RIETI Policy Discussion Paper Series 14-P-020

Age of De Jure Standard and its Determinants:
Dataset linking standard technology areas to economic survey data

TAMURA Suguru
RIETI

Research Institute of Economy, Trade & Industry, IAA

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

RIETI Policy Discussion Paper Series 14-P-020
August 2014

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Abstract

This paper discusses factors that relate to the age of valid standards. Unlike patents and copyrights, standards are created without a fixed effective time set by law. A linked dataset is first prepared by connecting the technology categories of the Japanese Industrial Standards—the de jure standards in Japan—to public economic censuses by the Japanese government such as the Basic Survey of Japanese Business Structure and Activities. The dataset is used for empirical analysis of the relationship between economic factors and age of standards. A notable result is that the "Electronic and Electrical Engineering" classification has a significant negative relationship with the age of standards, which may be explained by the fact that competition and technology divergence contribute to making the age of standards younger.

Key words: Age, De jure standard, De facto standard, Patent in practice
JEL classification: O30

This study is conducted as a part of the Project "Standard and intellectual property" undertaken at Research Institute of Economy, Trade and Industry (RIETI). The author appreciates the variable comments of Professor Aoki and Professor Nagaoka at Hitotsubashi university and Vice CRO Dr. Morikawa and Senior Fellow Dr. Thorbecke at RIETI.

1. Introduction

This paper discusses the factors related to age of valid standards. Unlike patents and copyrights, standards are created without legal time limits. This is true for de jure standards as well as de facto standards. Factors that determine the age of standards is the central focus of this paper. This research targets all Japanese Industrial Standards (JIS) that have been continuously valid.

In terms of their formation process, standards can be generally divided into three kinds: de jure standards, de facto standards, and consortium standards. De facto and consortium standards are generally formulated as the result of market mechanisms and competition, while de jure standards are usually formulated through the activities of public standards development organizations responding to requests from producers or consumers. Stated simply, de facto and consortium standards are formed among corporations to improve the marketization of their own technologies, whereas de jure standards are formulated with an additional consideration, namely, the public welfare. The effective term of intellectual properties other than standards, such as patents, are set by law. For this reason, the economic value of such intellectual assets has a fixed framework for research. As a result, the determinants of this economic value have been widely researched. In the case of de jure standards, however, they are abolished at the request from the users of the standards through a rules-based process, usually in five-year intervals. This leads to standards being in effect for different periods of time. Some standards exist for only a short period, while others are in effect for as long as 50 years. In this context, an older age implies that the standard has been in use for a long time and suggests that the technological information contained in the written standards is used for practical applications in industrial and social activities. It is thus appropriate to assume that the type or purpose of a standard and the characteristics of its industrial sector will influence the age of standards. Information on age is expected to be beneficial to policy makers and academic researchers when discussing the long-term value of standards as technological information.

i) Research subject and terminology

The scope of this research is as follows. Standards that have been abolished or have been amended are excluded. The research subject is current standards that have been continuously in effect and that have not been amended. JIS standards are reviewed every five years through a review process in which the opinions of standard users, such as those in the industrial and business sectors, are collected. Based on their opinions, it is decided whether each standard should be abolished, amended, or maintained. In brief, the term “age” in this research refers to the starting year of each standard. Given that new standards are created each year, the starting year of the existing standard varies.

Unlike in the case of patents, there is no annual maintenance fee for standards. However, because resources for total standard maintenance are limited, there are opportunity costs for keeping standards in effect. In the case of JIS, the costs are covered by the revenue from the sale of published booklets detailing each standard. Thus, if one standard ceases to be used in society at all, the sales of the standard's booklet should drop to nearly nothing. If such a standard is kept instead of replacing it with a new standard that will actually be used, the potential revenue from the new standard is lost. This is the opportunity cost of maintaining a standard that is no longer used. This implies that extending a standard involves opportunity costs at each review time. Therefore, JIS standards that are maintained, even with the chance to revise or discontinue the standard every five years, are thought to be valuable. We can then assume that the past number of chances for revision reflects the realized value of these standards.

ii) Aims of this study

One aim of this study is to provide novel statistical correlations among factors such as the age of a standard, the industrial category, and the number of corporations. Assembling the data for such statistical analysis is also a main aim of this research, so that the data can serve as a foundation for further progress in research on analyzing standards.

2. Literature Review

In recent research regarding standards, it has been pointed out that empirical and theoretical work considers mainly (1) costs, such as transaction costs and cost reductions in production; (2) competition, such as using standards to organize markets; or (3) communication and coordination, such as organizing the development of technology around agreed technical specifications (Blind et al. 2010). From a macroeconomic perspective, another research focus is the role of standards in international trade flows (Blind and Jungmittag 2005).

Another aspect to be considered with respect to age of standards is market competition. Bresnahan and Yin (2007) examined de facto standards in the web browser market by focusing on the competition between Internet Explorer and Netscape Navigator. In that study, the research subject was the time between the starting and ending dates of de facto standards. The web browser market share rapidly changed between 1996 and 1999, during which the market share of Internet Explorer climbed from 10% to 60%, while that of Netscape Navigator fell from 90% to 30%—a stark reversal. At the time, a pre-existing standard regarding computer operating systems was already established by Microsoft Windows. Control of distribution channels is suggested as one reason for this drastic market change. This case implies that control of distribution channels can strongly affect existing standards.

Yamada and Kurokawa (2005) researched aspects of ages of de facto standards for information technology and audiovisual standards. That study looked at the time between the starting and ending dates of de facto standards in those industries. Thirteen standards were examined, including those for CDs, DVDs, and VCRs, and this provides valuable data about age of the de facto standard for each product. Among the standards, the longest-lived was for the floppy disk (24 years), and one of the shortest was for the Betamax VCR (3 years). The research pointed out that an older age of de facto standards had a significant positive correlation with the profits arising from the standards (Yamada and Kurokawa 2005). The definition of the end of de facto standards was not specified, but the results of this research are worth noting since the analytical framework for dealing with the relation between the end of de facto standards and their relation on long-term profit is probably first presented there.

In regard to the formation of standards, it has been pointed out that in the case of audiovisual and information technology-related fields in Japan, de facto standards are likely to become fixed when the share of a product reaches 2–3% of the market. This can be historically observed in the cases of the VCR, video disc format, and gaming hardware (Yamada and Kurokawa 2005). In terms of the timing for forming a standard, it is observed that the earlier a firm establishes a majority market share, the more likely it is to establish a de facto standard (Yamada and Kurokawa 2005). The results of such cases can be applied to the analysis of de jure standards setting.

As for the usage and type of standards, the contribution of standards in emerging research areas is also an important topic. Nanotechnology in Germany is one area that has been studied in terms of this point (Blind and Gauch 2009). It has been pointed out that the market success of nanotechnology applications depends strongly on the development of related standards, which include marks, terminology, measurement, and testing methods, as well as safety and health aspects. This result implies that standards setting even before the start of production is important. Those findings explain the role of standards in terms of how they contribute to creating new markets from scientific discovery (Blind and Gauch 2009). In addition, this implies that standards play an important role at even the basic research stage and that standards related to marks, terminology, measurement, and testing methods in particular are important.

The de jure standardization framework of Japan is the Japanese Industrial Standards (JIS). JIS is prepared on a needs basis. Drafts of JIS standards are prepared within the interested group, so the standards are not formed by market competition only. A point of contrast with de facto standards is that the formation process of de jure standards occurs in public, and during the preparation, an agreement among the related groups is respected, whereas de facto standard setting is led by market share. Since, in the case of the JIS, the standard formation process is handled by a public agency and the result is open to the public, the starting date of each standard is clear and age is measurable. But in the case of de facto standards, both the starting date and the ending date are unclear. Regarding monetary cost, there is no maintenance fee for the usage of a standard, whereas in the case of patents, the patent owner must pay maintenance fees after the patent is awarded.

Regarding ages of standards, David (1985) studied keyboard arrangements. Specifically, that study examined the standard starting time and the reason of continuation of the key arrangement. The QWERTY key arrangement found on most keyboards today was established about 100 years ago. This key arrangement is not the most efficient in terms of ergonomics, and indeed was designed to restrain typing speeds because the mechanical parts of typewriters at the time had insufficient response times to keep up with the typing speed of humans. Such mechanical problems were later solved as typewriting machine technology improved, but the key arrangement remained. One reason for this is a lock-in effect arising from human skill. Even today, despite the typewriter having been replaced by the personal computer, the QWERTY key arrangement remains in use. This is an example of a de facto standard. This case also qualitatively demonstrates the cause and effect of a standard continuing without amendment. In this case, the user has a large influence over the end of standards.

In addition, it is valuable to understand not only why de facto standards are formed, but also why they are not formed. For instance, the four-channel stereo system is a case where de facto standards were not established (Postrel 1992). Four-channel stereo systems add two speakers to the conventional two-speaker system, allowing such systems to create better three-dimensional acoustic effects. While several audio manufactures established unique four-channel stereo standards in the 1970s, no de facto standard emerged because consumers could not distinguish between the competing standards, and eventually new media such as CDs replaced this analog recording media. With respect to the no establishment of standards, this case shows the influence of users as well.

As seen from the above cases, the beginning and end of de facto standards have been qualitatively analyzed through long-term observation. On the contrary, age of de jure standards have not been well investigated. However, the age of such standards, that is, those that have not been amended or abolished, is available and the basic data were reported previously but without statistical analysis (Aoki et al. 2012). De jure standards are formulated under the influence of public authorities, so the need for individual standards is determined from a policy perspective, rather than by market competition. However, even in the case of de jure formation, the need for individual standards is reflected during establishment of the standard. Therefore, even de jure standards are influenced by market needs, just as de facto standards are.

In the existing research on the age of de jure standards, there is a particular lack of long-term observation combined with quantitative measurement. The present research tries to view standards from both perspectives by studying factors associated with age and presenting the implications of the results. Doing so should be beneficial to elucidate the nature of standards setting by administrative authorities.

3. Hypotheses

3.1 Difference by industrial sector

Age may differ significantly by industry. This can occur due to, for example, technology orientation and technology replacement, which is high in some industrial categories and low in others. This leads to hypothesis 1.

Hypothesis 1:
Age of a standard significantly correlates with its industrial category.

3.2 Patent stock

The relationship with patent stock is worth surveying since standards and patents are fundamentally opposite effects: standards open technology information, while patents monopolize technology information. Hence, if the scale of patent stock is large, the need for the standards is anticipated to be weak in the industrial sector. Thus, this implies that the age of standards will be younger. This relationship will be observed more precisely since the number of patents in practice is used in this study.

Hypothesis 2:
Age of a standard significantly and negatively correlates with the scale of patent stock.

3.3 Difference by industry size

We examine industrial sector size to control for the number of the standards relating to a given industry. In the case of JIS, the number of standards relating to a given industry varies. For example, there are 72 standards in the category “Pulp and Paper” in the JIS of 2010, but 1535 standards in the “Electronic and Electrical Engineering” category. The difference may reflect the technological divergence of the industry.

The industry size or number of corporations may increase demand for specific standards and thus increase their value, leading to greater survival of standards. Another possibility is that an increase in industry size or the number of corporations leads to technological divergence of standards and decreases the demand for specific standards. This may decrease the survival of standards. To examine this relationship, we propose hypothesis 3.

Hypothesis 3:
Age of a standard significantly and positively correlates with the market size and the number of corporations in the industrial sector.

3.4 Difference by economic environment
To see differences due to the economic situation in the year when a standard is set, we consider the economic growth rate at the time. The role of standards in industrial policy has varied. One role is for process innovation, by reducing manufacturing costs through shape or production form unification. Such standardization simplifies manufacturing processes, reduces labor training costs, and improves product quality. Such factors are especially important for mass production. The role of standards is thus considered important for medium and small enterprises, which do not have sufficient technological assets to differentiate their products from competitors.

During the period of high economic growth from 1950–1970 in Japan, economic policy was directed toward improving competitiveness through process innovation. Standards at that time were mainly for supporting cost reduction by production process improvement. In contrast, during the period of slower economic growth from 1980–1990 the emphasis was development of unique technologies, and accompanying this change the role of standards shifted from process innovation to product innovation. Hence, the economic growth rate may be significantly related to age of standards. The GDP growth from National Accounts data prepared by the Cabinet Office of Japan is used for the analysis.

Hypothesis 4:
Age of a standard significantly and positively correlates with economic growth in the year of standard formation.

3.5 Difference by type of standard
Examination and measurement standards are thought to be more stable than non-measurement standards, because measurement standards generate data used for legislative purposes; legislation demands continuity, so related standards must be stable. On the other hand, the emergence of new technologies requires new standards for measurement, so radical innovation can lead to formation of

new standards for measurement. Hence, in industrial sectors where radical innovation is commonplace, even measurement standards can be short-lived. This implies that in such sectors even measurement standards are likely to be replaced in the same way that non-measurement standards are replaced.

Hypothesis 5:

Age of a standard is significantly correlated with type of standard and positively correlated with measurement standards.

4. Methodology

4.1 Estimation equation

Ordinary least squares estimation is used to test these hypotheses, according to the following estimation equations.

Estimate equation 1:

$$\begin{aligned} Age = {} & Type\ of\ standard\ (dummy) + industry\ category\ (dummy) \\ & + industry\ sector\ sales + number\ of\ corporations \\ & + economic\ growth\ rate + patent\ stock\ in\ practice + constant \end{aligned}$$

Age: The starting year of the standard

Type of standard: Whether this is a measurement, mark, or production standard

Patent stock in practice: the number of patents in practice

4.2 Variables

Table 1 gives explanations of the variables used. Note that in the actual statistical analysis multicollinearity is observed, so some variables are not used.

[Table 1]

i) Age of standard

We compiled a list of JIS standards that have not been amended or abolished since their initial establishment. From among approximately 10,000 existing JIS standards, about 1300 met this criteria.

ii) Type of standard

Standards are first categorized as being related to (1) measurement or (2) marks. Categorization is according to the wording used in each standard title. Titles including the word *kensa* (measurement) or *shiken* (examination) are taken to indicate measurement standards. The word *kigou* (mark) is taken to indicate mark standards; otherwise, the standards are categorized as non-measurement standards, which are categorized as a production standard. For the analysis, three dummy variables for “type of standard” are set for statistical analysis.

iii) Industrial sector category

JIS standards are not coded to specific industrial categories in the manner of the Results of the Basic Survey of Japanese Business Structure and Activities, which is an official Japanese government survey (Ministry of Economy, Trade and Industry 2012). We therefore tentatively established connections between individual JIS standards and the industrial categories of the Basic Survey as shown in Table 2. Currently, the JIS system has 19 technology areas, distinguished by an alphabetic code. The areas are as follows.

1. Section A: Civil Engineering and Architecture
2. Section B: Mechanical Engineering
3. Section C: Electronic and Electrical Engineering
4. Section D: Automotive Engineering
5. Section E: Railway Engineering
6. Section F: Shipbuilding
7. Section G: Ferrous Material and Metallurgy
8. Section H: Nonferrous Materials and Metallurgy
9. Section K: Chemical Engineering
10. Section L: Textile Engineering
11. Section M: Mining
12. Section P: Pulp and Paper
13. Section Q: Management System
14. Section R: Ceramics
15. Section S: Domestic Wares
16. Section T: Medical Equipment and Safety Appliances
17. Section W: Aircraft and Aviation
18. Section X: Information Processing
19. Section Z: Miscellaneous

Among the 19 areas, 16 areas pertaining to the industrial sector are used.

[Table2]

iv) Industrial sector scale

Industrial sector scale is represented by the total sales volume and the number of corporations, which are calculated from the Basic Survey of Japanese Business Structure and Activities. These factors are expected to describe the size of each industry. In addition, the number of corporations will indicate the competitive environment of each industry.

v) Economic environment

The economic environment at the time when a given standard is formulated is considered using real GDP growth rate for the year.

vi) Patents in practice

The number of patents in practice in each industrial sector is calculated from the Basic Survey of Japanese Business Structure and Activities. This factor is anticipated to indicate the merger of patents and standards.

5. Results

5.1 Descriptive statistics

Table 3 shows descriptive statistics for the variables. The dummy variable for type of standard is set for three standard categories: measurement standards (m_type), mark standards (mark_type), and production standards (p_type). Industrial category variables are dummy variables indicating industrial category of standards. The JIS defines 19 technological areas, distinguished by alphabetic codes. These section categories are different from those used in the Basic Survey of Japanese Business Structure and Activities, so we merged some categories to determine the size of the corresponding industrial sector. The variable names are listed as “Class #” in Table 2.

[Table 3]

5.2 Correlation coefficient

Table 4 shows the correlation coefficients between variables.

[Table4]

5.3 Analytical results

Model 1 to model 5 from estimate equation 1 uses ordinary least squares to estimate the relationship to age (Table 5). The industrial categories c3, c8, and c12 are omitted from the estimation because of multicollinearity. Among the remaining variables, c11 is used as the default factor for the analysis and is omitted from the estimation variables. As for the "type of standard" dummy, among p_type, m_type, and mark_type, the mark_type is set as the default and is omitted from the estimation variables.

In regard to hypothesis 1, industrial sector dummies were found to have a significant relationship with age for "Electronic and Electrical Engineering" (class2), "Chemical Engineering" (class6), "Textile Engineering" (class7), and "Ceramics" (class10) in model 1. Hence, hypothesis 1 is supported. Among these categories, "Textile Engineering" (class7) shows positive coefficients.

The coefficient of patent stock is negative in model 5. This implies that companies do not standardize technology when a patented technology is useful in the industrial sector. Hence, the age of the standard is young. This result supports hypothesis 2. As for the difference among industrial categories, in the case of "Electronic and Electrical Engineering" (class2), the sign of the industry dummy becomes positive in model 5 when patent stocks are considered. This implies that when the number of the patents in practice is held constant, industrial sector tends to have a positive correlation with the age of the standard in comparison with other industries.

Hypothesis 3 is also supported, indicating that market size has a significant positive relationship with age of standards. This is because demand for the standard will increase with sales. As for the number of corporations in the industrial sector, there is a negative relationship explained by competition and technology divergence, which results in the age of standards being younger.

For hypothesis 4, which is about the relationship with economic growth, a significant positive coefficient of GDP growth rate is found. Older standards are seen in periods of high economic growth, supporting hypothesis 4. Industrial policy in Japan in times of high economic growth, such as the 1970s, used standards for the improvement of production efficiency. After this period, economic growth decreased and standards were used for product innovation.

We next look at the robustness of the signs *Sales_size*, which represents the sales size of each industry; *corpnum*, which represents the number of the corporation; and *GDPrate,* which shows the GDP growth rate. In model 1, the signs of *Sales_size* and *GDPrate* are positive and significant and the sign of *corpnum* is negative and significant. The result does not change for *Sales_size* and *corpnum* in model 2 after deletion of *GDPrate* from model 1. Even in model 3, the result is the same for *GDPrate* after deletion of *Sales_size* and *corpnum* from model 1. These results imply that the sign and significance of these factors are robust.

Hypothesis 5 is not supported. The coefficient of type of standard was not found to be significant. One reason for this is the methodology for categorizing the type of standard, which is done from the titles of standards. Detailed classification according to the contents of standards may be necessary.

[Table 5]

6. Discussion

Looking at the differences by industrial technology, we see that "Electronic and Electrical Engineering" (class2), "Chemical Engineering" (class6), "Ferrous Material and Metallurgy" (class7), and "Ceramics" (class10) have significant relationships with age of standard in model 1. "Electronic and Electrical Engineering" (class2), "Chemical Engineering" (class6), and "Ceramics" (class10) show negative coefficients when controlling for industry size and economic environment. It is notable that "Electronic and Electrical Engineering" has a significant negative relation with age. This result seems to agree with the intuitive understanding that in such industries the product lifecycle is fairly short, and therefore the lifecycle of standards becomes short as well. Standards play an important role in new product development in the sector, so the launch of new products results in the more frequent revision of standards.

Market size had a significant positive relationship with age of standards in models 1 and 2, indicating that larger product markets lead to greater survival of standards. In relation to market competitiveness, which is exemplified by the number of corporations, a larger number of corporations is found to have a negative relationship with age of standards. This is explained by the reasoning that each standard is short-lived in order to make standards diverse because technological competition among companies becomes fierce. No significant relationship with type of standard was observed for models 1 to 5.

7. Policy implications

i) Extension of review interval

In the correlation results of models 1 to 4, industry dummies for "Ferrous Material and Metallurgy" (class4), "Non-Ferrous Material and Metallurgy" (class5), and "Textile Engineering" (class7) exhibit positive correlations. These results imply that the standards in these industries tend not to be amended after review and thus are older. Therefore, it might be effective to increase the review interval for standards in such industrial sectors (i.e., to make it longer than five years) in order to reduce the administrative costs.

ii) Improvement of data infrastructure

This paper is the first attempt to connect JIS standard categories with statistical categories used in the Basic Survey of Japanese Business Structure and Activities. We believe that the preliminary statistical insight provided here indicates that such links will prove to be academically and administratively helpful and will lead to more advanced policy evaluation. We hope that the responsible policy makers will address the issue of making JIS industrial codes compatible with existing statistical classifications, such as those in the Basic Survey of Japanese Business Structure and Activities.

Further, to improve the statistical data infrastructure, a detailed category of each standard is essential for analysis at more refined levels. Currently, there are only 19 JIS standard categories. Such a technology category reporting system can be obtained from patent statistics, and it would be beneficial to apply a similar technology categorization to JIS standards. In the current system, the industrial category and technology category are not set according to the committee decision regarding the draft of each standard. In the current standard setting process, the JIS committee of the Japanese Industrial Standards Committee authorizes the draft of a standard after a technical drafting committee has prepared it. A new proposed rule would allow the technical committee to add statistical industrial categories and technology category from other datasets, following the opinion of the drafting members. The classification is sometimes difficult to judge, but accumulation of such new activities will gradually improve and formulate a general understanding of statistical categorization of standards.

8. Conclusion

This analysis examined the relationship of factors on the age of de jure standards by using JIS data rather than de facto standards, which have been previously researched. The result of the analysis shows new findings about the cross section and we do not necessarily describe the cause and effect fully in this survey. Several interesting observations were made. First, the number of patents in practice has a negative relationship with the age of standards. This meets the intuitive understanding that patented technology does not become standards. As the number of patents in use increases, the motivation for standardization becomes weaker. Second, market size has a positive relationship with age of standard, while the number of corporations has a negative relationship. Third, past economic growth rate can well explain age of standard empirically. It is because, in the long run, standardization policy is affected by and responds to past economic conditions.

In addition, the limitations of this research and the need for further work are as follows. In this research, de jure standards that have not been amended or abolished after their formation are studied. This research framework is similar to a previous analysis of the de facto standard for QWERTY key arrangement, which also has not been amended or abolished since its creation (David 1985). This study considered de jure standards, whereas the previous study considered a de facto standard. The present research focuses on the same continuing standards for a different type of standard in an attempt to develop the results of the previous study.

Another research framework has been adopted in previous research on de facto standards (Yamada and Kurokawa 2005). In that work, abolished standards were taken as the research subject rather than existing standards. In future research, such a framework would useful to adopt. We anticipate using de jure standards that have been abolished and amended as research subjects so that we can make comparisons with Yamada and Kurokawa's work and develop the results of that study.

We conclude with a supplemental note. It is proposed that standard booklet sales can provide a method for directly monitoring the economic importance of each standard. If sales data were open, they would be a good indicator of the yearly dynamics of each standard's value. However, these data are not available, either domestically or internationally. De jure and international standards are sold as booklets or PDF files, but sales data regarding the JIS standards are not available, nor are those of most international de jure standards such as ISO/IEC standards. As domestic de jure standards, JIS standards are prepared for public use, such as for ensuring adherence to regulations, it would be desirable to open such related data so as to improve the policy of economic analysis.

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Tables:

Variable	Variable name in estimation equation	Explanation	Source	Notes
Age of standard	Year	Establishment year of the standard	Data from JIS (2011)	In Equation 1
Type of standard	p_type, m_type mark_type	Dummy variables for standard category: "p_type" indicates a production standard; "m_type" indicates a measurement standard; "mark_type" indicates a mark standard.	Data from JIS (2011)	Dummy variable In Equations 1
Industrial category	c1, c2, c3, …, c12	Dummy variable for industrial category	Data from JIS (2011)	Dummy variable In Equations 1
Industry size	Sales_size	Sales within the industrial category	Data from Results of the 2011 Basic Survey of Japanese Business Structure and Activities (billions of yen)	In Equation 1
Number of corporations	corpnum	Number of corporations in the specific industry category	Data from Results of the 2011 Basic Survey of Japanese Business Structure and Activities (thousand)	In Equation 1
Economic growth	GDPrate	Past real GDP growth rate of Japan	SNA, Cabinet Office of Japan (%)	In Equation 1
Patents in practice	usepatentstock	Number of patents in practice	Data from Results of the 2011 Basic Survey of Japanese Business Structure and Activities	In Equation 1

Table 1. Explanation of variables

JIS category	Industrial category according to the Basic Survey of Japanese Business Structure and Activities	2011 total sales (billions of yen)		Variable name
2:B Mechanical engineering	260 Production machinery	9410		Class1(c1)
3:C Electronic and electrical engineering	280 Electric parts and device 290 Electric machinery 300 Information and telecommunication	14200 13148 27027	Total: 54375	Class2(c2)
4:D Automotive engineering 5:E Railway engineering 6:F Shipbuilding W Aircraft and aviation	310 Transportation machinery	55481		Class3(c3)
7:G Ferrous material and metallurgy	220 Ferrous material and metallurgy	14792		Class4(c4)
8:H Nonferrous materials and metallurgy	230 Nonferrous materials and metallurgy	11007		Class5(c5)
9:K Chemical engineering	160 Chemical industry 170 Oil and coal product 180 Plastic industry 190 Rubber industry	31264 13393 7282 2792	Total:54731	Class6(c6)
10:L Textile engineering	110 Textile engineering	2259		Class7(c7)
11:M Mining	Mining	938		Class8(c8)
12:P Pulp and paper	140 Pulp and paper	5038		Class9(c9)
14:R Ceramics	210 Ceramics	4204		Class10(c10)
16:T Medical equipment and safety appliances	274 Medical equipment and safety appliances	1999		Class11(c11)
18:X Information processing	391 Software 392 Information processing	10288 6198	Total:16486	Class12(c12)
1:A Civil engineering and architecture 13:Q Management systems 19:Z Miscellaneous	N.A.			

Table 2. Overview of industrial sectors and JIS categories

Variable	Obs	Mean	Std.Dev	Min	Max
Year	1341	17.38404	7.339182	12	57
p_type	1341	0.4422073	0.4968341	0	1
m_type	1341	0.4951529	0.500163	0	1
mark_type	1341	0.0641312	0.245078	0	1
c1	1341	0.1715138	0.3770979	0	1
c2	1341	0.1319911	0.3386073	0	1
c3	1341	0.1319911	0.3386073	0	1
c4	1341	0.0134228	0.1151196	0	1
c5	1341	0.054437	0.2269626	0	1
c6	1341	0.2706935	0.4444838	0	1
c7	1341	0.0171514	0.1298838	0	1
c8	1341	0.0111857	0.1052084	0	1
c9	1341	0.00522	0.0720875	0	1
c10	1341	0.0395227	0.1949077	0	1
c11	1341	0.043997	0.205165	0	1
c12	1341	0.108874	0.3115972	0	1
Sales_size	1341	33851.54	22743.53	938	55481
corpnum	1341	1340.063	594.2178	37	1890
GDPrate	1341	1.740567	2.325731	-0.5	12.4
usepatentstock	1341	80595.23	69131.08	20	177747

Table 3. Descriptive statistics

	Year	p_type	m_type	mark_type	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	Sales_size	corpnum	GDPrate	usepatntstock
Year	1																			
p_type	0.1394	1																		
m_type	-0.1543	-0.8818	1																	
mark_type	0.0353	-0.2331	-0.2471	1																
c1	0.0611	0.1764	-0.2132	0.0828	1															
c2	-0.1033	0.0476	-0.016	-0.0661	-0.1774	1														
c3	0.1835	0.0964	-0.1306	0.0778	-0.1774	-0.1521	1													
c4	0.0937	-0.0256	0.04	-0.0305	-0.0531	-0.0455	-0.0455	1												
c5	0.0645	-0.1475	0.1437	0.0043	-0.1092	-0.0936	-0.0936	-0.028	1											
c6	-0.1778	-0.3769	0.4138	-0.0841	-0.2772	-0.2376	-0.2376	-0.0711	-0.1462	1										
c7	0.1058	0.0558	-0.0849	0.0592	-0.0601	-0.0515	-0.0515	-0.0154	-0.0317	-0.0805	1									
c8	0.1133	-0.0661	0.0648	0.0011	-0.0484	-0.0415	-0.0415	-0.0124	-0.0255	-0.0648	-0.0141	1								
c9	0.0019	-0.0437	0.0524	-0.019	-0.033	-0.0282	-0.0282	-0.0084	-0.0174	-0.0441	-0.0096	-0.0077	1							
c10	-0.1082	-0.1729	0.1972	-0.0531	-0.0923	-0.0791	-0.0791	-0.0237	-0.0487	-0.1236	-0.0268	-0.0216	-0.0147	1						
c11	0.0264	0.1604	-0.1397	-0.0413	-0.0976	-0.0837	-0.0837	-0.025	-0.0515	-0.1307	-0.0283	-0.0228	-0.0155	-0.0435	1					
c12	-0.0216	0.2962	-0.3222	0.0551	-0.159	-0.1363	-0.1363	-0.0408	-0.0839	-0.2129	-0.0462	-0.0372	-0.0253	-0.0709	-0.075	1				
Sales_size	-0.1051	-0.2122	0.239	-0.0579	-0.4891	0.352	0.371	-0.0978	-0.2411	0.5595	-0.1836	-0.154	-0.0918	-0.2645	-0.3006	-0.267	1			
corpnum	-0.1951	-0.0674	0.0832	-0.0353	-0.2689	0.323	-0.0539	-0.1764	-0.3947	0.564	-0.1919	-0.2333	-0.1138	-0.3067	-0.4435	0.2501	0.7539	1		
GDPrate	0.793	0.1222	-0.1471	0.0524	0.0569	-0.1103	0.1502	0.0657	0.0254	-0.1401	0.0834	0.0774	-0.0053	-0.0834	0.0421	0.0097	-0.0973	-0.1533	1	
usepatentstock	-0.2191	-0.3102	0.3556	-0.1007	-0.3459	0.2697	-0.2006	-0.1158	-0.2547	0.8565	-0.1501	-0.124	-0.0817	-0.2223	-0.2387	-0.2303	0.81	0.8112	-0.1846	1

Table 4. Correlation coefficients

	model1	model2	model3	model4	model5
p_type	0.7741	0.639	0.6887	0.4742	0.8705
	[]1.50	[]0.78	[]1.33	[]0.58	[]1.69*
m_type	0.379	-0.6466	0.5288	-0.3189	0.3122
	[]0.71	[]-0.76	[]0.99	[]-0.37	[]0.58
c1	0.3997	0.3166	-0.1603	-0.7733	17.2346
	[]0.94	[]0.47	[]-0.44	[]-1.33	[]3.43***
c2	-0.9888	-3.7033	-0.8131	-3.5714	156.1427
	[]-1.98**	[]-4.71***	[]-1.98**	[]-5.52***	[]3.34***
c4	2.1278	3.8662	2.2719	4.4073	-2.2496
	[]1.92*	[]2.21**	[]2.12**	[]2.58***	[]-1.32
c5	0.9188	0.2428	0.996	0.6196	-7.2863
	[]1.36	[]0.23	[]1.69*	[]0.66	[]-2.88***
c6	-1.2823	-3.3128	-1.2459	-3.4804	256.9969
	[]-2.67***	[]-4.38***	[]-3.35***	[]-5.93***	[]3.34***
c7	2.1821	4.3833	1.9114	4.0821	-12.2073
	[]2.16**	[]2.75***	[]2.02**	[]2.71***	[]-2.77***
c9	0.3766	-0.9323	0.1796	-1.148	-13.2259
	[]0.22	[]-0.34	[]0.11	[]-0.43	[]-3.01***
c10	-1.7148	-4.7188	-1.994	-5.1494	-10.9266
	[]-2.24**	[]-3.90***	[]-2.90***	[]-4.73***	[]-3.84***
Sales_size	0.0000378	0.0000771			0.0009893
	[]3.64***	[]4.71***			[]3.49***
GDPrate	2.4014		2.4237		2.3903
	[]44.80***		[]45.21***		[]44.68***
corpnum	-0.0011	-0.0026			0.0308
	[]-2.82***	[]-4.09***			[]3.24***
usepatentstock					-0.0021
					[]-3.36***
_cons	13.2496	19.6185	13.0315	18.925	14.6029
	[]17.76***	[]16.91***	[]24.74***	[]23.28***	[]17.27***
R-squared	0.6459	0.1104	0.6415	0.09	0.6489
Adj-R-squared	0.6424	0.1023	0.6385	0.0832	0.6452
N	1341	1341	1341	1341	1341

* p<0.1, ** p<0.05, *** p<0.01

Table 5. Estimation results (Models 1–5)