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Standards as a knowledge source for R&D: A first look at their incidence and impacts based on the inventor survey and patent bibliographic data[1]

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Abstract

This paper analyzes how standards as a knowledge source are important for R&D, how significantly the (backward) citations by a patent of standard-related documents measure such knowledge flow, and how significantly they affect the performance of downstream R&D. Using both the RIETI inventor survey in Japan and the bibliographic information of triadic patents families, we show that standard information—that embodied in the standards and related documents—has become very important as a knowledge source for the conception of R&D projects in the information and telecommunication area (ICT), and that the frequency of the patents citing standard documents has been increasing. The citation information in US patent documents can be effectively used to measure the knowledge flows from standards to inventions, although it covers only a limited portion of the knowledge flow. The R&D projects intensively using standard information tend to generate valuable patents and also a large number of patents, controlling for research labor input, the use of scientific literature, as well as that of patent literature. A patent that uses private international forum standards as a knowledge source is significantly more cited than a patent that uses national or international public standards as a knowledge source.

Keywords: standard, research productivity, and patent.
JEL classification: O31; O32; O34; L15

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1. Introduction

Standards have become very important in the innovation process in recent years, especially in information and communication technology area (ICT) where network externality is important. This paper empirically analyzes standards as a knowledge source for downstream R&D.A new standard plays a critical role in introducing innovations based on a new generation of technology. Many new and better products and services have been brought into the markets, for example, with the transitions from CD to DVD, from MPEG2 to MPEG4, and from 2G to 3G mobile phones. In such innovations, the progress of the platform technology defining the standard provides R&D opportunities for downstream innovations while the pursuits of these downstream innovations enhance the demand for further progress of the core technology. Thus, successful standard-based innovation creates a virtuous cycle between the progress of standard technology and the downstream innovations in the manner modeled as a general purpose technology (Bresnahan and Trajtenberg (1995) and Bresnahan (2010)). Disclosed standard documents may provide important technical information which can serve as a basis of new product or process development compatible with the standard. Furthermore, a standard based R&D may get benefitted from both from a large product market as well as a large number of complements, due to the network externality from the standard.

In this paper, we will analyze three specific questions: (1) how extensively the information embodied in standards and the related documents are used in R&D, (2) how significantly citations by a patent of standard related documents measure knowledge source for R&D, and (3) how they affect the R&D performance, depending on the types of the source standard bodies. We focus on open and collaborative standards where firms disclose the standard documents publicly. Although there exists anecdotal information of the importance of standard information for R&D, there is no systematic evidence available for these questions. For an example, Gandal et al. (2007) examined the relation between patenting and participation in standardization committees by engineers. They concluded that patenting is predicted by participation in earlier standardization meetings. According to their view, firms seem to get benefitted from producing a good complying with technical standards, which provides the benefits of compatibility with other firms' complementary goods or services, and the certification of performance, especially when the market is characterized with network effects. Greenstein and Stango (2007) provide the other interesting case studies on standards and standard-related patents. What we are going to provide in this paper is systematic and comprehensive assessment of the importance of standards as a knowledge sources for R&D, based on project level information from the survey of Japanese inventors and on the bibliographic information of patent documents.

To the best of our knowledge, there is no study exploiting these data to assess the knowledge flow from standards to inventions, although there is a large volume of literature using the citation information as an indicator of knowledge flow from patent and science literature (see Nagaoka, Motohashi and Goto (2010) for a survey). One of the main methodological tasks of this paper is to evaluate the backward citation to standard documents as an indicator of knowledge flow, since we know that a backward citation can be a very noisy measure of knowledge flow. Jaffe et al. (2002) did a direct survey on inventors to validate backward citation to patent literature in the US as a measure of knowledge flow. They found that the inventors were not aware of the majority of the cited patents, since they were given by the inventor's patent attorney or the patent office examiner[2]. In this paper, we evaluate the usefulness of backward citation to standard related documents by its comparison with the inventor's recognition of knowledge flow available from the inventor survey in Japan and

[2] Inventor citations and examiner citations can be very different in the US. Thompson (2006) finds that the distribution of inventor citations is more local than that of examiner citations so that localization effects of knowledge flow seem to exist, although the extent of localization identified is much smaller than that as suggested by Jaffe, Trajtenberg and Henderson (1993).

by examining who (examiners or inventors) cite standard documents. After establishing its usefulness, we will assess how extensively standard documents from different types of standard organizations (private international forum standards, national/regional standards, or international public standards) are used and how they affect the invention performance, taking advantage of the fact that the bibliographic information can help us identify the standard organizations which produced such documents.

Our empirical work exploits both the results of Japanese inventor survey, which we have implemented as a part of the research project of Research institute of Economy, Trade and Industry (RIETI), and the bibliographic information of the disclosure documents of the patents. In the RIETI inventor survey, we asked inventors to assess how standard related documents are important for conception of the invention. This is the first systematic attempt to assess the importance of standards as a knowledge source, as far as we can tell. The main targets of RIETI inventor survey are the R&D projects that yield OECD triadic patent families (3,700 patent families; priority year from 1995 to 2001) and the other (non-triadic) patents applied to Japan Patent Office (non triadic patents; 1,500 patents, priority year from 1995 to 2001). The OECD triadic patents family is a group of patents applied to the Japan Patent Office, the European Patent Office and granted from the US Patent and Trademark Office with common priorities, which have high quality to cover the international application costs, including the cost of translation to foreign language.

The rest of the paper is organized as follow. In section 2 we provide summary statistical data to see how standards have become important as a knowledge source for R&D, using both the RIETI inventor survey and the bibliographic information. In section 3, we provide more detailed description of the reference of the triadic patents to standard documents by different standard organizations, by technology areas, by year and by the location of inventions, in order to understand the nature of such references. In section 4 we describe the main hypotheses with respect to the effects of standards on downstream innovations which we will examine statistically in section 5. Section 6 concludes.

2. Standards as knowledge source for R&D

2.1. How often do inventors see standard as very important knowledge source?

The RIETI inventor survey asked inventors to characterize their R&D project which yielded the focal patent in terms of the objectives and nature of R&D and the commercialization process of the patented invention. The sample inventions have priority from 1995 to 2001. They have at least one Japanese inventor (an inventor with an address in Japan). Table B-1 shows the number of responses by technology sectors[3].

In the survey, inventors were asked to assess the importance of each of 12 knowledge sources for getting the idea of the research in 5 point Likert scale. Table 1 shows the percentage of inventors answering "very important" for each knowledge source. If we focus on triadic patents, patent literatures are most often identified as a very important knowledge source. 22.5% of the inventors of triadic patents answered that it is "very important. Following this, scientific and technical literatures are evaluated as "very important" by 17.6% of the inventors. Standard related documents are very important for only 1.6% of inventors of triadic patents, which is the same level as the importance of non-university public research organizations. However, the importance of standard related documents as knowledge sources significantly differs across technology areas, as shown in Table 1. Standard related documents are regarded to be very important by 10% of the inventors in Telecom area, 5% in Audiovisual, IT, and Agriculture &Food process machine areas. The aggregate share of these technology areas in triadic patents is about 15%. Telecom, IT and Audiovisual are the

[3] ISI classifications are made by transforming International patent classification. About the details, see Giuri et al. (2007)

technology areas that are considered to have strong network effects.

(Table 1)

2.2. Citation and knowledge flow

In order to assess how the backward citations of standard related documents measure the knowledge flow, we have constructed the database of non-patent literatures cited by the US patents in OECD triadic patent family database (April 2008 version) which cover the patents with priories from 1978 to 2006, using the EPO Worldwide patent statistical database (PATSTAT September 2009 version). We extracted the families at least one patent of which cites at least one standard related document (See Appendix A about how we searched the families). Based on this data, we examined whether the triadic patents surveyed in the RIETI survey cited standard related documents or not. For this, we checked non-patent literature citations by the US patents in same family with the focal patents.

As shown in Table 2, standard related documents are cited in total by 26 patent families or 0.7% of the surveyed triadic patents. About a half of them chose "important" or "very important" answers for the contribution of standard documents in getting the conceptions of research (0.33 % in 0.71 % as shown in Table 2).

Probability (standard is either important or very important| standard is cited)

$$= (0.14+0.19)/0.71 = 0.46 \quad (1)$$

Thus important knowledge flow exists for about half of the cases where patent cite standard documents. Even if standard documents are cited, they may be cited only for the purpose of defining the scope of inventions clearly. In this case citation does not represent knowledge flow, which amounts to half of the cases.

(Table 2)

One reason why the backward citations of standard documents often represent knowledge flow is that they are predominantly cited by inventors. The US patents granted after 2001 disclose information who add the reference documents (inventors or examiners). The inventors cite standard documents in 93% of the above patent families which were granted in 2001 (Table 3). This tendency holds for the sample of all the triadic patents citing standard related documents; 98% are cited by inventors, which is larger than that of non-patent literature as a whole (97%). This is much higher than the share of inventors' citation of patent literature; around 72% in our case, which is higher than the result of Alcácer and Gittelman (2006). This might be due to difference of samples. Our sample consists of patents applied to three major patent offices, so that they focus on more important patents.

(Table 3)

Next we would like to evaluate how well do patents citation track the knowledge flow by directly citing standard related documents. If we include the cases where the standard documents were important (but not "very important") as knowledge sources for the conception of the research, the shares of such patents amount to 8.3% of the total triadic samples surveyed (see Table 2). The standard related documents are cited for about one tenth of the cases where the standard documents are recognized to be very important for the underlying research. They are cited in less than 3 % of the patents for which the standard documents are recognized to be important. Thus,

Probability (standard is cited | standard is either important or very important)

$$= (0.14+0.19)/(1.5+6.7) = 0.04 \quad (2)$$

Thus, the backward citation to standard documents represents only a small part of important or very important knowledge flow from standard documents recognized by an inventor.

Why is backward citation to standard documents rare, despite of the fact that they do contribute to the conception of the research project fairly often (8% if we include "important" cases)? The US patent law requires inventors to disclose the documents relevant to evaluating the patentability of the patent applications, so that the reference in the patent documents is selective in terms of the relevancy to novelty and non-obviousness. For an example, even if the standard documents are important for an inventor for providing information on the potential use of his invention, the standard documents used for such purpose may not serve as prior art.

There might be a question of whether a patent cites standard documents, because such patent is one of the essential patents of a standard. If such is the case, the citation of the standard documents does not indicate the knowledge flow from the standard to a patent but the other way around. We think that our analysis is not affected significantly by such reverse causation. First, our analysis focuses on the patent with the earliest date of application in the family, so that we exclude continuation applications. Since the documents which a patent cites are prior arts, such documents had to exist at the time of the first patent application of such invention. Second, we already show the direct evidence from an inventor survey in section 2-3 that standard is an important knowledge source for the underlying R&D project in about half of the patents citing the standard documents. Third, appendix D provides case-based evidence that the essential patents of standards do not cite patent documents often.

3. Structure of backward citations of the standard documents by standard organizations, technology area and locations

As described above, when standard documents are cited in a patent, an inventor of the citing patent often highly evaluate the importance of standard documents as knowledge sources for the R&D project. In this section, we examine the structure of backward citations of the standard documents in three dimensions: source of standard documents, technology area and location, using all the triadic sample.

3.1. Frequency of citations received by standard setting organizations

A patent cites standard documents themselves, and standard drafts, contributions, proposals. We have identified the backward citations of 16 large standard setting organizations (SSO, hereafter). Table 4 shows the number of patent families citing the standard related documents by these 16 SSOs[4]. 3,817 families cite standard related documents of one of a SSO. The most cited standard documents are those of ISO (cited by 1,022 families). These documents are often IEC standard at the same time.

(Table 4)

3.2. Differences by technology area

Table 5 shows the top 10 ISI areas in terms of the number of the patent families citing standard related documents. The sample is limited to those from 1995 to 2001 in terms of the earliest priority year in a family in order to be comparable with the results of RIETI inventor survey. Telecom and IT are the two major areas in which the patents cite the standard documents most frequently, which are very much in line with the results of the RIETI inventor survey (See Table 1). In Telecom area, 964 families cite standard related documents, which make up 4.8% of total triadic families in this area. That is, 4.8% of the patents have backward citations of standard documents in this area. In Information Technology area, 3.6% of triadic families cite standard documents (Appendix Table B-2 shows the distributions of these backward citations across standard bodies). The pattern of these shares are lower than the percentages of the inventors who chose “very important” for the importance of standard documents in RIETI inventor survey (see Table 1), but they are consistent.

(Table 5)

[4] Note that there are duplications. For example, a patent cites ISO/IEC standard documents.

3.3. Time trend of citations of standard documents

Figure 1 illustrates how the total number of triadic families[5] (line, left axis) and the total number of the patent families citing standard related documents (bar, right axis) has evolved. Horizontal axis is the earliest priority year in a patent family. The average share of the patent families citing standard documents in total triadic families was about 0.2% in the period: 1985-1989. It increased up to 0.46% in 1990-1994, and then to 0.9% in 1995-1999. It increased 4.5 times in ten years from the latter half of the 1980s to the latter half of the 1990s.

(Figure 1)

The time trend of such patents citing the standard documents of each SSO is shown in Figures of Appendix C. They represent the share of patent families citing standard documents of a SSO in each year over the total number of families. Standards of ISO, ANSI, and JIS were cited from early years and experienced relatively modest increases. Standards of ITU, IETF, and ETSI became cited around 1990 and have sharply increased. Standards of ITU, IETF and ETSI are important in areas such as Telecom and Information technology. The importance of standards as knowledge sources has increased with the development of these industries as well as with increasing importance of patented technologies in these industries.

3.4. Geography of citations

Table 6 shows the numbers and the shares of patents[6] including at least one JP or US or DE resident person as an inventor who cite standard-related documents of each SSO in the period: 1995-2001 (earliest priority year). The numbers and the shares in triadic patents including an inventor of any of

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[5] Triadic patent family is the group of inventions applied to the European Patent Office and Japan Patent Office, and granted from the US Patent and Trademark Office. After 2000, the number of triadic families is decreasing due to the truncation.

[6] Inventor's residence country of US patent granted earliest in a triadic family

these three countries are shown in the last row. About 35% of the triadic family patents are yielded from the research activities which at least one US inventor took part in. 28% of the triadic family patents include a Japanese inventor and 15% of patents include a German inventor. The standard documents of international public standard setting organizations (ISO, ITU) are cited by the inventors of each country nearly according with the shares of the inventors' country in triadic patents.

(Table 6)

On the other hand, the national standards such as ANSI, JIS, and DIN are cited mainly by the inventors of their home countries. National standards are developed primary for the national markets needs. Technical information disclosed in these standards can be potentially a useful knowledge source for inventors in all countries, but there are only a limited number of the cases that the foreign inventors actually exploit this knowledge. The geographical structures of the citations of private international standard setting organizations (IETF, ETSI, and IEEE) vary significantly, but the US inventors are relatively important for IETF and IEEE. The fact that national standards are more cited does not necessarily imply that they are more important knowledge source.

4. Effects of standard on downstream R&D: two hypotheses

In this and the following sections, we assess econometrically how knowledge flow from standard may enhance the value of downstream research and which types of standards have the strongest effects. Disclosed standard documents would provide technical information such as interface information, which can serve as a technical basis for a new invention compatible with the standard. Such invention would get benefitted differently from a standard, based on the size of the network defined by the standard, including the availability of complementary inventions. That is, a standard would affect the performance of the downstream R&D since it defines the basic interface technology on which the R&D is based and the scale of network complementary to the R&D. Thus, we expect that the private value v_i of an invention *i* is affected both by the inventive inputs θ_i $for\ the\ invention$ such as human resources and knowledge resources (other than standard) as well as the characteristics of the standard (s) on which it is based.

$$v_i^s = f(inventive\ inputs\ \theta_i, characteristics\ of\ standard\ s; technology\ sector)$$

(3)

Similarly, we also expect that the invention based on a standard will be more cited as prior art, as the standard generates more network externality and stimulates more downstream R&D by more firms. Thus, we expect that the number of forward citations received by a patented invention *i* q_i is affected by both the inventive efforts θ_i $for\ the\ invention$ as well as the characteristics of the standard (s) on which it is based:

$$q_i^s = f(inventive\ efforts\ \theta_i, characteristics\ of\ standard\ s; technology\ sector)$$

(4)

It is well-known that the data on forward citations based on US patents is a good measure of a patent value as many studies show (See Nagaoka, Motohashi and Goto (2010) for a survey), even though it may not be a good measure of knowledge flow, as mentioned earlier.

There are two important characteristics of a standard which would affect the performance of R&D. One characteristic is the novelty of a standard, which incorporates new technology development swiftly. Another characteristic is the market size. These effects would be stronger when the standard covers a large market, especially when it is global rather than domestic. Thus, we can formulate the following two hypotheses on the effects of standard on the downstream R&D.

Hypothesis 1 on performance of a standard -based R&D:

The standard-based R&D project (the R&D project for which a standard plays an important role in the conception) tends to have high performance, due to the network externality from the standard. That is, for given inventive inputs, it tends to generate a higher value patent, a highly cited patents and more number of patents.

Hypothesis 2 on R&D performance of a standard:

A standard which absorbs recent technological development and serves a global standard enhances the R&D performance more. That is, a private and international standard tends to promote more downstream R&D.

5. Estimations and testing hypotheses

We evaluate the hypotheses formulated in the above section by implementing the following two tests. The first test is to assess the effects of the importance of standard related documents for the conception of the invention on the economic value and on the number of patents from an R&D project, all based on the survey over inventors. The second test is to assess the effect of the backward citation to standard documents on the frequency of forward citations for the patent based on such standard, based on bibliographic information. These two tests are complementary. The data from the inventor survey covers the performance comprehensively and measures knowledge flow from standard documents sources directly by 5 point Likert Scale (0 for non-use). The bibliographic data can identify the sources of standard information in detail.

5.1. Estimation model and data based on survey data

We will examine how the knowledge embodied in standard related documents affect economic value of a patent, using the sample of the RIETI inventor survey. When standard related documents were important in conception of a research for an inventor involving in the R&D project, does such R&D produce the inventions of high economic value? We use two kinds of performance variable as dependent variables. One is the economic value of the focal patent (4 rank scale: Top 10% in the same technical field, top 25%, top 50%, the other). The other variable is the number of granted (or expected to be granted) domestic patents yielded from the R&D projects (6 rank scale: only one patent are granted, 2-5 patents, 6-10 patents, 11-50 patents, 51-100 patents, more than 101 patents).

The main explanatory variables are the importance of three types of literatures (standard related documents, scientific & technical literatures, and patent literatures) as knowledge sources in conception of the research yielding the invention. We also introduced man-month used for the R&D, a dummy for PhD, triadic patent dummy, and dummies for the types of organization the inventor belongs to, as control variables. A larger project will generate more patents and perhaps more valuable patents while it is more likely to use all source of knowledge. The size of man-months controls for such endogeneity. The sample consists of the R&D projects yielding patents in three technology sectors (IT, Telecom, Audiovisual) as above. The sample size is 506 for the estimation with the economic value of a patent, 766 for the estimation for the number of granted patents. The basic statistics are in Appendix Table B-3 and the correlation coefficient matrix is in Appendix Table B-4. Estimation method is ordered logit. Thus, the estimation model is given by

$$\begin{aligned} \text{R \& D performance} = g(&\text{knowledge contribuion of three literature sources (standard, science, patent)}, \\ &\ln(\text{R \& D maonmonth}), \text{PhD}, \\ &\text{Triadic dummy, Dummy for inventors' organizations}) \qquad (5) \end{aligned}$$

5.2. Estimation result based on survey data

Table 7 shows the estimation results. Research projects using standard documents as knowledge sources exhibit significantly better performance (the coefficient of standard related documents are significantly positive in the first and the second model, although at 10% level in the latter), after controlling for man-months used for the R&D, use of scientific and technical literatures as knowledge sources. The more standard related documents are important, the higher is the economic value of the focal patent, and the more number of patents are yielded from the research projects. The effect of standard related documents on the performance measure is lower than that of science and technical literatures (especially the effects on the number of granted patents), but higher than that of patent literatures. Patent literature is often regarded to be very important knowledge source (see Table 1), but its importance is independent of the value of the focal patent. The coefficients of the basic inventive inputs such as the logarithm of the R&D man months and the PhD dummy are highly significant as expected. They are endogenous, since both the R&D performance and the use of these resources would rise as technological or market opportunities improve. We do not have instrument to control for this endogeneity. However, such endogeneity tends to reduce the coefficient of the standard related knowledge variable, since the latter is positively correlated with the level of inventive efforts. Thus, it tends to strengthen our finding that standard matters.

(Table 7)

5.3. Estimation model and data based on bibliographic data

The dependent variable is the number of forward citations of the patent family (the log (the number of forward citations+1)). The unit of analysis is the patent family. We exclude the citations within a patent family, that is, the citation from the subsequent patents[7] to the parent patents in the same family in constructing the number of forward citations so as to prevent the continuation practices to inflate the number of forward citations. We use dummy variables regarding the backward citations of national / regional public standards (ANSI, JIS, DIN, BSI, CEN, ETSI), the backward citations of international public standards (ISO, IEC, ITU), and the backward citations of private international

[7] Continuing applications often cite the priority applications in the same family

forum standards (IETF, W3C, IEEE, Ecma international, EIA/TIA, JEDEC), as explanatory variables. These dummy variables take 1 if at least one US patent in a family cites the standard documents of a focal standard body, including the draft and proposals, 0 otherwise. Thus, we have three different set of standard bodies which may be characterized by the following matrix in Table 8 (1).

(Table 8)

Table 8 (2) also shows the distribution of patent families by their citing patterns of three broad types of standards. Most of the families cite only one type. Although there are cases that two or three types of standard documents are cited together by one patent family, it is by far a minority. For an example, the number of families citing both National/regional standard and International public standard is only 34, which is only 2 % of the patent families citing standards. The number of families citing all three types of standards is 19, which is only 1%. This may not be surprising, given that only the most novel standard may matter as prior art for a patent application.

We also use two backward citation indexes: the average number of non-patent literatures cited in a family (when standard related documents are excluded) and the number of patent literatures cited (citations from a subsequent application to the parent application in a family are excluded). These variables are introduced to measure the extent of knowledge sources exploited in the invention activities which is an important component of the inventive input. The number of inventors is used to control the resources invested to the research. They are again endogenous, since both the number of the forward citations and the use of these resources would rise as the observed quality of R&D projects improves. However, as before, their endogeneity tends to strengthen our finding that standard matters if the dummies of the backward citations of the documents of standard organizations are found to be significant.

We introduce many additional controls to avoid introducing spurious correlations between the number of forward citations and a standard. The US domestic family size controls the effects on forward citations of continuing applications. That is, if continuing applications are more used for patenting the inventions based on a standard, the family size is larger and more forward citations are likely to be made, not because of network externality of an underlying standard but because of continuing applications. Our definition of family size is the number of US domestic applications in the INPADOC family. The number of patent offices applied for a patent further controls for the geographic scope of the inventors who potentially cite the US patents. If such number is large, more number of inventor would become aware of the inventions, so that more forward citations could be made, not because of international nature of a standard but because of the international nature of downstream inventions. A dummy including US inventors is used to control for important differences in citation behavior between US inventors and the other countries' inventors. Patents involving US inventors tend to cite significantly more number of patents by US inventors (Nagaoka and Tsukada (2011)). We also use the interaction terms between the dummies of technological area and those of the first grant year in a family, in order to control for truncations of citations, the differences of propensity of patenting and citations by technology area and their changes over time.

$$
\begin{aligned}
\text{Num. of forward citations} = f(&\text{Dummy for national standards}, \text{Dummy for international public standards}, \\
&\text{Dummy for private international standards}, \\
&\text{Num. of non-patent literatures cited}, \text{Num. of patent literatures cited}, \\
&\text{Num. of inventors}, \text{Domestic family size}, \text{Num. of patent offices}, \\
&\text{Dummy including US inventors}, \text{Dummies for year and technology}) \qquad (6)
\end{aligned}
$$

The estimation sample consists of the triadic patent families of three technological areas (IT, Telecom, Audiovisual) in the period from 1995 to 2001 (earliest priority year in family), so as to secure the comparability with the estimations using the inventor survey sample. The estimation method used is negative binomial regression. The basic statistics are in Appendix Table B-5 and the correlation coefficient matrix is in Appendix Table B-6.

5.4. Results based on bibliographic data

The basic estimation results are provided in Table 9. Model (1) and (3) (the second and the fourth columns of Table 9) are the results for estimating the coefficient of a dummy variable of whether the patent family cites any type of standard documents or not, without controlling for the level of backward citations. Model (2) and (4) introduce the number of non-patent literatures cited, the number of patent literatures cited and number of inventors to control for the effects of resources input to R&D. The dummy variable for standards has significantly positive coefficient in model (1) and (3), implying that the patents families citing the standard documents are significantly more cited. They have on the average 70% more citations according to Model (1), which is very significant.

(Table 9)

We can examine which type of standard organization produces the documents that the more cited patents are based on, from model (3) to (7). In model (3), three dummy variables for standards have significantly positive coefficients. The coefficient of the dummy for private international forum standards (IETF, W3C, IEEE, EIA/TIA, JEDEC and Ecma international) is the largest among the three types of standards (96% more cited than the patents with no such citation to the standard documents). The next is the dummy for national/regional standards (ANSI, JIS, DIN, CEN and ETSI) which indicates 45% more forward citations, and the lowest is the dummy for international public standards (ISO, IEC and ITU), indicating 22 % more forward citations. That is, the patents from the R&D projects exploiting information disclosed in standards developed by private international forum standard are most important for subsequent innovations as knowledge sources in the ICT fields. The order of the size of the coefficient does no change as we introduce more controls, as we will see.

The backward citations (references) by a patent of private international forum standards and national standards are still significant, but the coefficient of international public standards becomes insignificant, in model (4), in which the knowledge and human resources used for the research are controlled for by introducing the number of references to non-patent literatures, patent literatures, and number of inventors. Private international standards and national standards remain significant, after controlling for the family size (model (5)). Number of non-patent literatures and that of patent literatures are estimated to have significantly positive coefficients (17% for the non-patent literature and 22% for the patent literature). The results for non-patent literature indicate that the information disclosed in science and technical literatures are useful for research projects, especially given that these backward citations are provided mainly by inventors (see Table 3). However, we would need to avoid interpreting the coefficient of the number of patent literatures cited as knowledge flow, since it includes significantly the citations by patent examiners. It may reflect significantly the variations of the citation intensity by technology area not controlled by our broad technology class by year dummies. The number of inventors is also significantly positive, which means that research projects involving more inventors yield inventions of higher values. The significance of these results does not change a lot even after controlling for the US domestic family size and number of patent offices to which the invention are applied (although the coefficient of the patent literature is significantly affected by the inclusion of domestic family size).

In the appendix (Table B-7) we provide the result of estimations introducing the dummy variables of each standard organization. The main pattern is same as the results above. The effects of using standard documents such as those by ANSI, JIS, DIN, ISO, and ITU become insignificant once we control for the literature knowledge source variables. This indicates the important possibility that the invention based on these standards are highly cited only because many of these inventions belong to the technology areas where there are many related patents and the citation propensities are high. On the other hand, the importance of standards yielded from organizations such as IETF, W3C, Ecma International (Private international standards) and ETSI (Regional standards) are significant after controlling for various resource inputs (see model (4) in Table B-7) and even after controlling all the other variables (see model (7) in Table B-7).

There is a question of why private international forum standards are valuable knowledge source, relative to national and international public standards. We can decompose the sources of differences into two parts: those which we can explain from the difference of the mean values of independent variables and the difference of the fixed effects, based on the comparison between model (3) and model (7). The difference of fixed effects is very large. If we compare private international forum standards and international public standards, the difference of the coefficients of the dummies is 74% according to model (3). It is reduced to 57% according to model (7), so that the residual difference accounts for 80%. As for the difference of the mean values of independent variables, a comparison between model (3) and (4) suggests that more use of knowledge and human resources by the patent based on private international standard substantially account for the difference of the number of forward citations significantly (the difference of the coefficients of the dummies declines to 58%)[8].

One potential important difference between private and public standards is that private standards use novel technologies: they introduce new technical development more swiftly so as to meet new demand for standards. Although both public and private consensus standard often faces the problem of significant delay due to a stalemate or a war of attrition (see Farrell, J. and G. Saloner (1988), such problem may be more serious for the public standard, where the consensus decision making is important.

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[8] The descriptive statistics suggest that the use of knowledge resources is significantly more different than that of inventors.

6. Conclusions and implications

This paper has analyzed how extensively standard information becomes an important knowledge source for R&D, how significantly the (backward) citations of standard related documents measure such knowledge flow for R&D, and how significantly they affect the performance of downstream R&D, based both on the inventor survey in Japan and on bibliographic information of triadic patents family. It also analyzed how such knowledge affects the R&D performance. We use the RIETI inventor survey data, the OECD triadic patent families' database and the PATSTAT database for constructing the database for our analysis. Major findings are as follow.

The information embodied in standards and related documents are very important knowledge sources for the conception of R&D projects in the information and telecommunication area (ICT), according to the RIETI survey. Standard related documents are regarded to be very important by 10% of the inventors in Telecom area, 5% in Audiovisual, and in IT. Backward citations of standard documents are far less frequently made. Standard documents are cited only in 10 % of the cases even where standard documents are very important source of the knowledge for the conception of the research. This is perhaps because standard documents frequently provide non-technical information such as information on potential use of the invention for an inventor. On the other hand, around a half of the inventors citing standard documents recognize standard as important or very important for the conception of the R&D project. Once the standards are cited, it is a significant indicator of knowledge flow. One important reason for this is that inventors are by far the dominant source of the citations. Using this measure, we have found that the patents citing standard documents have been increasing in terms of the share of the total patents.

R&D projects using standards as a knowledge source have high R&D performance, although the effect varies across standards. The R&D projects using standard information more intensively tends to generate significantly more valuable patents and more number of patents in ICT, controlling for research labor input and the use of scientific literature and that of patent literature. Consistent with these results based on the RIETI inventor survey, an invention citing standard documents is more highly cited, controlling for the inventive inputs. To establish this, we have carefully controlled for the effects of continuation practices which are prevalent in standard related patenting as well as the bias of the citations for the invention with a US inventor.

Private international forum standards tend to generate more highly cited patents than national or international public standards. Our analysis suggests that more use of knowledge and human resources by the patent based on private international standard significantly account for such difference. However these variations of independent variables across these types of standards accounts for only a part of the difference of the performance. A part of the residuals in favor of private international forum standards would be its swiftness in adopting new technology. Surprisingly, international public standards do not compare well even with national/regional standards, although promoting downstream R&D is not the only objective of a standard organization.

The endogeneity of the basic inventive inputs such as the number of inventors tends to inflate their coefficients, which in turn would tend to cause the downward biases of the coefficients of the standard dummies. Thus, such endogeneity tends to reinforce our conclusions from the above findings that standards enhance R&D performance.

Finally, let us discuss some implications on future research and policy, including the limitations of our study. Our study combining the RIETI survey information and bibliographic information convincingly shows that the citation information in the US patent documents can be usefully used to measure the knowledge flows from standards to inventions, although it covers a relatively small part of the knowledge flow, even if the latter is very important. We have also shown that such information can also be used to assess how various standard organizations work as knowledge generating institutions. This finding will open up a number of interesting research questions.

Our research has also shown that standards do promote downstream innovations, although the extent varies significantly across standard setting organizations. This would imply that it is important for standard organizations to establish clear disclosure rule, so that the firms can have proper access to such information in planning their R&D. It would also be important for patent offices to cover standard documents as prior art information for their examination.

On the other hand, our research is still limited in clarifying the sources and mechanism of how standards promote downstream R&D. Standards may be valuable for downstream R&D when it quickly adopts new technology and/or it is global. It is important to clarify whether higher forward citations of the standard-based patents implies more market opening, more knowledge flow, more needs for combining the existing patents or the other things, and how the three types of standard have effect on the development of each other. In this paper, we have focused on the inventions citing standard related documents, to assess the importance of technical standard as a knowledge source of R&D. However, we have not developed the data which can identify those who developed the standards. Such task is going to be very time consuming and can be done only in a separate research project. Once we have such database, we can address such questions as whether a firm which has a strong position in a current generation of standard is also more or less likely to develop a future standard. We intend to address these research questions in the future.

Table 1: Incidence of each knowledge source being "very important" for the conception of research

		Literatures			Open forum		Organization, including the own firm						
		Scientific and technical literatures	Patent literatures	Standard documents	Trade fair or exhibitions	Technical conference and workshop	Your firm excluding co-inventors	Customers or product users	Suppliers	Competitors (Knowledge from their product)	University	Public research org. (Non-univ.)	Consulting firm and contracted R&D firm
Triadic patents		17.6%	22.5%	1.6%	3.0%	3.4%	18.0%	19.8%	6.7%	13.8%	2.7%	1.4%	0.5%
Non-triadic patents		14.2%	19.7%	1.5%	2.4%	2.3%	12.9%	18.2%	4.6%	12.7%	2.1%	1.0%	0.2%
ISI class (Triadic)	Telecom	24.2%	18.8%	10.1%	0.6%	7.5%	17.1%	9.5%	3.2%	11.5%	1.9%	0.6%	1.3%
	Audiovisual	14.2%	16.1%	5.3%	1.8%	3.6%	23.2%	16.0%	4.7%	11.2%	0.6%	0.6%	0.0%
	IT	18.9%	12.2%	5.0%	1.9%	5.6%	17.5%	20.6%	4.3%	12.5%	3.1%	2.5%	0.6%
	Agric&FoodProcess-Machines	14.7%	18.9%	5.7%	5.4%	0.0%	20.6%	17.1%	0.0%	8.8%	2.9%	2.9%	0.0%

Table 2: Incidence of backward citation of standard documents by the level of importance of knowledge flow from standard documents (% of the total, triadic patents surveyed)

	Citing standard	Not citing standard	Total	No. of patents
Very important	0.14%	1.4%	1.5%	56
Important	0.19%	6.5%	6.7%	246
Other	0.38%	91.4%	91.7%	3,356
Total	0.71%	99.3%	100.0%	3,658
No of patents	26	3,632	3,658	

Table 3: References (backward citations) of standard documents, patent literature and non-patent literature by inventors and examiners

(1) Patents of the Inventor Survey, which cite standard related documents.

	N	Percent
Inventor citation	25	92.6%
Examiner citation	2	7.4%

(2) All the triadic patents (Granted in 2001)

	Average number of citations	Share of inventor citations	Share of examiner citations
Patent literatures	16.80 (100%)	12.04 (71.65%)	4.77 (28.35%)
Non-patent literatures	10.34 (100%)	10.01 (96.86%)	0.32 (3.14%)
Standard documents	0.019 (100%)	0.018 (98.27%)	0.001 (1.73%)

Table 4: Number of the patent families citing the standard related documents by SSO

SSO	Num. of families
ISO	1022
IEC	664
IETF	596
ITU	536
ANSI	439
IEEE	385
ETSI	353
DIN	257
JIS	221
EIA/TIA	101
Others	222
Total	3817

* There exist duplications.

Table 5: Frequency of backward citations of the standard document by technology areas (top 10 ISI areas, earliest priority year in family: 1995-2001)

ISI area	Num. of families	%	Total
Telecom	964	4.8%	20,110
IT	680	3.6%	19,027
Analysis/Measurement/	122	0.8%	15,774
Audiovisual	63	0.8%	7,804
Electr/Energy	56	0.3%	20,255
Polymers	48	0.4%	11,003
MedicalTechn	37	0.3%	13,361
Pharmaceuticals/Cosme	36	0.2%	15,468
SurfaceTechn	36	0.3%	10,570
Optical	26	0.2%	14,900
Other	228	0.2%	116,521
Total	2,296	0.9%	264,793

Figure 1: Number of the patent families citing standard related documents

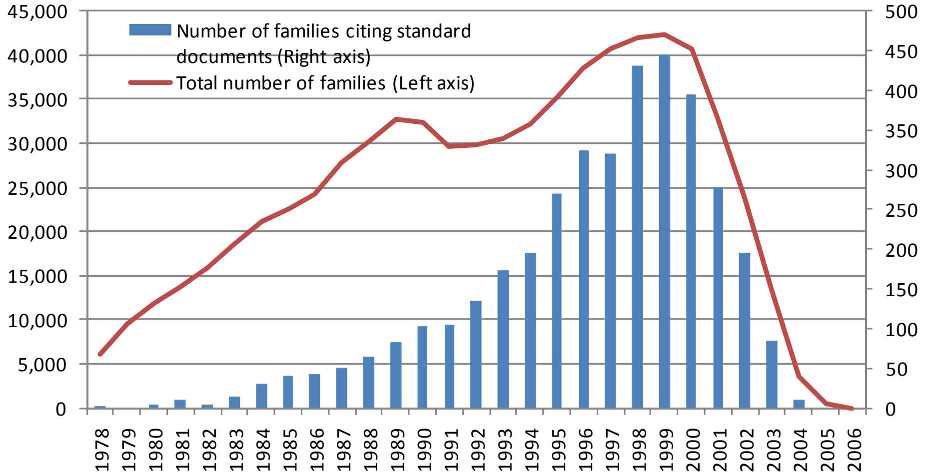


Table 6: The Number of patents with a JP/US/DE inventor and with a citation to standard-related documents of each SSO (earliest priority year: 1995-2001)

	Including JP inventor		Including US inventor		Including DE inventor		All
ISO	116	23.7%	231	47.1%	61	12.4%	490
ITU	111	28.3%	144	36.7%	29	7.4%	392
ANSI	19	8.8%	169	78.2%	3	1.4%	216
JIS	95	84.1%	16	14.2%	2	1.8%	113
DIN	7	5.9%	21	17.6%	75	63.0%	119
IETF	87	17.4%	321	64.1%	18	3.6%	501
ETSI	36	12.5%	64	22.3%	34	11.8%	287
IEEE	47	26.0%	113	62.4%	5	2.8%	181
Triadic	75,307	28.4%	93,345	35.3%	38,951	14.7%	264,772

Table 7: Estimation results: Determinants of R&D performance (sectors covered: IT, Telecom, Audiovisual)

		Orderd logit	
		(1) Economic value of the focal patents	(2) Number of granted patents from the R&D project
Importance as knowledge source in conception	Standard related documents	0.112** (0.052)	0.072* (0.041)
	Scientific and technical literatures	0.208*** (0.060)	0.133*** (0.046)
	Patent literatures	-0.101* (0.061)	0.014 (0.046)
ln(R&D man-month)		0.178*** (0.069)	0.523*** (0.057)
Phd		0.640** (0.315)	0.829*** (0.285)
Triadic dummy		0.242 (0.177)	0.187 (0.142)
Observations		506	766
Pseudo R-Squared		0.04	0.07
Log Likelihood		-612.57	-1001.53

Note: We also introducce the organization dummy (four size class of firms, University, etc)
Standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%

Table 8: Three types of standards

(1)Characterization of standard bodies

	Global scope	National or regional scope
Public	International public standards (ISO, IEC, ITU)	National/regional public standards (ANSI, JIS, DIN, etc.)
Private	Private international standards (IETF, W3C, IEEE, Ecma international, etc.)	

(2) Frequency of family by citing pattern of standards

	Citing one type of standards	Citing two types of standards						Citing three types of standards		Total
National/regional standard	349	*		*				*		
International public standard	563	*	34		39	*	52	*	19	1668
Private international forum standard	612			*		*		*		

Table 9: Results of negative binomial regression (1)

		Number of forward citations to family						
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Knowledge source	National/regional standards dummy			0.450*** (0.054)	0.203*** (0.051)	0.156*** (0.050)	0.152*** (0.051)	0.117** (0.050)
	International public standards dummy	0.701*** (0.028)	0.356*** (0.027)	0.221*** (0.044)	0.013 (0.042)	-0.052 (0.041)	0.002 (0.041)	-0.058 (0.041)
	Private international forum standards dummy			0.959*** (0.041)	0.577*** (0.039)	0.506*** (0.038)	0.574*** (0.039)	0.508*** (0.038)
	ln(Non-patent literatures cited + 1)		0.182*** (0.006)		0.182*** (0.006)	0.170*** (0.006)	0.181*** (0.006)	0.169*** (0.006)
	ln(Patent literatures cited + 1)		0.381*** (0.007)		0.379*** (0.007)	0.216*** (0.008)	0.364*** (0.007)	0.209*** (0.008)
ln(Number of inventors)			0.205*** (0.008)		0.204*** (0.008)	0.186*** (0.008)	0.205*** (0.008)	0.187*** (0.008)
ln(US domestic family size)						0.572*** (0.014)		0.555*** (0.014)
ln(Number of patent offices applied)							0.233*** (0.013)	0.183*** (0.013)
US inventor dummy		0.737*** (0.011)	0.465*** (0.011)	0.730*** (0.011)	0.461*** (0.011)	0.457*** (0.011)	0.472*** (0.011)	0.467*** (0.011)
Constant		2.610*** (0.160)	1.768*** (0.149)	-0.040 (1.201)	-0.317 (1.130)	-0.162 (1.109)	-0.600 (1.127)	1.753*** (0.146)
Observations		46433	46433	46433	46433	46433	46433	46433
Pseudo R-Squared		0.08	0.10	0.08	0.10	0.10	0.10	0.10
Log Likelihood		-145340	-142200	-145272	-142158	-141214	-142001	-141114

Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%
Dummy variables of ISI area by first grant year in family are included, but not reported.

Appendix A. Method to search standard or related documents in patent bibliographic data

Below is the SQL command to search standard documents. MySQL 5.1 fulltext index is made at the column "npl_biblio", in which Non-patent literatures bibliographic information are included. "npl_table" is the table name.

```
select * from npl_table
    where match(npl_biblio) against ('
        (+(ISO "International Organization for Standardization"
                "International Organisation for Standardization"))
        (+(IEC "International Electrotechnical Commission"))
        (+(ITU "International Telecommunication Union"))
        (+(JIS JISC "Japanese Industrial Standard"
                        "Japanese Industrial Standards"
                JSA "Japanese Standards Association"))
        (+(ANSI "American National Standards Institute"
                    "American National Standard Institute"))
        (+(DIN "Deutsches Institut für Normung"))
        (+("British Standard" (+BSI +(specifications requirements standards))))
        (+(AFNOR "Association française de normalisation"))
        (+("European Committee for Standardization" "European Standard"))
        (+("IEEE Standard" "IEEE Draft" "IEEE Std"))
        (+(ETSI "European Telecommunications Standards Institute"))
        (+(ECMA "European Computer Manufacturers Association"))
        ((+EIA +TIA) +("Electronic Industries Association"
                            "Telecommunications Industry Association"))
        (+JEDEC)
        (+(RFC IETF "Internet Engineering Task Force"))
        (+(W3C "World Wide Web consortium"))
    ' in boolean mode)
```

Appendix B.

Table B-1: Number of responses by ISI classifications

ISI Classification	Triadic patents		Important / Standard patents		Non-triadic patents		Total	
Agric&FoodProcess-Mac	37	1.0%	0	0.0%	0	0.0%	37	0.7%
Agric&Foods	68	1.9%	1	0.8%	1	0.1%	70	1.3%
Analysis/Measurement/	274	7.5%	4	3.4%	174	11.6%	452	8.6%
Audiovisual	173	4.7%	19	16.0%	69	4.6%	261	4.9%
Biotechnology	75	2.1%	3	2.5%	29	1.9%	107	2.0%
ChemEngineering	69	1.9%	4	3.4%	29	1.9%	102	1.9%
ConsGoods	152	4.2%	3	2.5%	17	1.1%	172	3.3%
ConstrTechn	51	1.4%	6	5.0%	0	0.0%	57	1.1%
Electr/Energy	300	8.2%	9	7.6%	135	9.0%	444	8.4%
Environment	68	1.9%	17	14.3%	20	1.3%	105	2.0%
Handl/Printing	185	5.1%	7	5.9%	118	7.9%	310	5.9%
IT	165	4.5%	8	6.7%	141	9.4%	314	5.9%
MachineTools	147	4.0%	0	0.0%	47	3.1%	194	3.7%
Materials	114	3.1%	5	4.2%	0	0.0%	119	2.3%
Matprocessing/Textile	130	3.6%	2	1.7%	19	1.3%	151	2.9%
MechElements	135	3.7%	0	0.0%	82	5.5%	217	4.1%
MedicalTechn	129	3.5%	0	0.0%	61	4.1%	190	3.6%
Motors	140	3.8%	0	0.0%	41	2.7%	181	3.4%
NuclearTechn	25	0.7%	0	0.0%	7	0.5%	32	0.6%
Optical	242	6.6%	10	8.4%	134	8.9%	386	7.3%
OrganicChem	165	4.5%	2	1.7%	43	2.9%	210	4.0%
PetrolChem/materialsC	48	1.3%	2	1.7%	1	0.1%	51	1.0%
Pharmaceuticals/Cosme	55	1.5%	0	0.0%	32	2.1%	87	1.6%
Polymers	97	2.7%	2	1.7%	52	3.5%	151	2.9%
Semiconductors	144	3.9%	7	5.9%	83	5.5%	234	4.4%
SpaceTech/Weapons	1	0.0%	0	0.0%	0	0.0%	1	0.0%
SurfaceTechn	59	1.6%	1	0.8%	1	0.1%	61	1.2%
Telecom	165	4.5%	7	5.9%	72	4.8%	244	4.6%
ThermProcesses	64	1.7%	0	0.0%	0	0.0%	64	1.2%
Transportation	181	4.9%	0	0.0%	93	6.2%	274	5.2%
Total	3,658	100%	119	100%	1,501	100%	5,278	100%

Table B-2 Number of families citing standard related documents by the ISI area and SSOs (Earliest priority years: 1995-2001)

ISI area	ISO	IEC	ITU	ANSI	JIS	DIN	IETF	IEEE	ETSI	EIA/TIA
Electr/Energy	3	13	0	11	17	5	2	14	1	0
Audiovisual	20	21	4	2	4	2	4	4	2	1
Telecom	108	94	258	92	1	8	244	61	244	33
IT	192	170	99	40	3	5	224	67	34	8
Semiconductors	3	2	0	0	1	2	1	4	0	0
Optical	3	4	3	6	5	1	1	1	0	3
Analysis/Measurement	20	12	25	15	7	12	18	25	5	2
MedicalTechn	12	7	0	11	3	3	0	1	1	2
NuclearTechn	1	0	0	1	0	0	0	0	0	0
OrganicChem	21	2	0	0	0	3	0	0	0	0
Polymers	24	2	0	2	6	20	0	1	0	0
Pharmaceuticals/Cosmetics	22	1	0	3	0	9	2	0	0	0
Biotechnology	10	3	0	2	0	1	0	0	0	0
Agric&Foods	5	0	0	0	0	0	0	0	0	0
PetrolChem/materialsChem	8	3	0	1	1	7	0	0	0	0
SurfaceTechn	4	2	0	6	13	10	1	0	0	1
Materials	1	0	0	3	6	3	0	0	0	0
ChemEngineering	3	3	1	2	1	2	1	1	0	0
Matprocessing/Textiles/Paper	3	0	0	2	2	5	0	0	0	0
Handl/Printing	5	1	1	2	10	1	0	1	0	0
Agric&FoodProcess-Machines	0	0	0	0	0	0	0	0	0	0
Environment	2	0	0	0	0	0	1	0	0	0
MachineTools	4	0	0	6	7	8	1	0	0	0
Motors	2	0	0	1	4	1	0	1	0	0
ThermProcesses	3	0	0	1	0	0	0	0	0	1
MechElements	6	1	0	3	13	7	0	0	0	0
Transportation	2	0	0	1	3	0	1	0	0	0
SpaceTech/Weapons	0	0	1	0	0	0	0	0	0	0
ConsGoods	3	1	0	2	5	1	0	0	0	0
ConstrTechn	0	0	0	1	1	3	0	0	0	0
Total	490	342	392	216	113	119	501	181	287	51

Table B-3: Basic statistics for the sample based on inventor survey

Variable	Obs	Mean	Std. Dev.	Min	Max
Economic value	504	3.048	0.915	2	5
Number of granted patents	766	2.320	1.146	1	6
Standard related documents	766	1.779	1.719	0	5
Scientific/technical literatures	766	2.903	1.826	0	5
Patent literatures	766	2.993	1.734	0	5
ln(R&D man-month)	766	2.118	1.312	0.405	4.575
Phd	766	0.072	0.258	0	1
Triadic dummy	766	0.614	0.487	0	1

Table B-4: Correlation coefficient matrix for the sample based on inventor survey

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Economic value	1							
(2)	Number of granted patents	0.2789	1						
(3)	Standard related documents	0.1543	0.1281	1					
(4)	Scientific/technical literatures	0.1644	0.1791	0.286	1				
(5)	Patent literatures	0.0364	0.1135	0.2451	0.5104	1			
(6)	ln(R&D man-month)	0.1402	0.3353	0.1419	0.1925	0.129	1		
(7)	Phd	0.1177	0.1475	0.0151	0.1505	0.0244	0.0769	1	
(8)	Triadic dummy	0.0372	0.0671	0.0136	0.0638	-0.0138	0.1345	0.0234	1

Table B-5: Basic statistics for the sample based on triadic patents

Variable	Obs	Mean	Std. Dev.	Min	Max
Number of forward citations	46,433	11.778	26.972	0	1364
Number of non-patent literatures cited	46,433	2.510	6.276	0	108
Number of patent literatures cited	46,433	11.629	16.438	1	506
National/regional standards dummy	46,433	0.009	0.097	0	1
International public standards dummy	46,433	0.014	0.119	0	1
Private international forum standards dummy	46,433	0.015	0.123	0	1
Number of inventors	46,433	2.379	1.628	1	23
US domestic family size	46,433	1.294	1.357	1	60
Number of patent offices applied	46,433	5.439	2.458	3	37

Table B-6: Correlation coefficient matrix for the sample based on triadic patents

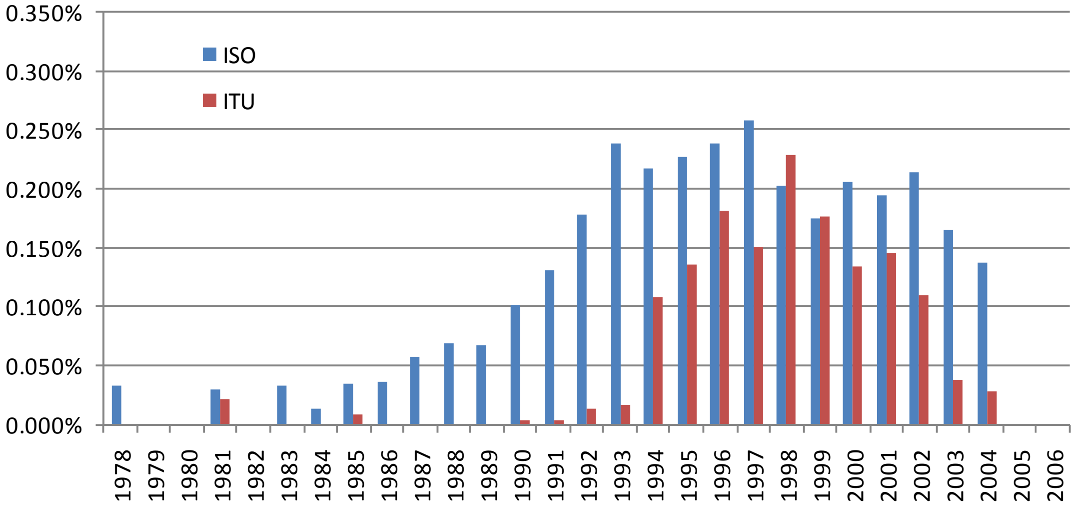
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	Number of forward citations	1.0000								
(2)	Number of non-patent literatures cited	0.1952	1.0000							
(3)	Number of patent literatures cited	0.3788	0.4248	1.0000						
(4)	National/regional standards dummy	0.0236	0.0576	0.0462	1.0000					
(5)	International public standards dummy	0.0312	0.0809	0.0629	0.0871	1.0000				
(6)	Private international forum standards dummy	0.1154	0.1511	0.1383	0.0923	0.0892	1.0000			
(7)	Number of inventors	0.0752	0.0707	0.0840	0.0067	0.0017	0.0162	1.0000		
(8)	US domestic family size	0.4794	0.1682	0.5784	0.0259	0.0640	0.0925	0.0690	1.0000	
(9)	Number of patent offices applied	0.0755	0.0364	0.1152	0.0720	0.0270	0.0131	0.0039	0.1100	1.0000

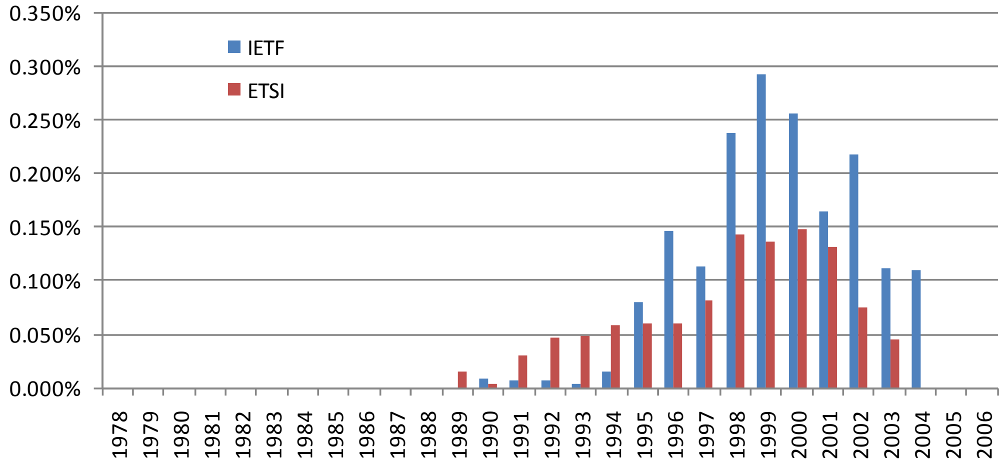
Table B-7: Results of negative binomial regression (2) with dummies for each standard body

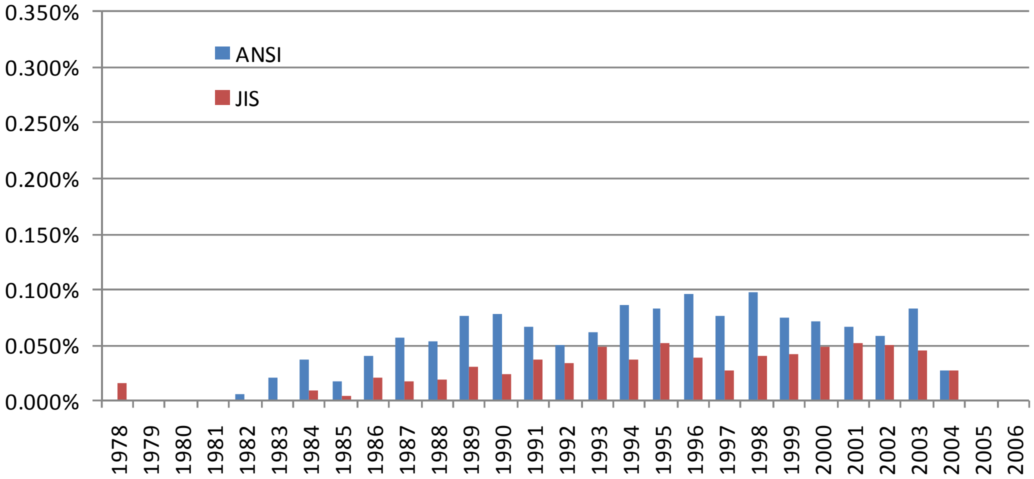
		Number of forward citations to family						
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
National/regional standards	ANSI	0.465*** (0.096)	0.457*** (0.095)	0.103 (0.091)	0.093 (0.091)	0.019 (0.090)	0.096 (0.091)	0.025 (0.090)
	JIS	0.859** (0.394)	0.806** (0.391)	0.322 (0.378)	0.292 (0.376)	0.095 (0.376)	0.265 (0.375)	0.100 (0.375)
	DIN	0.556** (0.282)	0.627** (0.280)	0.096 (0.267)	0.153 (0.266)	-0.009 (0.262)	0.055 (0.266)	-0.076 (0.263)
	CEN	0.166 (0.230)	0.116 (0.229)	0.109 (0.217)	0.075 (0.216)	0.127 (0.211)	0.028 (0.216)	0.088 (0.211)
	ETSI	0.420*** (0.069)	0.433*** (0.069)	0.254*** (0.066)	0.267*** (0.066)	0.239*** (0.065)	0.198*** (0.066)	0.185*** (0.065)
International public standards	ISO	0.292*** (0.104)	0.270*** (0.103)	-0.005 (0.111)	-0.003 (0.111)	-0.052 (0.109)	-0.033 (0.110)	-0.068 (0.108)
	IEC	-0.033 (0.111)	-0.018 (0.110)	0.078 (0.118)	0.077 (0.118)	0.038 (0.116)	0.095 (0.117)	0.049 (0.115)
	ITU	0.151** (0.060)	0.150** (0.060)	-0.012 (0.057)	-0.009 (0.057)	-0.057 (0.056)	-0.020 (0.057)	-0.064 (0.056)
Private international forum standards	IETF	1.042*** (0.051)	1.014*** (0.050)	0.689*** (0.048)	0.677*** (0.048)	0.639*** (0.047)	0.675*** (0.048)	0.639*** (0.047)
	W3C	0.823*** (0.144)	0.818*** (0.142)	0.432*** (0.136)	0.427*** (0.135)	0.313** (0.133)	0.447*** (0.135)	0.331** (0.133)
	IEEE	0.504*** (0.097)	0.492*** (0.096)	0.122 (0.094)	0.105 (0.094)	0.046 (0.093)	0.114 (0.093)	0.058 (0.093)
	EIA/TIA	0.597*** (0.171)	0.532*** (0.170)	0.097 (0.163)	0.104 (0.162)	0.007 (0.160)	0.073 (0.162)	-0.014 (0.160)
	JEDEC	0.107 (0.363)	0.070 (0.359)	0.220 (0.342)	0.193 (0.340)	0.137 (0.334)	0.255 (0.340)	0.192 (0.335)
	Ecma international	1.031*** (0.183)	1.034*** (0.181)	0.906*** (0.174)	0.907*** (0.173)	0.526*** (0.169)	0.832*** (0.172)	0.490*** (0.169)
ln(Non-patent literatures cited + 1)				0.187*** (0.006)	0.181*** (0.006)	0.169*** (0.006)	0.180*** (0.006)	0.168*** (0.006)
ln(Patent literatures cited + 1)				0.390*** (0.007)	0.380*** (0.007)	0.216*** (0.008)	0.365*** (0.007)	0.210*** (0.008)
ln(Number of inventors)			0.254*** (0.009)		0.204*** (0.008)	0.186*** (0.008)	0.205*** (0.008)	0.187*** (0.008)
ln(US domestic family size)						0.572*** (0.014)		0.556*** (0.014)
ln(Number of patent offices applied)							0.232*** (0.013)	0.182*** (0.013)
US inventor dummy		0.729*** (0.011)	0.703*** (0.011)	0.473*** (0.011)	0.461*** (0.011)	0.458*** (0.011)	0.472*** (0.011)	0.467*** (0.011)
Constant		-0.040 (1.200)	2.476*** (0.158)	-0.342 (1.136)	-0.320 (1.129)	-0.163 (1.108)	-0.601 (1.126)	1.753*** (0.146)
Observations		46433	46433	46433	46433	46433	46433	46433
Pseudo R-Squared		0.08	0.08	0.10	0.10	0.10	0.10	0.10
Log Likelihood		-145247	-144801	-142450	-142135	-141191	-141979	-141092

Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%
Dummy variables of ISI area by first grant year in family are included, but not reported.

Appendix C. Share of the patent families citing each standard over time






0.350%
0.300%
0.250%
0.200%
0.150%
0.100%
0.050%
0.000%
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JIS
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Appendix D. Backward citation to standard documents by the essential patents of standards

Table D-1 shows how many patent families covering the essential patents of three patent pools (MPEG[9], DVD[10], and WCDMA) cite standard-related documents. 25% of the essential patents of the MPEG patent pool do cite standard related documents. However, it is more an exception, since the MPEG standards have evolved over time in the working group of ISO/IEC. It has been upgraded from MPEG2 to MPEG4, and to AVC/H.264. On the other hand, only a few essential patents of other two patent pools cite standard related documents. A large part of these essential patents of the three standards do not cite standard documents.

Table D-1: Number of essential patent families of MPEG, DVD, and WCDMA citing standard related documents

	MPEG	DVD	WCDMA
Number of essential patent families	86	153	28
ISO	21	4	0
IEC	21	1	0
ITU	1	0	0
IETF	2	0	0
ANSI	0	0	0
IEEE	0	0	0
ETSI	0	0	0
DIN	0	0	0
JIS	0	1	0
EIA/TIA	0	0	2

[9] MPEG2, MPEG2 system, MPEG4 system, MPEG4 visual

[10] DVD4C, DVD6C

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