Do stronger patents induce more innovation? evidence from the 1988 Japanese patent law reforms

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Does an expansion of patent scope induce more innovative effort by firms? We examine responses to the Japanese patent reforms of 1988. Interviews with practitioners and professional documents for patent agents suggest the reforms significantly expanded the scope of patent rights. However, econometric analysis using both Japanese and U.S. patent data on 307 Japanese firms finds no evidence of an increase in either R&D spending or innovative output which could be plausibly attributed to patent reform.

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1. Introduction

Nordhaus (1969, 1972) initiated analysis of optimal patent design, and the tradeoffs inherent in the patent system — a system which creates static losses (by granting innovators temporary monopoly power) in order to realize dynamic social gains by inducing greater innovative effort. In the last 10 years, the theoretical literature on this subject has become increasingly sophisticated.

The policy debate surrounding intellectual property rights design and enforcement has also come to the forefront. Legal and procedural reforms in the U.S. in the early 1980s provided stronger protection to holders of existing patents. This policy shift took on an international dimension as several U.S. administrations placed intellectual property rights at the center of the agenda in bilateral and multilateral trade negotiations. Since the early 1980s, the U.S. has repeatedly sought to coerce its trading partners to significantly strengthen their own intellectual property rights regimes, bringing them more in line with the new U.S. model.

However, there has not been much empirical work to guide the theoretical literature on patent design or the international policy debate.[1] Recent theoretical work often assumes that firms' R&D is responsive to subtle changes in patent design. The U.S. position on intellectual property rights assumes that the additional innovation induced by stronger patent systems is substantial and strengthening of intellectual property rights abroad beneficial.[2] The empirical evidence, however, ranges from sketchy to nonexistent.

Does an expansion of the scope of patent rights induce more innovative effort? We analyze the response to the 1987 Japanese patent reforms, enacted in January 1988 (hereafter the 1988 reforms or "patent reform"). Japan's patent reforms expanded patent scope in an advanced industrialized economy — precisely the sort of context in which such a policy shift might be expected to have measurable effects on R&D input and innovative output.

We find *no* evidence of a statistically or economically significant increase in either R&D spending or innovative output that could plausibly be attributed to these reforms. The empirical evidence suggests that the responsiveness to changes in patent scope is limited. We discuss the implications for the current policy debate and the theoretical literature in the conclusion.

This article is organized as follows. Section 2 describes the pre-reform Japanese patent system and the 1988 reforms. Section 3 discusses the perceptions of the reforms by practitioners and demonstrates that patent reform expanded the scope of patent protection. Section 4 relates the 1988 reforms to the theoretical literature. Section 5 examines the aggregate impact of the patent reform. Section 6 empirically analyzes the impact of patent reform on R&D spending. Section 7 examines the effect of the patent reforms on Japanese firms' patenting in Japan and the U.S., and section 8 concludes.

2. The 1988 reforms

The Japanese patent system before the 1988 reforms

Japanese and American patent examiners followed similar standards of what constituted a patentable invention. A major difference between the two patent systems concerned the *scope* of a patent.[3] A claim defines the subject matter which an applicant regards as his or her invention. Japanese patents covered a single, independent claim — meaning that one novel advance was permitted per patent. In contrast, American and European patents often listed multiple, independently valid claims. The Japanese single-claim system meant that, compared with other nations, many more Japanese patents had to be filed to cover the same technology.

The scope of each individual claim also tended to be narrower in Japan than in the U.S. U.S. patents could claim protection for broad classes of a product, whereas in Japan only specific products that had been proven in practice could be patented. For example, if a new material could contain 10% to 50% of a certain ingredient, the U.S. patent could specify this range; in Japan the patent covered only the specific percentage that the inventor had used.[4] As each patent was so thinly defined under the Japanese patent system,[5] some critics even called it the *sashimi* system, after the Japanese sliced fish delicacy.[6]

From the single-claim system to the "improved" multiple-claim system

Before 1976, Japanese patent law allowed only one independent, single claim to be included in an invention. A 1976 amendment to the patent law allowed the inclusion of multiple *dependent claims*, which defined the technical ways to implement an independent claim, in the same patent application. This amendment did not substantially change the number of claims included in a patent.

In contrast, the 1988 reforms significantly expanded the extent to which multiple claims could be included in one patent. Patent applicants could now define the coverage of an invention with multiple claims, and those claims could be either independent of or dependent on other claims. In addition, the new law expanded the extent to which related inventions could be included in a single patent. For example, a final chemical compound and the intermediate products generated in its manufacture could now be covered by one chemical patent (Niihara ed., 1987). Patent experts contend that, after the 1988 reforms, *the scope of invention covered by a single patent application equaled or even exceeded that conferred by the U.S. and European patent systems* (Okamoto et al., 1996).

Patent term restoration for pharmaceuticals

The 1988 reforms also provided patent term restoration of up to five years for the period necessary for drug safety and efficacy examinations if the patented drug could not be implemented for more than two years due to delays in the examination process. This amounted to an effective extension of the length of patent rights in the pharmaceutical industry. Our data set includes most of the important Japanese pharmaceutical companies, allowing us to explore the innovation-inducing effects of increased patent length as well as increased patent scope.[7]

Motives of the series of reforms

When a patent system reform comes about primarily through the lobbying efforts of the system's primary beneficiaries, it is not clear that such a reform can be taken as exogenous. In the case of the 1988 reforms, much of the political impetus for change came, not from heavy domestic users of the patent system, such as Sony or NEC, but from Japan's trading partners — chiefly the U.S. The purpose of those reforms was to harmonize the Japanese patent system with that of other countries, and so was driven by motives largely exogenous to the wishes of Japanese firms.[8]

Many of the reasons for American dissatisfaction with the pre-reform Japanese patent system are well illustrated by the case of Fusion Systems (Harvard Business School, 1990). Fusion Systems was a small U.S. high-tech company which invented a microwave lamp in 1974. Fusion Systems sought patent protection in Japan for its invention, filing 20 patents in Japan by 1983. While 20 U.S.-style multi-claim patents might have been enough to secure Fusion Systems' intellectual property rights, the 20 single-claim patents the company filed in Japan left substantial "holes" in the intellectual product space it had sought to protect. Before Fusion Systems could correct this error, its chief competitor in the Japanese market, Mitsubishi Electric, exploited its mistake by filing 139 patents in closely related technologies — an example of a practice known as "patent flooding." After finding that Mitsubishi Electric's 139 patent applications had effectively prevented it from plugging the "holes" in its intellectual property protection, Fusion Systems appealed to USTR. Other U.S. firms with similar complaints put additional political pressure on the U.S. government to pressure the Japanese government for a stronger intellectual property rights regime. The major outcome was the introduction of the multi-claim system.[9]

3. Expected results of the reform and the perception by practitioners

The significance of the multi-claim system

In order to evaluate the expected and perceived outcomes of the 1988 reforms, we conducted a series of interviews in Japan in March–September, 1998. Six high-ranking officials at the Japanese Patent Office, general managers of intellectual property departments at ten major Japanese companies in electronics, office equipment, pharmaceuticals, chemicals, and food industries, and three officers at the Japan Patent Information Organization (JAPIO), a quasi-government organization which provides a Japanese patent database, were interviewed.

One might argue that before the 1988 reforms, innovators could duplicate the protection afforded by patents of greater scope by simply taking out multiple patents.[10] This argument would be incorrect if

(1) the multi-claim system substantially reduced the cost of a given level of patent protection, or (2) if the multi-claim system substantially improved the breadth of patent protection (meaning innovations that could not be completely protected under the old system could now receive full protection). Based on our interviews, on the professional literature used by Japanese patent agents, and on quantitative data, we will argue that patent reform did indeed produce effects (1) and (2). The extent and relative strength of these two effects, of course, are difficult to measure accurately, but we believe the effect of (2) is more substantial for reasons discussed below.

Financial implications of patent reform

The most obvious implications of patent reform are the reductions in private patenting costs to the firms. Taking out multiple patents to protect a single idea under the "sashimi" system could prove quite costly. Examination fees and agent fees, which are several times higher than the actual examination fees, had to be incurred for each patent if multiple patents were filed to protect a single innovation. Multiple patenting per invention would also increase the cost of enforcing patent rights if patent infringement took place, since a lawsuit would have to be filed for each patent infringed. Many companies suggested in interviews that the multiple-claim system brought an opportunity to save patent related fees through the combination of multiple claims (and therefore multiple inventions) in one patent application, because a substantial portion of patent fees are incurred per patent, not per claim.

As an illustration of the potential cost savings, we use the patent fee schedule as of 1996. Official fees including the filing fee and the examination fees are 105,300 yen per patent and 2,700 yen per claim. Okamoto et al. (1996) estimates that the agent fees incurred in the processing of these patent documents were 604,000 yen per patent. Finally, maintenance fees for the life of the patent, assuming the patent is registered at the fourth year from the filing, include 1,301,000 yen per patent and 132,300 yen per claim. Under this fee schedule, the total costs of protection for a patent are 2,010,300 yen per patent (denoted F, for the "fixed cost" of a patent) and 135,000 yen per claim (denoted V, for the "variable cost" of a claim).

In 1993, for example, the average number of claims per patent (denoted N) is 3.77. Under the 1996 fee schedule, the total cost for the life of a typical patent is $NV+F$ = 2,519,250 yen. Assuming that under the old system each claim has to be filed as an independent patent[11], the total cost for the life of a patent to cover the same invention was $N(V+F)$ = 8,087,781 yen. The cost saving from the multi-claim system is 5,568,531 yen, or 68.9%. The number of the total patent applications in Japan in 1993 was 366,486, and so the total cost saving would be 2,041 billion yen or $17 billion (using $1 = 120 yen). This illustration suggests that the total cost savings could be quite substantial.

While the private benefits of cost reduction for a given amount of patent protection are clear, the social benefits are less so. The "quality" of the marginal protected idea might decline with a large enough decline in the cost of patent protection. In fact, if this were the *only* real effect of patent reform, we would expect to observe firms "repackaging" the same number of ideas into fewer patents, but we would not necessarily expect such a reform to induce additional innovative output.

Real expansion of intellectual property rights under patent reform

An alternative interpretation of these reforms is that they actually increased the scope of intellectual property protection. When we went to those individuals most knowledgeable about these changes — Japanese Patent Office officials and the heads of intellectual property departments at major corporations — *they claimed that this increase in effective scope did occur*. This view is also *explicitly conveyed* in manuals for private sector patent experts which describe the impact of these reforms. These manuals documented the ways in which firms could exploit the new law to increase the extent of intellectual product space which they could appropriate with a given patent document, and the manuals illustrated these general points with several detailed specific examples (Hiraoka et al., 1988; Japan Patent Association, 1988).

In practice, the total protection afforded by multiple narrow patents fell short of the protection conferred by the new broader patents. All possible modifications to the original innovation were often not regarded by patent examiners as *bona fide* independent innovations. Interviewees suggested that, in practice, the “burden of proof” in establishing the improvement over the existing technology was less stringent for a claim than for a patent. Some firm managers also said that the multi-claim system allowed firms to describe an invention in multiple dimensions, which increased the opportunities to demonstrate that the invention really represented an innovation beyond the existing state-of-the-art and thereby increased the chances that a patent would be granted.

The multi-claim system also allowed the patent applicant to define the invention in ways which made infringement easier to prove and prosecute under Japanese legal practice.[12] Before 1998, claims were narrowly interpreted in patent infringement cases, making it difficult to successfully prosecute a patent infringer, even when that firm’s product was closely related to a patented invention. Under a single-claim system, the obvious solution to this would seem to be to take out several closely related patents. However, patent applications which were *too* close to a previously granted patent (even one held by the same firm or individual) would often be denied or invalidated on the grounds of its being insufficiently distinct from previous patents. This created a “commons” of intellectual product space around existing patent grants which no patent holder could effectively appropriate and within which any firm was free to operate.[13]

This situation changed with patent reform. Firms were now allowed to use claims “defensively.” In addition to describing independent innovations, the claims could be used to “fill in” the traditional “commons,” substantially strengthening the firms’ scope of intellectual property rights. It is this sort of effect that the theoretical literature highlights in models of patent scope. To the extent that this effect was present in the wake of Japanese patent reform, examining the Japanese case will allow us to get some sense of how firms respond to such an expansion of patent scope.

4. Theoretical linkage between the 1988 reforms and R&D

In this section, we establish a link between these institutional changes in Japan and the theoretical literature on patent scope. This requires that we briefly review this literature. However, due to space constraints, we will necessarily be selective and incomplete in our review.

In Nordhaus' original work, and in the famous exchange with Scherer that followed, emphasis was placed on the optimal length of a patent as a policy variable.[14] More recent papers have used more sophisticated modeling frameworks to consider both the optimal length and breadth (or scope) of a patent, although the exact definition of patent scope varies among the papers in the literature. For instance, Klemperer (1990) defines patent scope as the area of differentiated product space covered by a patent grant, whereas Gallini (1992) defines scope in terms of the cost of imitation. The definitions used by Klemperer and Gallini fit especially well with the 1988 reforms, since the multi-claim system allows firms to include all possible applications and related inventions within a single patent grant. Thus the reform certainly increased the differentiated product space covered and the imitation costs.

Within the theoretical literature, there is a general presumption (or explicit assumption) that broader patent scope or greater patent length will induce more R&D effort. This presumption of a positive relationship between patent scope and optimal R&D effort is formally proven by Denicolo (1996) in the context of a patent race model like that of Lee and Wilde (1980). We can easily show that, even after relaxing some of Denicolo's restrictive assumptions, the first-order impact of an expansion of patent rights, both in scope and in length, on the level of R&D is positive.[15]

We should point out, however, that there were some important dimensions of patent scope along which there was less strong evidence of change. The literature has also stressed *the ex-post* legal interpretation of patents in the courts vis-à-vis subsequent innovation as a dimension of patent scope. This is a particularly important dimension of scope in the U.S., because the U.S. Patent and Trademark Office tends to grant patents more or less automatically if an "inventive step" requirement is met. Often, the actual scope of a patent grant vis-à-vis other overlapping grants is ultimately decided through litigation in the court system after the patent is granted. In contrast, through 1995, the Japanese Patent Office allowed firms to register their opposition to a patent application before that patent was granted, and it used evidence submitted by these firms in deciding whether or not a given patent should be granted. Over the period covered by our data, patent disputes which would have been settled through post-grant litigation in the U.S. were handled within the Japanese Patent Office through the pre-grant opposition process. Thus, this "legal" dimension of patent scope may have been less important in Japan. We have no direct evidence of any change in this *ex-post* interpretation of the scope of patent claims by the courts immediately after reform.[16] Anecdotal evidence suggests a gradual turning of Japanese legal practice towards a more "pro-patent holder" position. Later, we will present circumstantial evidence consistent with this shift.

5. Aggregate effects of the 1988 reforms

A number of aggregate changes occurred after the 1988 reforms. Figure 1 shows the trend of patent applications in Japan in the postwar period. This figure shows that the growth rate of patent applications declined after 1988, though the actual number of applications is still increasing. In general, this pattern holds across technological fields, with applications actually *falling* in physics, electricity, and chemistry-related inventions.

Figures 1 through 4 about here

Figure 2 shows the number of claims per patent application by section of the International Patent Classification (IPC) System. There is an obvious increase in 1988, particularly in section C (chemistry-related inventions) and section A, which includes pharmaceuticals. General managers in the intellectual property division of pharmaceutical and chemical companies noted that they were quick to adopt the new system, because they had already learned how to utilize the more limited multi-claim system introduced in 1976. This feature of the 1976 revision in the patent law had been heavily utilized in patents of chemical compounds. On the other hand, the increase in class H (electricity-based inventions, which includes semiconductors and computers) and class G (physics-based inventions, which includes copiers), was more gradual, suggesting a learning process firms patenting in these areas had to go through before they could fully utilize the multi-claim system.

While applications have leveled off or fallen since patent reform, patent *grants* have followed a very different trend. Recall that one implication of the multi-claim system is that it makes the improvement of an invention over the existing technology easier to demonstrate, increasing the likelihood that a patent will be granted. If this effect is real, then we should expect to observe a sharp increase in grants 3-5 years after patent reform (based on the historical lags between file date and grant date). In fact, patent grants exploded in certain technology fields such as physics and electricity, almost tripling between 1991 and 1992, as can be seen in Figure 3. Less extreme increases can be seen in all technology fields. While this increase is consistent with the positive effects ascribed to patent reform, it is, at best, circumstantial evidence. Many other institutional changes — notably an increase in the number of patent examiners and the introduction of an electronic filing and processing system — are likely to have contributed to these changes.

Figure 4 shows trends in intellectual property lawsuits filed in Japan from 1983 through 1995. Patent-related lawsuits are only a component, but one can observe a striking and sharp upturn in the incidence of lawsuits in the most recent years. These are the years in which we would expect to begin observing grants of patents filed under the new system. Given the expense of civil litigation in Japan, we would only expect to see an increase if the plaintiffs believed that the likelihood of victory increased. Unfortunately, we have not yet been able to obtain quantitative data on the *outcomes* of this kind of civil litigation, but the observed trends suggest patent reform strengthened the position of incumbent patent holders.

6. Effects of the 1988 reforms on R&D

Data used in the empirical analysis

Examining the impact of these reforms at the micro level requires data on patenting, R&D, and other characteristics at the firm level. We constructed an original data set of 307 publicly traded

Japanese manufacturing firms, drawn from various industries. The actual number of firms used in our empirical work varies according to specification because data on some variables are not available for all firms in all years. Data on firm sales and industry affiliation are taken from the Japan Development Bank (JDB) Corporate Finance Database. Data on firm-level R&D expenditures are drawn from the *Kaisha Shiki Ho* R&D survey by *Toyo Keizai Shimposha*. This analysis also requires data on Japanese patenting at the firm level. Regrettably, such data are difficult to obtain and, relative to our U.S. data, extremely expensive. Despite the assistance of the staff of JAPIO, which provides the only practical electronic patent database in Japan, and despite their provision of a generous discount over the rates charged to commercial users, we were only able to obtain two series of patent data for each of our sample firms. First, we have information on the total patent *applications* in each of our sample years, from 1981 to 1994. Second, for a subsample of firms, we have obtained a random sample of up to 300 patent applications taken out by each firm in each year from 1983 through 1994, which includes information on the number of claims and the number of IPC classes each patent application contained. Based on that random sample, we can estimate changes in patent quality for all patents taken out by a firm in a given year.

Ironically, our data on the U.S. patenting of our Japanese firms are much more complete than our Japanese patent data. Initially, we obtained data on U.S. patenting, including complete information on the number of patent classes assigned to each patent, from the CASSIS CD-ROM disk published by the U.S. PTO. These data were matched with the REI patent database in order to obtain information on the number of claims and ex-post citations for each of these patents.

Finally, as a proxy for investment opportunity, we calculated “average Q” for each firm-year in our data set. This calculation was undertaken along the lines of Hoshi and Kashyap (1990). Summary statistics of the data are presented in Table 1.

Table 1 about here

Empirical framework

To estimate the impact of patent reform on R&D spending, we utilize the following simple log-linear equation.[17]

$$r_{it} = \beta_0 + \beta_1 q_{it} + \beta_2 s_{it} + \sum_c \delta_c D_c + \gamma_t + \theta_i + \varepsilon_{it} \qquad (1)$$

Here r_{it} is the natural log of real R&D spending by firm *i* in year *t* and q_{it} is a measure of firm-level "average Q." Since *q* is not being used in the standard investment equation, we do not interpret the regression coefficient multiplying it as a structural parameter of interest. *Q* is used here strictly as a control variable for firm-specific, time-varying changes in the "investment opportunities" available to individual firms over time. We add 14 industry dummy variables, *D*, to control for differences in levels of R&D spending across industries (possibly due to differences in technological opportunity). Although firm-level research productivity, θ_i, is not observed, we can deal with it econometrically by using fixed-effects models. Since firms' industry affiliations do not change over time, a fixed-effects estimate of (1) would cause the industry dummy variables to drop out along with the firm effect, θ_i. We also include the log of contemporaneous sales, s_{it}, as a measure of firm size. Like "*q*," this is intended purely as a control variable.

Unfortunately, the extensive theoretical literature on patent scope provides us with few practical suggestions for how to empirically measure patent scope nor does it even suggest the *units* in which it could be measured! Given this, we measure the change in patent scope by using a full set of year dummies (γ_t), into which the discrete regime change is absorbed. Because we cannot precisely quantify the percentage by which the appropriable intellectual product space expanded around an "average" patent as a consequence of patent reform, we cannot directly calculate an *elasticity* of firms' response to patent scope expansion. However, we can, in principle, calculate the numerator of such an elasticity — the percentage by which R&D inputs or R&D output increased. If the estimated numerator is a number close to zero, and the actual expansion of patent scope is *anything other than trivial*, then this would suggest that the underlying elasticity of firms' responses to patent reform is a very small number.

In essence, our identification comes from common shifts in a time trend. There were, of course, a number of other "macro" shocks, all more or less contemporaneous with patent reform, which could have also had a positive impact on firms' R&D effort.[18] However, in our initial regressions, we do not attempt to completely eliminate the effects of these other "macro" shocks. Therefore, we interpret our results as representing an "upper bound" of the real R&D response to patent reform.

Results

If patent reform induced additional R&D effort, then the time path traced out by the year dummies should show a "spike" at or around 1988, when the patent reforms went into effect. *The data do not show this*, and that fact is probably the single most important empirical contribution of this paper. Table 2 reports regression results from (1). Alternatively, the coefficients of the year dummies in column 1 are graphed out in Figure 5.[19] The coefficients indicate that, starting in the early 1980s, there was a substantial increase in R&D spending by Japanese firms. However, this increase *predated* patent reform, and it seems to have halted the year that patent reform went into effect. The years 1988 and 1989 were actually marked by a relative *decline* in R&D spending. The pre-reform trend of increasing R&D spending resumed in 1990, but it ended rather quickly with the onset of Japan's recession in 1992. One sees in this picture *no* evidence of an increase in R&D spending which could plausibly be attributed to patent reform.

Table 2 and 3 and Figure 5 about here

Equation (1) has no dynamics, which may be problematic. Since we observe the R&D expenditure of individual firms over time, high adjustment costs would suggest a positive relationship between current and lagged R&D. However, simply adding a lagged dependent variable to a fixed effects version of (1) would almost certainly produce *biased* estimates due to the correlation between the lagged terms and the errors which is induced by the transformation which eliminates the fixed effect.

GMM techniques offer a way of getting around this bias, at least in principle. We used the GMM estimator pioneered by Arellano and Bond (1991) to estimate a first-differenced version of (1) with a lagged dependent variable, under the assumption that *predetermined* levels of R&D constitute valid instruments.[20] The p-value of the Sargan overidentification test was .244, implying that we cannot reject the null hypothesis that the instruments are "valid." Estimation details are available from the authors upon request. The actual equation estimated was

$$\Delta r_{it} = \beta_1 \Delta q_{it} + \beta_2 \Delta s_{it} + \beta_3 \Delta r_{it-1} + \gamma_t + \varepsilon_{it} \qquad (2)$$

where the Δ operator denotes the first difference of the respective variable and its one-period lagged realization. As in (1), we use a full set of year effects to sketch out year-to-year shifts in R&D.[21] Regression results are given in column 2 of Table 2. The pattern of time effects shows no substantial change in R&D spending at the time of patent reform. This is yet more evidence that patent reform had no significant positive impact on firms' R&D spending.[22]

A number of other specifications were run to check the robustness of these results. In particular, we exploited the cross-sectional variance in our data set. Firms could be expected to differ in their desire or ability to exploit the opportunities conferred by patent reform. Perhaps by focusing on those firms which are most likely to react to the regime change, we might be able to find effects not visible in the full data set. For instance, if patent reform is truly driving the observed increase, then we might expect a measure of "technological orientation," based on cumulated patents prior to patent reform, to be positively associated with the R&D response to patent reform. We construct such a measure by counting the cumulated sum of Japanese patents applied for by all firms in our sample through 1987. We set a dummy variable, *patent_intensity*, equal to one for all firms with higher than the median number of cumulated patents in this year. We then interact this dummy variable with a second dummy variable, denoted *reform,* which is set equal to 1 from 1988 on, 0 otherwise, and this *reform* variable replaces the full set of year dummies. Thus, we create an interaction term — *patent_intensity*reform* — which is included in column 1 of Table 3. Our empirical specification becomes

$$r_{it} = \beta_0 + \beta_1 reform_t + \beta_2 q_{it} + \beta_3 t + \beta_4 s_{it} + \beta_5 patent\_intensity_i * reform_t + \sum_c \delta_c D_c + \theta_i + \varepsilon_{it} \quad (3)$$

where t denotes a time trend. If the regression coefficient on the interaction term were positive and statistically significant, this would constitute empirical evidence of an increase in R&D spending coincident with patent reform that was driven by technology-intensive firms. Instead, the interaction term is *negative* in a fixed effects specification, as is the reform variable itself, suggesting that more technology-intensive firms increased their R&D spending *less* than other firms at the time of patent reform.[23]

Alternatively, one might directly test the notion that patent reform induced additional R&D spending by measuring the extent to which R&D spending is associated with usage of the multiple-claim system. This is done empirically by dropping the *patent_intensity*reform* interaction term from (3) and adding a measure of the average number of claims used per firm per patent per year, *average_claim*. Results from this specification are given in column 2 of Table 3. Again, the coefficient of interest is *negative*, suggesting that the firms which made the most use of the multi-claim system are not the ones increasing R&D spending at the time of patent reform.

Third, exploitation of our industry cross-section did not produce results favorable to the view that patent reform is driving a large component of the observed increase in R&D. We collapsed our set of industry dummy variables down to eight and interacted them with the reform dummy variables in column 3 of Table 3. Among the coefficients of these interaction terms, the electronics/precision instruments industry cluster is *negative*, as is the chemicals/petroleum cluster. Given that these clusters are among the most patent and R&D intensive in Japan, these results are not supportive of the hypothesis that patent reform called forth additional innovative effort.

Finally, column 4 of Table 3 focuses on the pharmaceutical industry. We noted earlier that the 1988 reforms also instituted partial term restoration for drug patents. This amounted to an increase in effective patent length. In order to test the effect of these reforms on R&D effort in the pharmaceutical industry, we estimate a version of (3) (without the interaction term) on data drawn from 26 Japanese pharmaceutical firms. Some caution needs to be exercised in the interpretation of our results, as they are based on such a small sample. Nevertheless, patent reform is *not* associated with a statistically significant positive increase in R&D, even in this industry where the impact of increased scope is potentially strengthened by increases in length.

The best conclusion that can be drawn from this set of results is that there was a broadly observed increase in R&D spending in the 1980s which *largely predated* the onset of patent reform in Japan. Robustness checks suggest that relatively little, if any, of the upturn can be reasonably ascribed to the change in Japan's patent regime.

7. Effects of the 1988 reforms on patenting in Japan and the U.S. at the micro level

We now turn our focus to a study of Japanese firms' innovative output, as measured by their patents. We adopt a simple "innovation production function" in which R&D produces innovation, some fraction of which is patented. The standard approach in the literature has been to assume that this fraction is constant within firms over time, so that there is a stable relationship, at least within individual firms, between patenting and innovation. In the current context, this approach is problematic. The "units" of innovative output have changed as a direct consequence of patent reform, as it is now possible to "repackage" the firms' innovative output into a smaller number of broader patents. In order to obtain a consistent measure of Japanese innovative output before and after patent reform, we will need measures of patent *quality* as well as quantity. However, as a benchmark, we first look at simple counts of Japanese patents.

The basic empirical specification is as follows:

$$p_{it} = \beta_0 + \beta_1 r_{it} + \sum_c \delta_c D_c + \gamma_t + \theta_i + \varepsilon_{it} \qquad (4)$$

where p_{it} is a measure of patent quantity, quality or quality-adjusted patent counts, depending on the specification, for firm i in year t, r_{it} is the log of real R&D spending, and the *Ds* are industry dummies which fall out in a fixed-effects specification. In some specifications, we substitute year dummies (γ_t) with a *reform* dummy variable. Again, θ_i represents the firm-effect, which we interpret as the research quality of the firm. We also include the log of real sales as an additional control variable.[24]

Tables 4 through 6 about here

Evidence from an examination of Japanese patent applications is presented in column 1 of Table 4. Our results suggest a *deceleration* in the rate of growth of patent applications made by firms after the reform, which is consistent with the aggregate data presented in Figure 1. This slowdown is further illustrated in column 2, where we drop the full set of time dummies and instead estimate the impact of patent reform as a level shift, occurring in 1988. However, this slowdown in patent applications is balanced by a fairly dramatic increase in the number of claims per patent, which is shown in column 3. If one weights application counts by the number of average claims per patent, one finds a statistically significant increase in innovative output. This is shown in column 4 of Table 4.[25] As has been noted, patent reform created three separate incentives for Japanese firms to increase the number of claims per patent: 1) to economize on the costs of patenting, 2) to increase the likelihood of a patent grant by describing the invention from multiple dimensions, and 3) to expand the appropriable intellectual product space around a patent grant through the use of overlapping claims. Our findings suggest that firms responded to these incentives.

However, the fact that claims were so directly affected by the patent regime change makes them somewhat suspect as independent measures of patent quality. If firms really used multiple overlapping claims to more fully appropriate the product space around a given idea, then this "defensive" use of claims further obscures their reliability as measures of quality.[26] An alternative measure of patent quality, pioneered by Lerner (1994), is to use counts of the number of IPC subclass codes assigned to patents. Lerner has argued that the number of unique IPC classes contained in a patent document is a reasonable proxy for the breadth of technical knowledge embodied in that patent. In regressions not reported in the paper, we used this count, averaged over a random sample of a firm's patent applications in a given year, as a weight that reflects the patent quality of that firm's *t*th year patent cohort. Classes-weighted total patent counts did *not* significantly increase after patent reform.

It is thus difficult to come to any definitive conclusion based on the Japanese data alone. Fortunately, Japanese firms are quite aggressive about patenting in the U.S. Over the years covered by our sample period, Japanese corporations have accounted for roughly 25% of all U.S. patent grants, and firm interviews confirmed that Japanese firms are careful to patent their most useful inventions in both countries. As we have already noted, there were no major reforms in the U.S. patent system at the time of Japanese patent reform, and so there was no incentive for Japanese firms to change their U.S. patenting. However, if Japanese patent reform did indeed induce greater innovation, then some of this might have "spilled over" into higher levels of U.S. patenting. We will thus examine U.S. patenting, both simple counts and measures which reflect patent quality.[27]

We start with an estimate of the changes over time in overall patent grants in the U.S., with these patent grants re-dated by year of application. We estimate equation (4) with the annual count of U.S. patent grants as the dependent variable. Coefficient estimates are reported in column 1 of Table 5. Patenting in the U.S. did increase over the sample period, but this trend started in the early 1980s and there is *no* sign of a shift or acceleration around the time of patent reform. In the early 1990s, patenting peaks and starts to fall. There is no evidence from this of a patent reform induced increase in innovative output.

Nor is there any empirical evidence of a patent reform induced increase in the measures of U.S. patenting which reflect patent quality. Evidence on this point is provided in columns 2–4 of Table 4. Column 2 presents estimates of the overall time path of changes in the average number of claims per U.S. patent, using a full set of year dummies. It shows this quality measure increased, but the increase predates patent reform. Column 3 estimates the time path of changes in the total number of claims in

U.S. patents and finds no increase attributable to patent reform. Column 4 estimates the time path of changes in the total number of classes in U.S. patents and finds no increase attributable to patent reform.[28]

One test of patent quality in the U.S. remains to be conducted. If Japanese post-reform patents are relatively more "idea-rich," then one might expect them to be *more heavily cited* by subsequent patents, controlling for the time lag between grant of the cited patent and the lag of the citing patent.[29] To measure this empirically, we use the "citations function" approach pioneered by Caballero and Jaffe (1993). This approach allows us to measure the relative "citedness" of pre-reform and post-reform cohorts of patents.[30] These citedness coefficients are reported in Table 6. There is little evidence of any change in citedness after the reform.[31] The citedness actually declines slightly after patent reform, but this decline is only marginally significant and may be driven to some extent by truncation in our patent data, which effectively end in 1995. As an alternative to the "citations function" approach, we calculated citations per patent for different Japanese patent cohorts by simply summing up all citations from patents granted within four years of the cited patents' grant date. While this does not control for the general tendency for citations to increase over time or the fact that more recent patent cohorts have larger numbers of potential "citing patents," this alternative treatment is not as susceptible to "truncation effects." However, this alternative treatment of the data showed a qualitatively similar pattern — a slight decline in "citedness" after patent reform.

We conclude from this that Japanese firms changed the structure of their patent applications to exploit the new law, but that the new law failed to induce discernible increases in R&D or innovative output. This presents something of a paradox. Why would Japanese firms be responsive enough to the regime change to alter the number of claims per patent, yet remain unmoved with regard to the overall level of R&D or innovation? While our econometric results are unable to shed light on this apparent paradox, our interview results suggest a potential explanation.

A number of interviewed managers pointed out that the generation of most of their patent documents was contracted out to patent agents. For one company, this "outsourcing" amounted to more than 90% of their total patents. Even in companies where most patents were processed "in house," there were often bureaucratic barriers to communication between the intellectual property department and the R&D department. In situations like this, where there is such a profound organizational disconnect between the those in the firm (or outside the firm) dealing directly with the patent system and those in the firm actually conducting R&D, it is perhaps not surprising that the "feedback" from changes in the patent system to the conduct of R&D was limited.[32] Theorists in this literature typically assume that the "innovating unit," be it an individual or a firm, directly confronts and internalizes the incentives in the patent system. Our interviews drove home the reality that corporate R&D departments are embedded in larger organizations, and the feedback from changes in the patent system to their activities is anything but automatic.

8. Conclusion

Does an expansion of patent scope induce additional innovative effort? How responsive are firms to changes in patent design? This paper takes a first step towards providing answers to these questions by examining the response of a large cross-section of Japanese firms to the 1988 patent reforms. We find that Japanese firms have been rather *unresponsive* to the change in patent scope. Japanese firms have adjusted the nature of their patenting by increasing the number of claims per patent, but we find *no* evidence of an increase in innovative effort or innovative output that could be plausibly attributed to patent reform.

These results challenge the notion that broader patents will induce additional innovation. However, our work is not the only recent analysis which calls the value of stronger patents into question. Jaffe (2000) documents several studies which offer indirect evidence on this point. As Jaffe notes, in the U.S. a substantial increase in R&D spending *preceded* the legal and procedural reforms that are believed to have strengthened intellectual property rights, making it unlikely that the legal change *caused* the increase in R&D spending.[33] Kortum and Lerner (1998) study the increase in U.S. patenting that began in the mid-1980s, and conclude that strengthened intellectual property rights are unlikely to have been the primary cause. Similarly, Hall and Ham's (1999) study of patenting in the semiconductor industry casts doubt on the role of strengthened intellectual property rights in inducing additional innovation in that industry. Their results raise the possibility that strengthened intellectual property rights have lead to the socially wasteful accumulation of defensive patent portfolios. Finally, Schankerman's (1998) empirical estimates of the value of patent protection and the survey data by Cohen et al. (1998) suggest that patents are relatively weak, imperfect instruments of appropriation, so that substantial increases in their strength might be insufficient to induce additional innovation. Our conclusions are in line with this previous work.

It is also appropriate to reemphasize some caveats. The 1988 patent reforms are not a perfect natural experiment. Furthermore, our failure to find an increase in firms' innovative output or input in response to patent reform does not prove that there was no effect. More empirical work on this policy experiment in Japan will be necessary before coming to any final conclusions concerning its impact. Finally, it would be premature to generalize from our findings to other nations or other patent reforms. However, if stronger patents do *not* effectively induce more innovation, as our results suggest, then some theoretical models and related "pro-patent" public policies will need to be reexamined.

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Footnotes

[1] There is some work on the value of patent protection derived from surveys of firms, such as Cohen, Nelson, and Walsh (1996). Econometric studies have attempted to quantify the private value of patent protection using patent renewal data, i.e. Schankerman (1998). However, there has been *no* empirical work, to our knowledge, which tests firms' responses to the strengthening of a pre-existing patent regime.

[2] Jeffrey Kushan, a former U.S. Patent and Trademark Office official who has participated in international patent negotiations, claims that U.S. negotiators never pretended to act in the interests of other nations, but were quite open about their objective of defending the interests of incumbent U.S. patent holders. However, other public officials seeking to justify this position have frequently appealed to the sort of argument described in the text.

[3] Two other important differences include the practice of pre-grant disclosure and pre-grant opposition. The former practice has been discussed at length in the literature — see Ordover (1991). It was not affected by patent reform. The pre-grant opposition system was changed to a post-grant opposition system in 1996.

[4] Harvard Business School (1990).

[5] In addition, the U.S. system has the doctrine of equivalents which states that a product serving the same function as another may infringe its patent. This doctrine was not explicitly adopted in Japan until 1998.

[6] Another major difference between the U.S. and Japanese patent systems is the existence of a "second tier" intellectual property rights system — the utility model system. The Japanese Utility Model Law was established in 1896, modeled after the Utility Model Law in Germany.

[7] There were other changes to the Japanese patent system *after* 1988 which we regard as relatively minor. Changes include the application of the priority-claim system under the Paris Convention to domestic filing, the establishment of the new utility model system, the introduction of the electronic filing, and patent related fee increases.

[8] The Japanese patent reforms were plausibly (weakly) exogenous to the patenting and R&D spending of the Japanese firms we analyze. This feature of the patent reforms, combined with the fact that we observe Japanese firms' patenting behavior under a patent system which changed (Japan's) and one which did not (the U.S. patent system) provides our analysis with *some* features of a natural experiment.

[9] At the same time, the U.S. and other countries requested that Japan shorten the patent examination period. Due to a severe backlog, the average examination period (from the request of the examination to the end of the examination) reached 36 months in 1985. One cause of the delay was the very large number of patent applications filed by Japanese firms. The broadening of patent scope was expected to reduce the number of patent applications. Parallel to the 1988 reforms, the Japanese Patent Office asked the top 100 patenting companies, which account for 50% of the total patenting, to reduce the number of patent applications in 1988.

[10] The ideas in this section owe much to discussions with Mark Schankerman and Nancy Gallini, and we thank them for their detailed comments.

[11] Under the very limited multi-claim system before the reforms, the average number of claims per patent in 1987 was 1.21, and so this is not an unrealistic assumption.

[12] A longer version of the paper, available from the authors upon request, describes this issue in more detail, and provides specific examples drawn from the Japanese patent law literature.

[13] This does not imply that the pre-reform "inventive step" requirement was particularly high compared to that of the U.S. or that patents which represented minor modifications over existing patents were never granted prior to 1988.

[14] Nordhaus (1972) and Scherer (1972).

[15] A complete proof is available from the authors upon request. Of course, this theoretical result does not hold in every conceivable circumstance. Green and Scotchmer (1995), Chang (1995), Cadot and Lippman (1995), and Scotchmer (1996) model "sequential innovation" in which excessively broad patent protection can retard the rate of innovation. Merges and Nelson (1990) explore some of these issues.

[16] The most notable expansion of the *ex-post* interpretation of the scope of patent claims by the court was the explicit adoption of the doctrine of equivalents by the Supreme Court of Japan in 1998, 10 years after patent reform.

[17] A longer version of the paper, available from the authors upon request, illustrates how this equation can be formally derived from a firm's dynamic R&D investment optimization problem.

[18] These include the "bubble economy," yen appreciation (which might have driven firms to upgrade their product portfolios through R&D), and a series of high-profile U.S. patent litigation cases which might have driven Japanese firms to "ramp up" their patent portfolios. All of these would have had the effect of driving R&D spending up around the time of patent reform, which is why we view the estimates obtained by (1) as a plausible upper bound of the impact of patent reform on R&D spending.

[19] In this specification (and most others used in the paper), Hausman tests clearly rejected the random effects specification in favor of the fixed effects specification. This specification is based on data from 1981–1994, as are other specifications unless otherwise noted.

[20] The instrument set included a constant term and all lagged R&D levels up to r_{it-2}.

[21] That is, we estimate a separate constant term for each difference.

[22] This particular specification was estimated using the GMM command of TSP. This procedure deletes rows with missing values, which lowered our recorded number of observations. All other specifications were estimated using STATA. Strictly speaking, the overidentification test alluded to in the text of the paper is not a test of instrumental validity but rather a test that, conditional on some subset of instruments exactly identifying the parameters of interest, the overidentifying restrictions are valid.

[23] The estimated impact of patent reform in this specification is dependent on the assumed timing of reform. For instance, setting the date of reform equal to 1987 produces a positive, significant coefficient. On the other hand, one gets similar results when dating reform at 1985 (long before firms could have

plausibly anticipated patent reform), and one gets negative results dating patent reform in 1990. Even when one dates reform as occurring in 1987 (implying that firms anticipated patent reform and raised their R&D levels in that year), one still generally obtains negative results from the interaction terms. These specifications are available from the authors upon request.

[24] Since the log of zero is undefined, we first added "1" to each firm-year observation of patent output before taking the log. This transformation is fairly standard in the patents/R&D literature. Estimation of fixed effects Poisson and Negative Binomial specifications produced results qualitatively very similar to those reported in the paper.

[25] Due to the expense of obtaining Japanese patent data at the firm level, we were not able to obtain information on either the claims or IPC classes of individual firms' entire patent portfolios. Instead, for a subset of Japanese firms in our database, we were able to obtain a random sample of 300 patent applications per firm per year. Using this sample, we *estimated* the average number of claims (or classes) per patent per firm-year, and used them as weights. These data are available from 1983 to 1994.

[26] The use of "overlapping" claims means that there is not a simple correspondance between claims and independent innovations.

[27] The rules of the U.S. patent system did not change, but if a substantial fraction of Japanese patent applications consist of "direct translations" of their Japanese patent applications, then it is possible that some of the impact of Japanese patent reform might show up in increased U.S. patent quality rather than U.S. patent quantity. We wanted to allow for this, so we examine both quantity and quality as measured along a number of dimensions.

[28] Patent experts contend that the count of IPC codes is a better measure of the quality of a patent than the count of U.S. patent classification codes, but only the latter data were available to us.

[29] This approach is not available to us with the Japanese data due to the absence of reliable citations data.

[30] A complete description of our approach is available from the authors upon request.

[31] Jaffe and Trajtenberg (1997) and others who have worked with citations functions have shown that the ex-post citations to a patent continue to arrive, albeit with decreasing frequency, years and even decades after the grant of the cited patent. Because of this, our observations of the total citations to recent patent cohorts are truncated. We can only partially control for this.

[32] Unfortunately, we lack quantitative data at the firm level on the degree of "integration" between firms' intellectual property activities and their R&D departments.

[33] As Jaffe (2000) has noted, we find the same pattern in our Japanese data — an increase in R&D spending which *precedes* the strengthening of intellectual property rights.

Table 1. Summary Statistics

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Real R&D (million yen)	3,555	17,244.9	43,980.39	10.806	445,212.3
Real sales (million yen)	3,423	342,936.4	663,506.1	1,673.111	9,025,592
Counts of Japanese patents	3,555	935.003	3,058.867	0	34,334
Counts of claims per Japanese patent[1]	1,085	2.13	1.352	1	12.740
Counts of classes per Japanese patent[1]	1,085	1.491	.200	1	2.333
Counts of US patents	3,555	55.916	197.599	0	4,302
Counts of claims per US patent	3,560	9.39	4.600	1	64
Counts of classes per US patent	3,589	2.03	.668	1	7
Tobin's Q (average Q)	3,535	2.267	1.472	0.026	13.06
Citations per patent cohort[2]	186	2,428.64	2,328.0	323	9,106

Note:
1. Counts of claims and classes per Japanese patent are calculated from a random sample of a firms patent applications in year t. The numbers in our data base are average counts of claims and classes per firm-year.
2. Citations are measured per patent cohort, not per patent or per firm.

Table 2: The Impact of Patent Reform on R&D Spending

	(1) Fixed Effects	(2) GMM Dynamic Panel Estimates
Q	.003	.002
	(.009)	(.015)
Log(sales)	.482	.147
	(.040)	(.153)
1982	-.104	N.A.
	(.044)	
1983	-.019	N.A.
	(.042)	
1984	.143	N.A.
	(.042)	
1985	.248	.089
	(.043)	(.020)
1986	.347	.111
	(.044)	(.015)
1987	**.430**	**.054**
	(.044)	**(.013)**
1988	**.403**	**.012**
	(.044)	**(.020)**
1989	**.412**	**.009**
	(.046)	**(.024)**
1990	.530	.090
	(.047)	(.018)
1991	.556	.052
	(.048)	(.018)
1992	.611	.074
	(.049)	(.012)
1993	.565	-.047
	(.049)	(.014)
1994	.497	-.037
	(.048)	(.012)
One period lagged R&D		-.015
		(.021)
Constant	2.34	N.A.
	(.460)	
Number of observations	3,404	1,496

Dependent variable: (1) Log (real R&D spending), (2) First difference of log (real R&D spending) and its one-period lagged realization. Standard errors in parentheses.

Table 3: The Impact of Patent Reform on R&D Spending: Exploiting Cross-Section Variation

	(1) With Patent Intensity, Fixed Effects	(2) With Average Claim, Fixed Effects	(3) Allowing Reform Impact to Vary by Industry, Random Effects	(4) Pharmaceutical Firms Only, Fixed Effects
Reform	**-.006** **(.032)**	**-.046** **(.043)**	**.017** **(.088)**	**-.063** **(.044)**
Patent_intensity*reform	**-.081** **(.029)**			
Average_claim		**-.034** **(.015)**		
Q	.038 (.008)	.029 (.012)	.039 (.008)	-.009 (.012)
Time trend	.055 (.004)	.059 (.008)	.038 (.004)	.034 (.007)
Log(sales)	.556 (.040)	.512 (.070)	.912 (.026)	.642 (.073)
Electronics, precision instruments *reform			**-.204** **(.090)**	
Chemicals, petroleum*reform			**-.048** **(.088)**	
Basic manufacturing*reform (food, textiles, paper)			**.124** **(.101)**	
Steel, nonferrous metals*reform			**-.086** **(.098)**	
Fabricated metal products, Machinery*reform			**-.087** **(.092)**	
Transportation equipment*reform			**.014** **(.100)**	
Miscellaneous manufacturing *reform			**.065** **(.173)**	
Industry dummies	N.A.	N.A.	Jointly significant at the 1% level	
Constant	1.32 (.454)	2.64 (.863)	-2.88 (.304)	1.39 (.778)
Number of observations	3,404	1,023	3,404	335

Dependent variable: Log(real R&D spending). Standard errors in parentheses.
The reference sector in column 3 is "ceramics, materials."

Table 4: The Impact of Patent Reform on Japanese Patent Application Quantity and Quality

	(1) Log of Total Application Counts, Fixed Effects	(2) Log of Total Application Counts, Fixed Effects	(3) Average Counts of Claims per Patent, Fixed Effects	(4) Log of Claims-Weighted Total Patents, Fixed Effects
Reform		**-.017**		
		(.027)		
Log(R&D)	.070	.097	.049	.035
	(.018)	(.018)	(.069)	(.037)
Time trend		.019		
		(.004)		
Log(Sales)	.154	.186	.201	.171
	(.042)	(.041)	(.154)	(.082)
1982	-.010		N.A.	N.A.
	(.045)			
1983	.085		N.A.	N.A.
	(.042)			
1984	.177		-.042	.054
	(.043)		(.110)	(.059)
1985	.195		-.090	.058
	(.044)		(.114)	(.061)
1986	.230		-.122	.058
	(.045)		(.117)	(.063)
1987	**.286**		**-.095**	**.115**
	(.045)		**(.118)**	**(.063)**
1988	**.260**		**.863**	**.605**
	(.045)		**(.119)**	**(.064)**
1989	**.294**		**.986**	**.706**
	(.046)		**(.125)**	**(.067)**
1990	.301		.975	.695
	(.048)		(.133)	(.071)
1991	.290		1.19	.730
	(.050)		(.145)	(.077)
1992	.294		1.28	.859
	(.051)		(.147)	(.079)
1993	.310		1.74	1.06
	(.051)		(.147)	(.078)
1994	.249		2.77	1.32
	(.050)		(.140)	(.075)
Constant	1.81	1.30	2.49	2.67
	(.468)	(.456)	(.630)	(1.02)
Number of observations	3,423	3,423	1,023	1,023

Dependent Variable: Log of counts, log of quality-adjusted counts, or quality of Japanese patent applications in Japan. Standard errors in parentheses.

Table 5: The Impact of Patent Reform on Patent Grant Quantity and Quality in the U.S.

	(1) Log of Total Counts of Patents, Fixed Effects	(2) Avg. Claims per U.S. Patent, Fixed Effects	(3) Log of Total Number of Claims of U.S. Patents, Fixed Effects	(4) Log of Total Number of Patent Classes of U.S. Patents, Fixed Effects
Log(R&D)	.124	.118	.189	.151
	(.029)	(.195)	(.055)	(.039)
Log(Sales)	.380	1.08	.625	.464
	(.066)	(.445)	(.126)	(.089)
1982	.041	.256	.031	.035
	(.071)	(.479)	(.136)	(.096)
1983	.056	.406	.031	.040
	(.067)	(.451)	(.128)	(.090)
1984	.094	.148	.054	.090
	(.068)	(.460)	(.130)	(.092)
1985	.184	.681	.214	.230
	(.070)	(.471)	(.133)	(.094)
1986	.209	.552	.255	.226
	(.071)	(.478)	(.135)	(.096)
1987	.305	1.19	.475	.351
	(.071)	(.478)	(.136)	(.096)
1988	**.419**	**.781**	**.565**	**.494**
	(.071)	**(.480)**	**(.136)**	**(.096)**
1989	**.508**	**.791**	**.649**	**.544**
	(.073)	**(.492)**	**(.139)**	**(.099)**
1990	**.551**	**.862**	**.668**	**.578**
	(.075)	**(.509)**	**(.144)**	**(.102)**
1991	.513	.907	.638	.529
	(.079)	(.534)	(.151)	(.107)
1992	.447	1.26	.585	.485
	(.080)	(.544)	(.154)	(.109)
1993	.364	1.34	.539	.451
	(.080)	(.541)	(.153)	(.108)
1994	-.203	.766	-.380	.332
	(.079)	(.533)	(.151)	(.107)
Constant	-3.60	-6.85	-5.08	-3.94
	(.738)	(5.00)	(1.41)	(1.00)
Number of observations	3,423	3,420	3,422	3,422

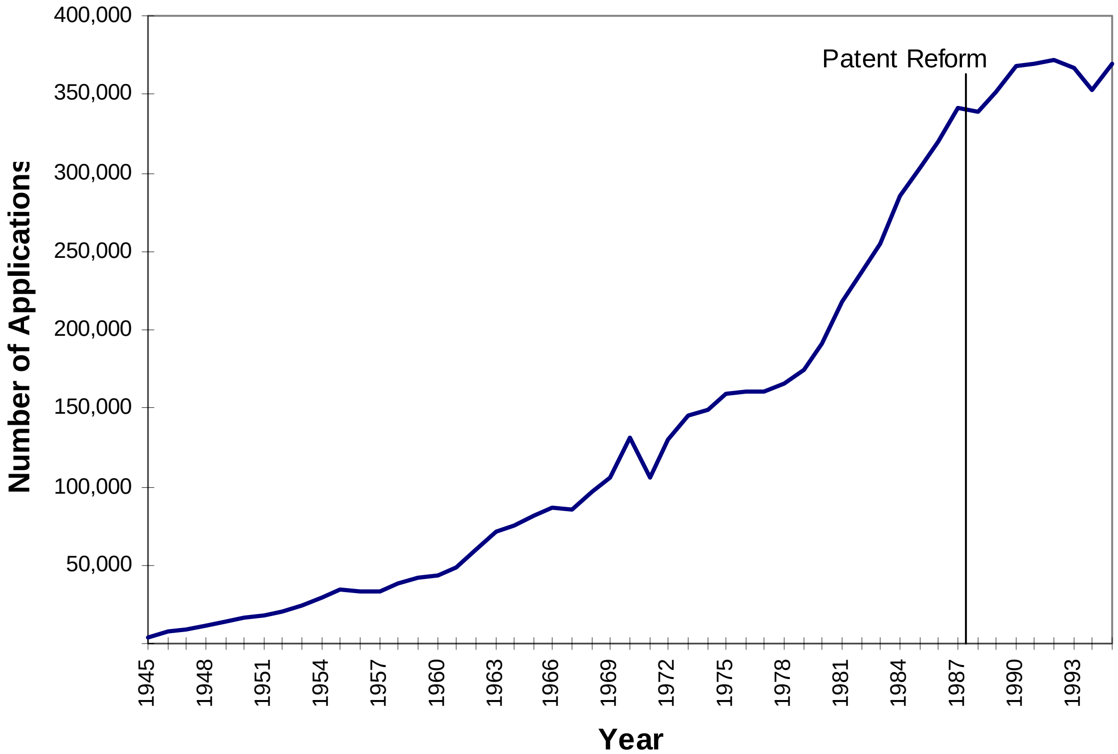
Dependent Variable: Log of counts, log of quality-adjusted counts, or quality of Japanese patent grants in the U.S. Standard errors in parentheses.

Table 6: Citations Function Estimates

Variable	Estimate	Standard Error
Diffusion parameter	.370	0.0084
Obsolescence parameter	.0000299	1.92E-6
Citations/patents 1977	1.11	.075
Citations/patents 1978	1.05	.073
Citations/patents 1979	1.05	.079
Citations/patents 1980	.95	.075
Citations/patents 1981	1.03	.080
Citations/patents 1982	1.03	.083
Citations/patents 1983	1.02	.088
Citations/patents 1984	.97	.089
Citations/patents 1985	1.01	.096
Citations/patents 1986	.99	.097
Citations/patents 1987	.98	.100
Citations/patents 1988	.96	.103
Citations/patents 1989	.87	.100
Citations/patents 1990	.86	.105
Citations/patents 1991	.81	.101
Citations/patents 1992	.78	.103
Citing period 1982–85	.86	.048
Citing period 1986–89	.80	.064
Citing period 1990–94	.76	.081

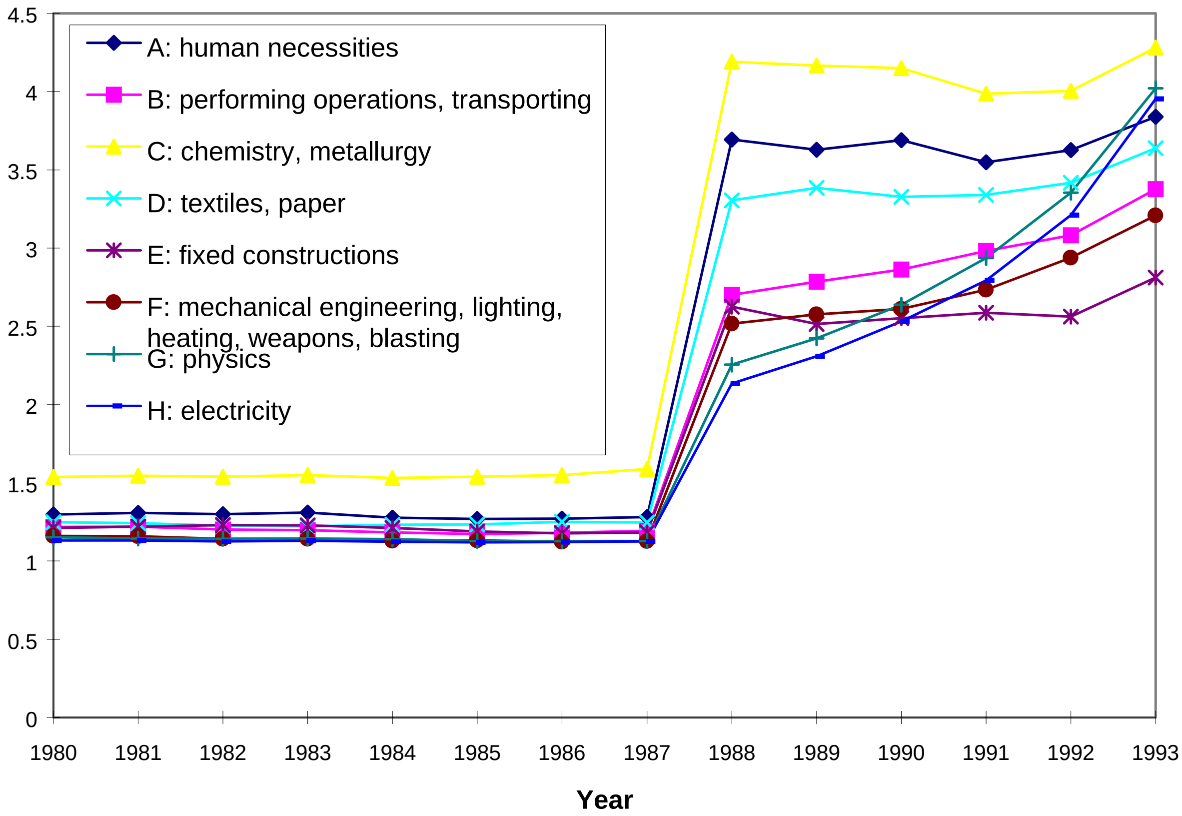
The coefficients for the years 77–92 give the “vintage effects” associated with cohorts of cited patents, as in Jaffe and Trajtenberg (1997).

Figure 1. Patent Applications in Japan



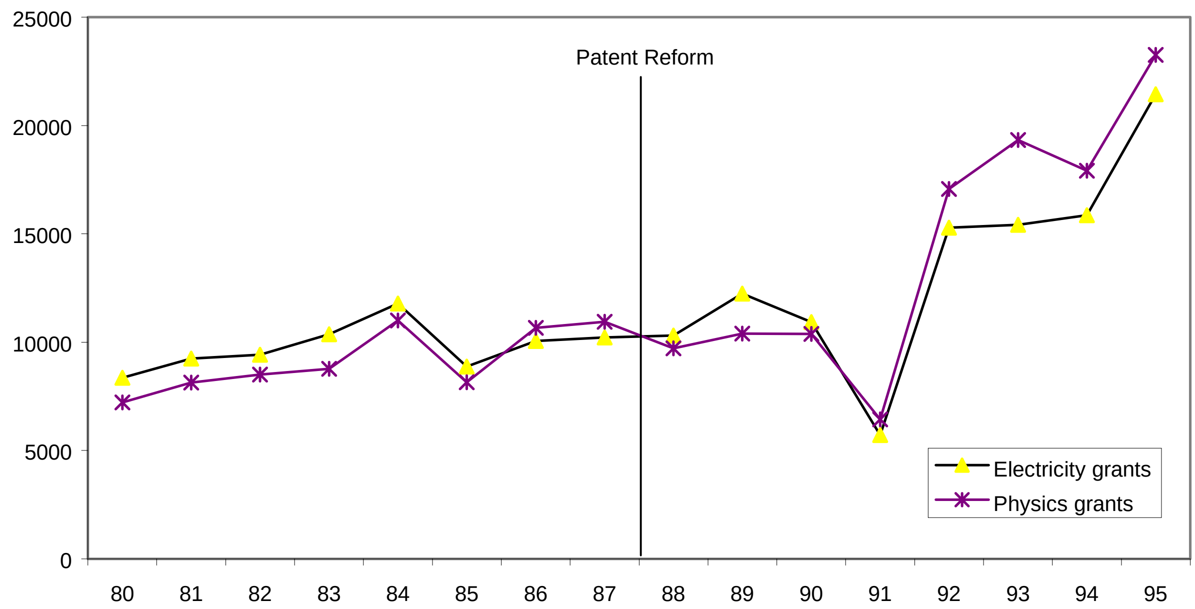
Data source: Japanese Patent Office.

Figure 2. Number of Claims per Patent Application



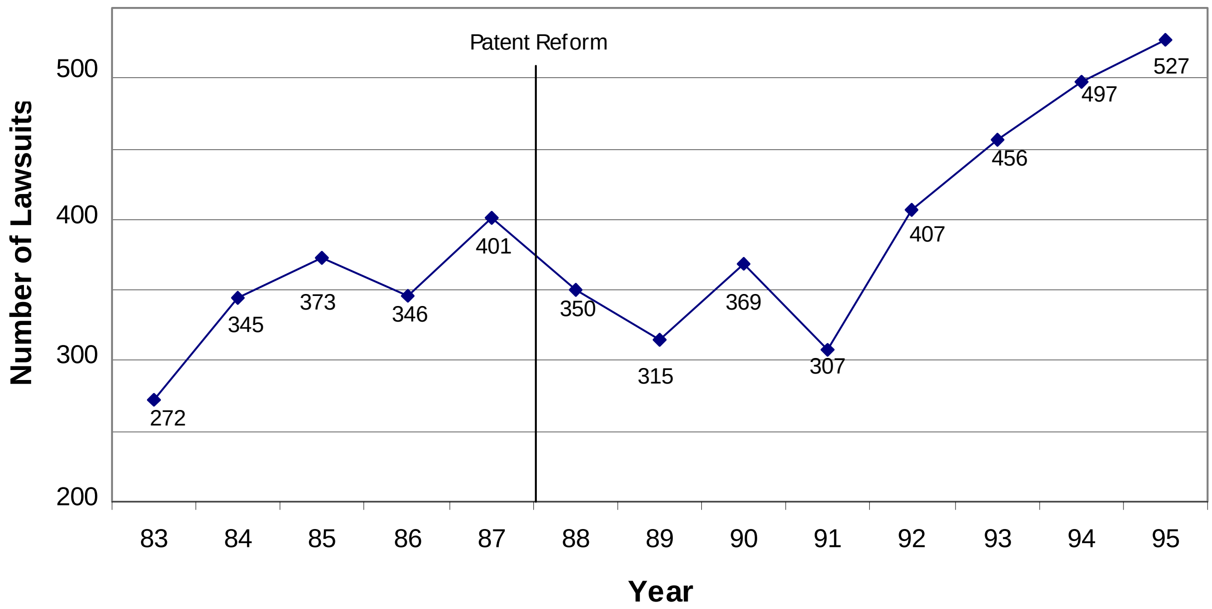
Data source: Japanese Patent Office. The number of claims per patent application to the Japanese Patent Office, by section of the International Patent Classification System.

Figure 3. Japanese Patent Grants in Physics and Electricity-related Technologies



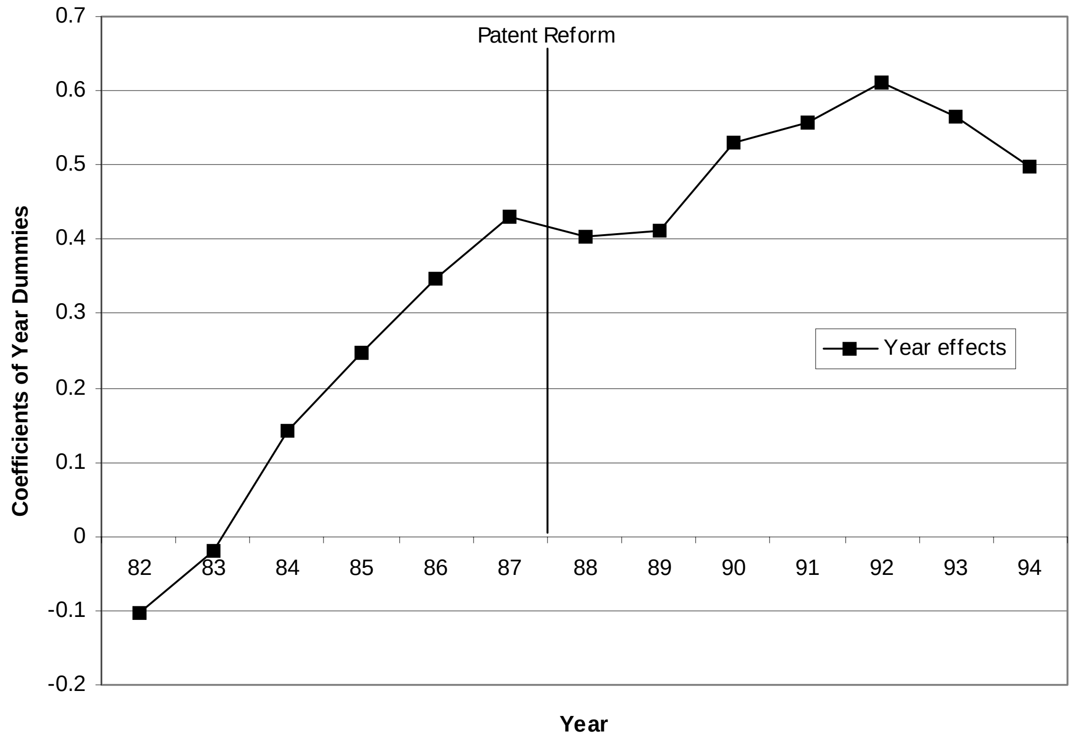
Data source: Japanese Patent Office.

Figure 4. Newly Filed Intellectual Property Lawsuits in Japan



Data source: Industrial Research Institute (1996).

Figure 5. Time Path of R&D Spending



Source: Table 2, Column 1. The reference year is 1981.