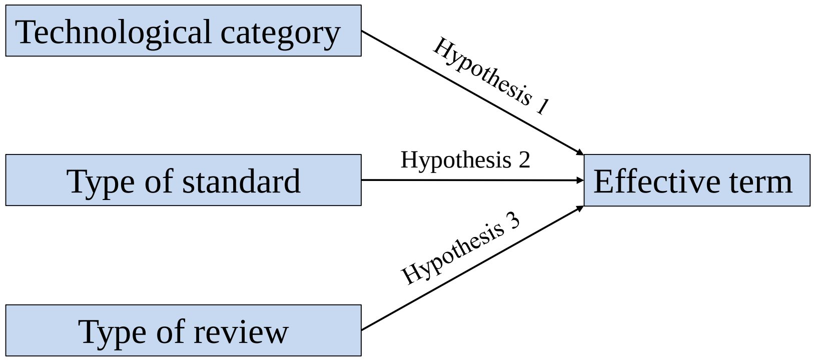

Figure 1. Hypothesis structure.

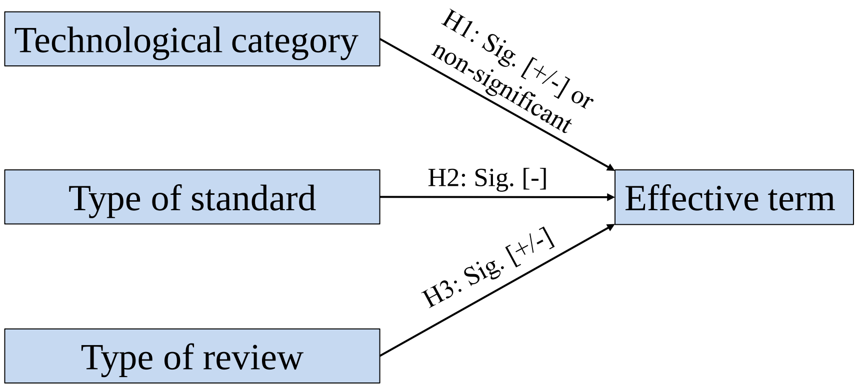

Figure 2. Hypothesis test results.

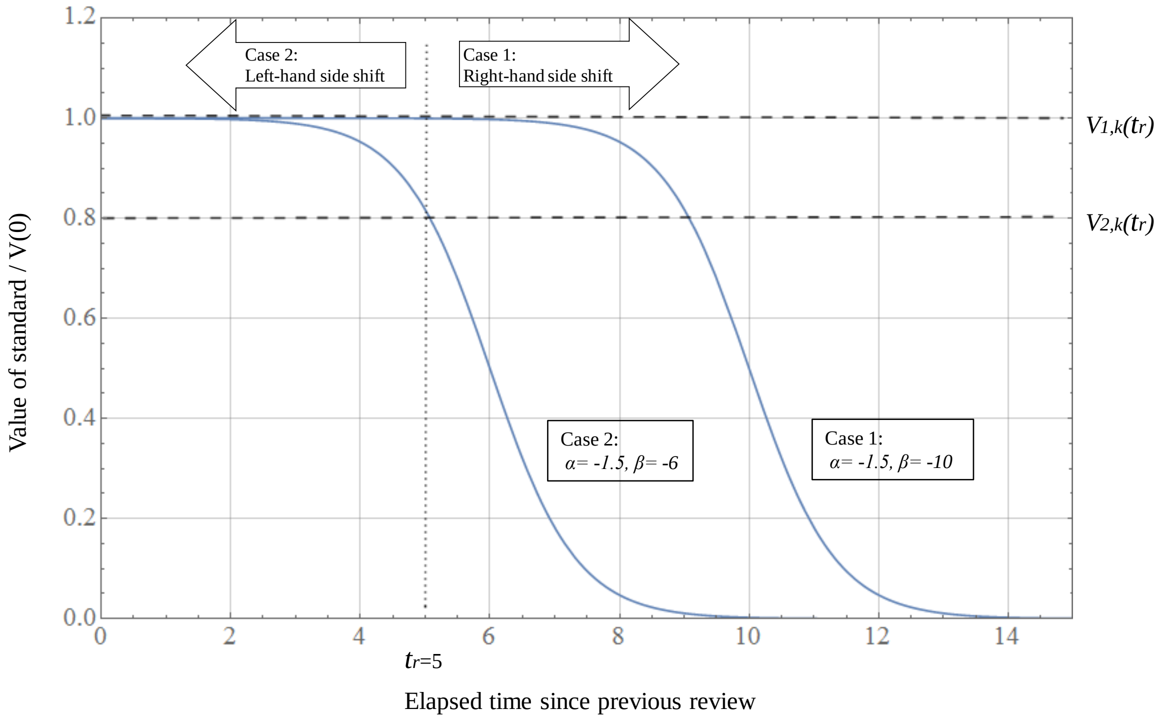

Figure 3. Value of standard over time.

Appendices:

Table B.1 List of design and symbol standards (JIS number)

JIS technological category																							
A	B					C	D	E	F	G	H	K	L	M	P	Q	R	S	T	W	X	Z	
A0005	B0002	B1017	B4002	B6340	B8385	C0301	D0032	E1305	F0050	G3191	H0001	K3804	L0001	M0101	P0138	Q14006	R1502	S0021	T0103	W0104	X0121	Z0105	Z8617-11
A0006	B0002-3	B1509	B4003	B6420	B8387	C0303	D0035	E1306	F0051	G3192	H0404	K6718-1	L0110	M3902	P0201	Q17030	R2101	S0023-2	T0307	W0111	X0122	Z0150	Z8617-12
A0007	B0005	B1510	B4005	B6450	B8394-1	C0401	D0102	E1307	F0052	G3193	H8250	K6718-2	L0120	M3907	P0202		R2102	S0026	T0922	W0112	X0124	Z0151	Z8617-13
A0008	B0005-1	B1512	B4053	B6451	B8394-2	C0456	D2501	E3011	F0053	G3194		K6734	L0121	M3914			R2103	S0052	T1006	W0113	X0127	Z0152	Z8617-14
A0009	B0005-2	B1512-1	B4118	B6452	B8395	C0602	D2502-1	E3012	F0090	G3316		K6735	L0201	M3915			R2104	S0101	T5503	W0114	X0131	Z0161	Z8617-15
A0012	B0011-1	B1512-2	B4119	B6571	B8396	C0617-1	D2620	E3301	F0411			K6811	L0217	M3917			R6004	S0102	T5505-1	W0115	X0209	Z0201	Z8617-2
A0013	B0011-2	B1512-3	B4120	B6701	B8398	C0617-10	D3603	E3302	F2210			K6884	L5121	M3918			R6211	S0103	T5507	W0116	X4107	Z1531-2	Z8617-3
A0014	B0011-3	B1512-4	B4125	B6702	B8403-1	C0617-11	D3603-1	E3307	F7006			K6899	L5138				R6211-1	S1010	T5901	W0117	X4108	Z1610	Z8617-4
A0015	B0021	B1512-5	B4126	B7022	B8403-2	C0617-12	D3603-2	E3308	F7801			K6899-1	L7509				R6211-10	S1011	T5904	W0118	X4163	Z1614	Z8617-5
A0017	B0026	B1512-6	B4127	B7111	B8404-1	C0617-13	D3603-3	E4010	F8011			K6899-2					R6211-11	S1012	T5905	W0119	X5111	Z1628	Z8617-6
A0061	B0027	B1514-3	B4128	B7115	B8404-2	C0617-2	D3603-4	E4017	F8012			K6899-3					R6211-12	S1015	T9251	W1300	X5112	Z3021	Z8617-7
A0151	B0028	B1536	B4129	B7128	B8404-3	C0617-3	D3604	E4051	F8013			K6899-4					R6211-13	S1071		W1831	X6192	Z3031	Z8617-8
A0204	B0031	B1536-1	B4141	B7129	B8404-4	C0617-4	D3631	E4502-2				K6932					R6211-14	S1101		W3902	X6194	Z3200	Z8617-9
A0206	B0041	B1536-2	B4216	B7132-1	B8404-5	C0617-5	D3632	E5401-2				K7511					R6211-15	S4602		W7109	X6302-9	Z3282	Z8781-5
A4301	B0090-5	B1536-3	B4237	B7132-2	B8434	C0617-6	D3642	E5402-2				K7512					R6211-16	S5051		W7112	X6310	Z3391	Z8840
A8301	B0102-1	B1536-4	B4258	B7158-1	B8437	C0617-7	D3651	E6001				K7513					R6211-2	S7101		W7117	X6320-2	Z4004	Z8842
A8310	B0102-2	B1536-5	B4314	B7169	B8601	C0617-8	D3701	E7202				K7520					R6211-3			W8301	X6321-2	Z4905	Z9021
A8310-1	B0121	B1540	B4350	B7170	B8663	C0617-9	D3903					K7521					R6211-4				X7197	Z4911	Z9022
A8310-2	B0122	B1566	B4354	B7176	B8665	C1103	D4002					K7522					R6211-5				X9008	Z4912	Z9023
A8312	B0124	B1583-1	B4414	B7219	B8667	C2513	D4010					K7523					R6211-6				X9101	Z4950	Z9095
A8315	B0125	B1584-1	B4751-1	B7220	B8668	C2515	D4220					K7527					R6211-7					Z6003	Z9096
A8326	B0125-1	B1584-2	B4751-2	B7221	B8669	C2517	D4304					K7535					R6211-8					Z8101-1	Z9097
A8411-1	B0125-2	B1601	B5002	B7222	B8824	C2518	D4701					K7536					R6211-9					Z8101-2	Z9100
A8411-2	B0138	B1701	B6006-1	B7230	B8824-2	C2560-3-1	D5011					K7537					R7201					Z8101-3	Z9101
A8904	B0139	B1721	B6006-2	B7281	B8824-3	C2802	D5201					K7538										Z8201	Z9104
A8905	B0143	B1722	B6006-3	B7421	B8839	C5062	D5202					K7540										Z8202	Z9105
A8912	B0162-4	B1723	B6012	B7913	B8924	C5064	D5203					K7541										Z8204	Z9108
	B0163-1	B2002	B6012-1	B7914-1	B8930	C5212	D5205					K7542										Z8205	Z9109
	B0163-2	B2005-3-1	B6012-2	B7914-2	B8931	C5213	D5206					K7550										Z8206	Z9115
	B0205-4	B2005-3-2	B6016-1	B8347	B9010	C5222	D6022					K7551										Z8207	Z9201
	B0209	B2005-3-3	B6064-1	B8357	B9070	C5223	D6024					K7552										Z8208	
	B0209-2	B2202	B6064-2	B8365	B9100	C5270	D6101					K7553										Z8209	
	B0209-3	B2203	B6064-3	B8366-1	B9126	C5721	D6102					K7554										Z8210	
	B0209-4	B2210	B6064-4	B8366-2	B9126-1	C5722	D6103					K7555										Z8221-1	
	B0209-5	B2292	B6065-1	B8366-3	B9126-2	C5723	D6105					K7556										Z8221-2	
	B0210	B2292-1	B6065-2	B8366-4	B9126-3	C5724	D6106					K7563										Z8221-3	
	B0211	B2292-2	B6066-1	B8366-5	B9126-5	C5725	D6107					K7564										Z8222-1	
	B0212	B2292-3	B6066-2	B8366-6	B9206	C6010	D6407					K7565										Z8222-2	
	B0216-3	B2293	B6104	B8366-7	B9209	C6822	D6601															Z8222-3	
	B0217-2	B2355-2	B6109	B8367-1	B9224	C7005	D6602															Z8250	
	B0218	B2355-3	B6109-1	B8367-2	B9508	C7009	D6703															Z8305	
	B0401-1	B2401-2	B6109-2	B8367-3	B9511	C7040	D6704															Z8313-1	
	B0401-2	B2402-1	B6131	B8367-4	B9516	C7103	D6705															Z8313-5	
	B0403	B2404	B6161	B8367-5	B9521	C7104	D6709															Z8316	
	B0404	B2406	B6163	B8367-6	B9522	C7506-1																Z8317	
	B0405	B3102	B6310	B8368-1	B9607	C8101																Z8317-1	
	B0408	B3700-202	B6337	B8368-2	B9614	C8702-2																Z8318	
	B0672-2	B3700-224	B6339-1	B8368-3	B9615	C9309																Z8503-4	
	B1002	B3700-225	B6339-2	B8368-4	B9911	C9310																Z8617-1	
	B1013	B3700-47	B6339-3	B8369	B9912																	Z8617-10	
					B9913																		

Note: n=635 (As of 2014)

Table C.1 Correlation coefficient.

	term	cat1	cat2	cat3	cat4	cat5	cat6	cat7	cat8	cat9	cat10	cat11	cat12	cat13	cat14	cat15	cat16	cat17	cat18	cat19	p_type	m_type	d_type	withdrawal	replacement	amendment	international	legislative
term	1.000																											
cat1	-0.012	1.000																										
cat2	-0.008	-0.104	1.000																									
cat3	-0.172	-0.103	-0.175	1.000																								
cat4	0.060	-0.045	-0.076	-0.076	1.000																							
cat5	0.037	-0.034	-0.058	-0.057	-0.025	1.000																						
cat6	0.108	-0.054	-0.092	-0.091	-0.040	-0.030	1.000																					
cat7	0.037	-0.047	-0.080	-0.080	-0.035	-0.026	-0.042	1.000																				
cat8	0.049	-0.048	-0.082	-0.081	-0.035	-0.027	-0.043	-0.037	1.000																			
cat9	0.111	-0.116	-0.196	-0.195	-0.085	-0.064	-0.102	-0.089	-0.091	1.000																		
cat10	0.056	-0.040	-0.067	-0.067	-0.029	-0.022	-0.035	-0.031	-0.031	-0.075	1.000																	
cat11	0.101	-0.033	-0.055	-0.055	-0.024	-0.018	-0.029	-0.025	-0.026	-0.062	-0.021	1.000																
cat12	0.040	-0.024	-0.040	-0.040	-0.017	-0.013	-0.021	-0.018	-0.019	-0.045	-0.015	-0.013	1.000															
cat13	-0.087	-0.020	-0.034	-0.034	-0.015	-0.011	-0.018	-0.016	-0.016	-0.038	-0.013	-0.011	-0.008	1.000														
cat14	0.018	-0.044	-0.075	-0.074	-0.032	-0.025	-0.039	-0.034	-0.035	-0.083	-0.029	-0.024	-0.017	-0.015	1.000													
cat15	0.003	-0.039	-0.066	-0.065	-0.029	-0.022	-0.034	-0.030	-0.031	-0.073	-0.025	-0.021	-0.015	-0.013	-0.028	1.000												
cat16	-0.078	-0.054	-0.092	-0.091	-0.040	-0.030	-0.048	-0.042	-0.043	-0.103	-0.035	-0.029	-0.021	-0.018	-0.039	-0.034	1.000											
cat17	-0.007	-0.026	-0.043	-0.043	-0.019	-0.014	-0.023	-0.020	-0.020	-0.048	-0.017	-0.014	-0.010	-0.008	-0.018	-0.016	-0.023	1.000										
cat18	-0.162	-0.058	-0.098	-0.097	-0.042	-0.032	-0.051	-0.045	-0.045	-0.109	-0.037	-0.031	-0.022	-0.019	-0.041	-0.037	-0.051	-0.024	1.000									
cat19	0.004	-0.071	-0.121	-0.120	-0.053	-0.040	-0.063	-0.055	-0.056	-0.135	-0.046	-0.038	-0.028	-0.024	-0.051	-0.045	-0.063	-0.030	-0.067	1.000								
p_type	0.170	-0.045	0.022	0.059	-0.025	0.027	0.137	-0.025	-0.099	-0.079	-0.026	-0.077	-0.080	0.056	-0.121	0.065	0.090	0.013	0.140	-0.059	1.000							
m_type	-0.159	0.052	-0.085	-0.043	0.007	-0.033	-0.130	0.040	0.118	0.110	0.033	0.084	0.087	-0.054	0.122	-0.068	-0.081	-0.028	-0.137	0.044	-0.909	1.000						
d_type	-0.038	-0.014	0.144	-0.042	0.045	0.013	-0.027	-0.031	-0.036	-0.065	-0.015	-0.010	-0.010	-0.009	0.009	0.002	-0.029	0.033	-0.019	0.038	-0.288	-0.138	1.000					
withdrawal	0.072	0.007	-0.038	-0.042	-0.029	0.054	0.063	-0.056	-0.018	0.058	0.038	0.018	0.023	-0.028	-0.039	0.061	-0.037	0.021	0.012	-0.019	0.177	-0.179	-0.008	1.000				
replacement	0.095	0.108	0.005	-0.020	0.009	-0.009	-0.018	-0.020	0.022	-0.022	0.001	-0.008	0.046	-0.012	-0.009	0.014	-0.009	-0.010	-0.029	-0.010	0.002	0.004	-0.014	-0.093	1.000			
amendment	0.661	0.052	-0.029	-0.057	0.031	0.054	0.071	0.017	0.047	0.026	0.054	0.056	0.024	-0.053	0.000	0.047	-0.036	-0.038	-0.160	-0.020	0.194	-0.181	-0.046	0.107	0.071	1.000		
international	-0.325	-0.103	0.060	0.173	-0.011	-0.078	-0.108	0.012	-0.059	-0.062	-0.024	-0.035	0.015	0.070	-0.072	-0.109	0.024	-0.012	0.164	-0.004	-0.127	0.097	0.080	-0.349	-0.002	-0.266	1.000	
legislative	-0.019	0.039	-0.058	0.066	-0.050	-0.039	-0.020	0.098	-0.055	0.031	-0.052	-0.038	-0.036	-0.013	-0.032	-0.002	0.189	-0.034	-0.077	-0.032	0.108	-0.091	-0.048	-0.233	0.002	0.098	0.071	1.000