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Does the Public Sector Make a Significant Contribution to Biomedical Research in Japan?
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Abstract

This paper examines the value of Japanese biomedical patents filed for 1991–2002, both before and after the introduction of the TLO Act in 1998 and the Japanese Bayh-Dole Act in 1999. We use *forward* citations to measure the value of the patents. Adjusting the heterogeneity of propensity to cite by subsequent patents in 19 major biomedical fields per year, we employ panel regressions controlling a fixed effect of the first assignee. Our main findings are as follows: (1) patents filed by a corporation and joint applications by corporations are highly valued; (2) if a corporation is the first assignee, a patent with a government co-assignee is highly valued; (3) although the value of government patents is not very impressive, it has risen since the pro-patent policies; and (4) there is no significant change in the value of university patents before and after the Japanese Bayh-Dole Act.

Key words: biomedical research, patent value, pro-patent policy, government research institute, university

JEL Classification No: L65, O34, O38

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1. Introduction

The amount of money that the Japanese government spends on biomedical research has dramatically increased since the latter half of the 1990s, reflecting the growing prevalence of opinions emphasizing the role of the public sector in research[1]. At the same time, the Japanese government has actively promoted pro-patent policies with the intention of advancing research collaboration among industries, universities, and governments and facilitating the commercialization of their research outcomes. Regrettably, however, primarily due to data constraints, very few solid empirical studies have been conducted on the research performance of the Japanese public sector per se[2].

The present study is focused on exploring the following two questions: (i) Did Japanese pro-patent policy measures that were introduced in the latter half of the 1990s encourage the public sector to file *valuable* patents? (ii) Are the values of corporate patents positively associated with the presence of co-assignees, especially when the co-assignees belong to the public sector, such as government research institutes and universities? We examine these policy questions by utilizing patent statistics on biomedical research[3]. Since there is a close association between producing scientific knowledge in biomedical research and implementing the knowledge in commercialization, and because patenting is one of the most effective tools for securing privately appropriable knowledge of biotechnologies, patent statistics would prove to be a beneficial source of information on the role of the public sector and its research collaboration with the private sector in the commercialization of the research outcome.

After the enactment of the *Basic Law on Science and Technology* in 1995, there was a wave of legislations that encouraged collaborative research among industries, governments, and universities. Table 1 provides a list of the policy initiatives. Several legislative measures in this list are emulated from relevant U.S. policies, such as the Bayh-Dole Act and the Small Business

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[1] Traditionally, the Japanese government placed top priority on energy-related research. However, the Basic Plan for Science and Technology—that has been introduced at every five year period since 1996—has gradually reallocated research expenditures to other technology fields, putting more emphasis on life science. Since the introduction of the Basic Plan, more than 400 billion yen has been allocated to the field of life science every year. For further details, see the Council for Science and Technology Policy (2005).

[2] In a series of careful survey studies, Levin et al. (1987), Klevorick et al. (1995), Mansfield (1995), Goto and Nagata (1997), Cohen et al. (2002a, b), and others provided valuable information about public sector research and its contribution to industrial R&D in Japan and the U.S. However, most prior studies on public R&D in Japan focused more on research consortia. For example, see Goto (1997), Odagiri et al. (1997), Branstetter and Sakakibara (1998, 2002), Odagiri (1999), Hayashi (2003), and Okada and Kushi (2004). These studies indicate that government support for research consortia enhances participants' R&D and/or patent application to a greater or lesser extent, depending on the organizational features of the research consortia.

[3] In this study, the term "public sector" is used to refer to both governments and universities. It should be noted, however, that university researchers and government researchers may be very different in propensity to patents, to the extent of their affinity to the open science culture, and the resulting values of their patents. These points will be discussed in later sections.

Innovation Research (SBIR) program. From among the policy initiatives mentioned in Table 1, the following two legislative measures are deserving of attention in this study because it is expected that they have a wide and profound effect on patenting activity and technology transactions in the public sector.

[INSERT TABLE 1 AROUND HERE]

First, the *Law on the Promotion of Technology Licensing by Universities* etc. (hereafter, "the TLO Act"), enacted in 1998, states that the government should support technology licensing organizations (TLOs) of universities and government research institutes. In addition, these institutes should obtain the partial remission of patent fees, and the licensees from the *approved* TLOs by the government may be given government investment under certain conditions.

Second, the *Law on the Special Measures for Revitalizing Industrial Activities* (hereafter, "the Japanese Bayh-Dole Act") was enacted in 1999; this act specifies Bayh-Dole provisions in Sections 30–33, such as permission to retain patents to inventions derived from publicly funded research as well as exclusive licensing of state-owned patents[4]. These provisions generated considerable interest among Japanese policy makers in emulating the Bayh-Dole Act of 1980 in the U.S., which is widely credited with stimulating significant growth in industry-university-government technology transfer and research collaboration.

At first glance, the TLO Act and the Japanese Bayh-Dole Act appear to have had significant effects on the way in which public sector researchers produce privately appropriable research outcomes. As will be discussed in detail in the following sections, patenting by both government research institutes and universities has exploded since the introduction of these two policy measures[5]. In addition, the number of patent applications that were jointly filed by both private and public sector researchers also significantly increased from 1998.

However, the incentive to patent by public sector researchers would be arguably very different from that by private sector researchers. As Argyres and Liebeskind (1998) indicate, the commercialization of government/university research would be hampered because of the historic commitment to create and sustain "intellectual commons" for the public at large. The informal, free flow of knowledge between public and private sectors may be an important

[4] The Japanese Bayh-Dole Act also provided, for the first time, somewhat flexible dual employment rules for university/government researchers across the private and public sectors; however, the Law on the Enhancement of Industrial Technologies, which was enacted in 2000, made further clarifications on these dual employment rules.

[5] It is almost impossible to separately evaluate the effect of the two policy measures. Therefore, in the regressions, we will utilize a year dummy for either 1998 or 1999, alternatively, for the purpose of a robustness check. See Section 7 for further details.

source of social benefit. Patenting may thereby inhibit the diffusion of scientific knowledge, which has been christened by Heller and Eisenberg (1998) as the "the tragedy of anticommons."

The effect of pro-patent policies on both public and private R&D has been the focus of recent empirical studies (Henderson et al., 1998; Mowery et al., 2001; Hall and Ziedonis, 2001; Agrawal and Henderson, 2002; Mowery et al., 2002; Thursby and Thursby, 2002; Mowery and Ziedonis, 2002; Owen-Smith and Powell, 2002; Owen et al., 2002; Lanjouw and Schankerman, 2004a; Mowery and Sampat, 2005; Hall, 2005; Murray and Stern, 2005; and others). These studies provoke, to a greater or lesser extent, a cautious view toward pro-patent policies and toward the Bayh-Dole-like measure in particular.

For example, Mowery and Sampat (2005) convincingly argue that efforts at emulating the Bayh-Dole policy are likely to have a modest success rate at best, without greater attention being paid to the underlying structural differences among the higher education systems. Mowery and Sampat (2005, p.123) also suggest that the emulated Bayh-Dole policies by OECD countries, including Japan, "ignore one of the central justifications for Bayh-Dole, i.e., that government ownership of publicly funded inventions impedes their commercialization."

In a related vein, Cohen et al. (1998), Cohen et al. (2002a, b), Agrawal and Henderson (2002), Walsh and Cohen (2004), and Murray and Stern (2005), among others, suggest that in the U.S., the channels of open science, such as publications, conferences, informal communications, and consulting, are the primary and important methods of transmitting scientific knowledge, as compared to patents and licenses. These studies emphasize that the informal flow of knowledge between universities and industries is essential and that patenting may play other roles such as defending against infringement litigation and obtaining bargaining chips in licensing negotiations.

Almost all Japanese universities and government research institutes are predominantly funded by the government and are tightly controlled by vertically divided bureaucracy[6]. Contrary to the case in the U.S., Japanese public sector researchers have to abide by strict office regulations that are virtually similar to those for civil servants. In addition, academic culture such as open science and priority-first sentiments seems to be endemic among public sector researchers. Concomitantly, it was very unlikely for Japanese public sector researchers to file patents until very recently (Odagiri and Goto, 1993; Odagiri, 1999; Kneller, 2003; Walsh and Cohen, 2004). Therefore, not only the number of patents but also the *value* of these patents filed by the public sector researchers, especially those patents that had been increasingly applied for since the introduction of the pro-patent policy, would deserve to be closely examined as a proxy

[6] Walsh and Cohen (2004) provide useful information about organizational and institutional differences between Japan and the U.S. with regard to public research and its collaboration with industry. They suggest that public research has a substantial impact on industrial R&D in both countries, although the institutional environments for university-industry linkages in the two countries are quite distinct.

for the effectiveness of the policy initiatives, translating their work into privately appropriable knowledge.

We use citation counts by subsequent patents (i.e., *forward* citations) as the patent value measure. Following Jaffe and Lerner (2001) and Hall, Jaffe, and Trajtenberg (2002), we adjust the heterogeneity concerning propensity to cite by subsequent patents in 19 major biomedical fields per year. In other words, we construct a weighted citation count (*normalized* forward citation intensity) that is defined by the difference between the actual number of citations received per patent and the *reference* citation intensity in each technology field, every year.

We employ several panel regressions, controlling for the individual effect of the first assignee of a patent and using the normalized citation counts as the dependent variable. Our main findings are as follows: (1) patents filed by a corporation as well as jointly filed patents by no less than two corporations are highly valued on average; (2) if a corporation is the first assignee, a patent with a government co-assignee is highly valued on average; (3) although the value of government patents is not very impressive, this value has risen since the introduction of the pro-patent policy; and (4) there is no significant change in the value of university patents before and after the Japanese Bayh-Dole Act. These findings may reflect the fact that the pro-patent policy in Japan is only now beginning to have some impact on the patenting activity of government research institutes. On the other hand, the findings do not appear to dictate the patenting behavior of university researchers. We are of the opinion that the institutional and organizational features of government research institutes and universities are keys to elucidate the salient responses between these institutes. Japanese universities may not yet accommodate themselves to patenting biomedical research outcomes despite the introduction of several facilitating policy measures in the late 1990s.

The rest of the paper is structured as follows. Section 2 describes data sources, technology classification, and assignee name matching. Section 3 lays out the empirical formulation. Section 4 provides a brief summary of our patent data in terms of technology class, assignee type, and industry classification. Section 5 explains the variable constructions. Section 6 provides summary statistics for selected variables; Section 7 presents empirical findings, and Section 8 concludes the paper.

2. Data Construction

2.1. Retrieval of Patent Data

We utilized several patent databases. First, we retrieved biomedical patents from the Derwent Innovation Index (DII) and the Derwent World Patent Index (DWPI) (Thomson ISI) by using 19 search equations that are defined by the Japan Patent Office (JPO) (2003). The search equations define 19 biomedical fields non-exclusively, by using a combination of International Patent Classifications (IPC) and key technical terms of the relevant technological categories[7]. Table 2 shows summary descriptions of these 19 biotechnology fields. We believe that these categories cover a broad range of technology fields associated with biomedical research.

[INSERT TABLE 2 AROUND HERE]

The patent retrieval procedure is as follows: the date of the search is March 1, 2004; the priority country is Japan; the priority date is from 1 January 1991 to the date of the search. Then, using several kind codes[8], we matched the patents with the IIP Patent Database (the Institute of Intellectual Property). The IIP Patent Database provides accurate information on the Japanese assignees because it is based on the original digitized database (*Seiri-Hyojunka* Database) compiled by the JPO. Moreover, patent documents from the IIP Patent Database are described in Japanese, which greatly alleviated our efforts in identifying assignee names, as will be explained in detail in the following section.

By using the above-mentioned search procedure, we retrieved 30 938 patents with the following items: application number, application date, designated state, IPC, assignee name, patent country, kind code, patent number, priority country, priority date, publication date, forward citations, backward citations, and *equivalent* patents (i.e., “Derwent family”)[9]. Then, we re-examined the priority information, assignee names, and priority country of each patent and excluded irrelevant or erroneous data. The dataset that remained comprised 30 350 patents. In addition, if an assignee belonged to a particular industry, we checked whether or not that assignee was a listed company by using the Japan Development Bank (JDB) Database and the Japan Bioindustry Association (JBA) Annual Report.

2.2. Assignee Name Matching

Assignee names in the Derwent patent data were provided in English, and unfortunately, were not accurate enough to infer the relevant Japanese assignee names (in some cases, the data were quite erroneous and misleading). Thus, we had to match the English assignee names with their corresponding Japanese names. First, we matched the first assignee with, if any, other co-assignees. Second, we retrieved the Japanese assignee names (written in Japanese) from the

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[7] Since a complete description of the 19 search equations will prove to be quite lengthy, we have omitted this due to space constraints. For further details, see JPO (2003).

[8] The IIP Patent Database is now available on the IIP homepage (http://www.iip.or.jp/).

[9] A “Derwent family” is a set of individual patents granted by various countries, covering all the equivalent patent applications corresponding to a single “invention”; these patents are compiled by ISI experts with knowledge on biomedical research, who read all relevant patent documents. Thus, a Derwent family does not necessarily correspond to the number of countries in which patent protections was sought.

IIP Patent Database and matched them with the DII/DWPI patent data by using several types of patent numbers and kind codes. We then supplemented the remaining missing assignee names by using the Intellectual Property Digital Library (IPDL) offered by the JPO. After time-consuming exploration, we identified 5 352 distinct assignees of the 30 350 patents in which the number of the first assignee was 3 577. We adopted original assignee names at the date of patent filing to avoid arbitrary aggregation or disaggregation of assignee names because there were many applicants that had undergone M&A, a company split, or a change in assignee name or institutional affiliation.

2.3. Classification of Assignee Types

Pro-patent policies, including the Japanese Bayh-Dole Act in 1999 and the TLO Act in 1998, are mainly intended for the public sector, which includes government research institutes and universities. The main aim of the present study is to detect the effect of these policy measures; therefore, we need to clearly distinguish private sector patents (mainly corporate patents) from public sector patents (i.e., government patents and university patents).

We classified all the assignees into one of the following types: corporations (*corp*), government research institutes (*gov*), universities (*univ*), individuals, and other types of assignees such as private foundations and public associations. If individual assignees have their own institutional affiliations, their true affiliations are often suppressed in patent documents under the Japanese patent filing routine. Thus, we had to search for the original affiliations of all the individual assignees by using the Yahoo! and Google search engines. Subsequently, we reclassified the patents that were filed by individual patentees into the above-mentioned three types of assignees to the greatest possible extent.

Moreover, we classified the combinations of co-assignees if they amounted to two or more. As will be explained in the next section, we distinguished between the first assignee and other co-assignees of a patent in order to control for a possible first-assignee fixed effect on patent values in regressions. First, if no less than two co-assignees are corporations and there are no other co-assignees belonging to universities and government research institutes, the patents filed for by those co-assignees were denoted as *corp_corp*. Second, we denote an industry-government patent as *corp1_gov* if a corporation is the first assignee of a patent and at least one co-assignee is a government research institute and there are no other co-assignees belonging to universities. Similarly, we denote a patent as *gov1_corp* if a government research institute is the first assignee and at least one co-assignee is a corporation and there are no other co-assignees belonging to universities. Finally, we denote an industry-university patent as *corp1_univ* if a corporation is the first assignee and at least one co-assignee is a university and there are no other co-assignees belonging to government research institutes. Similarly, we denote a patent as *univ1_corp* if a university is the first assignee and at least one co-assignee is a corporation and there are no other co-assignees belonging to government research institutes[10].

After time-consuming data exploration, we exclusively identified all the first assignees and co-assignees of 30 350 patents as follows: *corp* (21 664 patents), *gov* (1 611), *univ* (995), *corp_corp* (1 420), *corp1_gov* (323), *gov1_corp* (536), *corp1_univ* (636), *univ1_corp* (460), individuals (727), private foundations and public associations (1 350), and others (628).

3. Empirical Formulation: "Fixed Effect" Approach

We treat a first-assignee individual effect that is possibly associated with patent values. The first assignee of a patent may be the main inventor or solely the main contributor to the research fund. There may not be a significant reason for the sequence of co-assignees, and we have no additional information regarding the reasons for the order of these co-assignees. However, there are also no reasons for negating the fact that the first assignee would be the principal co-assignee. Therefore, we control for a possible "unobservable" fixed effect for the first assignee in regressions. In other words, our basic model for estimation is

$$(1)\quad Y_{i(t),j} = c_j + X_{i(t),j}\alpha + D^C_{i(t)}\beta + D^G_{i(t)}\gamma + D^U_{i(t)}\delta + D99_{i(t)} \times (D^G_{i(t)}\varsigma + D^U_{i(t)}\xi) + u_{i(t),j},$$

where $Y_{i(t),j}$ is a "normalized" forward citation intensity of a patent i filed in year t by the first assignee j. The column vector $X_{i(t),j}$ represents the impact of individual patent characteristics on patent values. $D99_{i(t)}$ is an indicator variable that takes on the value of unity if the priority year of patent i is 1999 or later, otherwise zero. $u_{i(t),j}$ is an error term. This specification essentially exploits cross-sectional variations of the pooled observations of patents that are filed by the first assignee of a patent across the years. The inclusion of individual effect c_j controls for all the "unobserved" individual characteristics of the first assignee. In other words, c_j captures all the attributes of the first assignee that do not vary across patents, such as innovative capacity and institutional capability of an in-house legal section[11]. Estimates of the parameters of interest are based entirely on the cross-sectional variation between Y_{ijt} and assignee type dummies $D_{i(t)}$ s.

[10] There are very few patents that are jointly filed by a corporation, a government research institute, and a university, as well as by both a government and a university in our dataset. We thereby do not make additional indicator variables for them.

[11] In other words, the present formulation does not explicitly consider the "learning to patent" on a year-by-year basis. For example, see Mowery et al. (2002) for the effect of university experience on patent value. The learning effect may cause some endogeneity issues because excellent legal expertise would enhance patent values. The present specification eliminates this possibility because, in Japan, it is rather unlikely that government research institutes and universities have rapidly accumulated experience in patenting and are adept to patent in a short time since the introduction of the pro-patent policy, at least until quite recently.

$D_{i(t)}$s represent row vectors of assignee type dummies of patent i in year t. A superscript of $D_{i(t)}$ represents a particular assignee type. Therefore, if a patent is filed by at least one corporation and there are no other co-assignees belonging to the public sector, we denote the row vector of the indicator variables as $D^C_{i(t)}$. On the other hand, if a patent is filed by at least one government research institute and there are no other co-assignees belonging to universities, we denote the row vector of the indicator variables as $D^G_{i(t)}$. In a similar manner, if a patent is filed by at least one university and there are no other co-assignees belonging to a government research institute, we denote the row vector of the indicator variables as $D^U_{i(t)}$. To be more precise, we define them as follows:

(2) $$D^C_{i(t)} = (corp_{i(t)},\ corp\_corp_{i(t)})$$

(3) $$D^G_{i(t)} = (gov_{i(t)},\ gov1\_corp_{i(t)}, corp1\_gov_{i(t)})$$

(4) $$D^U_{i(t)} = (univ_{i(t)},\ univ1\_corp_{i(t)}, corp1\_univ_{i(t)}).$$

By using these indicator variables, we examine the effect of a particular assignee type on the patent value. Under a fixed effect specification of the first assignee, a coefficient of the dummy variables in fact evaluates the impact of the relevant assignee type on the patent values compared to the "average" value of all the patents with the same first assignee type. For example, a coefficient of $corp_{i(t)}$ indicates the impact of a corporate assignee without co-assignees from either governments or universities, compared with the average patent value of all corporate patents. In a similar manner, a coefficient of $gov1\_corp_{i(t)}$ indicates the impact of the first assignee of a government with a corporation as a co-assignee, compared with the average patent value of all government patents. Thus, the first assignee type of a patent is an essential factor of our empirical specification.

We explore the impact of the pro-patent policy for the public sector on patent values by using several cross terms between a year dummy ($D99_{i(t)}$) and assignee type dummies for the public sector. In other words, we include the cross terms of a year dummy $D99_{i(t)}$ with both $D^G_{i(t)}$ and $D^U_{i(t)}$.

4. Basic Facts about Japanese Biomedical Patents

In this section, we summarize some basic facts about Japanese biomedical patents, which would greatly facilitate us in constructing relevant explanatory variables and clarifying the implications of regression results in later sections.

4.1. Patent Applications by Technology Classes

For the sake of convenience, we classified 19 technology fields into the following three broader categories: *basic technologies* (Figure 1), *post-genome technologies* (Figure 2), and *other technologies* (Figure 3). Figures 1 to 3 illustrate the increased trend of patenting in many technology classes. “Genetic engineering” and “gene analysis” are the most active fields in which patents are applied for in Japan. On the other hand, although the rate of increase in patenting on post-genome technologies is remarkable, particularly since the latter half of 1990s, the number of patents on these technologies is much smaller than that on basic technologies. With regard to other technologies, patenting on “micro-organisms and enzymes” exploded since 1997, whereas the number of patents on biomedical products, such as “biopharmaceuticals” and “biochemical products,” did not show a significant increase within our observation period.

[INSERT FIGURES 1, 2 & 3 AROUND HERE]

It is worth noting that the compositional change in the technology fields may reflect the Japanese backwardness in biomedical research. Post-genome technologies are essential to perform *translational research*, i.e., the combination of basic and applied research to produce clinically effective biomedical products or gene therapy/diagnoses. However, the number of patents of this kind is not yet impressive in Japan. Inventing biomedical products would be one of the ultimate goals of biomedical research, and it may be even more difficult to obtain important patents on biomedical products. On the other hand, “genetic engineering” and “gene analysis” are rather upstream technologies in the long-term process of biomedical research, and these are, if anything, mature research fields. However, these technologies are still the most active fields of patenting in Japan[12].

4.2. Patent Applications by Assignee Types

Figures 4 and 5 present the number of patents that were filed by a single assignee. As can be seen from Figure 4, the trend of corporate patents is quite similar to that of total patents: the trend was almost flat or rather decreased through the mid-90s and then increased steadily from 1998. On the other hand, government and university patenting is rising sharply, although the

[12] The growth of patenting in genetic engineering and gene analysis may be partly due to the enlargement of the patentable domain in the early 1990s. Roughly speaking, the patentable domain in Japan is ranked somewhere between the broader scope of the U.S. and the narrower scope in the E.U. For further details, see JPO (2003).

latter is somewhat lagging behind the former.

[INSERT FIGURES 4 & 5 AROUND HERE]

Figure 6 plots the number of patents with no less than two co-assignees; this number fluctuated to some extent, up to the mid-1990s. In the succeeding years, however, especially since 1998, we can observe a more or less upward trend in patenting by multiple co-assignees. In particular, industry-government patents (for simplicity, *corp_gov* in the figures denotes the sum of *corp1_gov* and *gov1_corp*) and industry-university patents (similarly, *corp_univ* in the figures denotes the sum of *corp1_univ* and *univ1_corp*) rose nearly twofold in the latter half of the 1990s.

In general, cooperative research between the public and private sectors seems to have always been quite active in Japan, while it was not so common for public sector researchers to file patents until recently (Odagiri and Goto, 1993; Goto, 1997; Odagiri, 1999; Kneller, 2003). However, there has been an increasing trend of patenting by the public sector in biomedical research. Figure 7 depicts the share of patents by various assignee types. The share of patents that were filed by the public sector almost doubled in the 1990s and accounted for more than 30% of the total patents in 2002.

[INSERT FIGURES 6 & 7 AROUND HERE]

Government patenting is highly concentrated with the following top five government research institutes: the Japan Science and Technology Agency (JST), the National Institute of Advanced Industrial Science and Technology (AIST), the Institute of Physical and Chemical Research (RIKEN), the National Agriculture and Bio-oriented Research Organization (NARO), and the National Institute of Agrobiological Sciences (NIAS)[13]. These government institutes are defined by the order of the total patent applications from 1991 through 2001 in biomedical research[14]. As shown in Table 3, they account for approximately 70% of the total patent applications by the government, and the top three government institutions (i.e., JST, AIST, and RIKEN) account for the majority of the government patents. This may partly reflect the fact that

[13] The jurisdictional authorities are as follows: Ministry of Education, Culture, Sports, Science and Technology for JST and RIKEN; Ministry of Economy, Trade and Industry for AIST; and Ministry of Agriculture, Forestry and Fisheries for NARO and NIAS. The jurisdictional relationships were not changed before and after reorganizations that had occurred several times in the 1990s.

[14] The government research institutes experienced reorganizations, split-ups, and consolidations several times during our observation period. Therefore, in order to rank these institutes, we compiled a list of all the patents filed by both former and current organizations for each research institute.

government subsidies are concentrated with these research institutes[15].

[INSERT TABLE 3 AROUND HERE]

4.3. Biomedical Patents by Industry

Figure 8 depicts the number of patent applications by industry over time. Industry classification is based on the Security Identification Committee of Japan. The underlying dataset in Figure 8 thereby consists of listed companies alone. It is necessary to mention three points here. First, chemical and food companies have been the main patentees in Japan. Traditionally, industrial biotechnology research was mainly carried out by chemical and food companies with strong capabilities in fermentation[16]. Corporate patenting is not dominated by pharmaceutical companies; rather, it is dispersed across many industrial sectors. Patenting by pharmaceutical companies increased only after 1999. This is in stark contrast with the situation in the U.S. and possibly in most countries in the E.U.

Second, an increasing number of patents by electronics companies—that have been the main actors in the Japanese industrial innovation—have been filed since the latter half of the 1990s. This is probably due to the fact that biomedical research has increasingly come to rely on information technologies such as "bioinformatics."

Finally, the large companies on the list still comprise the main patentees in biomedical research. These companies account for the majority (55.4%) of the total biomedical patents for the years 1991–2002 in Japan. According to the JBA, as of March 2004, there were only twelve listed new bio-venture firms (NBFs)[17]. All of these are listed in emerging equity markets such as JASDAQ, Mothers (Tokyo Stock Exchange), and Hercules (Osaka Stock Exchange). The share of patenting among NBFs accounts for approximately 3% in Japan.

[INSERT FIGURE 8 AROUND HERE]

5. Variable Constructions

5.1. Dependent Variable: Normalized Citation Intensity

This sub-section explains our patent value measure, which is constructed using forward

[15] These five research institutes account for approximately 20% of the total public R&D subsidies to independent administrative agencies (IAAs). With regard to the distribution of government research expenditures among public research institutes, see the National Institute for Science and Technology Policy (NISTEP) (2005).

[16] This fact was also pointed out by Henderson et al. (1999, p.297).

[17] See JBA (2005). According to the definition of the JBA, NBFs are firms that do research, or engage in manufacturing or consulting that is related to biotechnologies with less than 300 employees in manufacturing and less than 100 employees in research and service, and are 20 years-old at most from the time of establishment.

citations[18]. Following Jaffe and Lerner (2001) and Hall, Jaffe, and Trajtenberg (2002), we adjust the heterogeneity concerning the propensity to cite proceeding patents in the technology field k ($k = 1, 2, \ldots, K$) in year t ($t = 1, 2, \ldots, T$). In other words, we construct a weighted citation count (*normalized* forward-citation intensity) that is defined by the difference between the actual number of citations received per patent and the *reference* citation intensity for each technology field k in year t.

As mentioned in Section 2, the patent data at hand are classified by 19 technology fields *non-exclusively*. Therefore, our normalization procedure on patent values will be slightly complicated. The total number of forward citations received by patent i is denoted by C_i (the time subscript is suppressed for simplicity). We also define f_{ik}, which assumes the value of unity ($f_{ik} = 1$) if this patent corresponds to a technology field k, and zero otherwise. Then, we define the proxy for "patent scope" of patent i as

(5) $$pat\_scope_i = \sum_{k=1}^{K} f_{ik} \ ,$$

which represents the total number of technology fields. Then, we define the weight for the citation count for each patent i on technology field k as follows:

$$g_{ik} = \frac{f_{ik}}{pat\_scope_i} \quad (1/K \le g_{ik} \le 1).$$

Next, we construct the weighted total citation count on technology field k as

$$C_k = \sum_{i}^{n} C_{ik} g_{ik} \ ,$$

where n is the total number of patents filed in year t. Thus, the total citation counts in year t are equal to the total citation counts of C_k across all the technology fields in year t.

It is possible that each patent has multiple technology-field flags. Using this, we calculate the expected citation count for each technology field as follows:

$$C_k^e = \frac{C_k}{\sum_{i=1}^{n} f_{ik}}.$$

Then, we define the expected citation count for each patent in technology field k as follows:

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18 We aggregated all the forward citations of a patent, which occurred in a common patent family. Thus, the number of forward citations here represents the total number of citing patents that were filed in various countries. Self-citations may be a less accurate indicator of the importance of a patent but it is not possible to differentiate self-citations and citations by others with the existing data.

$$C_i^e = \sum_{k=1}^{K} \left(f_{ik} C_k^e \right).$$

Finally, we normalize the citation counts for each patent that is defined by the difference between the actual number of citations received per patent and the reference citation count. In other words,

(6) $$dciting_i = C_i - C_i^e \ .$$

This normalization adjusts the heterogeneity of technology characteristics: in addition, since the mean of $dciting_i$ is zero in any year t, there is no cohort (or "age") effect of a patent[19].

5.2. Independent Variables: Assignee Types and Other Patent Characteristics

Variable names and definitions are summarized in Table 4. There are three sets of independent variables that we will use in regressions: *assignee types*, *characteristics of patents*, and *other characteristics of assignees*, as listed in Table 4. We already explain assignee type dummies in Section 3.

[INSERT TABLE 4 AROUND HERE]

Regarding patent characteristics, *pat_scope* has already been defined in equation (5). This is a proxy for patent scope that is defined by the number of technology fields of a patent. Note that technology-field flags are assigned to each patent *non-exclusively*. Quite a large number of observations have multiple technology flags (the mean is 2.1 and the maximum is 14). There is no theoretical basis for the relationship between patent scope and patent value. As pointed out by Merges and Nelson (1990), patent scope would have a complex impact on innovation. This is an empirical issue that remains to be explored. Lerner (1994) relates the market value of biotechnology firms in the U.S. to the number of IPCs in a patent, which is regarded as the patent scope. Lerner also indicates that the firm's value is positively correlated with the patent scope. On the other hand, Harhoff et al. (2003) utilize a similar patent scope measure as an explanatory variable in patent value equations and find no significant impact on German patents.

Next, we define a dummy variable *jp_only* that denotes whether the JPO is the sole jurisdiction for which a patent protection was sought. This is a control variable for the fact that there are very few citations received by patents that are filed to the JPO alone. In Japan,

[19] Heteroscedasticity may be quite serious in regressions. Therefore, for estimation results, we will utilize heteroscedasticity robust standard errors in inferences.

citations of prior arts were not obligatory for patent examiners and applicants, which would greatly decrease the likelihood of a patent being cited by subsequent patents[20]. Therefore, patents in which protection for an invention was sought solely in Japan (and written in Japanese) are not very likely to be cited by subsequent patents.

In addition, we define *science_ratio* as a proxy for the extent of science-linkage for each patent. We define *science_ratio* as "the number of backward citations of non-patent articles" divided by "the total number of backward citations + 1." Since the number of equivalent patents has a significant positive correlation with the number of backward citations, as shown in the next section, *science_ratio* would have a strong positive correlation with the size of the patent family, even though we normalized this variable by the total number of backward citations. Accordingly, although a science-linkage indicator is frequently used in the literature to emphasize the role of academic research in industrial R&D[21], an estimated coefficient of this variable should be interpreted with caution in the present study.

With regard to the other characteristics of assignees, we define *pat_size* as the total number of biomedical patents filed by the first assignee of a patent in each year[22]. We examine whether there is a scale effect whereby prolific patentees file more valuable patents on average (this may also be called the *dilution* effect if there is a negative impact of patent size on the average patent value)[23]. Moreover, we define an indicator variable as *listed*; this denotes whether or not a patent is filed by a listed company. As mentioned earlier, industrial biomedical research has been performed primarily by listed companies in Japan and there are quite a few listed new bio-venture firms in Japan. However, it is yet uncertain whether the listed companies are producing more valuable patents in biomedical research.

5.3. Other Patent Value Measures

There are other patent value indicators that are extensively used in the literature[24]. We construct

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[20] However, the revised Japanese Patent Law of 2002 makes it obligatory for a patent applicant to disclose all prior arts that an applicant knows at the date of patent filing.

[21] For example, Narin et al. (1997) and McMillan et al. (2000) suggest that by using a similar science-linkage indicator to this paper, the U.S. biotechnology industry depends on public science more heavily than other industries. In a detailed study, Harhoff et al. (2003) also show that science-linkage has a strong explanatory power on the value of German biomedical patents. In a related vein, Tamada et al. (2004) and Branstetter and Kwon (2004) suggest that the Japanese biomedical industry is strongly indebted to scientific research.

[22] At first glance, it appears to be inconsistent to include assignee-specific variables with the first assignee fixed effect specification. However, we were able to estimate these variables by using "within" variation across years.

[23] Henderson et al. (1998, pp.125–126) show that smaller universities are patenting more intensively after the introduction of the Bayh-Dole Act, and the relative importance of university patents has fallen, while the sheer number of university patents has increased. Mowery et al. (2002) explicitly examine this issue in U.S. universities and present evidence of entrants' learning to patents. Also see footnote 11.

[24] There have been a series of detailed studies on patent value measures, such as forward and backward

three patent value indexes here for the sole purpose of comparison with the normalized citation intensity. First, we define *bwd_cites*, which is the total number of backward citations on both patent and non-patent articles.

Second, we define *fam_size*, which is the total number of "equivalent patents." It is possible that the family size of a patent affects the likelihood of forward citations by subsequent patents that are filed in other countries. It should be noted that, according to the definition of the DWPI, patents in the same family do not necessarily share the same priority date. DWPI defines a patent family as patents sharing the same "invention" as well as relevant inventions that are scrutinized by experts with relevant scientific knowledge. Therefore *fam_size* is not necessarily equivalent to the number of countries in which protection was sought.

Finally, we define *claim* as the number of claims for a patent that is filed to the JPO. The number of claims is somewhat less utilized in the literature as a patent value measure[25]. Numeric data on claims was retrieved from the IIP Patent Database. The sample size of *claim* is somewhat smaller than that of our basic dataset due to missing data in the IIP Patent Database. A patentee would have the incentive to claim as much as possible but patent examiners may require that claims be narrowed before granting. Thus, the number of claims at the time of patent filing tends to be larger than that at the time at which the patent is granted. We use the number of claims at the date of patent filing because it is almost complete in the available dataset.

6. Summary Statistics

6.1. Patent Values by Assignee Type

The summary statistics are shown in Tables 5 and 6. Since the standard deviations are quite large in many variables, correlations between patent values and assignee types should be carefully confirmed in panel regressions with a series of control variables. However, it is worth noting that there seem to be somewhat consistent differences among assignee types in patent value measures.

Table 6 presents the summary statistics on the selected variables by assignee types. This table shows that the average normalized citation intensity (*dciting*) is positive only for corporate patents (*corp* and *corp_corp*). Another salient point is the large number of patent applications that were filed by the first assignee belonging to government research institutes. It

---

citations, patent family, science-linkage, number of claims, and number of years in which a patent is renewed. For example, see Schankerman and Pakes (1986), Trajtenberg (1990), Tong and Frame (1994), Lanjouw et al. (1998), Harhoff et al. (1999), Jaffe and Trajtenberg (2002), Harhoff et al. (2003), Lanjouw and Schankerman (2004b), and Hall et al. (2005).

[25] A patent claim is a unit of invention as well as a unit of intellectual property rights. Tong and Frame (1994) examine the number of claims of U.S. patents. They show that much of the growth of Japanese patents in the U.S. is muted when claims instead of patents are examined.

should be noted that *pat_size* of government patents is, on average, particularly large (50.9). This reflects the fact that propensity to patents by government research institutes was very high, especially in the latter half of the 1990s.

[INSERT TABLES 5 & 6 AROUND HERE]

6.2. Science-linkage, Patent Size, and Patent Scope

As shown in Table 6, university patents have the highest value of science-linkage (*science_ratio*). Although this fact may not be surprising, given the importance of the open science culture in university research, it should be interpreted with caution. This may be due to the differences in technology fields wherein more non-patent articles tend to be cited. Alternatively, it may be due to the university researchers' higher propensity to cite academic articles. Thus, the relationship between science-linkage and patent values is quite uncertain.

Apart from universities, there appear to be no noticeable differences in *science_ratio* among assignee types. However, if anything, it is a stylized fact in the literature that science-linkage is a beneficial source of information about the importance of a patent, particularly biotechnology patents (Narin et al., 1997; McMillan et al., 2000; Harhoff et al., 2003; Tamada et al., 2004; Branstetter and Kwon, 2004).

In addition, the average value of *pat_scope* of government patents as well as university patents tends to be a bit higher than those of other types of assignees. On the other hand, patents filed by the private sector (*corp* and *corp_corp*) have relatively lower values of *pat_scope*. Further, it should be noted that on average, corporate patents have relatively fewer claims (*claim*). In other words, compared to public sector patents, the private sector is likely to file more technologically-focused patents with fewer claims. Thus, *pat_scope* may have some salient effects on patent values.

6.3. Correlation Matrix for Selected Variables

Table 7 provides a correlation matrix for the selected variables. It should be noted that there is a highly negative correlation between *jp_only* and *science_ratio* (–0.66). We suspect that backward citations of non-patent articles by subsequent patents occurred mainly by patents that were filed in jurisdictional patent offices other than the JPO.

Regarding the alternative patent value measures, significant positive correlations are detected among *dciting*, *fwd_cites*, *fam_size*, and *bwd_cites*. These alternative patent value measures have been frequently used in the literature, and there is no certain guiding principle that specifies the best patent value measure[26]. Furthermore, incorporating these alternative

[26] In unreported works, when we used the alternative patent value measures as dependent variables in

patent value measures in regressions as independent variables would have provoked a number of problems regarding multicollinearity and endogeneity. Therefore, we exclude *fam_size*, *bwd_cites*, and *claim* from a list of explanatory variables in regressions.

[INSERT TABLE 7 AROUND HERE]

7. Panel Regressions

7.1. Empirical Specification

We utilize the following sets of variables as explanatory variables in equation (1):

(7) $$X_{i(t),j} = (pat\_scope_{i(t),j},\ jp\_only_{i(t),j},\ science\_ratio_{i(t),j}).$$

These variables are estimated by exploiting cross-sectional variations of the pooled observations of patents filed by the first assignee j of patent i across several years. We also employ regressions with the following set of variables:

(8) $$X_{j(t)} = (pat\_size_{j(t)},\ listed_{j(t)}).$$

The variables in (8) are in fact invariant across i within j. However, they have within-year variations since the number of patents as well as the listing status of the first assignee j is not constant across the years. Therefore, it may be possible to estimate coefficients for them even under the fixed effect specification of the first assignee j.

The previous sections have already defined these variables and discussed their possible impacts on patent values. By using the normalized citation intensity ($dciting_{i(t),j}$) as a dependent variable, which is defined by equation (6) in Section 4, and introducing three sets of dummy variables—(2) to (4)—and the other explanatory variables in (7) and (8) into (1), we specify a "fixed effect" regression model as follows:

various specifications, we did not have satisfactorily meaningful results, except for the specification of the present study. For example, when we employed Poisson or negative binomial regressions using the number of forward citations as a dependent variable with a series of year dummies and technology dummies, we were able to obtain somewhat similar estimation results to those of the present study. However, significant cohort effects and possibly serious truncation biases of forward citations would have made the detection of the pro-patent policy effect almost impossible. It should be noted that the pro-patent policy measures were introduced quite recently (in the late 1990s) in Japan.

$$
\begin{aligned}
dciting_{i(t),j} = c_j &+ \alpha_1 pat\_scope_{i(t),j} + \alpha_2 jp\_only_{i(t),j} + \alpha_3 science\_ratio_{i(t),j} \\
&+ \alpha_4 pat\_size_{j(t)} + \alpha_5 listed_{j(t)} \\
&+ \beta_1 corp_{i(t)} + \beta_2 corp\_corp_{i(t)} \\
&+ \gamma_1 gov_{i(t)} + \gamma_2 corp1\_gov_{i(t)} + \gamma_3 gov1\_corp_{i(t)} \\
&+ \delta_1 univ_{i(t)} + \delta_2 corp1\_univ_{i(t)} + \delta_3 univ1\_corp_{i(t)} \\
&+ D99_{i(t)} \times (\varsigma_1 gov_{i(t)} + \varsigma_2 corp1\_gov_{i(t)} + \varsigma_3 gov1\_corp_{i(t)} \\
&\qquad + \xi_1 univ_{i(t)} + \xi_2 corp1\_univ_{i(t)} + \xi_3 univ1\_corp_{i(t)}) + \varepsilon_{i(t),j}.
\end{aligned}
$$

It should be noted that both the heterogeneity of year effect (i.e., cohort effect on forward citations) as well as the technological heterogeneity are fully adjusted, as discussed in Section 5. Therefore, we do not add a series of year dummies and technology field dummies to the present specification. Regarding policy effect dummies, we use either $D99_{i(t)}$ or $D98_{i(t)}$, alternatively, in regressions for the sole purpose of a robustness check.

The normalized citation intensity ($dciting_{i(t),j}$) is not a count variable, and the error term is assumed to be independently and identically distributed. Therefore, we apply an ordinary least square (OLS) method to the panel regressions[27]. However, regression disturbances may not be constant across observations. In order to alleviate the heteroscedasticity that may be related to the explanatory variables, we use heteroscedasticity robust standard errors in inferences for estimation results. The total number of observations is 30,350 and the number of first assignees is 3577[28].

7.2. Estimation Results

The estimation results are summarized in Table 8. The observation period is for the years 1991–2002. All the equations are employed by using the fixed effect model for the first assignee. This model is supported in all specifications according to the conventional Hausman test statistics. Heteroscedasticity robust standard errors are given in parentheses.

[INSERT TABLE 8 AROUND HERE]

The estimation results in Table 8 show that the corporate dummy (*corp*) is statistically

[27] In exploratory works, we employed several regressions by using simple OLS specifications clustered by the first assignee. However, we did not obtain satisfactorily meaningful outcomes. The first assignee fixed effect appears to have a strong impact on patent values, and there may be a lot of unobserved as well as observed individual effects. Therefore, we decided to use the fixed effect specification for the first assignee.

[28] We also employed regressions by excluding the patents that were filed in 2002 (1,726 patents) from our dataset in view of a truncation bias. Since there is an 18-month lag in the disclosure of patent application after filing, patents that were filed after September 2002 were not fully covered in our dataset. However, we obtained virtually similar results to those of the present study.

significant and positive in every specification. In other words, compared with the average patent value of all corporate patents, there is some significantly positive impact of a corporate assignee without co-assignees of either governments or universities on patent values. The coefficients of patents filed jointly by no less than two corporations (*corp_corp*) are also positive and significant. Thus, compared to the average patent value of all corporate patents, there is also a positive impact of the first assignee of a corporation with a corporate co-assignee on patent values. These results indicate that patents filed by the private sector without co-assignees of either governments or universities are highly valued on average.

On the other hand, coefficients of government patents (*gov*) are negative but insignificant in all specifications, except column (3). The coefficients of university patents (*univ*) are also negative but statistically insignificant in all specifications. Thus, it is very unlikely that *genuine* public sector patents (without corporate co-assignees) have higher values on average.

Regarding public-private collaborative patents, coefficients of industry-government patents (*corp1_gov*) are positive and significant. Thus, compared to the average patent value of all corporate patents, there is a positive impact of the first assignee of a corporation with a government co-assignee on patent values. This implies that if a corporation is the first assignee of a patent, those patents filed with a government research institute are highly valued on average. One possible reason would be the presence of numerous government sponsored research consortia in Japan, as has been extensively examined in the literature[29]. Regarding other combinations of co-assignees, we have virtually no statistically significant results for all specifications.

With regard to the policy effect, the coefficients on government patents ($gov \times D99$) are positive and strongly significant in all specifications. These results suggest that although the average value of government patents is not very impressive, this value has risen since the introduction of the pro-patent policy. On the other hand, there was no significant change in the value of university patents throughout the observation period.

We obtain virtually similar results if we use a year dummy of *D98*. The salient features in columns (5) and (6) represent the significantly positive coefficients of $corp1\_gov \times D98$. If we evaluate the policy effect by using the benchmark year of 1998, we could detect the positive policy impact of the first assignee of a corporation with a government co-assignee on patent values. This fact lends itself to several interpretations but we suspect that industry-government cooperative research is influenced by the pro-patent policy in an expeditious way.

In summary, the value of government patents has increased since the introduction of

[29] As Kneller (2003) and Walsh and Cohen (2004) suggest, Japanese public-private cooperative research is likely to leave the private sector to initiate patenting, and public sector researchers are listed as either co-assignees or inventors in a patent.

the pro-patent policy in the late 1990s. This may reflect the fact that the pro-patent policy in Japan is only now beginning to have some impact on the patenting behavior of government research institutes in the late 1990s. With regard to university patents, however, the pro-patent policy does not appear to dictate the patenting behavior of university researchers. The organizational and institutional features of Japanese universities may not accommodate themselves as yet to patenting biomedical research outcomes despite the introduction of several facilitating policy measures in the late 1990s. We will discuss some related issues in the final section.

Most other independent variables eventually end up having some explanatory power. Coefficients of *pat_scope* are negative and statistically significant in all specifications; this means that technologically-focused patents have higher values. This result seems to be somewhat inconsistent with prior findings in the literature. For example, Lerner (1994) obtains positive and significant coefficients of patent scope on the market value of biotechnology firms. On the other hand, Lanjouw and Schankerman (1997) report no significant coefficients of patent scope on the probability of infringement litigation, which would be closely related to patent values. Harhoff et al. (2003) also find that patent scope has no significant effect on German patent values. However, it should be noted that these studies define patent scope by using the number of four-digit IPC codes referred to in the patent. Our definition is somewhat different from them, and the technology fields are also distinct from each other. One method of technology classifications seems to be critical in order to detect the impact of patent scope on patent values.

With regard to the remaining explanatory variables, as expected, *jp_only* is negative and strongly significant. The scale effect of the first assignee (*pat_size*) is statistically significant and negatively correlated with the patent value. There appears to be a negative scale effect when prolific patentees file less valuable patents on average. The coefficient of *science_ratio* is positive and significant, as expected. Science-linkage appears to be positively associated with patent values, although there seems to be some mulicollinearity between *science_ratio* and *jp_only*. The coefficient of *listed* is negative but insignificant in various specifications. This suggests that listed large companies do not have a specific advantage in producing valuable biomedical patents.

8. Concluding Remarks

This paper examines the value of patents filed by various types of assignees both before and after the introduction of the pro-patent policy measures in the late 1990s. Our results provide little evidence to support the argument that the pro-patent policy encourages universities to translate their “important” research outcomes into patents. On the other hand, although government patents do not have very impressive patent values on average, the values began to increase after the introduction of the pro-patent policy. These results indicate that the Japanese pro-patent policy distinctively affects the patenting behaviors of government and university researchers. What lies behind these asymmetric responses is still rather uncertain but we are of the opinion that institutional and organizational features of government research institutes and universities are the keys to elucidate the causes of different responses between these institutes.

Finally, we would like to make some speculative comments on the possible sources for the different attitudes of public sector researchers toward the Japanese pro-patent policy. We believe that government research institutes have been strongly encouraged to file patents by jurisdictional authorities since the introduction of the First Basic Plan for Science and Technology in 1996 because the number of patents (as well as patent licenses) is regarded as one of performance indexes in an annual third-party review. Then, the review is reflected in the prioritization of budget allocation, according to the Basic Plan[30]. In addition, compared to universities, the government research institutes, especially the top 5 research institutes, are tightly supervised by vertically divided bureaucracy and are likely to be controlled via administrative guidance in a more expeditious way.

On the other hand, patenting may not be a part of the ordinary academic lives of university researchers. In Japan, most major research universities are national universities. Although they are closely supervised by the Ministry of Education, Culture, Sports, Science and Technology, they consider the publication of academic papers to be much more important, as is the case with top research universities in the U.S. (Mowery et al., 2001; Agrawal and Henderson, 2002). The increased trend of university patenting can be partly explained by the recent facilitating policy measures that somewhat alleviate red-tape routine in government research funding, donations by the private sector, hiring temporary researchers, commissioned research, and negotiations pertaining to the ownership of research outcomes. However, they still require cumbersome procedures with quite a few administrative staffs under one-fiscal year budget constraint.

It is possible that the public sector plays an important role in biomedical research that is characterized by the high importance of basic research done at universities and public research institutions. However, there are many steps before basic research can lead to commercialization. In particular, at the stage of the commercialization of scientific knowledge, one of the important factors affecting collaborative R&D incentives is an ex ante agreement governing the ownership of innovative output (Aghion and Tirole, 1994). Since intellectual

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[30] This review process was officially stipulated as a mission of the Council for Science and Technology Policy (CSTP) in 2001. Since then, every research project is ranked as either S, A, B, or C by the CSTP, which possibly affects budget request negotiations between jurisdictional authorities and the Ministry of Finance.

property rights are likely to belong to the research partners as a whole, industry-university-government collaboration in research tends to be accommodating the government's intention of widely disseminating research results. This, however, could possibly weaken the private sector's incentive to collaborate for research.

Producing and transmitting scientific knowledge can assume a wide variety of forms, depending on research areas, organizations, participants, and other factors. Accordingly, there is no single answer with respect to how to obtain public support for biomedical research. Patenting is a means rather than an end. Consequently, pro-patent policy measures must be designed by giving due consideration to the characteristics of the institutional and organizational features of the public sector on a case-by-case basis.

The present study opens up a number of questions for further study. First, we focused our research purpose rather narrowly on the patenting activity of the public sector. However, patenting is not necessarily closely associated with research activity itself, and there would be some discrepancy between propensity to patent and research incentive. Therefore, our findings would be subject to a number of caveats. For example, could the increase in the co-applications of the patent be regarded as the result of effective research collaborations among "inventors"? This study did not utilize any information about inventors, which is in fact also available in patent documents. It would be beneficial to scrutinize the characteristics and configurations of inventors for each patent although this is time-consuming work. By way of a future study, we will investigate an inventors' analysis.

Second, we must admit that the observation period of the present study—particularly the duration after the introduction of the pro-patent policy measures—may be too short to convincingly detect any policy effects on patenting. An on-going investigation is needed before any strong conclusions can be drawn about the role of the public sector in biomedical research, which typically requires a very long-term R&D process.

Third, since 2001, there have been several organizational reforms for the public sector in Japan. In April 2001, almost all public research institutes were reorganized into "independent administrative agencies" (IAAs) that appeared to be independent of the government, as literally interpreted. However, they have been financially as well as managerially supervised tightly by a vertically divided bureaucracy. With regard to Japanese national universities, these were reorganized into semi-private entities, so-called "national university foundations," in April 2004. The National University Foundation is an intermediate legal entity that functions in between government agencies and public foundations. However, these organizational changes are beyond the scope of the present study that uses data on patents between the years 1991 and 2002.

Finally, is it desirable to encourage governments and universities to file patents in the first place, that reflect the salient features of Japanese innovation system, such as the low mobility of researchers, weak patent protection, and backwardness in bio-medical research. Undoubtedly, these issues are important, but the lack of solid explorations on these issues is mainly due to data constraints in Japan.

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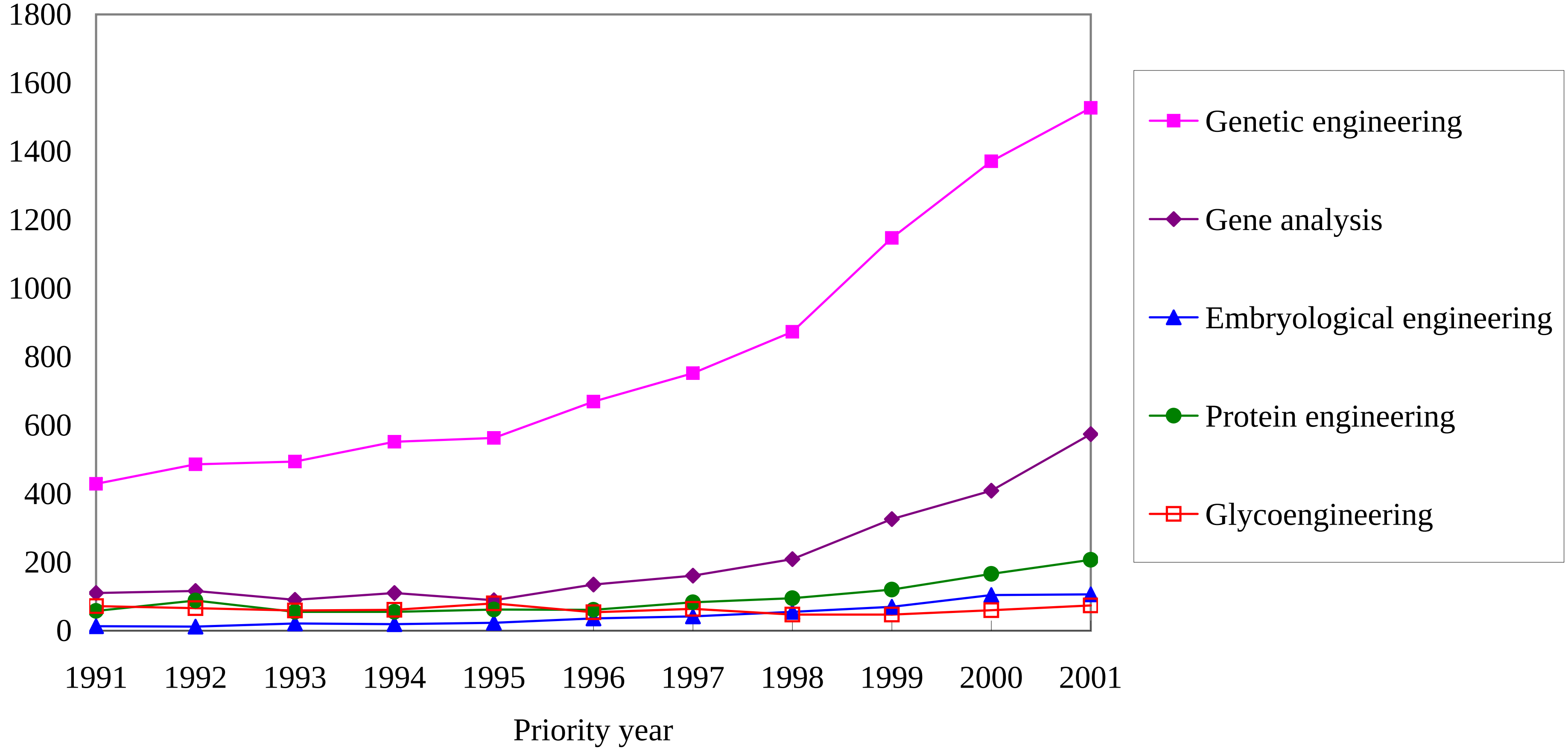
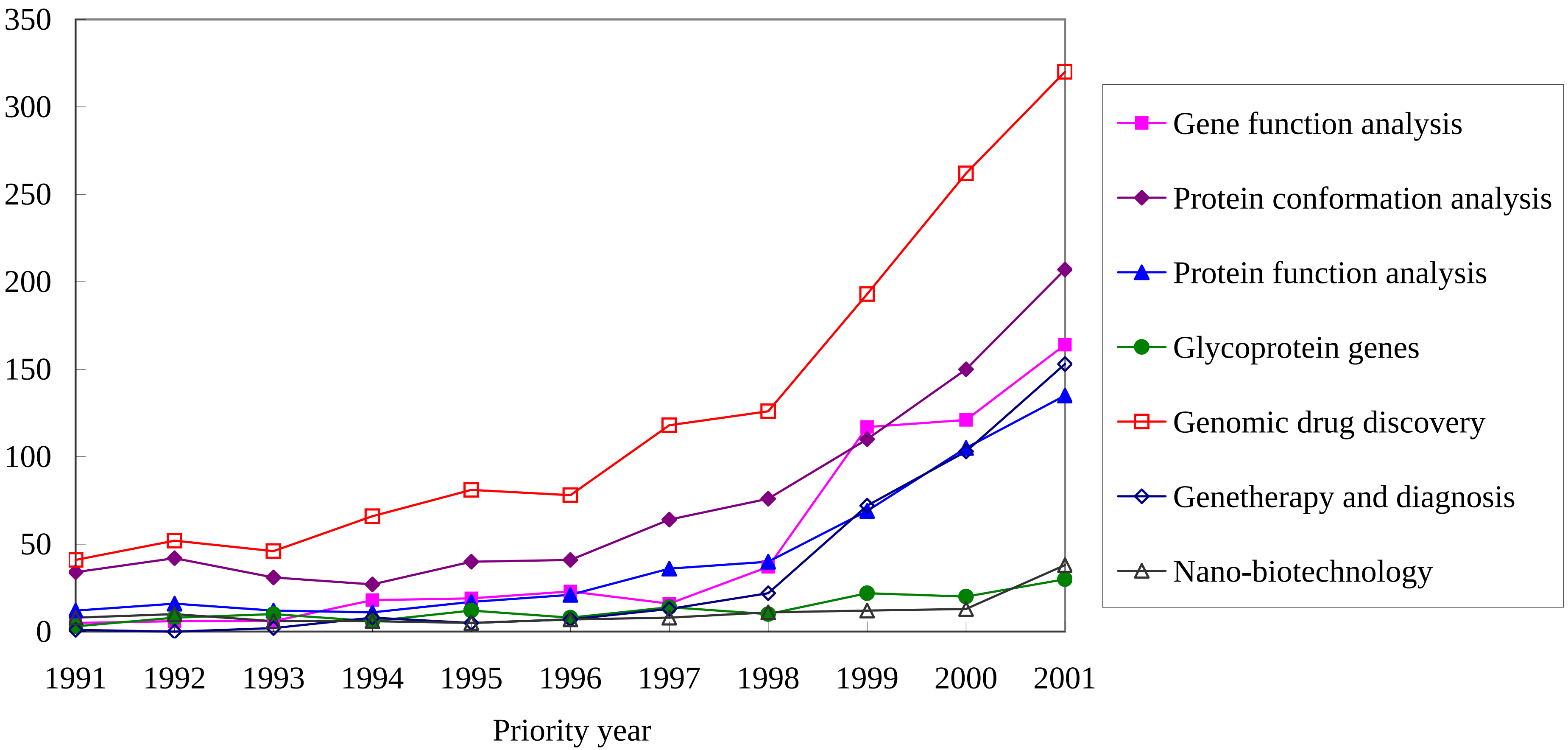
Figure 1 Number of biomedical patents (basic technologies)



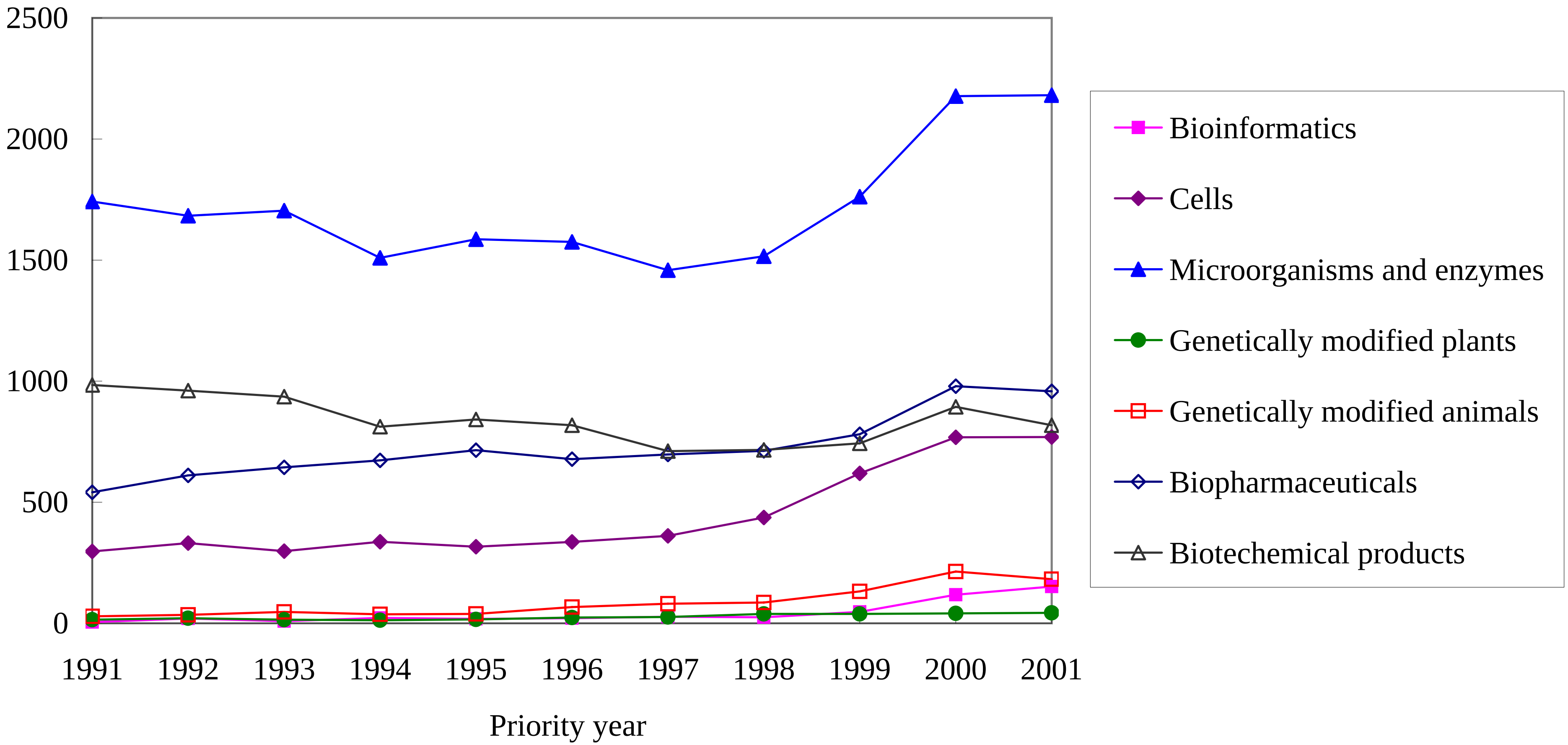
Note: Here, technology classifications are based on the Japan Patent Office (2003). See Table 2 for a summary description of the biomedical fields. The number of patent counts in 2002 are omitted from this figure due to significant truncation bias. Refer to the text for further detail.

Figure 2 Number of biomedical patents (post-genome technologies)



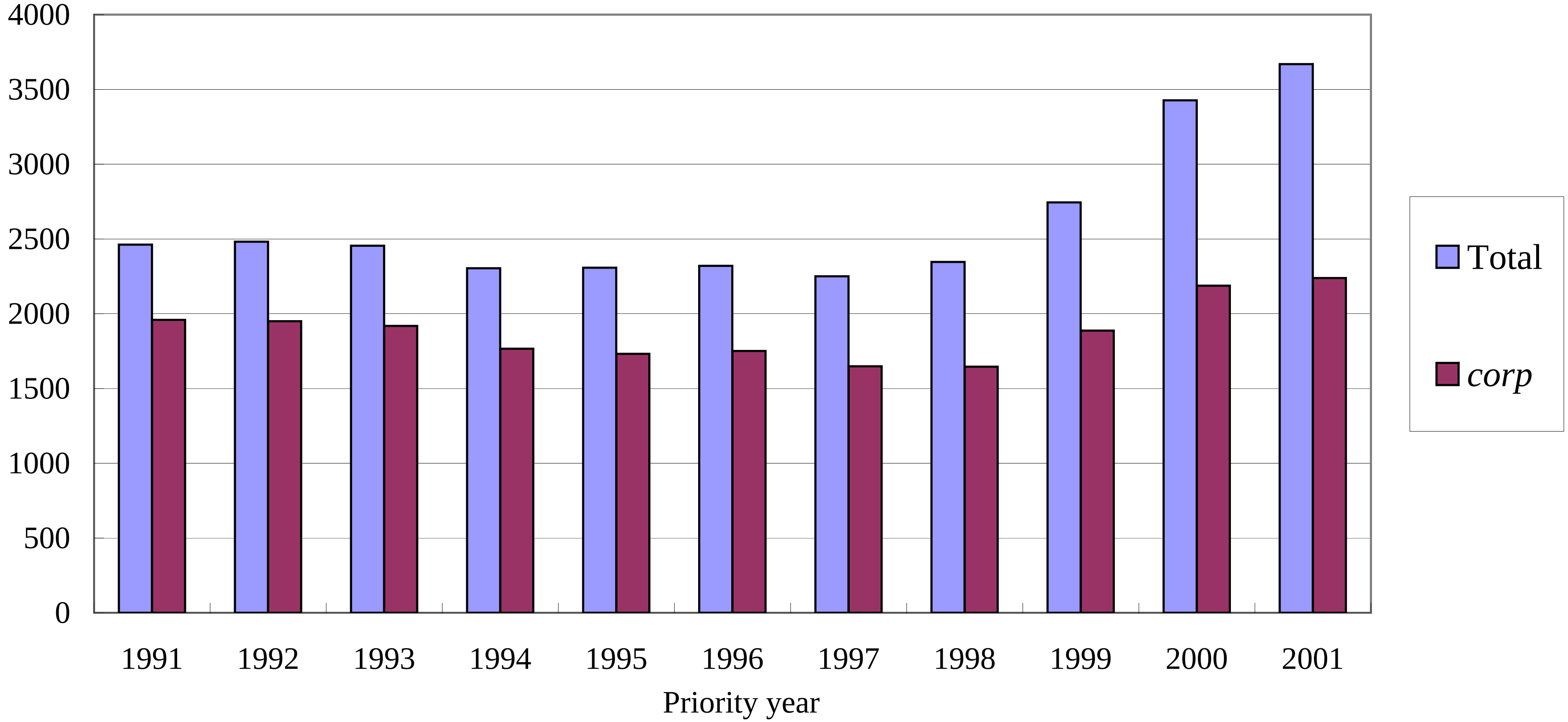
Note: In this figure, technology classifications are based on the Japan Patent Office (2003). See Table 2 for a summary description of the biomedical fields. The number of patent counts in 2002 are omitted from the figure due to significant truncation bias. Refer to the text for further details.

Figure 3 Number of biomedical patents (other technologies)



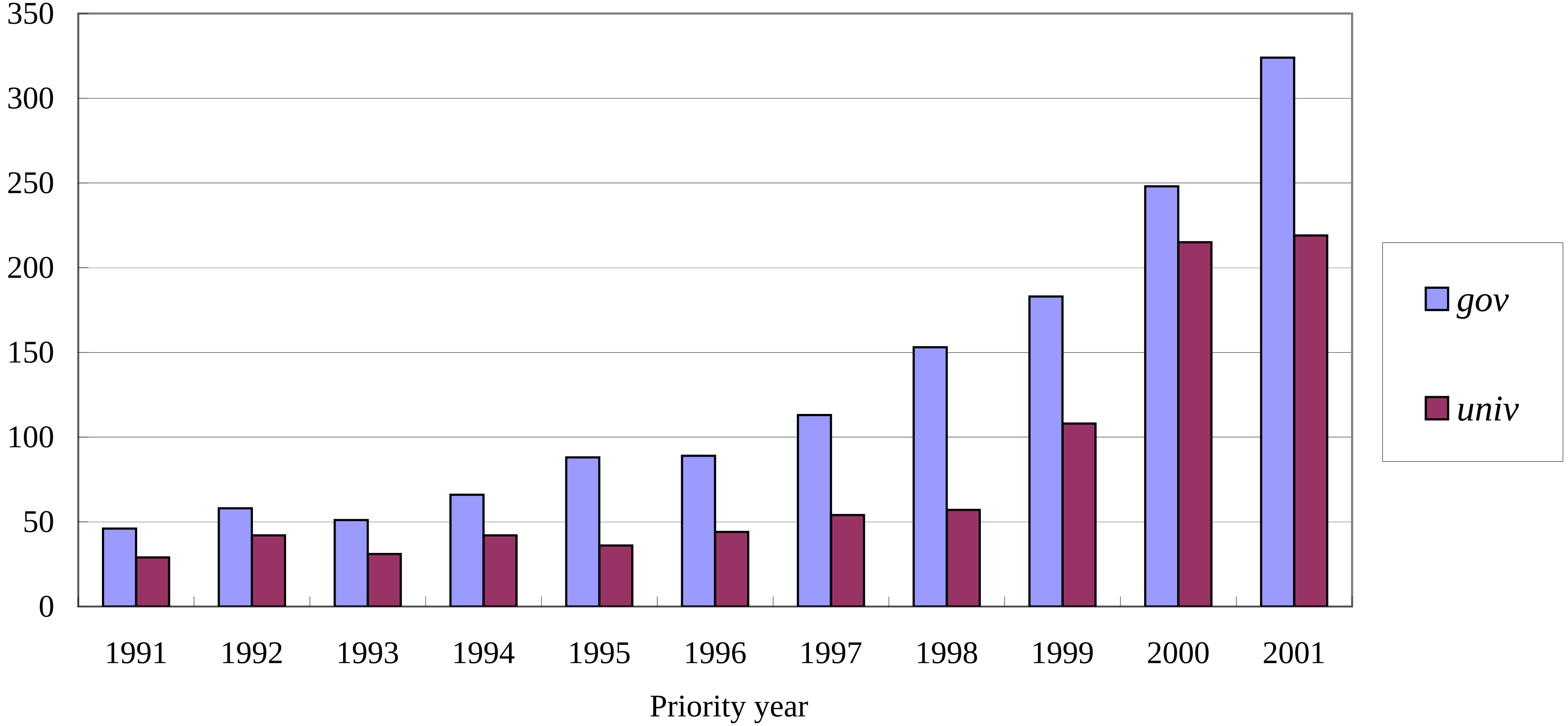
Note: In this figure, the technology classifications are based on the Japan Patent Office (2003). See Table 2 for a summary description of the biomedical fields. The number of patent counts in 2002 are omitted from the figure due to significant truncation bias. Refer to the text for further details.

Figure 4 Number of patent filings by single assignee (*corp*)



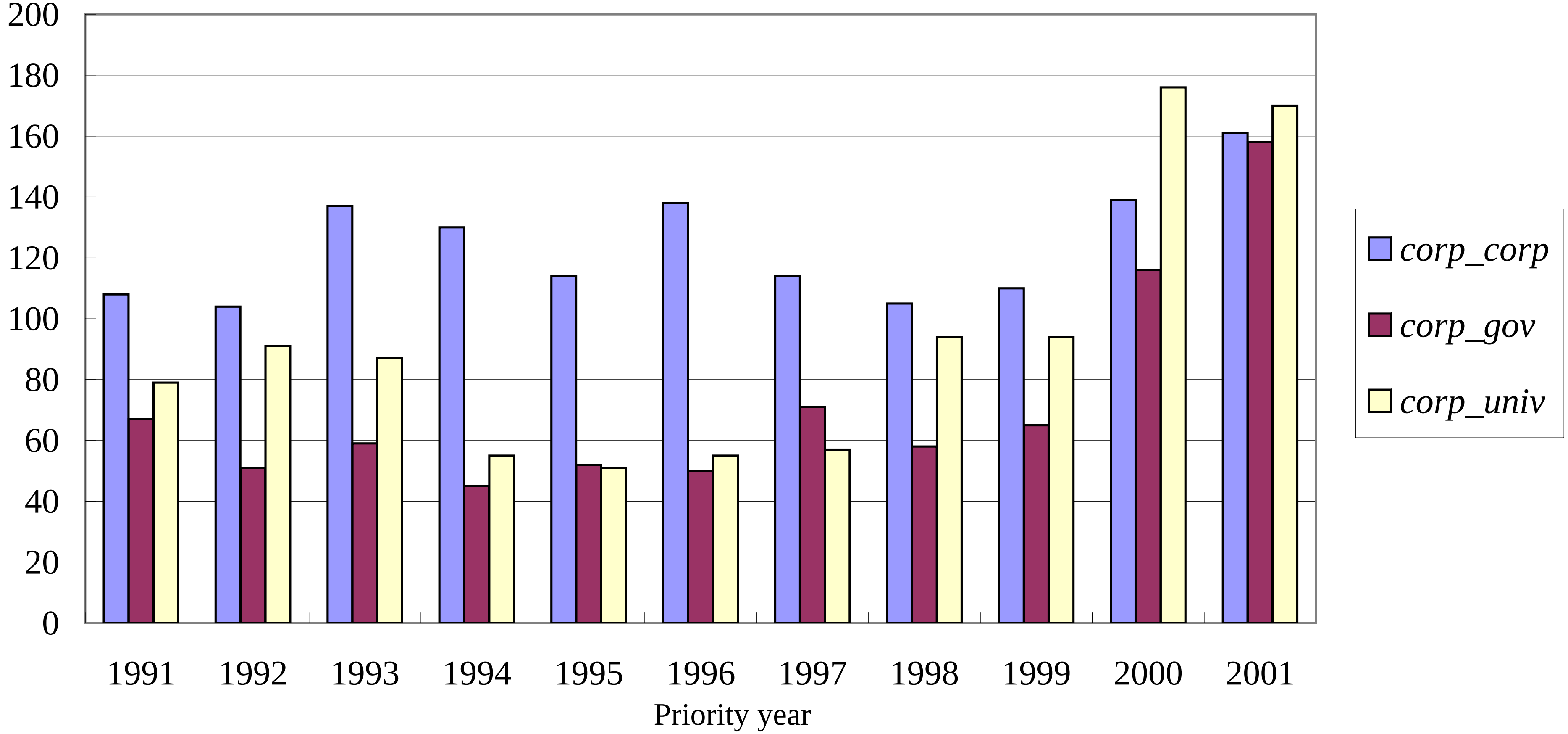
Note: The classification of assignee types are based on the authors' definitions. *corp* denotes a corporation. The number of patent counts in 2002 is omitted from the figure due to significant truncation bias. See the text and Table 4 for further details.

Figure 5 Number of patent filings by a single assignee (*gov, univ*)



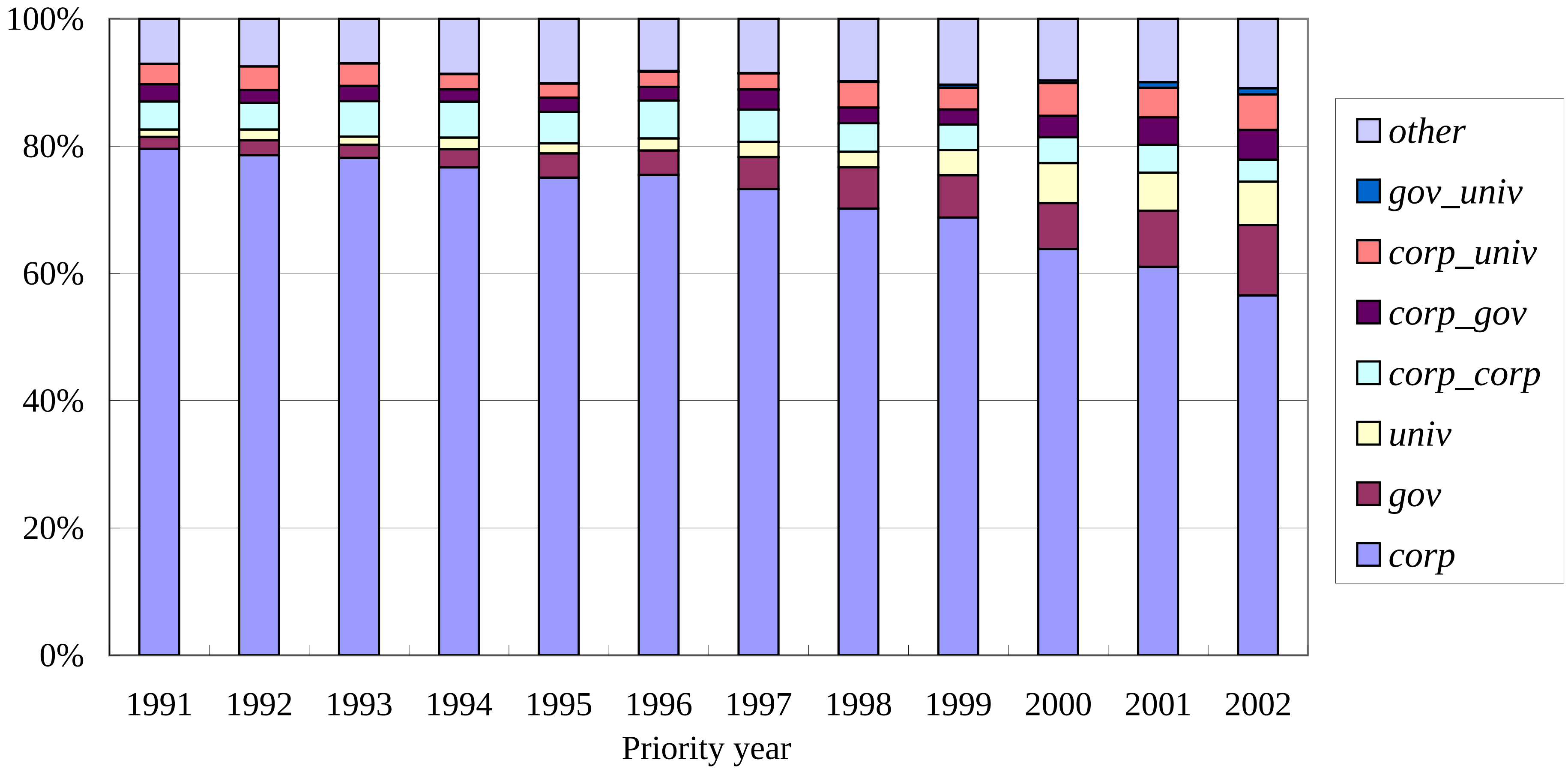
Note: The classification of assignee types are based on the authors' definitions. *gov* denotes a government research institute, and *univ* denotes a university. The number of patent counts in 2002 is omitted from the figure due to significant truncation bias. See the text and Table 4 for further details.

Figure 6 Number of patent filings by multiple co-assignees
(*corp_corp*, *corp_gov*, *corp_univ*)



Note: In the figure, *corp_gov* includes the number of patents filed by both *corp1_gov* and *gov1_corp* . *corp_univ* in the figure also includes the number of patents filed by both *corp1_univ* and *univ1_corp* . With regard to the variable definitions, refer to Table 4. The number of patent counts in 2002 is omitted from the figure due to significant truncation bias.

Figure 7 Biotechnology patents by assignee type (%)



Note: In the figure, *corp_gov* includes the number of patents filed by both *corp1_gov* and *gov1_corp* . *corp_univ* in the figure also includes the number of patents filed by both *corp1_univ* and *univ1_corp* . Other variables are defined in a similar manner. With regard to the varible definitions, see Table 4.

Figure 8 Biomedical patents by industry
(Top 8 industrial sectors for the years 1991–2001; listed companies only)

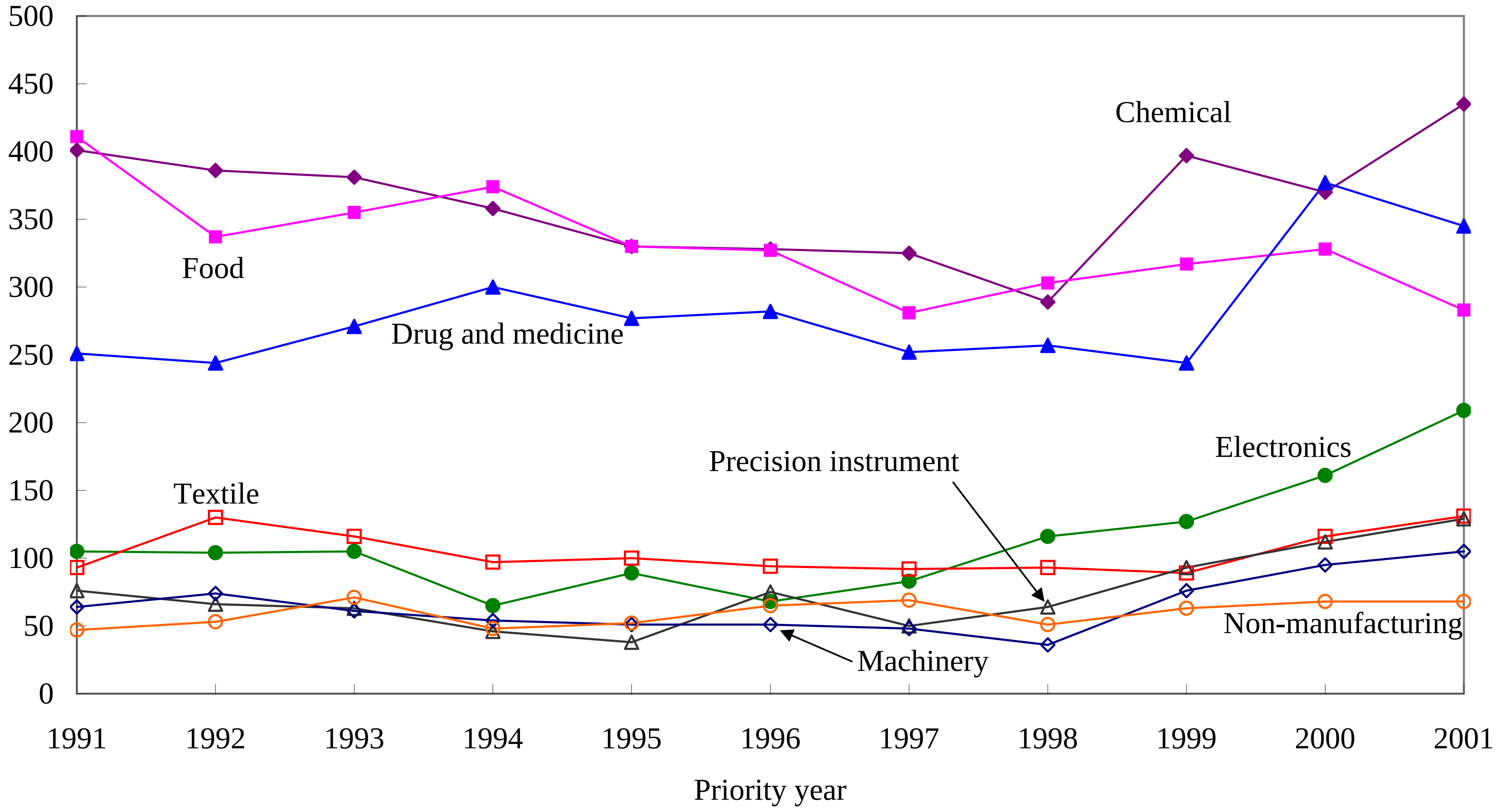


Table 1 Major Policy Initiatives relating to Industry-Government-University Collaboration in Japan, 1995-2002

Year	Initiatives	Provisions
1995	The Basic Law on Science and Technology	The Basic Law on Science and Technology states that the government should declare the direction of promotional initiatives for science and technology (S&T), and achieve a national consensus on the promotion of S&T; the government should formulate a *five-year basic plan* for S&T in order to comprehensively and consistently implement policies.
1996–2000	The First Basic Plan for Science and Technology	Promotion of institutional reforms such as a tenure system, a program to support 10,000 post-doctorals, and industry-government-university collaboration in research. Increase in government R&D expenditure (17 trillion yen in five years).
1998	The Law on the Promotion of Technology Licensing by Universities, etc.	The so-called "TLO Act." Subsidization to the approved TLOs of universities, national research institutes, etc. Partial remission of patent fee. Government investment to licensees.
1998	The Law on the Promotion of Research Exchange	Remission to the rent of state-owned real estate and facilities for the use of industry-university-government collaborative research.
1999	The Law on Special Measures for Revitalizing Industrial Activities	The so-called "Japanese Bayh-Dole Act," including Bayh-Dole provisions such as permission to retain patents to inventions derived from publicly funded research as well as exclusive licensing of state-owned patents. Permission of dual employment for university/government researchers.
1999	The Law on the Promotion of New Business Incubation	The so-called "Japanese *SBIR* program." Debt guarantee for new business incubation.
2000	The Law on the Enhancement of Industrial Technologies	Clarifying dual employment rules for the researchers of national universities/government research institutes. Partial remission of application/grant fees for patents filed by university/government researchers.
2001	The Council for Science and Technology Policy (CSTP)	This council was established along with the comprehensive reshuffling of administrative organizations in 2001. The main role of this council is to harmonize S&T policies across ministries and agencies at the initiative of the CSTP (headed by the prime minister).
2001–2005	The Second Basic Plan for Science and Technology	Raising the government R&D expenditure to 24 trillion yen in five years. Strategic priority setting in S&T (technologies on life science, information and communications, environmental science, and nano-technologies & materials).
2002	Biotechnology Strategic Scheme	The Biotechnology Strategy Council was convened in 2002 in order to establish a BT strategy for Japan and to advance the necessary policies. The current scheme (Biotechnology Strategic Scheme) was adopted in 2002.
2002	The Basic Law on Intellectual Property	The Basic Law on Intellectual Property states that the government should promote the creation, protection, and utilization of intellectual properties. Following this law, the Strategic Council on Intellectual Property was established in 2002.

Table 2 Technology classification

	#	Classification	Definition
Basic Technologies	1	Genetic engineering	Genetic engineering *in vitro* . Preparation and use (process) of DNA, RNA, vector/plasmid, host, etc., in relation to genetic engineering. Novel genes or proteins obtained by the process or used in the process.
	2	Gene analysis	Technologies analyzing DNA structure, such as SNPs, gene sequencing, including genetic polymorphism. Bioinformatics used for the process.
	3	Embryological engineering	Technologies on cell manipulation/differentiation/proliferation based on embryology studying the generation/differentiation at molecular level. Novel animals and cells obtained by using these technologies.
	4	Protein engineering	Technologies altering a protein function by artifically altering a part of the protein's structure. Bioinformatics used for the process. Modifications (genes and proteins) obtained by the process.
	5	Glycoengineering	Carbohydrate chain and the analysis of its structure/function. Gene relating to glycosylation. Technologies altering the functions of proteins/cells by modifying thr carbohydrate chain. The carbohydrate chains obtained by this modification and its production.
Post-genome Technologies	6	Gene function analysis	Technologies experimentally analyzing gene function.
	7	Protein conformation analysis	Technologies determining protein sequence and conformation. Technologies analyzing protein structure/function *in silico* (protein informatics).
	8	Protein function analysis	Technologies experimentally analyzing protein function.
	9	Glycoprotein genes	Enzyme-gene and protein participating in biosynthesis/transference of carbohydrate chain. Technologies relating to them. The use of these.
	10	Genomic drug discovery	Technologies identifying disease-related genes. Novel genes or proteins obtained by this process. Technologies exploring/determining/optimizing lead compound by using post-genome technologies.
	11	Genetherapy and diagnosis	Technologies on disease treatment using transgene technology. Technologies on diagnosis using genetic information.
	12	Nano-biotechnology	Technologies on observation, measurement, and function analysis of molecules and cells. Technologies on manipulation of molecules and cells. Technologies on preparation of nanostructure.
Other Technologies	13	Bioinformatics	Technologies acquiring information on structure/function of gene, protein, and carbohydrate chain obtained in a wet lab. Database that accumulates this information. Technologies retrieving/displaying useful information from the database. Technologies used through data processing.
	14	Cells	Animal/plant/human cell and tissue used in life science. These cells modified by exogenous gene. Culture apparatus for cells.
	15	Microorganisms and enzymes	Technologies manufacturing useful materials by using microorganisms, enzymes, and their biocatalyst functions.
	16	Genetically modified plants	Technologies altering plant breeding by using genetic engineering. Technologies relating to them.
	17	Genetically modified animals	Technologies altering animal breeding by using genetic engineering. Technologies relating to them.
	18	Biopharmaceuticals	Biopharmaceuticals. Biotechnologies for manufacturing them.
	19	Biochemical products	Chemical product manufactured by biological process and its manufacturing technologies.

Table 3 The top 5 government research institutes in biomedical research

#	Organization	Patent application	%	Top 3 (%)	Top 5 (%)
1	Japan Science and Technology Agency (JST)	676	25.1		
2	National Institute of Advanced Industrial Science and Technology (AIST)	528	19.6	56.7	
3	Institute of Physical and Chemical Research (RIKEN)	322	12.0		70.4
4	National Agriculture and Bio-oriented Research Organization (NARO)	191	7.1		
5	National Institute of Agrobiological Sciences (NIAS)	177	6.6		
	Total	2692			

Note: These data are based on biomedical patents where priority years are the years 1991–2001, and the priority country is Japan. The top 5 research institutes are defined by the order of the total number of patent applications in relation to biomedical research from 1991 to 2001.

Table 4 Variable names and definitions

Dependent variable	
dciting	Normalized forward-citation intensity defined by the difference between the actual number of citations received per patent and the reference citation intensity for each technological category in year *t*. Refer to the text for further details.

Independent variables	
Single assignee	
corp	Dummy variable that takes on the value of unity if the single assignee of a patent is a corporation, otherwise zero.
gov	Dummy variable that takes on the value of unity if the single assignee of a patent is a government research institute, otherwise zero.
univ	Dummy variable that takes on the value of unity if the single assignee of a patent is a university, otherwise zero.
Multiple co-assignees	
corp_corp	Dummy variable that takes on the value of unity if there are no less than two co-assignees are corporations and there are no other co-assignees belonging to universities and government research institutes.
corp1_gov	Dummy variable that takes on the value of unity if a corporation is the first assignee of a patent and at least one co-assignee is a government research institute and there are no other co-assignees belonging to universities, otherwise zero.
gov1_corp	Dummy variable that takes on the value of unity if a government research institute is the first assignee of a patent and at least one co-assignee is a corporation and there are no other co-assignees belonging to universities, otherwise zero.
corp1_univ	Dummy variable that takes on the value of unity if a corporation is the first assignee of a patent and at least one co-assignee is a university and there are no other co-assignees belonging to government research institutes, otherwise zero.
univ1_corp	Dummy variable that takes on the value of unity if a university is the first assignee of a patent and at least one co-assignee is a corporation and there are no other co-assignees belonging to government research institutes, otherwise zero.
Characteristics of patents	
pat_scope	A proxy for "patent scope" that is defined by the total number of technological field flags of a patent. The 19 technological fields are defined by using the Japan Patent Office (2003). Refer to Table 2 for further details.
jp_only	Dummy variable that takes on the value of unity if Japan the sole country for which a patent is filed. This is a control variable for the fact that there are very few citations received by patents that are filed to the JPO alone.
science_ratio	A proxy for the extent of science-linkage for each patent defined by "the number of backward citations of non-patent articles" divided by "the total number of backward citations + 1."
Other characteristics of assignees	
pat_size	Total number of patent applications filed by the first assignee per year.
listed	Dummy variable that takes on the value of unity if a patent is filed by a listed company at the date of patent filing, otherwise zero.
Policy effect (year dummy)	
D99 (or *D98*)	Dummy variable that takes on the value of unity if the priority year is 1999 (or 1998) and later, otherwise zero. In Japan, several policy initiatives for industry-government-university cooperation in research have been implemented since 1998, as shown in Table 1.

Table 5 Summary statistics

Variable	Obs	Mean	Std Dev	Min	Max
Single assignees					
corp	30350	0.71	0.45	0	1
gov	30350	0.05	0.22	0	1
univ	30350	0.03	0.18	0	1
Multiple co-assignees					
corp_corp	30350	0.047	0.21	0	1
corp1_gov	30350	0.011	0.10	0	1
gov1_corp	30350	0.018	0.13	0	1
corp1_univ	30350	0.021	0.14	0	1
univ1_corp	30350	0.015	0.12	0	1
Characteristics of assignees					
pat_size	30350	16.33	24.19	1	191
listed	30350	0.55	0.50	0	1
Characteristics of patents					
pat_scope	30350	2.10	1.50	1	14
jp_only	30350	0.71	0.45	0	1
science_ratio	30350	0.08	0.20	0	0.98
Patent value indexes					
dciting	30350	0.00	3.89	–15.235	146.77
fwd_cites	30350	1.10	4.06	0	148
bwd_cites	30350	2.26	7.37	0	347
fam_size	30350	2.21	2.63	1	68
claim	27605	7.59	8.36	1	223

Table 6 Summary statistics by assignee type (mean values)

Assignee Types	Observation (obs. for *claim*)	*dciting*	*pat_size*	*pat_scope*	*jp_only*	*science_ratio*	*fwd_cites*	*fam_size*	*claim*	*bwd_cites*
corp	21664 (19983)	0.05 (4.18)	15.70 (17.80)	2.04 (1.45)	0.72 (0.45)	0.08 (0.19)	1.22 (4.34)	2.28 (2.80)	7.47 (8.43)	2.54 (8.13)
gov	1611 (1412)	-0.20 (1.74)	50.86 (59.14)	2.55 (1.69)	0.70 (0.46)	0.08 (0.21)	0.47 (1.81)	1.96 (1.57)	8.52 (9.00)	1.00 (3.22)
univ	995 (833)	-0.11 (1.96)	4.49 (4.58)	2.44 (1.62)	0.63 (0.48)	0.10 (0.22)	0.58 (2.02)	2.05 (2.04)	8.62 (9.43)	1.25 (3.36)
corp_corp	1420 (1307)	0.10 (3.30)	9.40 (11.70)	1.74 (1.13)	0.76 (0.43)	0.06 (0.16)	1.15 (3.50)	2.11 (2.35)	6.91 (7.26)	2.53 (6.97)
corp1_gov	323 (265)	-0.27 (1.48)	9.42 (12.09)	2.51 (1.86)	0.71 (0.46)	0.06 (0.17)	0.48 (1.51)	1.73 (1.70)	7.55 (7.05)	1.09 (3.59)
gov1_corp	536 (471)	-0.20 (1.79)	24.65 (33.39)	2.10 (1.48)	0.75 (0.43)	0.08 (0.20)	0.66 (1.86)	1.85 (1.78)	7.43 (7.60)	1.47 (4.02)
corp1_univ	636 (535)	-0.34 (2.12)	10.44 (12.23)	2.30 (1.64)	0.65 (0.48)	0.10 (0.21)	0.79 (2.33)	2.03 (2.04)	8.55 (9.51)	1.61 (4.71)
univ1_corp	460 (430)	-0.04 (3.52)	2.01 (2.42)	2.28 (1.59)	0.74 (0.44)	0.07 (0.19)	0.92 (3.81)	1.89 (1.96)	8.03 (6.37)	1.26 (3.81)

Note: All statistics are based on biomedical patents whose priority years range from 1991 to 2002 and the priority country is Japan. The average value of the normalized patent citation intensity (*dciting*) is zero. The sample size of the claim is smaller than the basic dataset due to missing data in the IIP Patent Database. The standard deviations are given in parentheses.

Table 7 Pearson correlation matrix for selected variables

	dciting	*pat_size*	*science_ratio*	*pat_scope*	*listed*	*jp_only*	*fwd_cites*	*fam_size*	*claim*	*bwd_cites*
dciting	1									
pat_size	0.026	1								
science_ratio	0.200	0.060	1							
pat_scope	–0.0453	0.171	0.287	1						
listed	0.080	0.105	0.017	0.005	1					
jp_only	–0.2524	–0.1132	–0.6588	–0.2915	–0.0173	1				
fwd_cites	0.945	0.008	0.244	0.044	0.036	–0.2516	1			
fam_size	0.390	0.027	0.543	0.157	0.040	–0.6421	0.447	1		
claim	0.069	0.171	0.146	0.320	0.014	–0.2076	0.043	0.117	1	
bwd_cites	0.417	0.009	0.318	0.014	0.046	–0.4403	0.452	0.645	0.067	1

Note: Variables within the dotted lines are used in regressions as explanatory variables.

Table 8 Panel regressions: patent values and assignee types, 1991–2002

Dependent variable: Normalized citation intensity (*dciting*)

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
Assignee types						
corp	0.475***	0.499***	0.357**	0.500***	0.475***	0.500***
	(0.180)	(0.181)	(0.178)	(0.181)	(0.180)	(0.181)
gov	–0.062	–0.166	–0.386***	–0.169	–0.078	–0.159
	(0.132)	(0.137)	(0.141)	(0.136)	(0.152)	(0.154)
univ	–0.213	–0.158	–0.341	–0.161	–0.124	–0.070
	(0.339)	(0.335)	(0.341)	(0.335)	(0.413)	(0.409)
corp_corp	0.469**	0.481**	0.389*	0.499**	0.469**	0.498**
	(0.202)	(0.203)	(0.202)	(0.205)	(0.202)	(0.205)
corp1_gov	0.481**	0.463**	0.396*	0.465**	0.468**	0.448**
	(0.214)	(0.213)	(0.218)	(0.213)	(0.215)	(0.214)
gov1_corp	–0.026	–0.023	–0.211*	–0.022	–0.011	0.042
	(0.121)	(0.120)	(0.119)	(0.127)	(0.121)	(0.126)
corp1_univ	0.156	0.165	0.099	0.167	0.173	0.185
	(0.207)	(0.208)	(0.206)	(0.208)	(0.206)	(0.207)
univ1_corp	0.318	0.323	0.196	0.369	0.341	0.378
	(0.356)	(0.355)	(0.357)	(0.351)	(0.355)	(0.350)
Characteristics of patents						
pat_scope	–0.365***	–0.345***	–0.317***	–0.345***	–0.365***	–0.345***
	(0.030)	(0.029)	(0.030)	(0.029)	(0.030)	(0.029)
jp_only	–2.044***	–2.482***		–2.482***	–2.045***	–2.483***
	(0.098)	(0.085)		(0.085)	(0.098)	(0.085)
science_ratio	1.607***		4.276***		1.605***	
	(0.268)		(0.227)		(0.268)	
Other characteristics of assignees						
pat_size		–0.009***	–0.007***	–0.009***		–0.008***
		(0.002)	(0.002)	(0.002)		(0.002)
listed				–0.097		–0.093
				(0.125)		(0.125)
Policy effect	**Year dummy = *D99***				**Year dummy = *D98***	
gov × year dummy	0.243**	0.443***	0.579***	0.445***	0.237*	0.377***
	(0.118)	(0.130)	(0.133)	(0.130)	(0.137)	(0.141)
univ × year dummy	–0.071	–0.119	0.034	–0.120	–0.194	–0.238
	(0.175)	(0.175)	(0.275)	(0.278)	(0.373)	(0.374)
corp1_gov × year dummy	0.352	0.287	0.386	0.287	0.536**	0.505**
	(0.319)	(0.337)	(0.281)	(0.337)	(0.237)	(0.241)
gov1_corp × year dummy	0.051	0.031	–0.056	0.024	–0.133	–0.156
	(0.222)	(0.215)	(0.231)	(0.215)	(0.254)	(0.256)
corp1_univ × year dummy	0.108	0.116	0.095	0.116	–0.063	–0.071
	(0.243)	(0.242)	(0.227)	(0.242)	(0.230)	(0.223)
univ1_corp × year dummy	0.039	–0.013	0.257	–0.006	–0.162	–0.038
	(0.356)	(0.182)	(0.294)	(0.358)	(0.368)	(0.360)
Constant	1.722***	2.244***	0.166	2.295***	1.723***	2.286***
	(0.169)	(0.182)	(0.157)	(0.193)	(0.169)	(0.193)
Observations	30350	30350	30350	30350	30350	30350
Number of assignees	3577	3577	3577	3577	3577	3577
R^2	0.082	0.074	0.046	0.074	0.082	0.074
F	52.09***	52.34***	22.72***	49.44***	52.51***	49.84***
Hausman	36.82***	141.53***	884.89***	122.87***	57.89***	169.06***

Notes : All equations are employed by using fixed effect models for the first assingee. Year dummy (*yr99* or *yr98*) takes the value of unity if a priority year of a patent is 1999 (or 1998, respectively) and later, otherwise zero. Heteroskedasticity-robust standard errors are given in parentheses. *, **, *** convey statistical significance at the 90%, 95%, 99% levels, respectively.