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Science linkages in technologies patented in Japan

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We constructed an original database concerning science linkages based on text of Japanese Patent Gazette published since 1994. We discovered that Japanese inventers cite many academic papers in the texts of the patent applications in the Japanese Patent System. Based on this finding, we constructed science citation index by data mining the texts of Japanese patent system for the first time. First, more than 880,000 patent data classified into about 600 categories. Then, we extracted non-patent references from all the granted patents and counted the number of them. This number shows the strength of the linkage between science and technology and therefore is called "science linkage index." The science linkage indexes among different patent classifications differ significantly from each other. The technologies related to bio -technology were by far the closest to science. It suggests that the process of creating new technology differs from technology to technology.

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1. Introduction

1.1. The Relationship between Science and Technological Change

That publicly supported science serves as the engine of technological change and therefore economic growth is widely recognized among scientists and economists. This recognition has been a large motivating factor for government to provide the support it has for academic research to date (Narin *et al*., 1997). For instance, according to Mansfield, the development of 10% of new products and process could not have been developed without substantial delay in the absence of recent academic research (Mansfield, 1991). As more attention has been focused on science as the source of technological change that would lead to economic value, there has also been increased interest in the linkage between science and technological change (Narin *et al*., 1997). Similar interest has grown regarding the importance of the impact of academia on the economy (OECD, 1990).

In short, it is becoming clear that many of the factors of long-term economic growth stem from technological change in addition to the imput of labor and capital. Science has gained recognition as one of the factors that bring about that technological change.

1.2. The Need for the Analysis of the Science Linkage in Japanese Patents

In recent years, it has become accepted that, albeit with certain qualifications, the "Science Linkage," which indicates the number of academic papers cited per patent as computed by using “patents” as an indicator of technological change and “Non Patent References (NPR)” mainly consisting of academic papers as an indicator of science, has validity as an indicator for understanding the effect that science exerts on technology. For this reason, there have been numerous earlier studies that have attempted to elucidate the relationship between patents and science by measuring the science linkage of patents applications filed in the US and Europe.

The reason the data concerning Japanese patents have not been well researched is not because Japanese patents lack in importance. To the contrary, we believe it is essential to do research on patent applications filed at the Japan Patent Office if one is to study the mechanisms of technological change in Japan, a region that has a gross domestic product that is on a par with the US and Europe. This is because patents for technology relating to non-export items, which target the domestic market exclusively, and patents relating to items that lack export competitiveness, would probably not be filed in countries outside Japan for the reason that there is no need to protect the intellectual property in the country in which the application would be filed. The only technologies that are worth patenting outside Japan are those pertaining to export items or those relating to items or technologies necessary for local production, and for which there is enough incentive in terms of protecting intellectual property in the country of patent application to justify the patenting costs that are reportedly more than double what they are for domestic applications. Therefore, studies on technological changes in Japan and the associated linkages with science are not sufficient in scope if they are limited to the analysis of those patents applied for in the US and other foreign countries, as such patents may be subject to various biases such as export competitiveness, as outlined above. In the interest of perceiving Japan as a single intellectual cluster, exploring the factors for the technological changes occurring there, and conducting international comparisons between Japanese patents and those applied for to Patent Offices in the US and Europe, there is a need to study the data on Japanese patents.

However, through our investigations, we could find no studies on science linkage pertaining to Japanese patents. Many of the surveys and studies on science linkage concern American patents, mostly because the data is well organized. Due to the poor organization of data in regard to Japanese patents, only American and European patents are discussed in the comparative survey on the number of citations per patent conducted by Michel et al of the European Patent Office (Michel et al., 2001). Even in the FY2001 Edition of the Kagaku Gijutsu Hakusho (White Paper on Science and Technology 2001), a comparison between the science linkages of patent applications from the UK, France, Germany, Japan, and the US that were filed at the US Patent and Trademark Office notes that the Science linkage for Japan ranks the lowest of the five countries, and therefore concludes that said results are an indication that the “outcomes of papers are not utilized to any great degree.” While the data cited by this White Paper were taken from the Science and Technology Indicators 2000 put out by the National Institute of Science and Technology Policy, the original source of said data is the National Technology Indicators Database of CHI Research Inc. In short, the data pertaining to the Japan Patent Office, which is one of the three major patent offices in the world, have not been well researched to date.

1.3. The Advantages of the Analysis of Japanese Patents

There are two advantages to analyzing Japanese patents. One is the lack of the above-mentioned bias that can be expected in an analysis of patents originating in Japan and applied for in overseas Patent Offices. The other is that patents filed in Japan, unlike those filed at the US Patent and Trademark Office, are not required to list reference documents.

Under the Japan Patent Law, the Examiner does not require the applicant to list reference documents on the front page. For that reason, the number of citations of patents and papers etc. that are listed in the front pages of Japanese patents may well be smaller than those in US patent front pages.

Applicants filing patents in the US are required by law to list relevant references in order to clarify the scope of the technology. A patent may be rejected on the grounds of failure to meet this requirement. According to Michel of the European Patent Office, there is a tendency in patents applications filed in the US for the representative, such as a patent attorney, of the individual who devised the new technology, and not the individual his/herself, to try to avoid having the patent rejected by attempting to list as many references as possible that may be related, without regard to whether the inventor relied on them when devising the new technology. Additionally, the Examiner of US patents places no restrictions on doing so, and tends to take the references, including other patents and papers etc., that are recorded in the patent application and list them, as is, on the front page of the patent. Furthermore, the Act began to be applied more rigorously in the 1990s, which is said to have led to the increase in citations (Michel *et al*., 2001). In short, the front page of US patents may well include references that were not in the inventor's mind when the technology was devised, and it is impossible to discern from the front page of the publicly released patent which of the references they are. Put differently, there is a possibility that the reference document data cited in the front page of US patents are contaminated with noise, that is, matters outside the knowledge found in the papers etc. that was in the inventor's mind when the invention, or technological advance, flashed in his or her mind.

On the other hand, with Japanese patents, there is no legal requirement for the applicant to list relevant patents and other non patent references to prove the novelty of the technology being applied for. Therefore, it is not likely for Japanese patent data, as opposed to American patent data, to include citations that are made solely out of fear of having the patent application rejected. This is the second advantage of studying Japanese patent data.

1.4. The Need for and Advantage to Analyzing Patent Applications in their Entirety

In our study, we did not limit our research to the front page of Japanese patents, but analyzed the entire application. The need for analyzing Japanese patents in their entirety is that the Japan Patent Law does not require the applicant to list reference documents on the front page and only studying the references in the front page of the Japanese patent application may not give us sufficient reference data in the entire patent application document. In fact, our preliminary study showed that only 4.2% of the references cited in the entire patent application were mentioned in the front page of the patent application (Tamada *et al.*, 2002). Therefore, to study science linkage in Japanese patents, we need to study not only the front page of patent application but also the entire patent application document.

The advantage of analyzing patents in their entirety is that, while on the one hand, due to the main text of the patent containing no reference documents subsequently added by the Examiner, it is likely that only those papers known to the devisor of the technology at the time of the invention would be listed, while on the other, the inclusion of the front page should make it possible, to a certain degree, to prevent any attempt by the applicant to conceal known technology.

The main text of a patent is written by the applicant, and aside from typographical errors, is not corrected by the Examiner. In other words, it is reasonable to assume that the patent main text contains a pure expression of the knowledge contained in the other patents and papers that were known at the time to the devisor of the technology in question. Therefore, it is highly likely that the main text of Japanese patents contains the papers and patents that may have played a part in the invention of the technology applicable to industry, or, as Solow put it, technological change, in a form without noise.

On the other hand, limiting the analysis to the main text is problematic, in that the main text may not cover all the related technical documents, such as patents and papers etc., if the applicant of the patent makes an attempt to knowingly conceal known technology in order to try to prove the novelty of his or her technology. However, the Examiner of the patent uses the front page of the patent to list the related reference documents that were used when the patent was examined.

In our study, we decided to study both the main text and front page of Japanese patents, which are likely to be unaccompanied by the bias brought about by law as in US patents, and, due to the verification by the Examiner, are unlikely to have omissions of related patents and academic papers that relate to the technology in question.

1.5. The Purpose of the Study

To summarize the above, studies on the relationship between technological change and science have been conducted using the academic papers cited in the front page of US and European patents. However, Japanese patents have not been researched to any great degree. Moreover, by studying the patent specification in its entirety, including the main text, it is likely that measurements may be made, with less noise, of the known papers etc. that were used as references within the mind of the inventor who devised the new technology. In this study, we will focus on Japanese patents, which have not been researched to any great degree to date, and make measurements of the academic papers that are cited on the front page and within the specifications. By doing so, we will aim to elucidate the way in which science exerts an influence on patentable technological changes in all the technological filed in a certain time period.

2. Material and Metods

2.1. The Configuration of the Study

In order to elucidate the way in which science exerts an influence on patentable technological changes, we will study the relationship between "patents," which are a subset of technological change, have novelty in view of the Japan Patent Law, are refereed under a certain set of uniform standards as having potential for practical use and having utility, and have been listed in the official gazette as having patentability, and "articles such as papers etc. that are carried in periodical journals and proceedings of academic conferences ('papers etc.')," which are the formalization of knowledge produced by science, cited in the "patents." This endeavor, in other words, can be described as the act of investigating the linkage between the scientific knowledge that has been codified and released to the public and the technical knowledge that has been codified and protected as intellectual property which increase productivity and lead long-term economic growth.

First, a Japanese patents database was constructed, to serve as the basis of our study. Second, we extracted patents belonging to the four technical fields that were identified as important in the Second Science and Technology Basic Plan: biotechnology, nanotechnology, information technology (IT), and environmentally related technology. Furthermore, 300 samples were selected from each of those patent subsets by random sampling. Then, strength of linkage to science in each technological field was analyzed, based on the average numbers of the citation of papers etc. in 300 randomly selected patent samples in each technological field.

Third, we attempted an automatic extraction by computer of patent citation information from the patent database, using as a "teacher" the information relating to other patents and papers etc. cited by patents that has been extracted from patent samples via visual inspection by humans. We identified which technological fields in the International Patent Classification (IPC), a technical classification that classifies every single patent, contain many science linkages in Japanese patents.

2.2. Construction of Japanese Patent Database

In order to analyze according to technological field the bibliographical information on other patents and papers etc. that are cited in patents in Japan, there is a need to conduct cross-sectional searches through massive amounts of patent information, classify and extract the information according to technological field, and conduct random sampling so as to avoid statistical unevenness.

However, in Japan, up to 1997, one had to pay to have access to patent information. In addition, unlike corporations that could make bulk purchases of information in the form of magnetic tape, the ordinary social science researcher working on a limited research budget really had no choice but to use the database service called PATOLIS. However, since the search formats of PATOLIS consisted mostly of searching for one item at a time, such as for a similar patent, to accommodate the needs of corporations and patent attorneys, and because the fee structure was dependent on the volume searched, it was difficult to conduct all-inclusive, cross-sectional analyses of Japanese patents from a policy science perspective.

From fiscal 1997, the Japanese Patent Office also started offering a service called the "Industrial Property Digital Library (IPDL)" and allowed access to information through the Internet free of charge. This is a major leap forward, and a revolutionary matter. However, searching from the website is limited to a maximum of 500 items, searchable by International Patent Classification or technical term, and the information is difficult to process as is. These factors are believed to have been part of the reason why analysis relating to citations in patent data in Japan was not carried out to any great degree.

In order to conduct an analysis of the citations consisting of other patents and papers etc. that are cited in the patents in Japan, which is the purpose of our study, it was desirable to obtain, as much as possible, the raw data of patent gazettes which have been given patent rights. Therefore, in our study, we obtained approximately 1,100 CD-ROMs worth of electronic patent gazette data of *Tokkyo Koho* (Published Examined Patent Application) and *Kokai Tokkyo Koho* (Published Unexamined Patent Application) between 1993 and October 2001 inclusive that have been put into CD-ROM form, to use as the basis of our analysis.

Firstly, in order to make possible the analysis for each technical field, we stored all of the *Koho* CD-ROM data in our computer. The reason for entering all of the CD-ROM data into the computer was that it is practically impossible to have random, high-speed access to a given piece of data, and conduct the computations, such as the extraction of patents of a specific technical field, that are required of this study, with the CD-ROM data spread out over multiple individual CD-ROMs. The disk space occupied by the CD-ROM data published as *Koho* by the time we started our analysis was as much as 800 GB or so.

Furthermore, we converted the character code of the stored data so that it was easier to handle. *Koho* CD-ROM data includes a mixture of text and image data, and moreover, the text data is recorded in JIS code, not the Shift-JIS code that is used in general-purpose personal computers. We therefore removed the image data from the CD-ROM data, created a program for converting the character code of the remaining text data, and converted the stored CD-ROM data. As a result of this procedure, we succeeded in creating one text file containing all the text information for each patent application in the *Koho* CD-ROM patent data.

Merely converting the data contained in the *Tokkyo Koho* and *Kokai Tokkyo Koho* CD-ROMs into text data is not enough to mitigate the difficulty involved in the various types of analysis required for achieving the purposes of our study, such as the extraction of specific technical fields, investigating the addresses of the applicants, and measuring the claims, for the reason that the text information in the patent applications is still in a state of “solid typesetting,” so to speak. It becomes necessary, therefore, for the purpose of full-fledged data analysis, to make it so that the operations such as conducting searches for the desired patent content, narrowing searches, combining the information with other information, and extracting the information, as well as the results of such operations, can be handled in a logical manner by means of commands based on a certain set of grammatical rules. These objectives can be achieved by using database management software.

In our present study, we decided to use MySQL, which is a relational database management software that is available for free, including the source code. We converted and registered the text data extracted from the CD-ROMs into a form that could be handled by MySQL.

In order to register data with MySQL, the process from data readout to registration had to be conducted by some means. We developed a specialized program for this purpose. Specifically, we had to first read out the text data file for each patent, then classify it according to patent classification, and then finally register the information according to the classification.

The CD-ROMs we obtained were all stored in a computer that was created exclusively for the processing of data. The qualities required of this computer were the following three. Firstly, the computer had to have an external storage capacity capable of storing over 1,100 650MB CD-ROMs and have ample space left over after storing the data created from the processing of these CD-ROMs.

Secondly, it had to have high speed computing capabilities and internal memory space capable of processing enormous volumes of data. Thirdly, the unit had to be equipped with safety measures in case of power failure or system error.

The specifications of the computer that we made were: external storage unit (hard disk array) 1,100 GB (about 50 times that of ordinary personal computers); dual CPU configuration (approx. 2 GHz); 1,024 MB RAM. Such high levels of performance in a machine would have been out of the reach of the individual user five years ago. In that sense, our present study would have been practically impossible without the advances in computer technology.

2.3. Automatic Extraction of Cited Reference

To overcome the limits of manual cited paper extraction, and to measure the science linkage of a large number of patents based on uniquely identifiable technology areas, it is necessary to automate the extraction of cited scientific papers. Fortunately, Japanese patents are almost entirely in electronic form since 1994, so it is comparatively easy to use computers. Therefore, if the extraction of cited papers can be automated reasonably with no exclusions and no extra information extracted using visual inspection as a model, it should be possible to measure science linkage over comprehensive technology areas for all patents in the database.

Because of no obligation to state the reference cited in front-page of patent document in Japan, it causes arbitrary description of reference cited such as just embed it in the text of the patent document. Hence it poses the difficulty to take a big picture of the relation between patent and reference cited.

The extraction of the reference cited from all of patent documents by humans is impossible. To extract it automatically, we have to construct the automatic reference cited extraction system. One of the difficulties of automatic extraction of reference cited is due to no regulation to unify the way of description of reference cited in the Japanese patent document.

So we had to find out a lot of rules and categorize it according with the way the reference cited are described.

Regular expressions were applied to the pattern-match of the reference cited. Regular expression is a context-independent syntax that can represent a wide variety of character sets and character set orderings, where these character sets are interpreted according to the current locale.

The ways of the description of patent reference and non-patent reference are so different that we extracted them independently. In the case of extracting non-patent cited, regular expressions is applied to detect six types of feature, “Japanese index”, two types of “English index”, two types of ordered combination of numbers and marks, that implies the series of the volume and the page of the magazine, and the year in Roman numerals. To extract the patent cited we just constructed three rules of regular expressions with using Kanji (Japanese) characters.

Table 1 shows the results of automated extraction of reference cited. We separated the data from patent data-base in five categories, Bio-technology, Nano-technology, IT-technology, Environment-technology, and mixed categories which indicate the mixture of pre-nominate four categories.

(Table 1)

Because we extracted the data from two patent data-base system, examined-public-Info and unexamined-public-Info, we divide each of five categories in two sub categories corresponding to the patent data-bases.

For instance, “Env-tech unexam” means the data belongs to categories of environment technology, which was extracted from the patent data base of unexamined-public-Info.

Noise in the Table1 indicates the error data that is not reference cited. Precision ratio and recall ratio is calculated by noise and leakage. We calculate the precision ratio by Table 1 shows that leakage of the data. The recall ratio is 98 % and the precision ratio also 98%. It shows that the system is tolerance to practical research.

2.4. Measurement of Science Linkage throughout the International Patent Classification

Patent Gazettes contain a single technology area for each patent in them to be classified based on the International Patent Classification. This means that all the patents on patent gazettes are uniquely classified in one of the technology categories. Of course, sometimes, one patent mainly belongs to Category A, but may also belong to Category B, in which case Category B appears as a "secondary category". However, each patent has only one "primary category".

In the International Patent Classification, all technology areas are divided into eight sections, which are in turn divided into more specific classifications. Specifically, a section is divided into classes, each class into subclasses, each subclass into main groups, and each main group into subgroups. Each subgroup is further divided into a nested structure, starting from a 1-dot subgroup, 2-dot subgroup (a subset of the 1-dot subgroup), a 3-dot subgroup (a subset of the 2-dot subgroup), and so on up to a 6-dot subgroup. This leads to nearly 600 mutually exclusive subclasses and over 30,000 subgroups as a whole, giving a reference manual of over 1,600 pages.

In this study, from the patent database, nearly 650,000 patents, granted from 1995 to 1999, were classified at the most specific subgroup level and cited papers were automatically measured for each and every patent. As noted earlier, categories are nested at the subgroup level, and while not comprehensive, analysis at the comprehensive and exclusive subclass levels can be accomplished by summing the number of papers cited in the patents at the narrower levels.

3. Results and Discussion

Because of filling in the references in the front page of Japanese patent application is not mandatory and quite incomplete, it is necessary to create a program to automate the extraction of cited documents to comprehensively understand the linkage between technologies and sciences. As a result, a program with very high degree of precision (approximately 98 %) was successfully created. This enabled us to extract cited patents and papers automatically from each and every patent in our database and investigate science linkage comprehensively at the desired level of international patent classification.

Of nearly 650,000 patents granted and published on Patent Gazettes from 1995 to 1999, we investigated science linkage of technology areas in about 600 categories. Table 2 lists the top 20 subclasses by the average number of papers etc. per patent. For Japanese patents, the No. 1 area was "C12N microorganisms or enzymes: compositions thereof" with an average of 14.6, followed by "C07K organic chemistry, peptides" with an average of 12.2. The technological area which has the third largest average number of papers etc. per patent was "C12Q a method of measurement or a method of testing microorganisms or enzymes, a composition or a test paper for the method, the method for preparing the composition, and status response control in a microbiological or enzymological method" with an average of 7.6. The average for all was 0.5.

This is in line with the trend of science linkage in European patents studied by Michel et al. (2001). The Japanese top 10 areas which were automatically extracted and ranked by science linkage according to the International Patent Classification include 6 of the European top 10 technology areas. The top 3 areas are identical in Japan and Europe. This similarity of the pattern of the strength of the science linkage between Japanese patent and European patent suggest that the linkage between technology and science differs not because of the place where the technology was invented, but because of difference in dependence upon scientific knowledge of different technological subclass.

(Table 2)

Figure 1 shows the average science linkage by subclass, the number of papers cited in patents measured for each of the subclasses (600 categories) divided by the number of patents that belong to that category. The strengths of science linkage among technological fields vary greatly. The science linkage of "C12N microorganisms or enzymes: compositions thereof" is the strongest and it is about 30 times greater than the average for all.

(Figure 1)

Most subclasses which have strong science linkage are biotechnology related, while several other subclasses are information technology related. The fifth area in the top 20 list is "G03C Photographic-sensitized material, photography (e.g., motion pictures, X-ray photography, multicolor photography, stereoscopic photography,) auxiliary photographic processing methods." The 11th is "G09C ciphering or deciphering apparatus for cryptographic or other purposes involving the need for secrecy," the 18th is "G06E optical calculating machine," and the 19th is "G10L analysis or synthesis of speech, speech recognition." These technological areas are the subclasses of the international patent classification within the section G, physics, and they are related to information technology.

4. Conclusion

We constructed an original database concerning science linkages based on text of Japanese Patent Gazette published since 1994. We discovered that Japanese inventers cite many academic papers in the texts of the patent applications in the Japanese Patent System without legal obligation.

Based on this finding, we constructed science citation index by data mining the texts of Japanese patent system for the first time. The science linkage indexes among different patent classifications differ significantly from each other. The technologies related to biotechnology were by far the closest to science. Some technologies related to photography, encryption, optical computing, and speech recognition also showed strong linkage to science. It suggests that the process of creating new technology differs from technology to technology.

Table 1: The calculation result of automatic cited reference extraction

	patent reference			non-patent reference		
Categories	patent cited	noise	leakage	non-patent cited	noise	leakage
Env-tech unexam	531	1	0	55	2	11
Env-tech exam	1296	0	5	73	0	3
Mixed unexam	1355	7	6	435	6	18
Mixed exam	2342	14	2	672	11	32
IT-tech unexam	234	2	4	46	8	2
IT-tech exam	977	5	6	115	2	18
Bio-tech unexam	875	14	6	3420	112	31
Bio-tech exam	1322	25	13	4267	22	32
Nano-tech unexam	476	4	2	83	11	11
Nano-tech exam	1867	1	1	213	3	14
SUM	11275	73	45	9379	177	172

	patent reference	non-patent reference
Recall ratio	99.6%	98.2%
Precision ratio	99.4%	98.1%

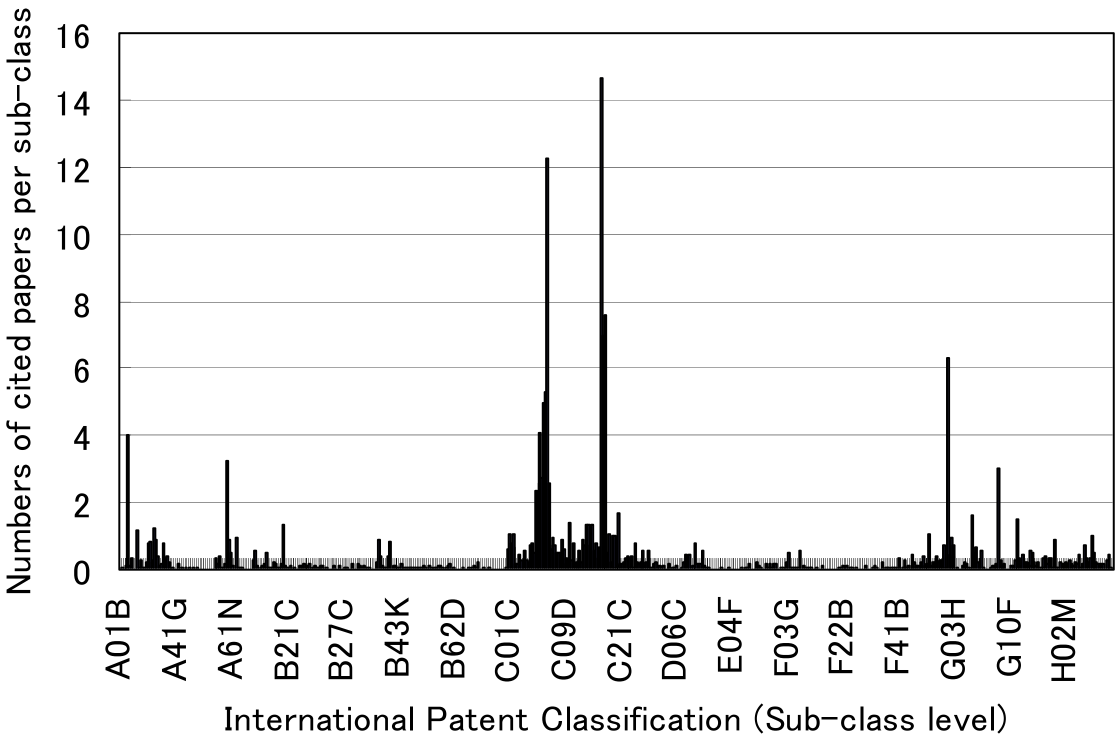
Table 2: Top 20 Subclasses by Average Science Linkage

Subclass	Number of Patents	Average Science Linkage
C12N microorganisms or enzymes; compositions thereof; propagation, preservation, and maintenance of microorganisms, mutation or genetic engineering, culture medium	44425	14.6
C07K Peptides	18390	12.3
C12Q A method of measurement or a method of testing microorganisms or enzymes, a composition or a test paper for the method, the method for preparing the composition, and status response control in a microbiological or enzymological method.	5442	7.6
C12P A method for synthesizing the desired chemical material or chemical composition by using fermentation or an enzyme, or the method for separating an optical isomer from a racemic mixture	9617	7.0
G03C Photographic-sensitized material, photography (e.g., motion pictures, X-ray photography, multicolor photography, stereoscopic photography,) auxiliary photographic processing methods.	24018	6.3
C07J Steroids	1373	5.3
C07H Sugars, derivatives thereof, nucleosides, nucleotides, and nucleic acids	2837	5.0
C07D Heterocyclic compounds	24241	4.1
A01H New plants or a treatment to obtain them, propagation of plants by tissue culture	596	4.0
A61K Medical, dental, or cosmetic chemical preparations	23852	3.3
G09C Ciphering or deciphering apparatus for cryptographic or other purposes involving the need for secrecy	233	3.0
C07G A compound having an unknown structure (in organic chemistry)	138	2.7
C07F Non-cyclic, carbon cyclic, or heterocyclic compounds [containing an element other than carbon, hydrogen, a halogen, oxygen, nitrogen, sulfur, selenium, or tellurium (in organic chemistry)]	3651	2.6
C08B Polysaccharides and derivatives thereof (organic high polymer compounds, manufacturing or scientific processing thereof, compositions based thereon)	1155	2.6
C07B General methods (in organic chemistry) or an apparatus thereof	468	2.3

C07C Non-cyclic compounds, carbon cyclic compounds (in organic chemistry)	15291	2.0
C14C Chemical processing of a raw hide, a pelt, or leather	51	1.6
G06E Optical calculating machine	56	1.6
G10L Analysis or synthesis of speech, speech recognition	1761	1.5
C09H Manufacturing method of glue or gelatin	18	1.4

Note: The technology categories enclosed in bold boxes are also ranked in the European top 10.

Fig. 1: Significant difference in science linkage among different technological classifications



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