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Abstract

This paper examines the value of Japanese biomedical patents that were filed for the years 1991-2002 by various types of (co-)assignees, public sector researchers in particular, before and after the introduction of pro-patent legislative measures such as the TLO Act in 1998 and the Japanese Bayh-Dole Act in 1999. We use citation counts by subsequent patents (*forward* citations) as the patent value measure. Adjusting heterogeneity of propensity to cite by subsequent patents in 19 major biomedical fields in each year, we employ panel regressions controlling for a fixed effect of the first assignee of a patent. 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, it 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 is now just beginning to have some impact on the patenting activity of government research institutes. On the other hand, it does not appear to dictate the patenting behavior of university researchers. We think that institutional and organizational features of government research institutes and universities are keys to elucidate the salient responses between them.

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

JEL Classifications No: L65, O34, O38

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1. Introduction

Government spending in biomedical research has dramatically expanded since the latter half of 1990s in Japan, reflecting 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 policy with intent to advance research collaboration among industry, university and government and to facilitate commercialization of their research outcome. Regrettably, however, there are very few solid empirical studies concerning research performance of the Japanese public sector *per se*, mainly due to data constraint[2].

The purpose of the present study is rather focused on exploring the following two questions: (i) did Japanese pro-patent policy measures which were introduced in the latter half of 1990s encourage the public sector to file *valuable* patents?, and (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]. Because producing scientific knowledge in biomedical research is closely associated with implementing the knowledge into commercialization, and because patenting is one of the most effective tools for securing privately appropriable knowledge of biotechnologies, patent statistics would be a beneficial source of information about the role of the public sector and its research collaboration with the private sector in commercializing research outcome.

After the enactment of the *Basic Law on Science and Technology* in 1995, a wave of legislations took place encouraging collaborative research among industry, government and university. A list of the policy initiatives is provided in Table 1. Several legislative measures in the list emulated relevant US policies, such as the Bayh-Dole Act and the Small Business Innovation Research (SBIR) program. Among the policy initiatives in Table 1, the following two legislative measures would deserve to pay our attention here, because they have been

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[1] Traditionally, the Japanese government put top priority to energy-related research. But the Basic Plan for Science and Technology which has been introduced every five year period since 1996 has gradually reallocated research expenditures to other technology fields, putting more weight on life science. Since the introduction of the Basic Plan, more than 400 billion yen has been allocated to life science every year. See Council for Science and Technology Policy (2005) for more detail.

[2] In a series of careful survey studies, Levin et al. (1987), Klevorick et al. (1995), Mansfield (1995), Goto and Nagata (1997) and Cohen et al. (2002a, b), among others, provided valuable information about the public sector research and its contribution to industrial R&D in Japan and the U.S. But most prior studies on public R&D in Japan rather focused on research consortia. See, for example, 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 enhance participants' R&D and/or patent application to a greater or lesser degree, depending on organizational features of research consortia.

[3] The present study mentions "public sector" as indicating both government and university. It should be noted, however, that university researchers and government researchers may be very different from each other in propensity to patent, to the extent of their affinity to open science culture, and the resulting values of their patents. We will discuss these points in later sections.

widely expected to have profound effect on patenting activity and technology transaction of the public sector.

[INSERT TABLE 1 AROUND HERE]

First, *the Law on the Promotion of Technology Licensing by Universities etc.* (hereafter "the TLO Act") which was enacted in 1998 states that the government should support technology licensing organizations (TLOs) of universities and government research institutes. In addition, universities and government research institutes should obtain 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 which specifies Bayh-Dole provisions in Sections 30 to 33, such as permission of retaining patents to inventions deriving from publicly funded research as well as exclusive licensing of state-owned patents[4]. These provisions reflected 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 effect on the way in which public sector researchers produce privately appropriable research outcome. 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 filed jointly by both private and public sector researchers also significantly increased since 1998.

However, incentive to patent by public sector researchers would be arguably very different from private sector researchers. As Argyres and Liebeskind (1998) indicate, the commercialization of government/university research would be hampered because of their historic commitment to create and sustain "intellectual commons" for the public at large. Informal free flow of knowledge between public and private sectors may be an important source of social benefit. Patenting may thereby inhibit diffusion of scientific knowledge, which has been christened "the tragedy of anticommons" by Heller and Eisenberg (1998).

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

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

The effect of pro-patent policy 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, among others). These studies provoke, to a greater or lesser degree, a cautious view to pro-patent policy, toward the Bayh-Dole-like measure in particular.

For example, Mowery and Sampat (2005) convincingly argue that the efforts at emulation of the Bayh-Dole policy are likely to have modest success at best without greater attention 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 the channels of open science such as publication, conference, informal communications, and consulting are keys for transmitting scientific knowledge, with patents and licenses as ranked much less important in the U.S. These studies emphasize that informal flow of knowledge between university and industry is essential, and that patenting may have other roles such as defending against infringement litigation and obtaining bargaining chip in licensing negotiation.

Almost all Japanese universities and government research institutes are funded predominantly by the government and are tightly controlled by vertically divided bureaucracy[6]. Contrary to the U.S., Japanese public sector researchers have to abide by strict office regulations which 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 the public sector researchers. Concomitantly, it had been very unlikely to file patents for Japanese public sector researchers until quite recently (Odagiri and Goto 1993; Odagiri, 1999; Kneller, 2003; Walsh and Cohen, 2004). Therefore not only the number of patents but the *value* of patents which were filed by the public sector researchers, especially those patents which had been increasingly applied for since the introduction of the pro-patent policy, would deserve to be closely examined as a proxy for the effectiveness of the policy initiatives translating their work into privately appropriable knowledge.

[6] Walsh and Cohen (2004) provide beneficial information about organizational and institutional differences between Japan and the U.S. regarding 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.

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 heterogeneity concerning propensity to cite by subsequent patents in 19 major biomedical fields in each year. Put differently, we construct weighted citation count (*normalized* forward citation intensity) which is defined by the difference between the actual number of citations received per patent and the *reference* citation intensity in each technological field in every year.

We employ several panel regressions controlling for an individual effect of the first assignee of a patent and using the normalized citation counts as a 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, it 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. These findings may reflect the fact that the pro-patent policy in Japan is now just beginning to have some impact on the patenting activity of government research institutes. On the other hand, it does not appear to dictate the patenting behavior of university researchers. We think that institutional and organizational features of government research institutes and universities are keys to elucidate the salient responses between them. Japanese universities may not accommodate themselves, as yet, to patenting biomedical research outcome 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 empirical formulation. Section 4 gives a brief summary of our patent data in terms of technology class, assignee type and industry classification. Section 5 explains variable constructions. Section 6 provides summary statistics for selected variables. Section 7 presents empirical findings. 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 Derwent Innovation Index (DII) and Derwent World Patent Index (DWPI) (Thomson ISI) by using 19 search equations which are defined by Japan Patent Office (2003). The search equations define 19 biomedical fields non-exclusively by using the combination of International Patent Classifications (IPC) and key technical terms of the relevant technological categories[7]. Table 2

[7] Since complete description of the 19 search equations are quite lengthy, we omitted them to save space. See Japan Patent Office (2003) for more detail.

shows summary descriptions of the 19 biotechnology fields. We think that these 19 categories cover a broad range of technology fields associated with biomedical research.

[INSERT TABLE 2 AROUND HERE]

Patent retrieval procedure is as follows: date of search is 1 March 2004; priority country is Japan; priority date is from 1 January 1991 to the date of search. Then we matched them with the IIP Patent Database (Institute of Intellectual Property) by using several kind codes[8]. The IIP Patent Database gives us the Japanese assignee information accurately, because it is based on the original digitized database (*Seiri-Hyojunka* Database) which is compiled by the JPO. Moreover, patent documents of the IIP Patent Database are described in Japanese, which greatly alleviated our effort to identify assignee names, as will be explained in detail in the next 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 priority information, assignee names, and priority country of each patent and excluded irrelevant or erroneous data. The remaining dataset comprises 30,350 patents. In addition, if an assignee belongs to industry, we checked whether each assignee was a listed company or not by using JDB Database (Japan Development Bank) and JBA Annual Report (Japan Bioindustry Association).

2.2. Assignee Name Matching

Assignee names in the Derwent patent data were given in English and unfortunately they were not accurate enough to infer relevant Japanese assignee names (in some cases they were quite erroneous and misleading). Thus we had to match the English assignee names with relevant 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 IIP Patent Database and matched them with the DII/DWPI patent data by using several types of patent numbers and kind codes. We supplemented the remaining missing assignee names by using IPDL (Intellectual Property Digital Library offered by the JPO). After time-consuming exploration,

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

[9] "Derwent family" is a set of individual patents granted by various countries and it covers all the equivalent patent applications corresponding to a single "invention" which is compiled by experts of ISI 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.

we identified 5352 distinct assignees of the 30,350 patents in which the number of the first assignee is 3577. 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 have had experience of M&A, company split-up, or the change of assignee name or institutional affiliation.

2.3. Classification of Assignee Types

The pro-patent policy such as the Japanese Bayh-Dole Act in 1999 and the TLO Act in 1998 are mainly intended for the public sector such as government research institutes and universities. Because the main concern of the present study is to detect the effect of these policy measures, we need to distinguish clearly between private sector patents (mainly corporate patents) and public sector patents (i.e., government patents and university patents).

We classified all 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 original affiliations of all individual assignees by using the search engines of Yahoo! and Google. Then we reclassified patents which were filed by individual patentees into the above-mentioned three types of assignees to the greatest extent possible.

Moreover, we classified their combinations of co-assignees if there are two or more co-assignees. As will be explained in the next section, we distinguish between the first assignee and other co-assignees of a patent, because we will 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, we denote those patents 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]

[10] There are very few patents which are jointly filed by a corporation, a government research institute and

After time-consuming data exploration, we identified all the first assignees and co-assignees of 30,350 patents exclusively as follows: *corp* (21,664 patents), *gov* (1611), *univ* (995), *corp_corp* (1420), *corp1_gov* (323), *gov1_corp* (536), *corp1_univ* (636), *univ1_corp* (460), individuals (727), private foundations and public associations (1350), and others (628).

3. Empirical Formulation: "Fixed Effect" Approach

We treat a first-assignee individual effect which is possibly associated with patent values. The first assignee of a patent may be the main inventor or solely the main contributor of research fund. There may be no significant reasons for the sequence of co-assignees, and we have no additional information about the reasons for the order of co-assignees. But there are also no reasons for negating the fact that the first assignee would be the principal co-assignee. We therefore control for a possible "unobservable" fixed effect for the first assignee in regressions. That is, 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 a priority year of a patent i is 1999 and later, otherwise zero. $u_{i(t),j}$ is an error term. This specification essentially exploits cross-sectional variations of the pooled observations of patents which are filed by the first assignee of a patent across years. Inclusion of individual effect c_j controls for all "unobserved" individual characteristics of the first assignee. That is, the c_j captures all 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.

$D_{i(t)}$'s represent row vectors of assignee type dummies of a patent i in year t. A superscript of $D_{i(t)}$ represents a particular assignee type. That is, if a patent is filed by at least one corporation and there are no other co-assignees belonging to the public sector, we denote

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a university all together, as well as by both a government and a university in our dataset. We thereby do not make additional indicator variables for them.

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

the row vector of 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 indicator variables as $D^{G}_{i(t)}$. In a similar way, 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 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 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 patent values compared with the "average" value of all 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 of either governments or universities compared with the average patent value of all corporate patents. In a similar way, 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. That is, we include cross terms of a year dummy $D99_{i(t)}$ with both $D^{G}_{i(t)}$ and $D^{U}_{i(t)}$.

4. Basic Facts on the Japanese Biomedical Patents

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

4.1. Patent Applications by Technology Classes

For convenience sake, 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 increased trend of patenting in many technology classes. “Genetic engineering” and “gene analysis” are the most active fields in patenting in Japan. On the other hand, although the rate of increase in patenting on post-genome technologies is remarkable especially since the latter half of 1990s, the number of patents is much smaller than that of basic technologies. Concerning other technologies, patenting on “micro-organism and enzyme” exploded since 1997, whereas the number of patents on biomedical products, such as “biopharmaceuticals” and “biochemical products,” did not specifically rise within our observation period.

[INSERT FIGURES 1, 2 & 3 AROUND HERE]

It is worth noting that the compositional change in 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 producing clinically effective biomedical products or gene therapy/diagnoses. However, the number of patents of the sort is not, as yet, impressive in Japan. Inventing biomedical products would be one of the ultimate goals of biomedical research, and it may be all the 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 they are, if anything, mature research fields. But these technologies have been still the most active fields in patenting in Japan[12].

4.2. Patent Applications by Assignee Types

Figures 4 and 5 present the number of patent that was filed by a single assignee. Figure 4 shows that the trend of corporate patents is quite similar to that of total patents which was almost flat or rather decreased through mid-90s and then increased steadily from 1998. On the other hand, government as well as university patenting is rising sharply, although university patenting is somewhat lagging behind.

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[12] The growth of patenting in genetic engineering and gene analysis may be partly due to the enlargement of patentable domain in the early 1990s. Roughly speaking, the patentable domain in Japan is ranked somewhere in between the broader scope of the US and the narrower scope in EU. See Japan Patent Office (2003) for more detail.

[INSERT FIGURES 4 & 5 AROUND HERE]

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

Generally speaking, cooperative research between public and private sectors seems to have 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). In biomedical research, however, there is an increased trend of patenting by the public sector. 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 reached more than 30% of total patents in 2002.

[INSERT FIGURES 6 & 7 AROUND HERE]

Government patenting is highly concentrated with the following top 5 government research institutes; Japan Science and Technology Agency (JST), National Institute of Advanced Industrial Science and Technology (AIST), and Institute of Physical and Chemical Research (RIKEN), National Agriculture and Bio-oriented Research Organization (NARO), and National Institute of Agrobiological Sciences (NIAS)[13]. The top 5 government institutes are defined by the order of the total patent applications since 1991 through 2001 in biomedical research[14]. As is shown in Table 3, they account for around 70% of the total application by the government, and the top 3 government institutions (i.e., JST, AIST and RIKEN) occupy the majority of government patents. This may partly reflect the fact that government subsidies are concentrated with these research institutes[15].

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[13] 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 which 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 the government research institutes, we compiled all patents filed by both former and current organizations for each research institutes.

[15] These five research institutes account for around 20% of total public R&D subsidies to independent administrative agencies (IAAs). Concerning the distribution of government research expenditures among public research institutes, see NISTEP (2005) for detail.

[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. Three points are deserved to mention here. First, chemical and food companies have been the main patentees in Japan. Traditionally industrial biotechnology research was mainly done by chemical and food companies with strong capabilities in fermentation[16]. Corporate patenting is not dominated by pharmaceutical companies and rather dispersed across many industrial sectors. Patenting by pharmaceutical companies increased only since 1999. This would be starkly contrasted with the situation in the U.S. and possibly in most European countries.

Second, electronics companies that have been the main actors in industrial innovation in Japan increasingly file biomedical patents since the latter half of 1990s. It is probably due to the fact that biomedical research is increasingly relied on information technologies such as “bioinformatics”.

Finally, listed large companies are still the main patentees in biomedical research. Listed large companies occupy the majority (55.4%) of the total biomedical patents for the years 1991-2002 in Japan. According to the Japan Bioindustry Association (JBA), there are only twelve listed new bio-venture firms (NBFs) as of March 2004[17]. All of them are listed in emerging equity market such as JASDAQ, Mothers (Tokyo Stock Exchange), and Hercules (Osaka Stock Exchange). The share of NBFs’ patenting is just around 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 by using forward citations[18]. Following Jaffe and Lerner (2001) and Hall, Jaffe and Trajtenberg (2002), we adjust

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

[17] See Japan Bioindustry Association (2005). According to the JBA’s definition, NBFs are firms doing research, manufacturing or consulting which relates to biotechnologies with less than 300 employees in manufacturing and less than 100 employees in research and service, and 20 year-old at most from establishment.

[18] We aggregated all forward citations of a patent which occurred in a common patent family. Thus the number of forward citations here is the total number of citing patents which 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 distinct self-citations and citations by others with the data at hand.

heterogeneity concerning propensity to cite on technology field k (k =1, 2,…, K) in year t (t =1,2,…, T). Put differently, we construct weighted citation count (*normalized* forward-citation intensity) which is defined by the difference between the actual number of citations received per patent and the *reference* citation intensity for each technological field k in year t.

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

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

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

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

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

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

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

Each patent has possibly multiple technology-field flags. We thereby calculate 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 on technology field k as follows:

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

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

(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 we will use in regressions: *assignee types*, *characteristics of patents*, and *other characteristics of assignees*, as are listed in Table 4. We already explain assignee type dummies in Section 3.

[INSERT TABLE 4 AROUND HERE]

Regarding patent characteristics, *pat_scope* is already defined in equation (5). This is a proxy for patent scope which 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 on the relationship between patent scope and patent value. As is pointed out by Merges and Nelson (1990), patent scope would have complex impact on innovation. It is an empirical issue 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 patent scope, and indicates that the firm's value is positively correlated with patent scope. On the other hand, Harhoff et al. (2003) utilize a similar patent scope measure as 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 which are filed to the JPO alone. In Japan, citations of prior arts were not obligatory for patent examiners as well as applicants, which would greatly decrease the likelihood that a patent was 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.

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

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

In addition, we define *science_ratio* as a proxy for the extent of science-linkage for each patent. We define *science_ratio* by "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 is shown in the next section, *science_ratio* would have a strong positive correlation with the size of 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 at the present study.

Concerning 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 that prolific patentees file more valuable patents on average (or it may be called a *dilution* effect if there is a negative impact of the patent size on the average patent value)[23]. Moreover, we define an indicator variable, *listed*, that denotes whether a patent is filed by a listed company or not. As mentioned before, industrial biomedical research has been mainly performed by listed companies in Japan and there are quite few listed new bio-venture firms in Japan, but it is not very certain that listed companies are producing more valuable patents or not 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 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

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[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 biotechnology industry in the U.S. depends on public science much more heavily than other industries. In a careful study, Harhoff et al. (2003) also show that science-linkage has a strong explanatory power for the value of German biomedical patents. In a related vein, Tamada et al. (2004) and Branstetter and Kwon (2004) suggest that the biomedical industry in Japan is strongly indebted to scientific research.

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

[23] Henderson et al. (1998, pp.125-6) 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 at the same time the sheer number of university patents has increased. Mowery et al. (2002) explicitly examine this issue in the U.S. universities and present evidence of entrants' learning to patent. See also footnote 11.

[24] There is a series of careful studies on patent value measures such as forward and backward citations, patent family, science linkage, the number of claims, and the number of years a patent is renewed. See, for example, 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).

patents and non-patent articles.

Second, we define *fam_size* which is the total number of “equivalent patents.” The family size of a patent would possibly affect the likelihood of forward citations by subsequent patents filed in other countries. It should be noted that, according to the definition of DWPI, patents in the same family do not necessarily share the same priority date. DWPI defines a patent family as those sharing the same “invention” as well as relevant inventions which 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* which is the number of claims in 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. 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 an incentive to claim as much as possible but patent examiners may require that claims be narrowed before granting. Thus the number of claims at patent filing tends to be larger than that at patent 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

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

Table 6 presents summary statistics on selected variables by assignee types. Table 6 shows that 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 which were filed by the first assignee belonging to government research institutes. It should be noted that *pat_size* of government patents is particularly large on average (50.9). This reflect the fact that propensity to patent by government research institutes is very high, especially in the latter half of 1990s.

[INSERT TABLES 5 & 6 AROUND HERE]

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

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*). It may not be surprising given the importance of open science culture in university research, although it should be interpreted with caution. This may be due to the differences in technology fields which tend to cite more non-patent articles. It may be otherwise due to higher propensity to cite academic articles by university researchers. Thus the relationship between science linkage and patent values are not very certain.

There appears to be no noticeable difference in *science_ratio* among other assignee types than university. However, it is, if anything, a stylized fact in the literature that science-linkage is a beneficial source of information about the importance of a patent, a biotechnology patent in particular (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*. Note further that the corporate patents have relatively fewer claims (*claim*) on average. That is, the private sector is likely to file more technologically-focused patents with fewer claims compared to the public sector patents. 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 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 mainly occurred by patents which were filed in other jurisdictional patent offices than the JPO.

Regarding the alternative patent value measures, there are significant positive correlations 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 which is best to use as a patent value measure[26]. Furthermore, incorporating these alternative patent value measures in regressions as independent variables would have provoked a number of problems regarding multicolinearity and endogeneity. We therefore exclude *fam_size*,

[26] In unreported works, when we used the alternative patent value measures as dependent variables in 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 as well as technology dummies, we were able to have somewhat similar estimation results to the present study. But significant cohort effects and possibly serious truncation bias of forward citations would have made detecting the pro-patent policy effect almost impossible. Note that the pro-patent policy measures were introduced quite recently (in the late of 1990s) in Japan.

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 a patent i across years. We also employ regressions with the following set of variable:

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

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

We already define these variables and discuss possible impacts of them on patent values in previous sections. 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:

$$\begin{aligned}
dciting_{i(t),j} = c_j &+ \alpha_1 pat_scope_{i(t),j} + \alpha_2 jp_only_{i(t),j} + \alpha_3 science_ratio_{i(t),j} \\
&+ \alpha_4 pat_size_{j(t)} + \alpha_5 listed_{j(t)} \\
&+ \beta_1 corp_{i(t)} + \beta_2 corp_corp_{i(t)} \\
&+ \gamma_1 gov_{i(t)} + \gamma_2 corp1_gov_{i(t)} + \gamma_3 gov1_corp_{i(t)} \\
&+ \delta_1 univ_{i(t)} + \delta_2 corp1_univ_{i(t)} + \delta_3 univ1_corp_{i(t)} \\
&+ D99_{i(t)} \times (\varsigma_1 gov_{i(t)} + \varsigma_2 corp1_gov_{i(t)} + \varsigma_3 gov1_corp_{i(t)} \\
&\qquad + \xi_1 univ_{i(t)} + \xi_2 corp1_univ_{i(t)} + \xi_3 univ1_corp_{i(t)}) + \varepsilon_{i(t),j}.
\end{aligned}$$

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 we already discuss in Section 5. Therefore we do not add a series of year dummies as well as technology field dummies to the present specification. Concerning policy effect dummies, we use either $D99_{i(t)}$ or $D98_{i(t)}$ alternatively in regressions for the sole purpose of 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. We therefore apply an ordinary least square (OLS) method in panel regressions[27]. However, regression disturbances may not be constant across observations. To alleviate the heteroscedasticity which may relate to the explanatory variables, we use heteroscedasticity robust standard errors in inferences for estimation results. Total number of observation is 30,350 and the number of first assignees is 3577[28].

7.2. Estimation Results

Estimation results are summarized in Table 8. Observation period is for the years 1991-2002. All equations are employed by using the fixed effect model for the first assignee. Fixed effect models are supported in all specifications according to the conventional Hausman test statistics. Heteroskedasticity 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 significant and positive in every specification. That is, there is some significantly positive impact of a corporate assignee without co-assignees of either governments or universities on patent values, compared with the average patent value of all corporate patents. Coefficients of patents filed jointly by no less than two corporations (*corp_corp*) are also positive and significant. Thus there is also some positive impact of the first assignee of a corporation with a corporate co-assignee on patent values, compared with the average patent value of all corporate patents. 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). 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.

As for the public-private collaborative patents, coefficients of industry-government

[27] In exploratory works, we employed several regressions by using a simple OLS specifications clustered by the first assignee. But 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. We therefore decided to use the fixed effect specification for the first assignee.

[28] We also employed regressions by excluding patents which were filed in 2002 (1726 patents) from our dataset in view of a truncation bias. Since there is an eighteen-month lag in the disclosure of patent application after filing, patents that were filed after September 2002 are not fully covered in our dataset. But we obtained virtually similar results to the present study.

patents (*corp1_gov*) are positive and significant. Thus there is some positive impact of the first assignee of a corporation with a government co-assignee on patent values, compared with the average patent value of all corporate patents. This means 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 a lot of 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 in all specifications.

Concerning the policy effect, 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 on average, it has risen since the introduction of the pro-patent policy. On the other hand, there is 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*. Salient features in columns (5) and (6) are significantly positive coefficients of $corp1\_gov \times D98$. If we evaluate the policy effect by using the benchmark year in 1998, we detect positive policy impact of the first assignee of a corporation with a government co-assignee on patent values. This fact is susceptible of various interpretations, but we suspect that industry-government cooperative research is influenced by the pro-patent policy in an expeditious way.

To sum, the value of government patents have increased since the introduction of the pro-patent policy in the late 1990s. This may reflect the fact that the pro-patent policy in Japan is now just beginning to have some impact on the patenting behavior of government research institutes in the late 1990s. Concerning university patents, however, the pro-patent policy do not appear to dictate the patenting behavior of university researchers. The organizational and institutional features of the Japanese universities may not accommodate themselves, as yet, to patenting biomedical research outcome 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 turn out to have some explanatory power. Coefficients of *pat_scope* are negative and statistically significant in all specifications, which mean 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 market value of biotechnology firms. On the other hand, Lanjouw and Schankerman (1997) report no significant coefficients of patent scope on probability of infringement litigation which would be closely related with patent values.

[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.

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. A method of technology classifications seems to be critical to detect the impact of patent scope on patent values.

As for the remaining explanatory variables, *jp_only* is negative as expected and strongly significant. The scale effect of the first assignee (*pat_size*) is negatively correlated with patent value and statistically significant. There appears to be some negative scale effect that 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 mulicolinearity between *science_ratio* and *jp_only*. Coefficients of *listed* is negative but insignificant in various specifications. This suggests that listed large companies are not specifically advantageous in producing valuable biomedical patents.

8. Concluding Remarks

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

As final remarks, we would like to make somewhat speculative comments on possible sources of the different attitudes of the public sector researchers to the pro-patent policy in Japan. We believe that the 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 annual third-party review. Then the review is reflected in prioritization of budget allocation concerning the Basic Plan[30]. In addition, the government

[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 affect budget request negotiations between jurisdictional authorities and the Ministry of Finance.

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 compared with universities.

On the other hand, patenting may be far from 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, publications of academic papers seem to be much more important, as is the case in the U.S. top research universities (Mowery et al., 2001; Agrawal and Henderson, 2002). Increased trend of university patenting may be partly explained by the recent facilitating policy measures which somewhat alleviated red-tape routine in government research funding, donations by the private sector, hiring temporary researchers, commissioned research, and negotiations concerning the ownership of research outcome. But they still require cumbersome procedures with quite a few administrative staffs under one-fiscal year budget constraint.

The role of the public sector is possibly important in biomedical research. Biomedical research is characterized by the high importance of basic research done at universities and public research institutions. However, there are many steps before basic research leads to commercialization. In particular, at commercialization stage of scientific knowledge, one of the important factors affecting collaborative R&D incentive is an *ex ante* agreement governing the ownership of innovative output (Aghion and Tirole, 1994). Because intellectual 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 disseminating research results widely. This, however, could possibly weaken the incentive to collaborate in research by the private sector.

Producing and transmitting scientific knowledge can take a wide variety of forms depending on research areas, organizations, participants, and other factors. Accordingly, there is no single answer with respect to methods of public support for biomedical research. Patenting is a means rather than an end. Consequently, pro-patent policy measures must be designed with sufficient attention to the characteristics of 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 patenting activity of the public sector. But 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 co-applications of patent be regarded as the result of effective research collaborations among "inventors"? The present study did not utilize information about inventors at all which is in fact also available in patent documents. It would be beneficial to scrutinize characteristics and configurations of inventors for each patent although it requires a time-consuming work. We will proceed to investigate an inventors' analysis in near future.

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

Third, there have been several organizational reforms for the public sector in Japan since 2001. In April 2001, almost all public research institutes were reorganized into "independent administrative agencies" (IAAs) which seem to be independent of the government as literally interpreted. But they have been financially as well as managerially supervised tightly by vertically divided bureaucracy. As for Japanese national universities, they were reorganized to semi-private entities, so-called "national university foundations," in April 2004. National university foundation is an intermediate legal entity in between government agency and public foundation. However, these organizational changes are beyond the scope of the present study using data on patent with priority years between 1991 and 2002.

Finally, is it really desirable to encourage government and university to file patent in first place, reflecting the salient features of Japanese innovation system such as low mobility of researchers, weak patent protection, and backwardness in bio-medical research? These issues must be undoubtedly important, but the lack of solid explorations on these issues is mainly due to data constraint in Japan.

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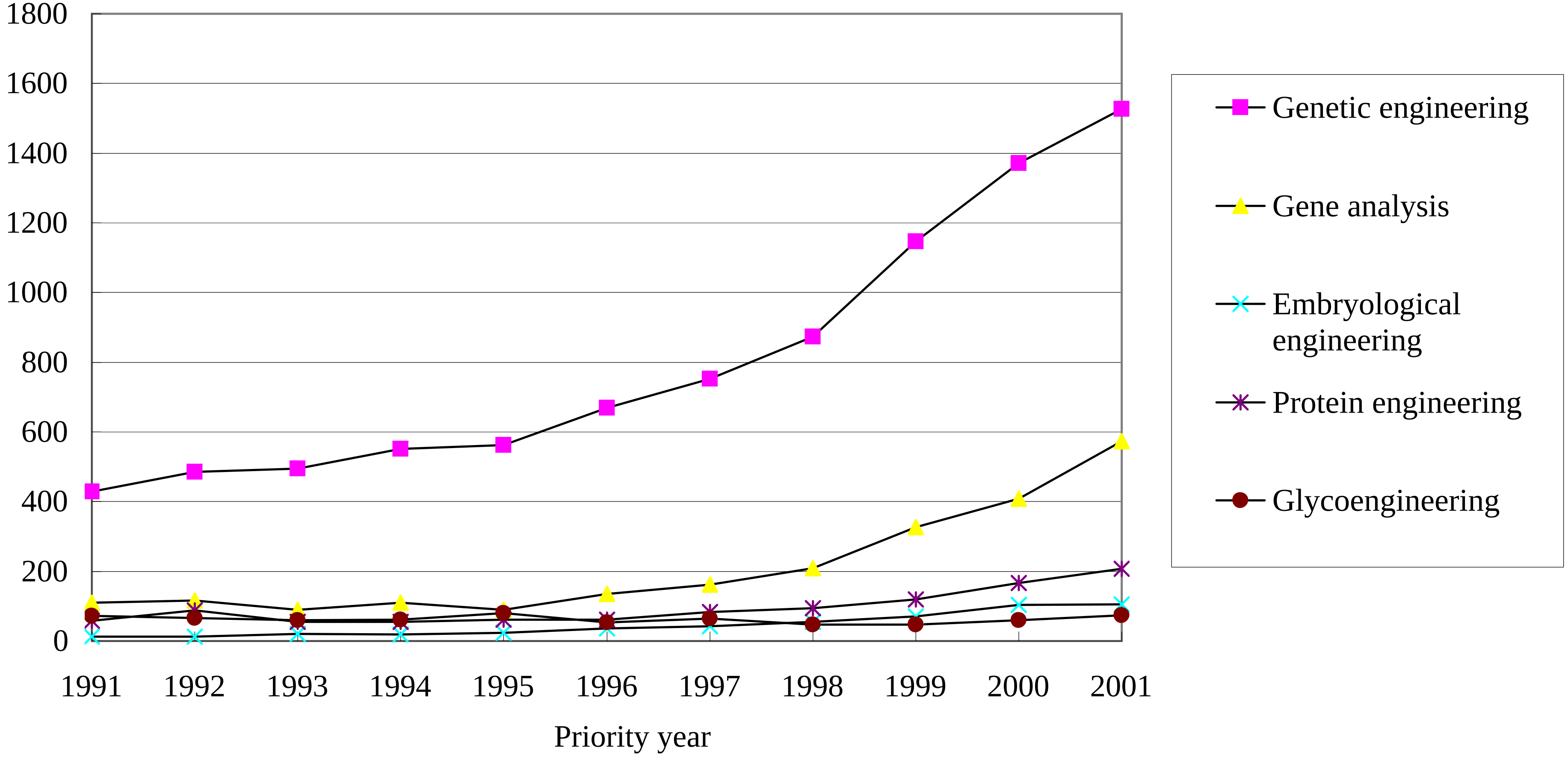
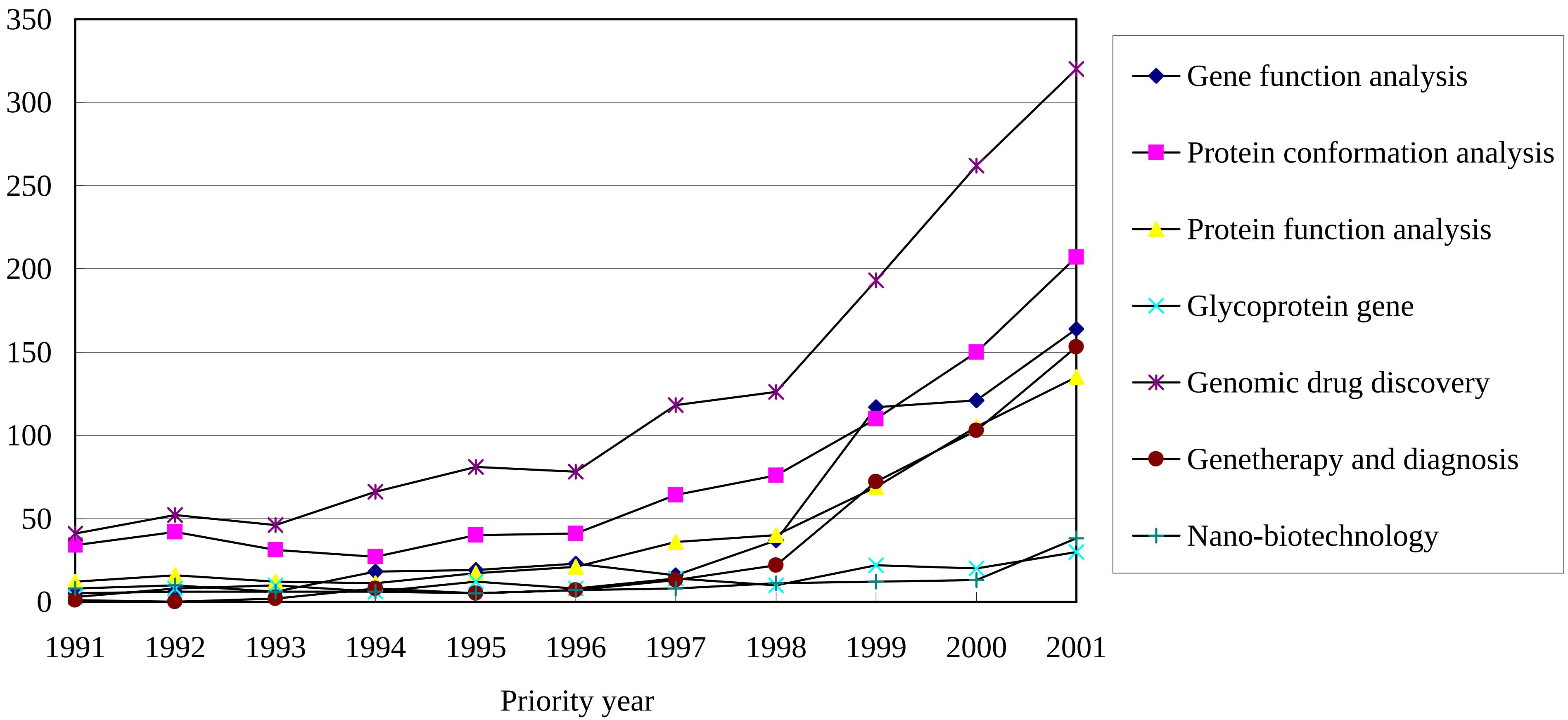
Figure 1 Number of biomedical patents (basic technologies)



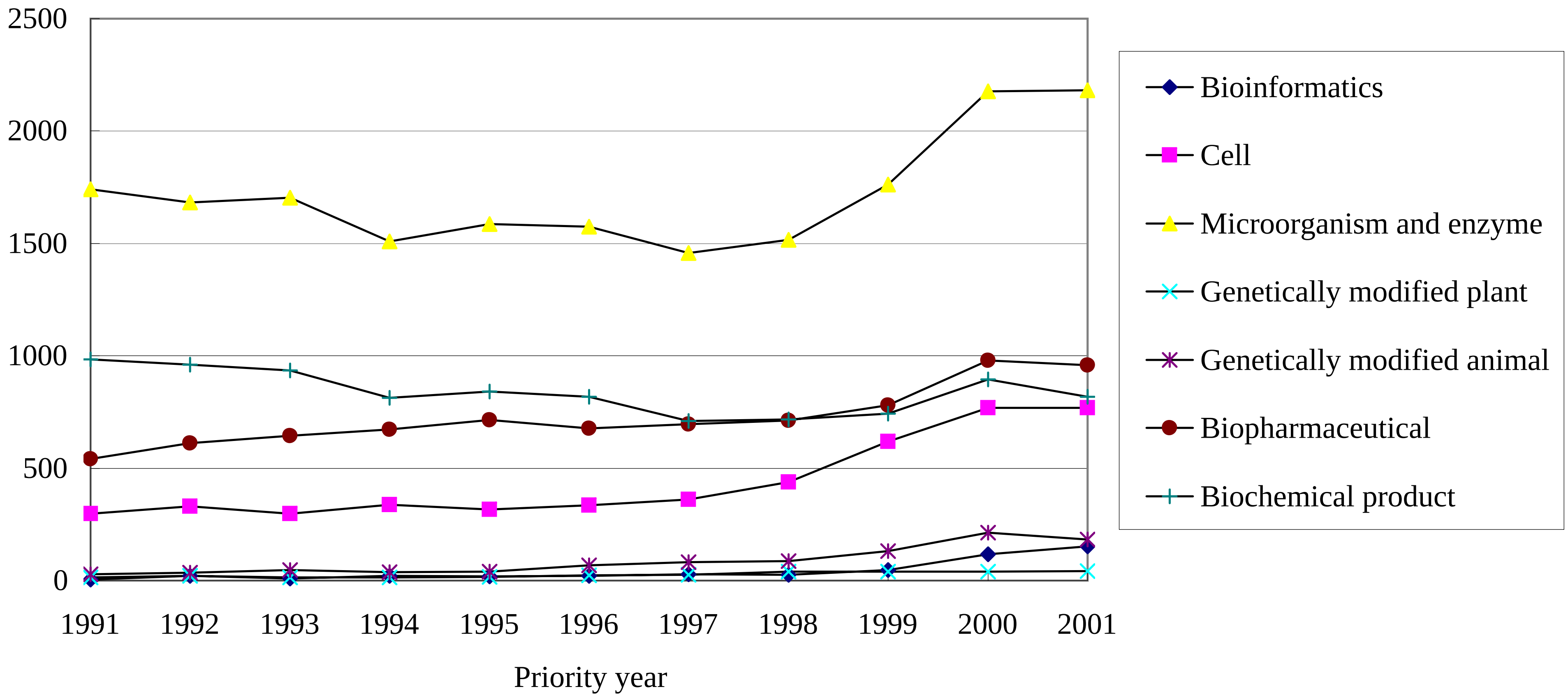
Note: Technology classifications here are based on Japan Patent Office (2003). See Table 2 regarding summary descriptions of the biomedical fields. T numbers of patent counts in 2002 are omitted from the figure due to significant truncation bias. See text for more detail.

Figure 2 Number of patents (post-genome technologies)



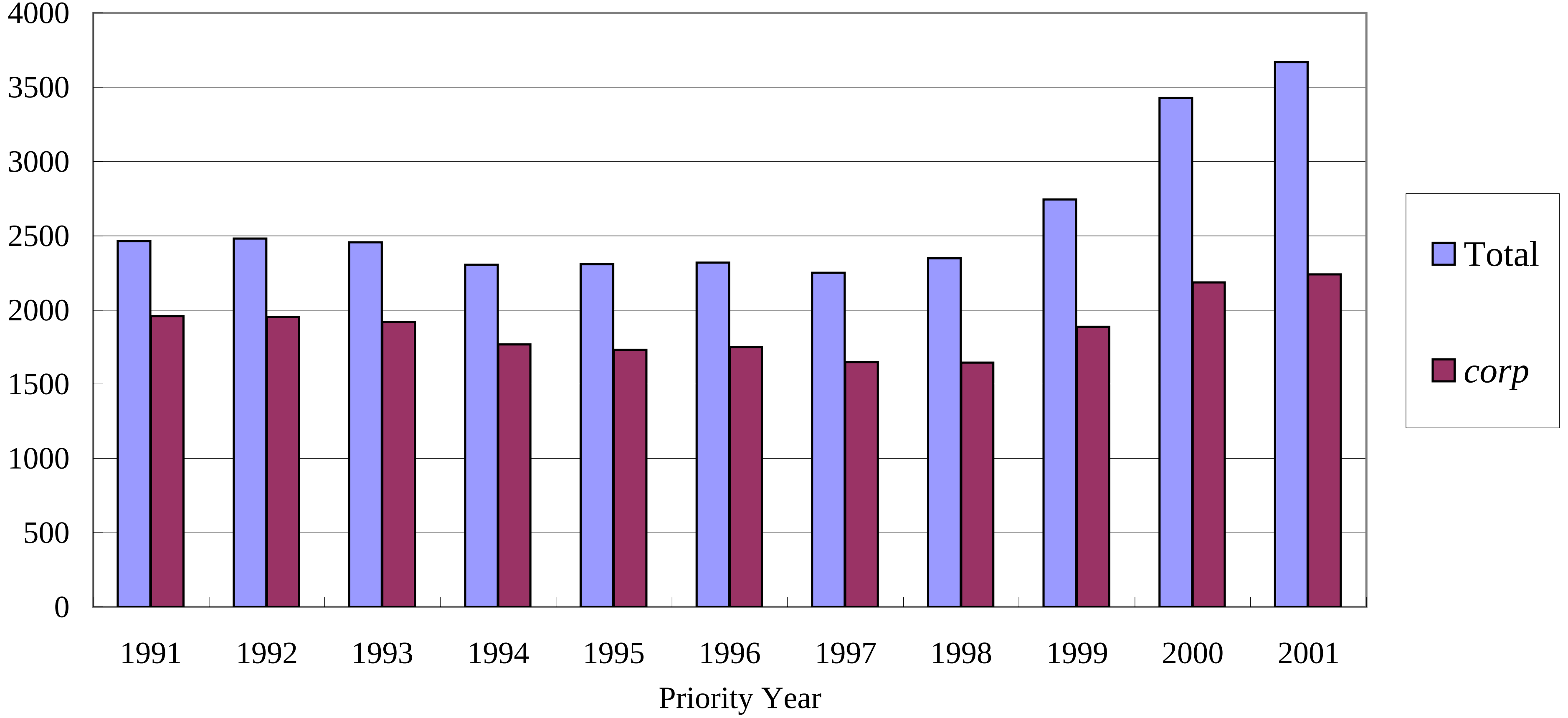
Note: Technology classifications here are based on Japan Patent Office (2003). See Table 2 regarding summary descriptions of the biomedical fields. T numbers of patent counts in 2002 are omitted from the figure due to significant truncation bias. See text for more detail.

Figure 3 Number of patent filings (other technologies)



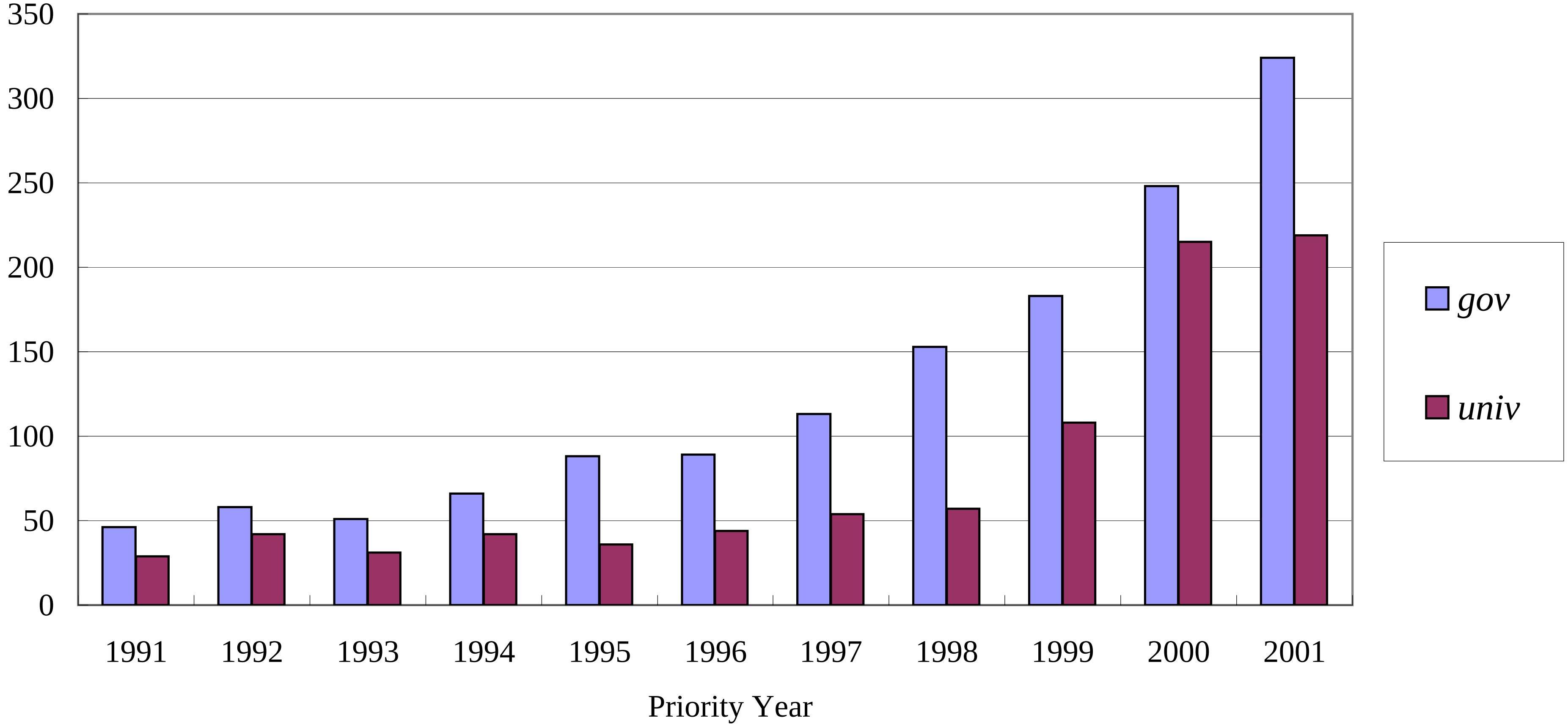
Note: Technology classifications here are based on Japan Patent Office (2003). See Table 2 regarding summary descriptions of the biomedical fields. T numbers of patent counts in 2002 are omitted from the figure due to significant truncation bias. See text for more detail.

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



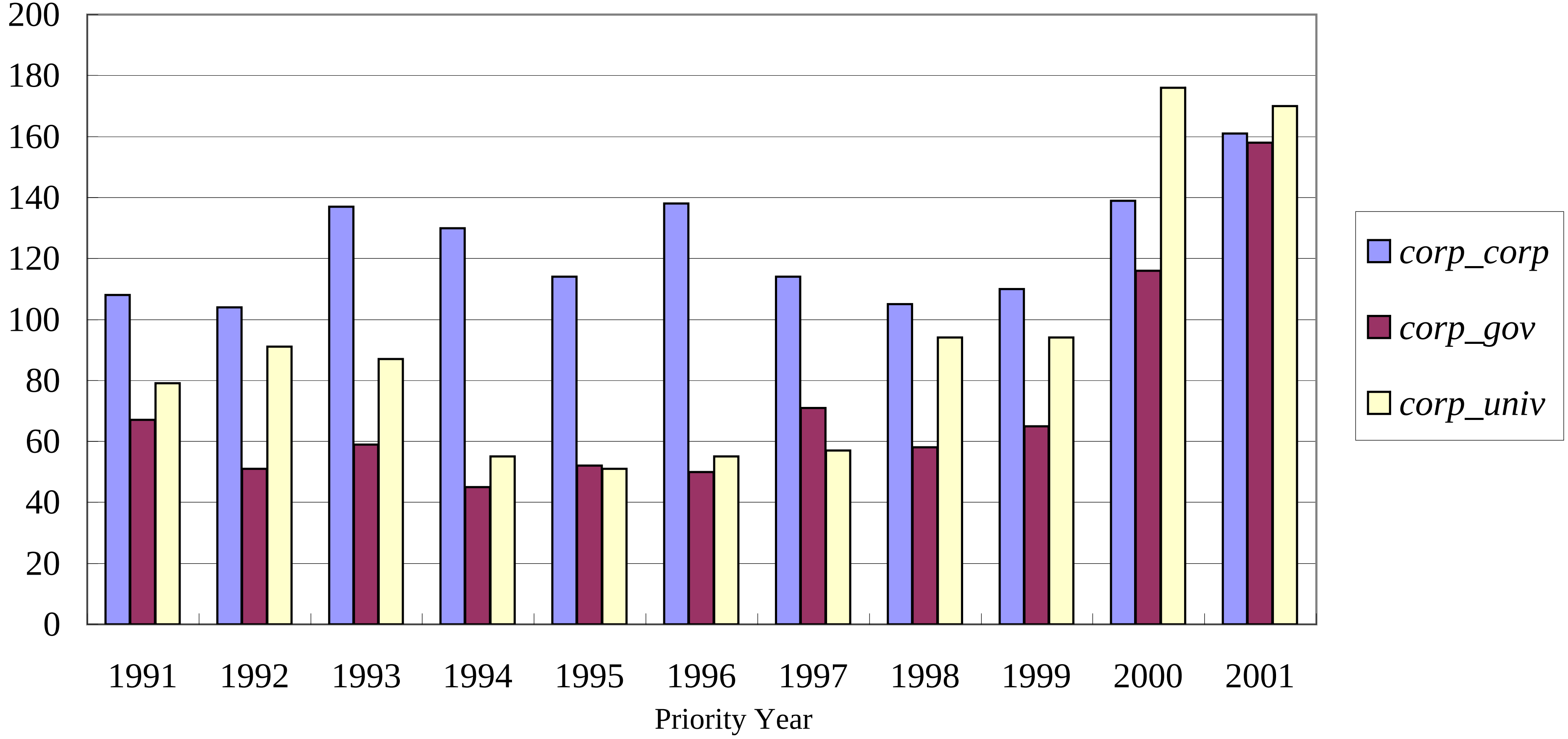
Note: The classification of assignee types are based on the authors' definitions.*corp* denotes a corporation. The number of patent counts in 2002 is omitted from the figure due to significant truncation bias. See text and Table 4 for more detail.

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



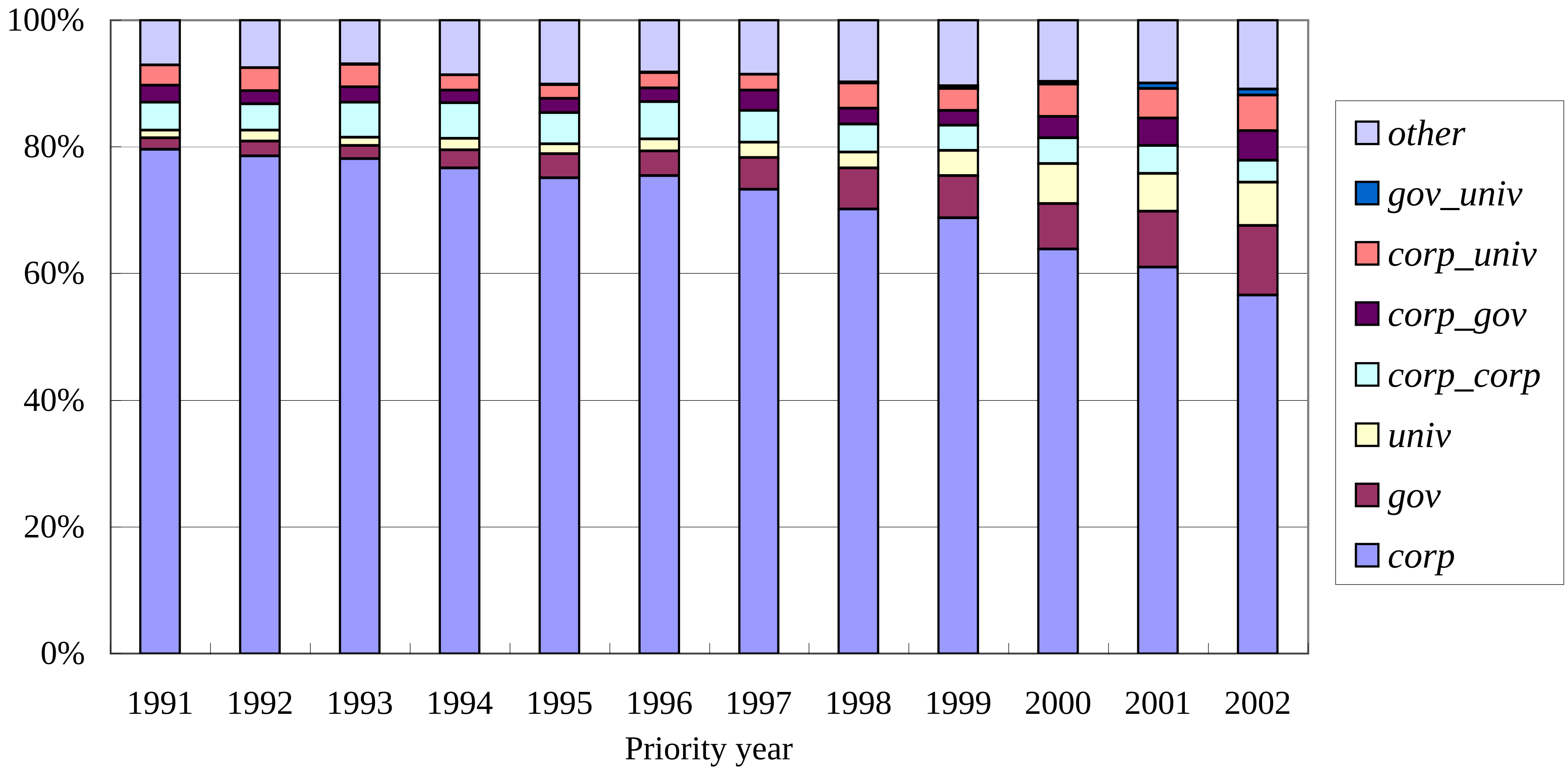
Note: The classification of assignee types are based on the authors' definitions.*gov* denotes a government research institute, and univ denotes a university. The number of patent counts in 2002 is omitted from the figure due to significant truncation bias. See text and Table 4 for more detail.

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



Note: *corp_gov* in the figure 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* as well. Concerning the variable definitions, see Table 4 for more detail. The number of patent counts in 2002 is omitted from the figure due to significant truncation bias.

Figure 12 Biotechnology patent by assignee type (%)



Note: *corp_gov* in the figure 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* as well. Other variables are defined in a similar way. Concerning the varible definitions, see Table 4 for more detail.

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

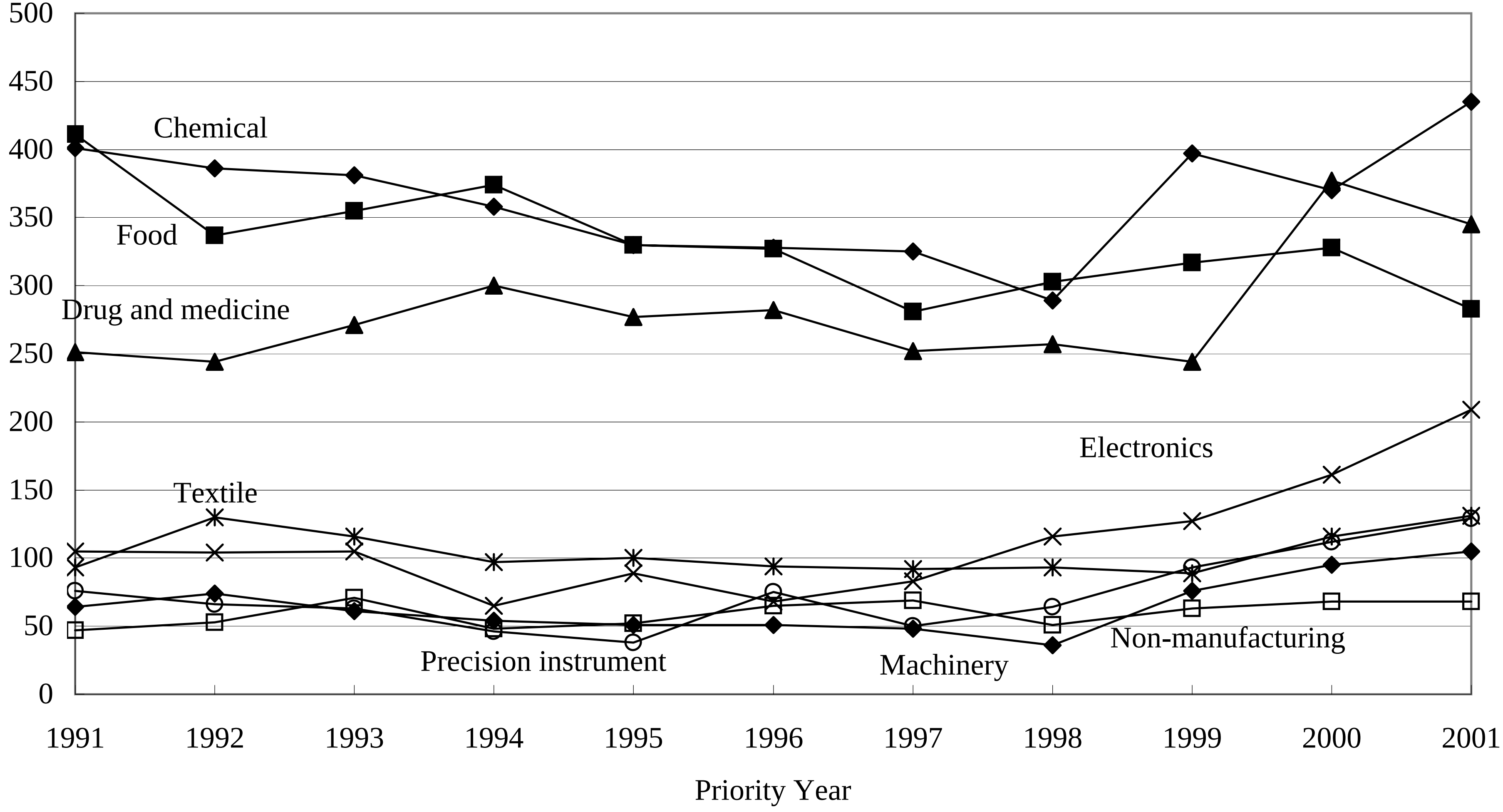


Table 1 Major Policy Initiatives relating to Industry-Government-University Collaboration in Japan, 1995-2002

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; that 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 estates and facilities for the use of industry-university-government collaborative research.
1999	The Law on the Special Measures for Revitalizing Industrial Activities	The so-called "Japanese Bayh-Dole Act," including Bayh-Dole provisions, such as permission of retaining patents to inventions deriving from publicly funded research as well as exclusive licensing of state-owned patents. Permission of dual employment of 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 fee of 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 is being convened since 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 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 Technolgies	1	Genetic engineering	Genetic engineering in vitro. Preparation and use (process) of DNA, RNA, vector/ plasmid, host etc. in relation to genetic engineering. Novel gene or protein obtained by the process or used in the process.
	2	Gene analysis	Technologies analyzing DNA structure, such as SNPs, gene sequence 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 animal and cell obtained by using these technologies.
	4	Protein engineering	Technologies altering a protein function by altering a part of protein's structure artificially. Bioinformatics used for the process. Modifications (gene and protein) obtained by the process.
	5	Glycoengineering	Carbohydrate chain and the analysis of its structure/ function. Gene relating to glycosylation. Technologies altering function of protein/ cell by modifying carbohydrate chain. Carbohydrate chain obtained by this modification and its production.
Post-genome Technologies	6	Gene function analysis	Technologies analyzing gene function experimentally.
	7	Protein conformation analysis	Technologies determining protein sequence and conformation. Technologies analyzing protein structure/ function *in silico* (protein informatics).
	8	Protein function analysis	Technologies analyzing protein function experimentally.
	9	Glycoprotein gene	Enzyme-gene and protein participating in biosynthesis/ transference of carbohydrate chain. Technologies relating to them. Use of them.
	10	Genomic drug discovery	Technologies identifying disease-related gene. Novel gene or protein 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. Technologies on diagnosis using genetic information.
	12	Nano-biotechnology	Technologies on observation, measurement and function analysis of molecule and cell. Technologies on manipulation of molecule and cell. 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 accumulate these information. Technologies retrieving/ displaying useful information from the database. Technologies used through the data processing.
	14	Cell	Animal/ plant/ human cell and tissue used in life science. These cell modified by exogenous gene. Culture apparatus for cell.
	15	Microorganism and enzyme	Technologies manufacturing useful materials by using microorganism, enzyme and its biocatalyst function.
	16	Genetically modified plant	Technologies altering plant breeding by using genic engineering. Technologies relating to them.
	17	Genetically modified animal	Technologies altering animal breeding by using genic engineering. Technologies relating to them.
	18	Biopharmaceutical	Biopharmaceuticals. Biotechnologies for manufacturing them
	19	Biochemical product	Chemical product manufactured by biological process and its manufacturing technologies

Table 3 The top 5 government research institutes in biomedical research

#	Organization	Patent application	%	The top 3 (%)	The 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	The 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	The National Institute of Agrobiological Sciences (NIAS)	177	6.6		
	Total	2692			

Note: These data are based on biomedical patents where priority years are for the years 1991-2001 and a priority country is Japan. The top 5 research institutes are defined by the order of the total number of patent application in relation to biomedical research since 1991 through 2001.

Table 4 Variable Names and Definitions

Dependent variable

Variable	Definition
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. See text for more detail.

Independent variables

Variable	Definition
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 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 institutes 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" which 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). See Table 2 for more detail.
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 citation received by patents which 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 application filed by the first assignee each 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 take the value of unity if a 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 is shown in Table 1.

Table 5 Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Single assignee					
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	-15.24	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 are from 1991 to 2002 and the priority country is Japan. Average value of the normalized patent citation intensity (dciting) is zero. Sample size of claim is smaller than the basic dataset due to missing data in the IIP Patent Database. Standard deviations are 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	-0.045	0.171	0.287	1						
listed	0.080	0.105	0.017	0.005	1					
jp_only	-0.252	-0.113	-0.659	-0.292	-0.017	1				
fwd_cites	0.945	0.008	0.244	0.044	0.036	-0.252	1			
fam_size	0.390	0.027	0.543	0.157	0.040	-0.642	0.447	1		
claim	0.069	0.171	0.146	0.320	0.014	-0.208	0.043	0.117	1	
bwd_cites	0.417	0.009	0.318	0.014	0.046	-0.440	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.