R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States

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ABSTRACT

National surveys of R&D labs across the manufacturing sectors in the U.S. and Japan show that intraindustry R&D information spillovers are greater in Japan than in the U.S. and the appropriability of rents due to innovation less. As in prior studies, patents are reported to be relatively ineffective in protecting innovations in most industries in the U.S. Patents score, however, about as well as other appropriability mechanisms (e.g., lead time and use of complementary capabilities) in Japan, where no appropriability mechanism is particularly effective as compared to the U.S. Patents are also observed to play a more central role in diffusing information across rivals in Japan, and appear to be one of the key reasons for greater intraindustry R&D spillover there, suggesting that patent policy can significantly increase information flows and, in turn, R&D spillovers. Strategic uses of patents, particularly for negotiations, are more common in Japan than in the U.S. (where they are concentrated in the complex product industries).

1. INTRODUCTION

The ability of firms to appropriate at least some of the value created by their innovations is essential if there is to be incentive to innovate. On the other hand, the economy-wide benefits from an innovation depend to a considerable degree on the extent to which the new knowledge associated with it becomes available to others. This article reports the results of a survey research study that examined the ability of firms in the U.S. and Japan to appropriate the returns to their innovations, firms' uses of the various means of appropriation (e.g., secrecy, patents, lead time advantages) and the magnitude and channels of intraindustry R&D spillover in the two countries. As the key policy instrument conditioning appropriability, we focus particularly on the role of patents.

A comparison of appropriability conditions and spillovers between Japan and the U.S. promises to deepen our understanding of the nature and determinants of appropriability conditions--that is the means employed by firms to protect their profits due to invention, and the success of those means. Prior research (e.g., Scherer, et al. [1959], Taylor and Silberston [1973], Mansfield [1986], Levin, et al. [1987]) has shown that in many R&D performing industries, firms employ a number of mechanisms in addition to patents to profit from their innovations, including secrecy, first mover advantages and the exploitation of complementary capabilities. These studies showed that, compared to these other mechanisms, patents were of minor importance in the preponderance of industries, although in some, such as drugs, they were quite important. A comparison between Japan and the U.S. should add to these insights by showing whether appropriability conditions depend on cross-national differences in culture, policy and institutional environments, or are rather a function of factors, such as technology, that would tend to vary little across the boundaries of industrialized nations

Regarding the power of policy to affect appropriability conditions and spillovers, the role and effectiveness of patents is of central concern. We will explore whether the important differences in patent law and judicial and administrative practice between the U.S. and Japan affect appropriability. Notwithstanding such policy differences, our initial suspicion was that patents would prove to be as ineffective in impeding the introduction of competing products and processes in Japan as in the U.S. (Scherer et al. [1959], Mansfield [1986], Levin, Klevorick, Nelson and Winter [1987], Cohen, Nelson and Walsh [2000]) and Britain (Taylor and Silberston [1973]). Aside from any impact that they may have on appropriability, we also want to see if the different patent policies in the two nations may impact differences in the diffusion of technical knowledge, as suggested by Ordover [1991].

In brief, while R&D spending as a percent of GDP is higher in Japan than the U.S., intraindustry R&D information spillovers appear to be greater in Japan for almost all industries, and the appropriability of rents due to innovation appears to be less. U.S. respondents report secrecy as a major appropriability mechanism, while in Japan, secrecy is reported not to be very effective. One of the key reasons for greater intraindustry R&D spillover in Japan appears to be that patents diffuse information across rivals much more readily than in the U.S., and this cross-national difference emerges not only due to the policy differences highlighted by Ordover, but due to ways patents are used in the two nations. Specifically, while our findings on the uses of patents reveal that strategic patenting—particularly for negotiations with other firms—is common in the industries such as semiconductors and computers in the U.S., such strategic uses of patents are common across the entire manufacturing sector in Japan.

In Section 2, we review our sampling and survey methods. Section 3 compares the R&D information flows and spillovers across rivals within industries. Section 4 compares the appropriability of rents due to innovation. Section 5 considers how the different patent systems of the U.S. and Japan influence intraindustry R&D spillovers. Section 6 concludes the paper.

2. METHOD, DATA AND SAMPLES

The data come from a survey of managers of R&D units of manufacturing firms in the U.S. and Japan. We asked respondents to answer questions in terms of the *focus industry* that represented the bulk of their R&D effort. By obtaining answers for a firm's activities and experience in a given product market (which we call a business unit) rather than the firm as a whole, we reduce the measurement error associated with differences in conditions across the several industries in which a firm might be active. Where possible, our surveys employed objective scales, which tend to be both more interpretable and more readily compared across respondents--a feature which is particularly useful for comparisons across nations where language and culture differ. First drafted in English, the questionnaire was translated into Japanese and then independently back-translated into English to assure consistency. While most questions were identical between the two surveys, a small number of questions differed. The surveys were mailed during the summer of 1994. Both the American and Japanese teams conducted follow-up mailings and phone calls to maximize response rates (cf. Dillman [1978]).

The population sampled in the U.S. included all R&D units belonging to manufacturing firms located in the U.S. The U.S. sample was drawn from a frame consisting of eligible labs in the Directory of American Research and Technology [Bowker, 1994] or, if not included there, labs attached to firms listed in Standard and

Poor's COMPUSTAT tapes. We surveyed 3240 labs located in the U.S. and received 1478 responses, for a raw response rate of 46% and an adjusted response rate of 54% of the eligible sample.[1] The U.S. survey data are supplemented with published data on firm sales and employees from COMPUSTAT, Dun & Bradstreet and similar sources.

The population sampled in Japan included firms with capitalization over 1 billion yen located in Japan and conducting R&D in manufacturing industries. The sample was drawn from the mailing list that Japan's Science and Technology Agency has collected from various directories and newspaper articles. In this list there were 1219 firms meeting the population definition. According to the report on the Survey of Research and Development by the Statistics Bureau of the Management and Coordination Agency, 1722 firms in total fall into this category. Our Japanese sample list includes 71% of the firms in the population. Of these 1219 firms, we received responses from 643, for a response rate of 52%.

In order to make the two national samples as comparable as possible, we truncated our samples to include only respondents belonging to firms with annual sales of $50 million or above.[2] We also excluded responses from foreign-owned labs in order not to confuse our cross-national comparisons. In this truncated sample there are 826 observations from the US and 593 from Japan. Because the two national samples sometimes contain very different numbers of observations for any given industry,[3] we constructed weights that correct for the differences in industry mix in each country which

[1] A nonrespondent survey found that 28% of the nonrespondents in the U.S. were not in fact in the target population (for example, they did no manufacturing or belonged to non-manufacturing business units). After correcting the sample size accordingly for ineligible cases, the U.S. response rate was adjusted upward to 54%.

[2] We reran the analyses for the firms in the U.S. sample with sales revenue of less than $50 million. The results are not qualitatively different from the results for the larger U.S. firms reported in this paper.

[3] For example, the number of observations differ by a factor of two or more between the two nations for the food, plastic resins, metals, steel, special purpose machinery and computer industries.

are then used in constructing overall sample means. When reporting aggregate results for each national sample as a whole, we report the weighted averages to rule out the possibility that country differences are due to variations in industry mix. When we make comparisons between these country averages, we use either weighted least squares or weighted logistic regressions as appropriate (Allison, 1999). When we do comparisons across survey item averages within a country (for example, comparing whether secrecy or patents score higher), we use paired t-tests or non-parametric tests (Agresti and Agresti, 1979, DiMaggio and Louch, 1998).

Presenting summary statistics on firm and business unit sizes for the two samples, Table 1 shows that the U.S. sample contains substantially larger firms, though the business units are more comparable in size, particularly as reflected in the medians. This difference is due in part to the fact that the largest American firms consist of many divisions, while the comparable Japanese businesses consist of groups of independent firms.

Consistent with public sources, our data indicate that Japanese firms spend more on R&D relative to sales than comparable U.S. firms. For our sample, the comparison means for own-financed R&D expenditures divided by sales are 2.26% for the U.S. and 3.70% for Japan ($t=6.89$, $p<.0001$).[4] Our survey data suggest that the overall Japanese sample R&D intensity exceeds that of the U.S. largely because the Japanese R&D intensities in the least R&D intensive (i.e. below 2% in the U.S.) industries tend to be considerably higher than the American R&D intensities. In contrast, in the most R&D intensive industries such as drugs or semiconductors, the average U.S. R&D intensities tend to be comparable to those of the Japanese. Public data show that over the last 20 years, Japan has consistently spent more on non-defense R&D as a percent of GDP than has the U.S. (see Chart 1.) Over the last five years, the Japanese average has been between 2.6% and 3.0%. During this same period, the U.S. average has been between

[4] Our sample data excludes outliers, defined as business units with R&D intensities greater than 100% or more than 3 interquartile ranges from the median.

1.9% and 2.2%. If we include defense spending, the gap narrows, but Japan still spends relatively more. In 1994, Japan spent 2.63% in terms of total R&D, while the U.S. spent 2.49%. In 1998, Japan spent 3.06% while the U.S. spent 2.59%.

3. INTRAINDUSTRY R&D INFORMATION FLOWS AND SPILLOVERS

In this section, we compare the extent of R&D-related information flows across rivals--the key source of within-industry R&D spillovers--in the U.S. and Japanese manufacturing sectors. We begin our analysis by examining responses to a key question in the survey that considers the importance of information originating from a broad range of information sources, of which rival firms are one. We asked respondents to indicate whether, over the prior three years, information from competitors either suggested new R&D projects or contributed to the completion of existing projects.

As shown in Figure 1, the results for information originating from competitors show clear differences between the U.S. and Japan. In Japan, information from rivals suggests new R&D projects for 48% of the respondents, exceeding the corresponding 41% figure for the U.S. (X^2[1 d.f.]=6.9, $p<.01$). This difference, although a relative one of almost 20% and statistically significant, is dwarfed by the difference in the frequencies with which respondents in Japan and the U.S. claim that information from competitors contributes to the execution of existing R&D projects. In Japan, 51% of the respondents claim that information from rivals contributes to project execution, versus only 13% in the U.S. (X^2[1 d.f.]=213.9, $p<.0001$).[5] These results suggest not only that intraindustry flows are more extensive in Japan than in the United States, but that they play a different role in the two nations. In the U.S., these flows predominantly guide R&D project

[5] The industry-level results show little deviation from the aggregate patterns. For 25 of the 26 industries for which we have more than five observations for both samples, the percent of respondents indicating that information from rivals contributes to R&D project completion is greater in Japan than in the U.S. For 20 of 26 industries, the same comparison holds for the percent of respondents indicating that information from rivals suggests new projects.

selection, whereas spillovers affect project selection and project completion comparably in Japan.

Further reflecting the extent of intraindustry R&D knowledge flows, we asked respondents to indicate when they first became aware of the R&D project leading to a rival's major innovation. The questionnaire permitted respondents to choose from one of the following four stages in the innovation process: project initiation, research stage, the development stage, or product or process introduction. In the United States, only 15.6% of the respondents indicated they knew about the rival’s project prior to the development stage, compared to 43.9% of the Japanese respondents (X^2[1 d.f.]=125.2, p<.0001), confirming that Japanese R&D units are better informed of the R&D activities of their rivals than their American counterparts.

While our survey data thus suggest that R&D-related information flows are greater among rivals is greater in Japan than in the U.S., a question is whether this difference corresponds to a similar difference in intraindustry (nonpecuniary) R&D spillovers as well, which Griliches [1992] and others identify as a major source of productivity growth. The key is whether the observed information flows are largely the outcome of market-mediated transactions or not. Our analysis of the different channels through which firms might learn about the R&D activities of rivals (discussed in detail below) indeed show that of the five channels that are commonly most important in both countries, four—namely publications, public meetings or conferences, informal information exchange and competitors’ products (via, for example, reverse engineering)—are not market-mediated, and the fifth, namely patents, is only partially so. Thus, we can plausibly claim that not only are intraindustry R&D information flows greater in Japan, but intraindustry spillovers as well.

4. APPROPRIABILITY

While there are factors other than intraindustry R&D spillovers alone that might condition the appropriability of profits due to innovation, spillovers are likely a key determinant. Thus, if the extent of intraindustry spillovers are indeed greater in Japan than in the U.S., we should expect, ceterus paribus, that Japanese firms appropriate less of the returns to their R&D activities than American firms. Our survey provides two proxy measures for the appropriation of profits due to innovation.

Building on the work of Levin, et al. [1987], our first measure is premised on the notion that the longer it typically takes rivals within an industry to imitate a firm's innovation or to introduce a competing innovation, the greater will be the innovating firms' profits from their innovations. We asked each respondent how long it took for a competing product or process innovation to appear after they had introduced a significant innovation. This question was posed separately for patented and unpatented product and process innovations.[6] Consistent with our finding of greater intraindustry spillovers in Japan, we find that the "imitation lags" for all four types of innovation to be much more compressed in Japan than in the U.S. Figure 3 presents the results for the two national samples, comparing the mean imitation lags (computed on the basis of lag category midpoints) for the U.S. and Japan. The lags are substantially longer in the U.S., ranging from 40% longer for unpatented product innovations to about 80% longer for patented process innovations (all country differences significant, $p<.0001$). These qualitative patterns from the aggregate sample apply to all the industries except computers, where the imitation lags associated with patented processes and unpatented products and processes are longer in Japan than in the U.S.

[6]The response categories for this question were less than six months, six months to one and a half years, one and a half to three years, three to five years and more than five years. To compute aggregate and industry averages, midpoints were employed, except for the last, open-ended category to which we assigned a value of eight years.

To construct a second measure of appropriability, we asked each respondent to estimate the percent of their product and process innovations for which patents, secrecy[7], lead time, complementary sales and service, and complementary manufacturing facilities and know-how were effective in protecting the "competitive advantage" from those innovations. Figure 4 shows the average percent of product and process innovations (based on category midpoints) for which each mechanism is judged to be effective in Japan and the U.S.[8] With the sole exception of patents, which appear to be comparably effective in Japan and the U.S. in absolute terms, U.S. respondents consider all mechanisms to be more effective than do the Japanese respondents, scoring every mechanism, on average, at least twenty percent higher (all country differences, except patents, significant, p<.01). Thus, consistent with the finding of more compressed imitation lags and greater intraindustry spillovers in Japan, the comparison of absolute scores suggest that the effectiveness of all appropriability mechanisms except patents is greater in the U.S.

A comparison of the rankings of the different mechanisms between the two nations show sharp differences with respect to secrecy and patents. The results are displayed in Figure 4. For protecting product innovations in the U.S., secrecy is pervasively ranked as

[7] Note that "secrecy" is not limited to formal trade secrecy protection, and that secrecy and patents are not exclusive. The following quote from a U.S. pharmaceutical manufacturer illustrates the importance and uses of secrecy:

> Secrecy is very important. It is important until you file for the patent, at which point it starts getting disclosed. But, until that point, it is phenomenally important. We have lots of training programs with employees to enforce the importance of secrecy. The thing is, we are so regulated on the basic product, we have to tell about it. To get approval, we have to tell the FDA how to make it. Once it gets into clinical research, we shout it from the rooftops. We want the doctors to know about it so they will start using it. On the other hand, the preferred way of making it, techniques, the solvents, reaction conditions, these we will keep as trade secrets. If we know of minor improvements that make a major difference in the product, techniques for doing research, these we keep secret.

Thus, firms may try to maintain secrecy about a project or a result until the patent is granted in the U.S. (or published in Japan, see below). Or, firms may patent some aspects of the innovation while trying to keep other parts secret. Concerns over secrecy are manifest in such practices as non-disclosure agreements, and in practices designed to prevent leaking of information.

[8] The response categories were 0-10%, 11-40%, 41-60%, 61-90%, 91-100%.

one of the most effective mechanisms across industries, and in the aggregate sample, it is reported to be the most effective mechanism along with lead time. In contrast, of all the major appropriability mechanisms, secrecy is judged to be the least effective mechanism for protecting product innovations in Japan. For process innovations, this difference is even clearer, with U.S. firms reporting secrecy as far and away the most important mechanism, over even lead time and complementary manufacturing capabilities (both significant, $p<.0001$). For Japan, in contrast, secrecy protects process innovations only about as well as lead time ($t=1.06$, $p>.25$) and a little better than patents ($t=3.15$, $p<.01$), with complementary manufacturing as the dominant mechanism (significantly above secrecy, $t=6.35$, $p<.0001$). In absolute terms, the U.S. aggregate scores for product and process secrecy are approximately double those for Japan ($p<.0001$).

Another difference between the two nations' responses bears on the evaluation of the relative effectiveness of patents. Similar to the earlier finding of Levin, et al. [1987] and consistent with the earlier findings of Scherer, et al. [1959], Mansfield [1986], among others for the U.S., and Taylor and Silberston [1973] for the U.K., American respondents report patents to be the least effective of the major mechanisms in protecting product innovations (significantly below sales/service, $t=4.35$, $p<.0001$). In sharp contrast, Japanese respondents report patents to be about as effective as the other major appropriability mechanisms for product innovations, ranking a little below lead time ($t=1.27$, $p>.20$) and a little above complementary manufacturing capabilities ($t=3.75$, $p<.001$). The almost identical absolute scores on patent effectiveness between the two nations suggest caution, however, before concluding that patents are strong in Japan. Rather, we may be observing not that patents are more effective in Japan than in the U.S., only that the other mechanisms are weaker.

Thus, appropriability overall appears to be less in Japan than in the U.S., consistent with our finding of greater spillovers in Japan. Of particular note is the relatively low ranking of secrecy as an effective mechanism in Japan, and the relatively high score for secrecy in the U.S., further supporting the point that spillovers are greater in Japan.

5. PATENTS AND INTRAINDUSTRY R&D SPILLOVERS

Reflecting a broad consensus, Ordover [1991: 48] argued that “The Japanese patent system is a complex web of policy choices more or less consciously structured to affect R&D diffusion while maintaining overall incentives for R&D investment. The Japanese patent system subordinates the short term interests of the innovator in the creation of exclusionary rights to the broader policy goals of diffusion of technology.”[9] From the analysis of the prior sections, we can see that intraindustry R&D information spillovers are greater and (ceteris paribus) appropriability less in Japan than in the United States. In this section, we will consider whether the two nations’ distinct patent systems could importantly affect the cross-national difference we observe in intraindustry R&D spillovers. What is at stake is, first, whether patent policy can importantly shape R&D spillovers--a key determinant of productivity growth (Griliches [1992])--and, second, whether the U.S. and other governments (other than Japan) should pay closer attention to the disclosure function of patents than they have historically.

5.1 Contrasting Features of the Japanese and U.S. Patent Systems

Ordover’s [1991] comparison of Japanese and U.S. patent policy describes several of the critical differences in the two patent systems. The Japanese patent system was originally set up in the 19th century not only to encourage domestic inventors, but also to facilitate technology transfer from the West, and, to this end, emphasized heavily the

[9] The U.S. GAO (in a report criticizing the Japanese patent system) summarizes the difference as follows: "The United States...seeks to foster technology development by protecting individual patentees and granting them exclusive rights to their inventions. ... By contrast, … the Japanese patent system seeks to promote technology development by disseminating technology, rather than rewarding inventors with exclusive rights" (U.S. GAO [1993:18-19]).

disclosure function of patents.[10] Several contrasting features of the two patent systems reflect the Japanese system's greater emphasis on the diffusion of innovation. First, the Japanese Patent Office discloses all patent applications 18 months after the applications are filed.[11] Since only a small fraction (Westney [1994, p. 162] estimates 17%) of the patent applications in Japan are approved, the preponderance of patent applications in Japan are disclosed with no ultimate benefit of intellectual property protection.[12] In the U.S., in contrast, until this past year, patent applications were only disclosed upon issuance, and since roughly 60% of applications are approved (Westney [1994, p. 162]),[13] the remaining 40% of the applications are never published.[14] Moreover, since the average pendency period in the U.S. is 20 months (U.S. GAO, 1997), a substantial fraction of the published applications are published later than 18 months.

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[10] The continued significance of this perspective is reflected in recent (1998) changes to a "pro-patent policy", which are designed to "reform the Japanese patent system from the conventional catch-up style system to the world's front running system that realizes 'speedy, strong and broad' protection of rights." (JPO Annual Report, 1999, p. 2).

[11] Reflecting the sentiment expressed by interviewed Japanese patent officials that even 18 months is too long to effectively achieve the disclosure function in face paced technologies, the JPTO recently implemented a system of early (pre-18 month) disclosure, allowing firms to volunteer to have their application published as soon as it passes the formality check (usually 5 months after submission), or any time after that up to 18 months later. Current (February, 2001) estimates are that 20-30 applications per month are published early.

[12] There is legal protection in Japan after the patent is disclosed such that an applicant has the right to demand compensation if someone uses the disclosed patent before the patent grant. Also, in Japan, patent applications may be withdrawn or abandonned prior to public disclosure. In either case, an application will not be disclosed. If the application is withdrawn, it is as though the application was never made, and no claim of any sort is conferred on the applicant. If, in contrast, the application is abandoned before disclosure, then the patent application will be kept secret and still confers priority, precluding others from patenting the same invention. Apparently, however, only a small fraction of applications are withdrawn or abandoned.

[13] More recent estimates put the approval rate at a higher level, closer to 80%.

[14] As a result of the American Inventors Protection Act of 1999, the U.S. will publish applications 18 months after filing (for applications filed after November 28, 2000) making the systems more comparable starting in 2002. Strictly domestic patents can still be exempted from 18 month disclosure.

Second, Ordover [1991] argues that patents may be applied for earlier in the innovation process in Japan due to a first-to-file rule of priority as opposed to the first-to-invent rule of priority that applies to the U.S. Third, a procedural difference may importantly affect the disclosure function of patents. Specifically, at the time our survey was administered in 1994, Japanese patents were subject to a "pre-grant opposition period." For three months after a request for examination was submitted and before the examination itself, competitors or anyone else could challenge the validity of the prospective patent. Moreover, Japanese examiners relied heavily on the evidence provided during this period of pre-grant opposition in their subsequent determination.[15] No analogous opposition process applies to the U.S. Rather, the validity of a U.S. patent is more typically challenged in the courts after a patent is issued (with a presumption of validity). Thus, not only does the Japanese patent regime place more information in the public domain sooner and induce the filing of a patent application sooner in the innovation process, but the opportunity for pre-grant opposition provides a stronger incentive to monitor competitors' patent filings early on.

In our survey we examined firms' reasons not to patent, and our findings suggest that patents more effectively serve the information disclosure function in Japan than in the U.S. In the survey, we asked respondents to report the most important reason for not applying for a patent on the most recent invention which they decided not to patent. The reasons include: difficulty in demonstrating the novelty of the invention, the ease of legally inventing around it, the information disclosed in a patent application, and the costs of applying for or defending a patent. Consistent with Ordover's and others' conjecture that Japanese patents are more conducive to information diffusion, Japanese firms are substantially more likely than American firms to identify concerns over disclosure as the most important reason not to apply for a patent (46% v. 26% in the U.S., X^2[1 d.f.]=54.0, $p<.0001$). In fact, in Japan, concern over disclosure scores higher than demonstration of

[15] However, in 1996 (after this survey was administered), pre-grant opposition was ended in Japan and replaced with a system of post-grant opposition. Third parties now have six months from publication to decide to oppose the grant.

novelty (41%, difference n.s.), while in the U.S., disclosure is significantly below novelty (33%, t=2.51, p<.05).

In addition to different priority systems, disclosure rules and the presence of a pre-grant opposition system, the analysis of Cohen, Nelson and Walsh [2000] suggests yet another dimension of policy and patenting practice that may make patents in Japan more effective vehicles of information disclosure than in the U.S. Specifically, they argue that the number of patentable elements in a commercializable new product will importantly affect the way patents are used, with important implications for information sharing across rivals. They distinguish between "complex" versus "discrete" product industries[16] on the basis whether a new, commercializable product or process is comprised of numerous separately patentable elements versus relatively few. In the U.S., for example, new drugs or chemicals typically are comprised of a relatively discrete number of patentable elements. In contrast, electronic products in the U.S. tend to be comprised of a larger number--often hundreds--of patentable elements and, hence, may be characterized as complex. In complex product industries, firms rarely have proprietary control over all the essential complementary components of the technologies they are developing. Firms hold rights over technologies that others need, and vice-versa, creating a condition of mutual dependence that fosters extensive cross-licensing, related negotiations and extensive sharing of information. The question for our purpose is the extent to which this mutual dependence is due to different physical characteristics of products and associated technologies, or whether patent policy itself may play a role.

While Cohen, et al. [2000] distinguished between complex and discrete product industries largely on the basis of technology and the physical character of the products, we wish to entertain the possibility that policy and related patenting norms can also play a critical role. For example, the recent ruling in the U.S. that gene fragments are separately patentable suggests that the commercialization of a single biotechnology drug product may now require rights over numerous patents (Heller and Eisenberg [1998]). In Japan, it is conceivable that almost all products are “complex” per our definition because, in Japan, patents are typically defined more narrowly, encompass fewer claims, and the claims themselves tend to be interpreted more narrowly creating widespread technological interdependence (Ordover [1991], Granstrand [2000]).[17] For example, in Japan in 1994, the average number of claims per patent was less than five, whereas in the U.S. it was easily double that (Japan Patent Office [1998]). Regarding the scope of claims, one former Japanese patent examiner told us he felt it was his job to narrow the claims to those spanned by the enablements, rather than broadly interpret the claims, as is U.S. practice.[18] Our survey findings are consistent with the notion that there are more patents per commercializable innovation in Japan than in the U.S. Specifically, we compute the average number of patent applications per million dollars of R&D expenditure to be 0.6 in the U.S. versus 2.8 in Japan ($p<.0001$). While some of this difference may reflect a difference in R&D productivity, it likely that much of the difference is due to the different practices regarding the number of patents per innovation.

The question, therefore, is whether policies that increase the number of patents per commercializable innovation might stimulate uses of patents such as cross-licensing that lead to greater information sharing, or is such an effect largely due to differences in product technology and characteristics as identified by Cohen et al. [2000] for the U.S. manufacturing sector. Our data for the U.S. and Japan allow us to test the extent to which country differences in patent systems versus purely technological differences that distinguish industries drive such uses of patents.

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[16] Kusonoki, Nonaka and Nagata [1998] make a similar distinction, using the terms “materials” and “systems” industries..

[17] This distinction, however, may be becoming less clear since Japan adopted a doctrine of equivalents.

[18] This was particularly the case in pharmaceuticals (and perhaps chemicals more generally), where Japanese firms had lobbied for stricter interpretations of claims in order to create space for domestic patenting around European and American pharmaceutical company patents.Recently, however, there are have been attempts to broaden claims in Japan by requiring examiners to justify in writing their narrowing of claims. In addition, a 1998 Supreme Court ruling introduced the doctrine of equivalents, further broadening patent scope.

To compare the relative effects of national policy versus industry differences in affecting how patents are used, we divide our sample into discrete and complex product industries. Lacking direct measures of the number of patents per product or process, we follow Kusanoki et al. [1998] (and our interviews) and operationalize the distinction between complex and discrete product technologies by assigning industries with ISIC codes less than 2900 (e.g., food, textiles, chemicals, drugs, metals and metal products) to the "discrete" product technology category and those with ISIC codes of 2900 or above (e.g., machinery, computers, electrical equipment, electronic components, instruments, and transportation equipment) to the "complex" category, and exclude ISIC 3600 (other manufacturing). We conduct a series of comparisons of uses of patents between the two industry types, across the two countries. While uses of patents within each of the two groups of industries are surely heterogeneous, such heterogeneity provides for a conservative test of group differences by biasing the results toward zero.[19] Our expectation is that the uses of patents that reflect mutual dependence will be more common in complex than in discrete industries. Also, we expect such uses to be more common in Japan than in the U.S. Finally, and this is the critical test of the effect of

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[19] To compare the uses of patents between the two industry types and across the two countries, we use a weighted logistic regression (using SAS PROC GLM) where the weights are each respondent's country-standardized number of patent applications, the dependent variable is a specific reason for patenting, and the independent variables are two binary variables (COMPLEX and JAPAN) and their interaction. We then report the means for each cell of the two by two table, and the analysis of variance estimates for the effects of each variable and the interaction term. This method, analogous to a t-test for differences in group means (Allison [1999]), permits us both to account for the dichotomous (yes/no) character of the reasons to patent and, at the same time, weight those reasons by the number of country-standardized patent applications to better reflect how the "average" patent is used .

Since some firms account for many more of the patent applications in an industry than do others, using unweighted responses would give the small firms' patents relatively greater influence on the totals. In addition, because of the substantially different average number of patent applications in Japan versus the U.S., the Japanese scores overwhelm the U.S. scores in the cross-industry comparison. To reduce this gap, we have created a country-standardized patent application measure. We begin with the unadjusted mean and standard deviation for each country (U.S. mean=29, sd=84; Japan mean=438, sd=1220). We then transform the scores by country (using SAS PROC STANDARD) for each respondent to create a country standardized variable with a mean=100 and sd=250. This country-standardized variable then becomes the weight in the regression analysis.

difference in patent policy, the gap between discrete and complex product industries should be smaller in Japan than in the U.S.

To consider these issues, we turn to our data on the reasons to patent in the U.S. and Japan. We asked respondents to report the reasons motivating their decision to file their most recent patent application, and to indicate which of these was the most important. The reasons considered include: to measure the performance of their firm's researchers, to obtain licensing revenue, to improve their position in subsequent negotiations (e.g., cross-licensing negotiations), to prevent patent infringement suits, to prevent copying, to prevent other firms from patenting a related invention ("patent blocking"), and to enhance the reputation of the firm.

Aside from the cross-industry differences, we find some sharp cross-national differences. Generally, we find what might be called strategic uses of patents (e.g., to block others' patents, for use in negotiations, to prevent infringement suits) to be common in both nations but more prevalent in Japan. For example, we find that, for the U.S., preventing rivals from patenting related inventions--what we call "patent-blocking"--was almost as pervasive as the prevention of copying as a motive for patenting.[20] For product innovations, 81% of U.S. respondents report blocking as a motive for patenting, second only to the prevention of copying which was reported by 96% of U.S. respondents (and significantly above preventing suits, $t=8.82$, $p<.0001$). We see a similar result for process innovations (also significantly above preventing suits, $t=7.07$, $p<.0001$). And yet, while this use of patents is common in the U.S., Japanese firms rated patent blocking

[20] The more pervasive use of patent applications for blocking in Japan appears to be at least partly the consequence of patent law and administrative practice there. Since publication of a patent application after 18 months places the technology in the public domain, the published application alone, prior to any grant, can successfully prevent rivals from patenting identical or closely related inventions. Thus, it is not surprising that applicants do not request examination for a sizable share of applications. For example, for the 341,095 applications submitted in 1987, there were 162,431 requests for examination by 1994, representing only 47.6% of the applications submitted. The recently instituted early disclosure system in Japanese firms, while not yet commonly used, is another means of patent blocking, since by opening an application earlier than the standard 18 months, firms can put their application in the prior art and block others' patents sooner.

even higher (country difference is significant, X^2[1 d.f.]=46.2, p<.0001), with 95% of respondents indicate blocking as a reason for applying for a patent on a product innovation, exceeding the 91.5% who report prevention of copying as a reason (t=2.64, p<.01).[21] For process innovations, the greater importance of patent blocking in Japan is even more sharply drawn (country difference significant, X^2[1 d.f.]=58.2, p<.0001).[22] In addition to blocking, defensive patenting also looms larger in Japan than in the U.S. In Japan, the prevention of suits, listed by 89% and 80% of respondents for product and process inventions, respectively, is comparable to the prevention of copying as a reason for patenting (neither the product nor process scores differ significantly, p>.15). Although the prevention of suits is an important motive for applying for patents in the U.S., both of the Japanese figures far exceed the comparable numbers for the U.S. of 61% and 50%.[23] Use of patents in negotiations is substantial in Japan at 63% and 52% for product and process inventions respectively, substantially exceeding the U.S. figures of 48% and 40% (both country differences significant, p<.0001).[24]

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[21] The industry level results also show the motive of blocking to be at least as pervasive in Japan as in the U.S. across all industries except machine tools.

[22] Reinforcing the finding that patent blocking is relatively more important in Japan, we find that 22% and 31% of the Japanese respondents list blocking as the *most important* reason for patenting, respectively, product and process inventions--much more than in the U.S. scores of 5% and 7%, respectively (country differences for both product and process significant, p<.0001).

[23] The country differences are significant (for product, • ^{2}[1 d.f.]=107.2, p<.0001; for process, X^2[1 d.f.]=98.6, p<.0001). Japanese manufacturers concern over suits was apparently heightened in the last decade by very visible infringement suits, including those filed by Texas Instruments against Fujitsu and Honeywell against Canon.

[24] There is one other contrast between the two national samples with regard to reasons for patenting. Our data indicate that U.S. firms rarely (i.e., less than ten percent of respondents) rely on patents as a measure of the internal performance of their firms' researchers. In contrast, approximately half of the Japanese respondents report using patents in this way (for products, • ^{2}[1 d.f.]=205.7, p<.0001; for process, • ^{2}[1 d.f.]=168.3, p<.0001), although they almost never cite it as the most important reason. Westney [1994] claims that it is this measurement of internal performance that mainly explain why firms patent so prolifically in Japan, despite the fact that only 17% of Japanese patent applications are actually granted. One might add to this Pitkethly's [1995] finding from a survey of a small number of firms that financial incentives to patent are almost universally provided to individuals by Japanese firms; those incentives, however, are modest. Our investigation suggests that while performance measurement is another reason

We now consider our conjecture that greater mutual dependence in complex product industries and in Japan leads to greater use of patents for negotiations. Figure 8 shows for each country the weighted averages for discrete and complex product industries for various reasons to patent product innovations. As noted above, the use of patents to "improve your position in negotiations with other firms, for example, in cross-licensing agreements" (labeled "Negotiate") is more common in Japan than in the U.S. (as noted above). Use of patents in negotiations is also more common in complex product industries than in discrete product industries. The overall averages (not in the chart) are 82% "yes" for complex product industries, but only 50% "yes" for discrete product industries (p<.0001).[25] This confirms our expectations about the role of sector on uses of patents. However, the chart shows that this gap is primarily among U.S. firms, while in Japan, firms are very likely to acquire patents for use in negotiations *in both complex and discrete product industries*. For the U.S. respondents, 78% of those in complex product industries report using patents for negotiations, while only 33% do so in discrete product industries. In contrast, in Japan, the percent reporting use in negotiations as a reason to patent is not only higher overall than it is in the U.S., but also nearly the same across the two groups of industries, about 85%. This narrowing of the gap (p<.0001) suggests that firms (across the two groups of industries) in Japan are more similar than are firms in the U.S. in their use of patents for negotiating.

motivating Japanese firms to patent, the other "strategic" rationales for patenting highlighted above are more central to the way that patents are regarded in both countries.Our data provide the basis for this claim. For example, only 1.2% of Japanese respondents claim performance measurement as the most important reason for applying for product patents, while 22.4% and 18.3% report blocking (t=11.3, p<.0001) and the prevention of suits (t=9.78, p<.0001), respectively, as the most important reasons.

[25] The differences for process innovations are similar (73% for complex v. 43% for discrete, p<.0001). In general, we are less certain about our predictions for process patents, because it is more difficult to know (without extensive knowledge of each industry) about the nature of the manufacturing process, and, thus, whether commercializable process innovations are "discrete" or "complex."

As noted above, patent blocking is another common motive for patenting in both nations, though more prevalent in Japan. Cohen et al. [2000] identify two forms of patent blocking, but only one of these tend to foster extensive information sharing. In the first form of patent blocking--which does not promote information sharing--firms may use patents to prevent other firms from patenting substitutes by aggressively patenting substitutes for some core invention, adopting what we call a “fence” strategy. Alternatively, in complex product industries where a given innovation is comprised of numerous complementary elements, firms hold rights over technologies that others need to compete, and vice-versa, creating a condition of mutual dependence. Firms exploit this mutual dependence by using patents to block the rivals’ commercial use of their (the rivals’) patents. By preventing other firms from dominating a technology, a firm will assure itself of “player” status in an industry in the sense of assuring themselves access to negotiations over rights and, in turn, the technology of rivals--or, at least conferring the “freedom of action” that comes from the ability to countersue if sued. In this way, firms achieve reciprocal access to one anothers' technologies via extensive cross-licensing and related negotiations.

In addition to the work of Hall and Ham [1998] for the U.S. semiconductor industry and Granstrand [2000] for selected Japanese firms, our interviews also confirm the importance of this “player” strategy. One American R&D manager from the communications equipment industry (a “complex” product) stated: “Mostly, your patents are used in horse trading. You come together and say, 'Here's our portfolio.' In our industry, things all build on each other. We all overlap on each other's patents. Eventually we come to some agreement: ‘You can use ours and we can use yours.’” Japanese firms echoed this sentiment, noting that products tended to span patent portfolios and that patents were often used in cross-licensing agreements to secure “freedom of design” or “freedom of operation”, the ability to make a product without interference from rival patent holders. These firms further noted that patents become a vehicle for spillover since they become the currency with which technology is traded: According to one Japanese office equipment maker, “Patents are not a good tool to get money. We always consider shaking hands (royalty-free cross-license). This cross-license gives us more freedom of design. Money is not so important as getting the other's technology when we license to other companies." Similarly, an IBM publication states: "The IBM patent portfolio gains us the freedom to do what we need to do through cross-licensing—it gives us access to the inventions of others that are key to rapid innovation." (*Think*, 1990, no. 5, pp. 10,11).

To identify the use of patents for such a "player" strategy, we create a variable, Player, which is "yes" if the firm uses its patents *both* to prevent others from patenting *and* negotiate cross-licensing agreements, and "no" otherwise. We expect the player strategy to be more common in complex product industries than in discrete product industries, and to be more common in Japan than in the U.S. While others have pointed to the importance of such uses of patents for specific samples (cf. Cohen, et al. [2000] for the U.S. overall, Granstrand for a small sample from Japan, Hall and Ham [2000] for the U.S. semiconductor industry), our data allow us to directly compare the prevalence of these strategies for a large sample across the manufacturing sectors of the two countries.

In terms of industry differences, we do indeed find that the use of the player strategy is significantly higher in complex than in discrete product industries (73% v. 47% for product innovations, 60% v. 43% for process innovations, both differences $p<.0001$). The row labeled "Player " in Figure 8 shows by country and industry type the percent of respondents who report using a patent for blocking and for negotiations. We see that this use of patents for a player strategy, while very different by industry type in the U.S., is pervasive in Japan, with both discrete and complex product industries scoring higher than the U.S. average for even complex product industries (the interaction effect is significant, $p<.0001$).[26]

As described above, the second strategy which involves patent blocking is what we call the "fences" strategy. In this case, firms patent substitutes for core inventions in order to maintain exclusivity over the technology. Those substitutes may represent

[26] We find similar results for process patents.

improvements upon the original product or not, and the firm may have no intent of commercializing those inventions.[27] To the degree, however, that protecting some "core invention" patent requires it to be surrounded by numerous other patents, the transaction costs of licensing increases and the likelihood of licensing declines. Also, since the goal is exclusivity, these patents would not be used for cross-licensing negotiations. Therefore, to measure this strategy we create a variable, Fences, that is "yes" when firms report using a patent for patent blocking (i.e., to patent to prevent others from patenting related inventions), *but not* for licensing nor use in negotiations, and "no" otherwise. We expect the fences strategy to be most common in discrete product industries, where the relatively low number of patentable elements per innovation makes fence building feasible. We also expect this strategy to be more common in the U.S., with a patent system that puts greater emphasis on exclusivity.[28]

The row labeled "Fences" in Figure 8 shows patent application-weighted percentages of respondents reporting blocking as a motive, but not the motives of use in negotiations or licensing. The overall averages for product innovations (not shown in the chart) for discrete is 33%, but for complex is only 10% ($p<.0001$). For process innovations, the results are similar (34% versus 15%, $p<.0001$). Figure 8 shows, as conjectured, that the use of patents to build such "fences" to be less common in Japan no matter the industry (both the country effect and the interaction effect are significant, $p<.0001$).[29] Thus, while in some (discrete product) industries in the U.S., patent blocking is a mechanism to generate appropriability through building patent fences, such fence building in Japan is quite rare, across both kinds of industries.

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[27] For example, in the 1940's du Pont patented over 200 substitutes for Nylon to protect its core invention (Hounshell and Smith [1988]). Turner [1998] documents the case of the "Fan" patent where Du Pont patented an improvement on its already commercialized color proofing process for photographic film in order to prevent the preemption of its existing product.

[28] Note that if exclusivity is very strong, then fence-building is not necessary, since one or two patents can maintain control of the market. This is the case in pharmaceuticals.

[29] We find a similar result for process patents.

Our results indicate that Japanese firms, compared to U.S. firms, are much less likely to use their patents as a means to exclusivity (the fence strategy), and much more likely to use them as a means of gaining market access and freedom of operation/freedom of design (the player strategy). This suggests that the Japanese patent system spawns a patent strategy across its entire manufacturing sector that is confined to the complex product technologies in the U.S.

These results suggest how a patent policy and practice that increase the number of patentable elements in a commercializable innovation can induce further R&D spillovers across rivals. By encouraging aggressive patenting (to block others from patenting) and cross-licensing negotiations (as the solution to technological inter-dependence), the Japanese patent system both generates more disclosure of information and encourages firms to share that information by cross-licensing. By encouraging many patent applications and the use of cross-licensing to settle disputes, the Japanese patent system both directly and indirectly increases information flows among firms.

5.2 Patents as a Channel of Information Flow

Thus, numerous features of the Japanese patent system support knowledge diffusion, including those identified by Ordover [1991] and as well as the Japanese patent system's encouragement of numerous patents per product discussed above. The logical next question is—So what? How important are patents as a channel of intraindustry R&D knowledge flow spillover in Japan versus the U.S., and are patents that much more important as a vehicle for R&D spillover in Japan as conjectured?

In our survey, we consider the relative importance of the different channels of R&D information flow across rivals. In both Japan and the U.S., we asked respondents to score on a four point Likert scale the importance to a recently completed, major R&D project of each of the following sources of information: patents, informal information exchange, products (via, for example, reverse engineering), publications, public meetings and conferences, recent hires, licenses, joint or cooperative ventures, contracts with other firms and trade associations. Presenting the percent of respondents reporting that a given information source was “important” or “very important” (i.e., scoring at least a “three” on the four-point scale), Figure 2 provides the comparisons for the aggregate samples.

First, we find that the same five sources of information on rival R&D--namely publications, public meetings or conferences, patents, informal information exchange and competitors' products (via, for example, reverse engineering)--are the five most important sources in both nations. Figure 2 also lends additional support for the conclusion of the analysis of Section 3 above that intraindustry R&D information flows are greater in Japan by showing that eight of the ten sources are rated more highly in Japan than in the U.S.[30] Moreover, the only two sources that are rated in absolute terms more highly in the U.S., namely recent hires and trade associations, are relatively unimportant in both nations as sources of information on rival R&D.[31]

In terms of the key sources of spillover, we see that the biggest gap between the two countries is in the importance of patents. The absolute score for patents in Japan exceeds that of the U.S. by 70% (X^2[1 d.f.]=175.7, p>.0001). In addition, patents are clearly the most important channel in Japan, scoring over 30% higher than the next most

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[30] The country differences are significant (p<.05) for all but publications.

[31] Recent hires are easily the least important channel in Japan, with a score, 10.5%, less than half of the next least important channel, trade associations (t=5.72, p<.0001), which in turn has a score of 21.7%, approximately half of the score for the next least important channel, licenses (t=13.31, p<.0001). In light of the convention of lifetime employment in Japan, it is sensible that recent hires would play less of a role in R&D spillovers than in the United States. We should note that, despite the “convention” of lifetime employment, there is a mid-career labor market for technical personnel in Japan and that this does provide a channel for spillovers. However, our results suggest that this channel is not as important as other sources, nor as important as it is in the U.S.
It is less clear, however, why trade associations should be more important as an information source in the U.S. However, even in the U.S., both trade associations and new hires score significantly below the leading sources. Trade associations score significantly below customers’ products, the lowest of the top five (t=6.65, p<.0001).

highly ranked channel in Japan, publications (t=9.25, p<.0001). In the U.S., patents are ranked third behind publications and informal information exchange, and quite close (i.e., within ten percent) to the sources of informal information exchange, public meetings and conferences, and competitors' products (none of these are significantly below patents).[32] While patents surely play a role in diffusing information across rivals in the U.S., they appear to be the dominant channel for information diffusion within Japan. Moreover, while some of the information conveyed by patents is conveyed via licensing, Figure 2 shows that licenses are a much less important source of information than patents generally, suggesting that a considerable portion of the information contained in patents is conveyed via public disclosure.[33]

Thus, our findings suggest that a primary explanation for the differences in spillover between Japan and the U.S. is the different patent systems in two countries.[34]

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[32] Two other sources score significantly higher in Japan, licenses and contracts. However, these two sources are relatively unimportant sources of information in both nations. They are the two least important information sources in the U.S. (significantly below the next lowest, hires, t=4.30, p<.0001) and are ranked only seventh and eighth in Japan (a little below joint ventures, t=1.8, p<.10). The higher ranking of licenses and contracts in Japan, and particularly their much higher absolute scores, would be consistent with an environment where patents play a more important role in information diffusion since licensing typically requires a technology having been patented, and contracts often involve patented technologies.

[33] The difference between the scores for patents and licenses are significant in each country (the paired t-test [Agresti and Agresti,. 1979] results for the U.S. are t=14.87, P<.0001; for Japan, t=18.90, p<.0001).

[34] Our argument that the role of Japanese patents in diffusing information across rivals is a key reason for the difference in R&D spillovers between the U.S. and Japan assumes that the patent filings of U.S. firms in Japan are not a major source of information to U.S. firms on the R&D activities of their American rivals. Although one might believe that U.S. firms have strong incentives to patent in Japan, only a fraction of U.S. patent applications are filed there. For example, American firms filed about 89 thousand patent applications in the U.S. in 1991. In contrast, they filed less than 16,000 applications in the same year in Japan (Science and Technology Agency, Japan [1995]). Moreover, those 16,000 applications in Japan are not equivalent to the same number of U.S. patent applications because U.S. firms tend to bundle on average roughly ten claims per patent (personal communication, F. Narin), while common practice in Japan historically is to file one application per claim, (although this has begun to change in the 1990's after a 1988 change in the allow that allowed multiple claims), implying that U.S. firms filed a number of applications in Japan equivalent not to 18% of the number filed in the U.S., but as much as an order of magnitude less than that. This absence of aggressive

There are, however, undoubtedly other possible explanations. These might include, for example, differences in the significance of innovations ("major v. incremental"), managerial practice regarding the monitoring of extramural information, the role of R&D consortia, geographic proximity, and market structure. Although our ability to empirically probe these alternative explanations is limited, we do so in a supplemental analysis reported in Appendix A. In this exercise, we find little evidence for the claim that the difference in spillovers is due either to more incremental innovation in Japan, or due to Japanese firms' expending more effort on monitoring rivals, or due to geographic proximity. We do find weak evidence for the impact of Japanese R&D consortia on information flows, and some evidence in behalf of a role for market structure. Nonetheless, our findings compel us to conclude that patent policy appears to play an important role in generating intraindustry spillovers, and, one might conjecture, the efficiency of innovative effort as well.

6. CONCLUSION

Our comparative analysis of spillovers and appropriability conditions in the U.S. and Japan suggest that there are some important differences as well as similarities between the two nations. Intraindustry R&D information spillovers appear to be greater and the appropriability of rents to innovation appear to be less in Japan than in the U.S. The survey results provide at least a partial explanation for these differences, namely that

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filing in Japan by American firms may be due to the primary focus on the domestic market for most firms in most industries, due to the high cost of filing and maintaining overseas patents (leading firms to only file critical patents overseas) and, in part, because American firms fear the early disclosure of the Japanese patent system. (Japanese firms may also fear this disclosure (see Figure 5), but they must operate within the parameters of their domestic patent system.) American firms also report problems associated with the filing and enforcement of their patents in Japan, including the length of time involved, the cost, and the scope of patent protection granted (US GAO, 1993). Moreover, the official language of Japanese patents is Japanese, reducing the availability of this information to most U.S. R&D personnel. Abstracts have, however, been available in English since 1990.

the sources of information on rival R&D, particularly patents, appear to make more information available to rivals.

Our results shed light on the nature of appropriability conditions. We find systematic cross-national differences in appropriability mechanisms employed (e.g., secrecy), in the appropriability of rents, and in the extent of information spillovers. This in turn suggests that factors that cut across industries account for these differences, probably in the broader policy or institutional environment. One such factor highlighted in our findings is the differences between the two nations in patent law and related judicial and administrative practice.

Our data also suggest that these different patent systems are associated with differences in patenting strategies in each country. Overall, our results suggest that firms in both nations derive significant competitive advantages of both a strategic and sometimes defensive character that transcend the rationale of using patents in any strict sense to prevent copying a given invention. While patents surely need to prevent copying to some degree to satisfy these objectives, they need not be effective in a categorical sense. What patents accomplish is the establishment of a legal claim that either constrains others' behavior or anticipates and sometimes defends against the actions of others. Moreover, it appears that Japanese firms actually exploit disclosure as a competitive weapon, similar in function to the American practice of "defensive publication" where firms publish selected technical details of a new development in publicly accessible company journals in order to place the information in the public domain and thus either legally foreclose others from patenting related inventions or make it uneconomic to do so.[35] Using patents for blocking, prevention of suits and negotiations often also ensure a firm can compete in a given product market. Given the weakness of patents as a form of appropriation, firms are not necessarily able to keep rival firms out. But, they can use patents to establish or strengthen a non-exclusive right to be a player in

[35] Japanese firms also use defensive publication to block other firms' patents partly because it is often less expensive and sometimes quicker than filing a patent application.

a technological domain. Patents also serve as a vehicle for extracting technical information from rivals through cross-licensing.

In addition, we find that industry differences in these motives are significant in the U.S., with the use of patenting for negotiations and what we call a “player” strategy to be more common in complex product industries. However, in Japan, such uses of patents are pervasive across both discrete and complex product industries. This finding suggests that this difference in patent strategy is due to the different patent systems (or some other national-level characteristic) and that this difference can overwhelm even the technical basis for patenting strategy. In particular, the Japanese patent system not only encourages spillover, but also tends to generate technological interdependence among competitors, leading to patents becoming a method for securing player status and the freedom to compete as much as securing monopoly and the right to exclude. The prevalence of these strategic uses for patents suggests one reason firms patent as much as they do. Successful execution of the player strategy, cross-licensing strategy, and the prevention of suits, depends in part on having many patents. As one Japanese respondent put it, “You have to show up to the table with something in your briefcase.”[36]

Cohen et al. [2000] for complex product industries and Hall and Ham [2000] for semiconductors in the U.S. and Granstrand [2000] for Japan have argued that patents are likely being used as weapons in mutually reinforcing, noncooperative strategic interactions where firms feel increasingly compelled to patent either because they need to protect themselves from suits or from being blocked, or they want to block rivals or use patents as bargaining chips in negotiations. Resembling the outcome of an arms race, firms in both nations could well be accumulating more patents than what is collectively optimal. Our results suggest, however, that if patenting is excessive, the social costs of that excess may differ between the two nations. In Japan, patents apparently diffuse

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[36] Similarly, von Hippel [1988, p. 53] observed that when threatened with an infringement suit, semiconductor firms will typically send “a pound or two” of copies of patents germane to the

information more effectively than in the U.S. and consequently confer a greater social--if not private--benefit. In addition, U.S. firms may suffer greater litigation costs than in Japan where the pre-grant opposition period along with related cultural and institutional norms apparently dampen the drive to litigate.

An important limitation to our study is that we are observing similarities and differences in R&D spillovers and appropriability conditions between the U.S. and Japan at a point in time. We know, however, that patent law and administrative and judicial practice have been changing over time in both nations. In fact, there have been several changes since our 1994 survey. Since differences in the patent systems appear to have profound effects on the observed patterns, the patterns we observe today may therefore not endure. Policy changes also raise the question of the degree to which differences in institutional environments across nations are exogenous, reflecting nations' cultures and unique histories, or endogenous to global economic competition. In the case of patent policies, there appears to be an important endogenous component, stimulated by high profile infringement suits between U.S. and Japanese firms, trade disputes and, more generally, competition between the two nations' industries and firms. Ironically, some of the differences--no less the similarities--between the two nations' patent systems may result from the same interactions between Japanese and U.S. firms. For example, Japanese firms appear to have aggressively embraced patents partly in reaction to prominent infringement suits filed by American against Japanese firms over the prior ten to fifteen years. At the same time, American firms may have drawn a different lesson from the same events, namely that patents provide only partial protection and must be supplemented wherever possible by other ways of protecting their inventions, such as secrecy. More generally, further study is needed to understand the dynamics of the changes in patent policies and other institutions that critically affect the innovative capabilities and performance of nations.

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business of the potential plaintiff and suggest it is they who are the infringers, culminating in cross-licensing.

Mazzoleni and Nelson [1998] point out that the academic literature (and much of the policy debate) on patents has focused attention on the impact of patents on appropriability. By revealing that patents can have important and pervasive effects on information diffusion and R&D spillovers, and perhaps, in turn, on the efficiency of innovative effort, our results imply that the information diffusion effects of patents deserve at least equal time from policymakers and academics. Accordingly, these results may offer some limited implications for current policy. The U.S. has recently adopted a policy of automatic disclosure of (most) patent applications after 18 months, similar to the practice in Japan and Europe. Our findings suggest that such disclosure may contribute to greater diffusion of information across rivals, which is certainly a benefit to social welfare. One question is whether automatic disclosure after 18 months will significantly affect R&D spillovers in the absence of the other features of Japanese patent system that also affect diffusion such as the first-to-file priority rule, pre-grant opposition and narrow construction of claims. A second question--and one that is fundamental to our understanding of the determinants of innovation--is whether more disclosure undermines incentives to invest in R&D to begin with. Despite operating under a patent system promoting the rapid diffusion of information, Japanese firms' R&D intensities substantially exceed those of U.S. firms overall (although not in the most R&D intensive industries). To the degree that disclosure does not dampen R&D incentives, a patent regime that strongly supports disclosure yields an unambiguous social welfare benefit. More analysis, particularly one that controls for the other factors conditioning R&D spending, is required, however, before concluding that a patent system similar to Japan's would benefit the U.S.[37] More generally, it is not obvious whether an optimal patent policy exists or can be achieved given cross-national differences in institutions, history, culture, etc. However, our results suggest that the role of patents in promoting spillovers should at least be an important part of this policy discussion.

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[37] The central issue in such an analysis are the offsetting effects of intraindustry information flows on R&D efficiency and incentives highlighted by Spence [1984], Levin and Reiss [1984] and Cohen and Levinthal [1989], and among others. Using industry-level data from the U.S., Cohen and Walsh [2000] find that, controlling for the affects of spillover on appropriability, spillovers have a positive affect on R&D intensity.

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Appendix A: Other Explanations for Greater R&D Spillovers in Japan

In addition to differences in the patent system, there are surely other possible explanations for greater spillover in Japan. We consider each of these in turn. In brief, we typically find that the differences in these other factors are generally small compared to the differences in the role of patenting.

We begin with differences in the significance of innovations. The literature has long suggested that innovation tends to be more incremental in Japan than in the U.S. Consequently, R&D information spillovers may be more easily exploited by rivals. While Japanese innovation may have been more incremental in the past, that was not necessarily true by the 1990's. Rosenberg and Steinmueller [1988], for example, claim that R&D in the U.S. tends to be much more incremental than commonly thought. Our U.S. and Japanese questionnaires posed a question that partially addresses the point. In response to a question on the percent of R&D projects initiated with the goal of improving the performance or quality of existing products (as distinct, for example, from creating altogether new products), Japanese respondents overall reported 37.9% while U.S. respondents reported 40.3% (X^2[1 d.f.]=3.73, p<.10). Thus, our limited data do not support the notion that, in the mid-1990s, Japanese R&D is any more incremental overall than is American R&D.

The literature also suggests that Japanese firms are more aggressive than American firms in exploiting extramural knowledge (e.g., Mansfield [1988]). Consequently, Japanese firms may report greater use of rivals' R&D findings because they expend more effort in monitoring and exploiting extramural information, not because there is either more information that "spills out" from rivals or that that information is easier to exploit.[38] Our survey questionnaire poses two questions on the subject of firms' attention to extramural information. First, we asked the respondents in Japan and the U.S. to estimate the amount of time their R&D personnel devote to monitoring and gathering information on new scientific and technical developments. Japanese respondents report that they devote, on average, 12.5% of their R&D effort to

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[38] Of course, the "information availability" versus "effort" explanations are not mutually exclusive. Indeed, the notion of an endogenous "absorptive capacity" (Cohen and Levinthal [1989]) suggests that the more potentially useful information there is in a firm's environment, the

monitoring and gathering information, in comparison to 12.1% reported by the American respondents (t=0.75, p>.45). We also asked respondents to indicate the percentage of their R&D projects that are at least partly initiated to keep up-to-date with new developments, which again can be viewed as one measure of effort dedicated to exploiting extramural information. Again, there is no striking difference between the U.S. and Japanese respondents. Japanese respondents indicate that this reason for initiating projects applies to 32% of their projects on average, while American respondents report 33% on average (X^2[1 d.f.]=0.2, p>.65).[39]

Another explanation that has been proposed, based partially on interviews with Japanese firms, is that the geographic concentration of Japanese industry, and particularly Japanese R&D labs, in the Tokyo region generates greater spillover in Japan. We could not test this directly. However, we note that while the U.S. population of firms is more geographically dispersed than the Japanese firms, the U.S. economy is characterized by many industry-specific geographic clusters (Porter [1998]). Thus, while firms overall may be dispersed, firms in particular industries are often quite concentrated, with Detroit and Silicon Valley being two famous examples. Thus, there may be less of a gap in information flows across rivals due to proximity than the initial impression of concentration in Japan would suggest.

We have evidence that bears indirectly on the influence of geographic proximity in the two countries. We start with the assumption that of the major spillover mechanisms (patents, publications, conferences, reverse engineering and informal information exchange), informal information exchange is the one most likely to be structured by

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more effort the firm will expend to evaluate and exploit it. It is, however, a matter of degree and relative emphasis.

[39] As further evidence that there are not systematic differences in the level of monitoring, we note that, while Japanese firms report greater use of information from rivals, they do not uniformly report greater use of outside information. Cohen, et al. [2000] report that, while flows from public research appear to be greater in Japan, those from customers are not obviously so, and those from suppliers appear to be less. This suggests that the greater intraindustry information flows observed in Japan do not reflect some practice on the part of Japanese firms that affect flows from all information sources generally, but are due to factors that affect intraindustry information flows specifically. Thus, while our data cannot reject the “superior effort” explanation for the greater information spillovers observed in Japan, they do not provide any support for the argument either.

proximity. A second source that may also be heavily conditioned by proximity is recently hired technical personnel. We compared the importance of each of these sources by country. We find that informal information exchange is greater in Japan than in the U.S. (57% v. 51% scoring it at least "moderately important", $p<.05$), consistent with the geographic proximity argument. However, the gap (6 percentage points), while statistically significant, is relatively small, compared to the gap in the patent scores for the U.S. and Japan (36 percentage points). Also, in terms of relative ranks, informal information exchange is the second most important source in the U.S., and only the third most important in Japan. In the case of new hires, as noted above, the U.S. firms score this well above the Japanese firms (26% v. 11%, $p<.0001$), although in both countries this is a relatively low ranked source. Thus, we find only limited evidence that local information flows are greater in Japan than in the U.S.

Another explanation for the higher spillovers in Japan is the greater use of government-sponsored research consortia (Saxonhouse [19XX], Branstetter and Sakakibara [1997]). We were not able to test this directly, since we do not have any measure of participation in these consortia. We do find that Japanese firms report joint or cooperative research projects to be a more important source of information on rivals. Figure 2 shows that 42.9% of Japanese firms compared to 34.4% of American firms considered this an important source of information on rival R&D (X^2[1 d.f.]=111.3, $p<.0001$). But this source ranks only sixth in importance in both countries (significantly below the fifth highest in each country, $p<.001$). Thus, while such consortia appear to be relatively more important in Japan, they do not appear to be the primary explanation for the substantial difference in spillovers across the two countries.

An additional source of difference in spillovers may be market structure, or, more precisely, the number of direct competitors. The argument is simple. To the degree that there are more direct competitors, appropriability will be less partly due to competition, and partly due to a greater likelihood of a rival profiting from your R&D. Expressed in terms of R&D information flows, the latter point can be recast as suggesting that the greater the number of rivals working in a similar area, the greater the likelihood of picking up relevant information from one of them.

Allowing us to explore this argument for Japan and the U.S., we asked respondents how many firms, by region (e.g., North America, Asia, Europe), "are able to introduce competing innovations in time to effectively diminish your firm's profits from your innovations." Assuming that information from geographically proximate firms is most accessible, we compare the average number of domestic firms identified in both nations. In Japan, the average number is 5.0 firms, while the average in the U.S. is 3.9 firms, again suggesting appropriability is less in Japan ($t=3.64$, $p<.001$). We then conducted a simple regression analysis to consider the impact of this difference on intraindustry R&D information flows across industries in the two countries. For each industry, we calculated the average number of domestic rivals in that industry. We then divide industries into "crowded" or not, with a cutoff of 5 or more rivals as the definition of crowded. We then regress two information flow measures (receiving information from rivals that either: 1. suggested new projects; or 2. contributed to project completion) on our measure of industry structure (crowded versus not) and on country, to see if the country difference is still significant after controlling for differences in industry structure. We find that industry structure does matter, with "crowded" industries reporting greater spillover (though the difference is not significant in the case of contributing to project completion). However, even controlling for structure, we find that country has a significant effect on spillovers. In fact, the effect is stronger than before controlling for country, suggesting that beyond structure, there are important country-level differences.

TABLE 1

Firm and Business Unit Size: Distributions in U.S. and Japan

	Sales ($Mil.)			**Employees**		
	U.S.	Japan	Sig.	U.S.	Japan	Sig.
Firm Size						
Median	1245	558	___	8600	1476	___
Mean (unweighted)	6067	1956	****	30009	3720	****
Mean (comparison weight)	6020	1793	****	29272	3462	****
Business Unit Size						
Median	300	361	___	1000	850	___
Mean (unweighted)	2403	1264	*	6282	2229	****
Mean (comparison weight)	2813	1122	***	6791	1945	****

Notes: 1 US$=102.8 ¥ , March 1994 exchange rate

*P<.05; **p<.01; ***p<.001; ****p<.0001

Chart 1. Non-defense R&D as a percent of GDP, Japan and U.S., 1981-1998.

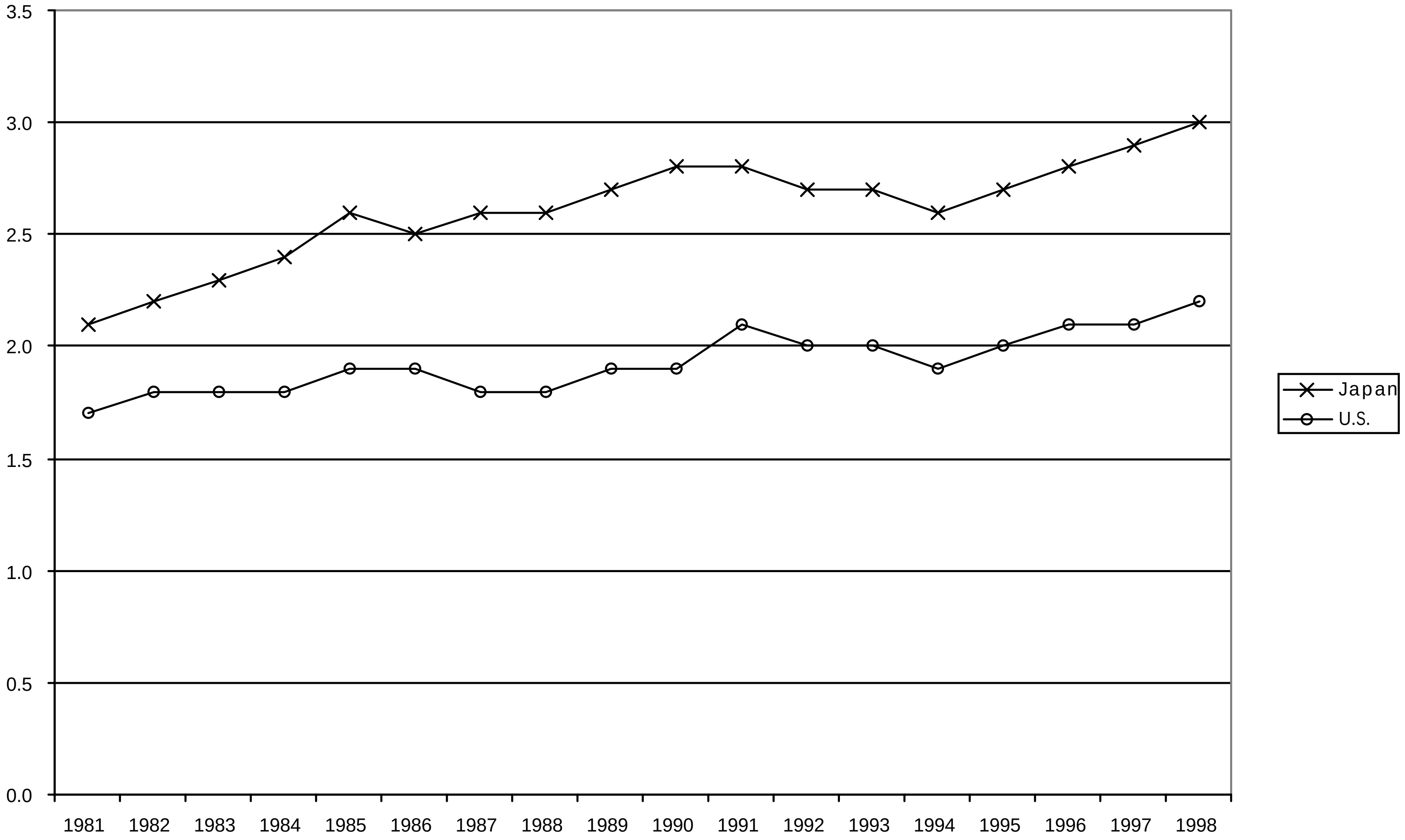
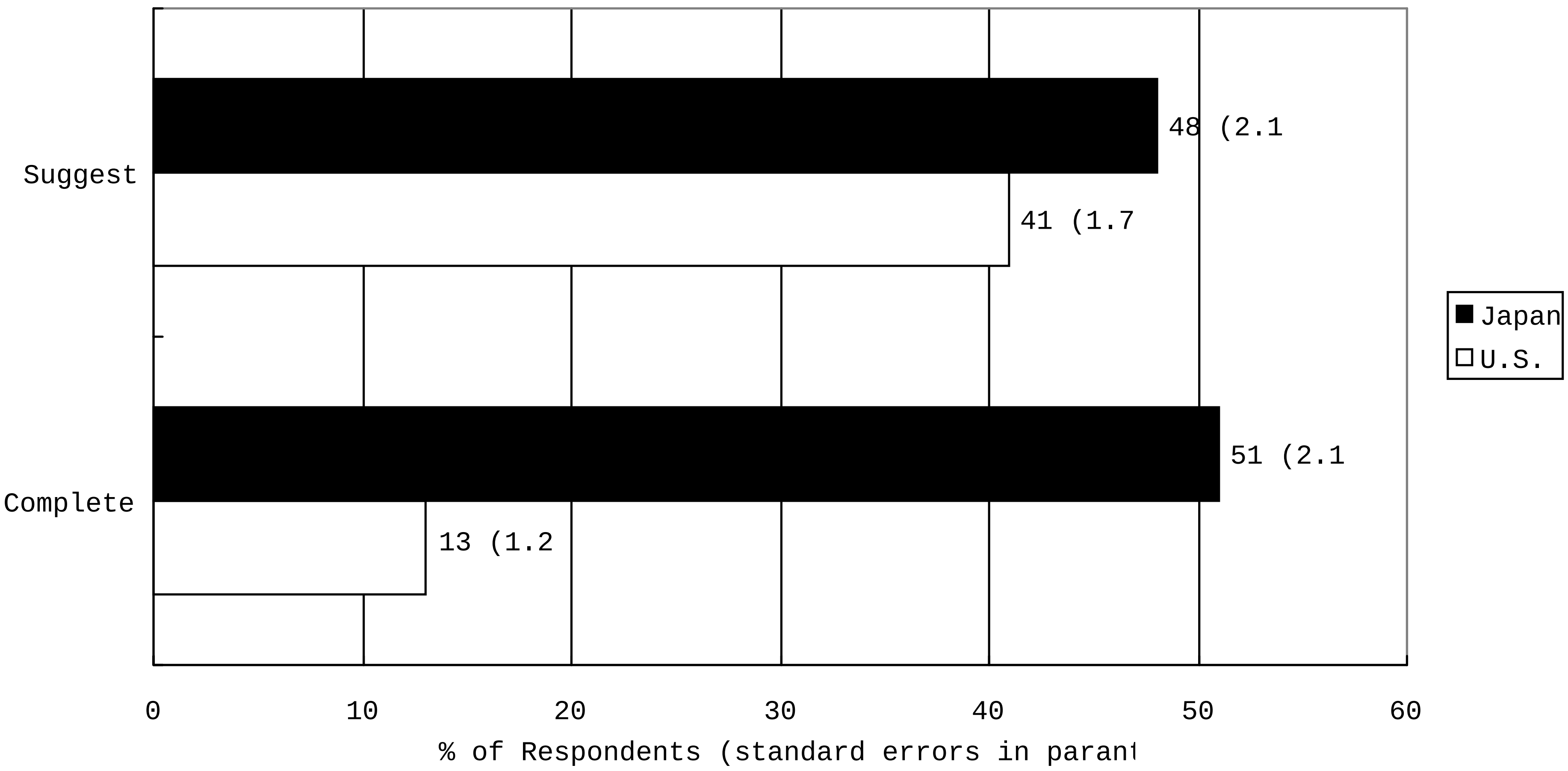


Figure1. Competitors as Information Sources for Suggesting New Projects or C
to Completion of Existing Projects, for Japan and U.S.



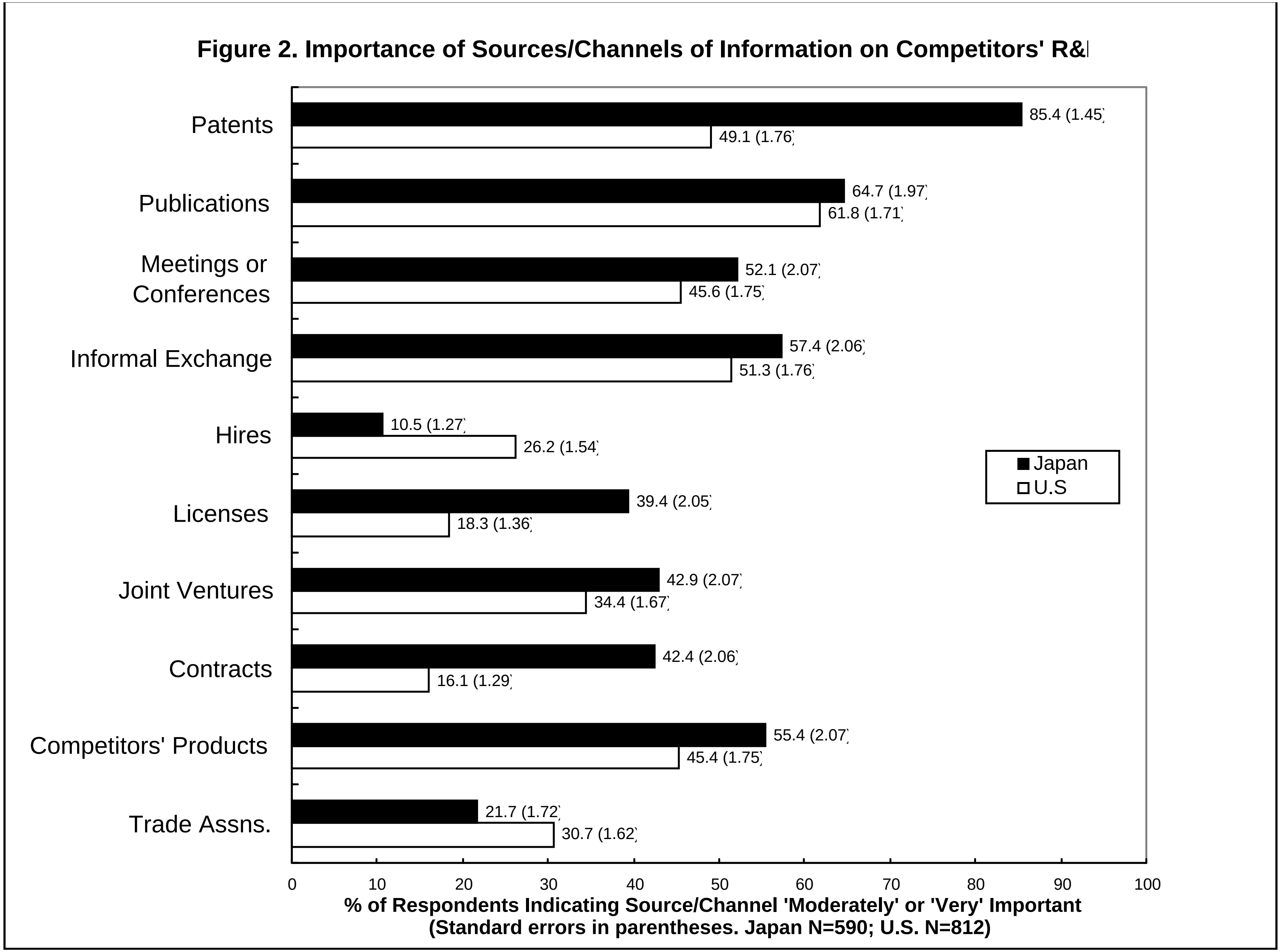
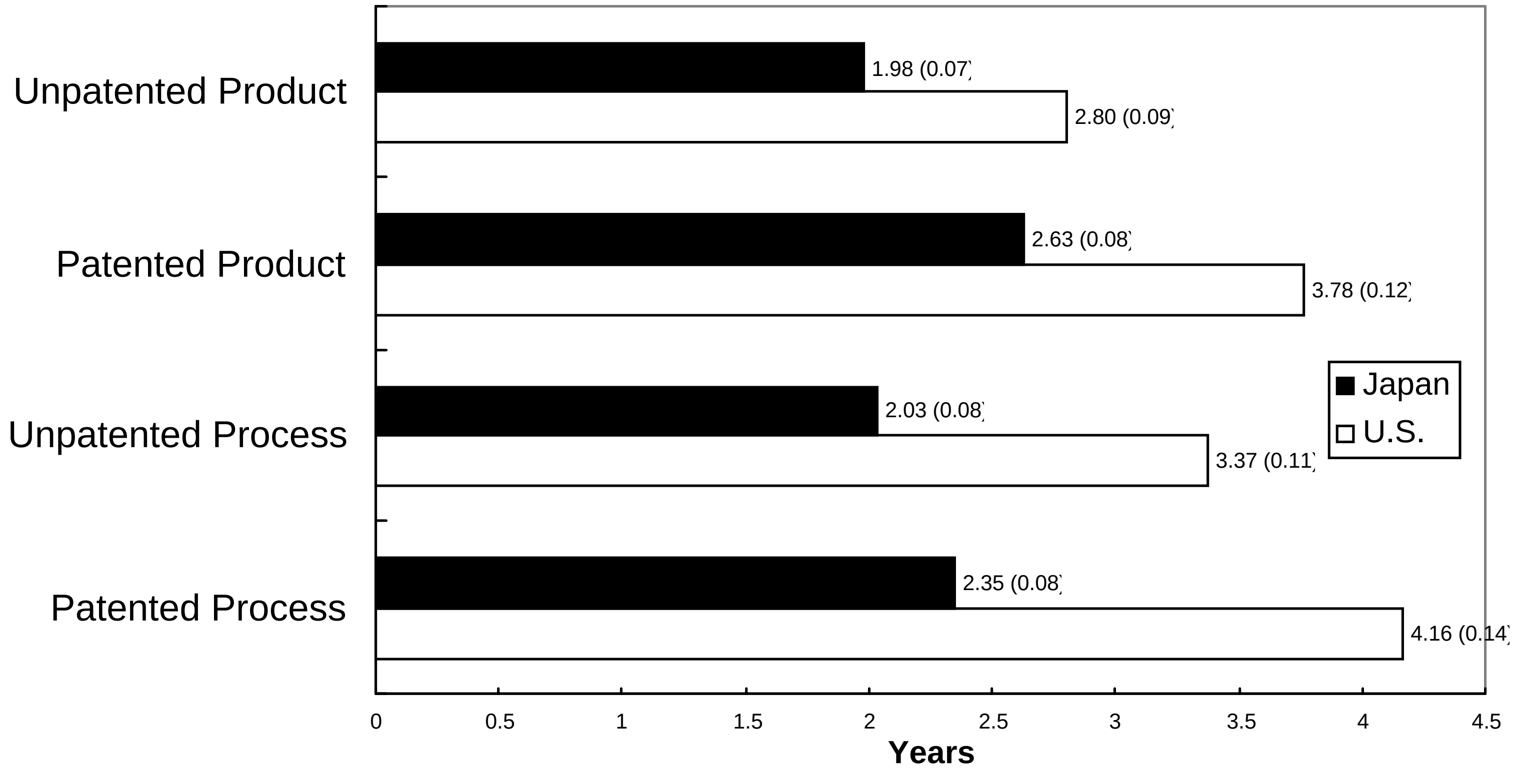


Figure 2. Importance of Sources/Channels of Information on Competitors' R&
Patents
85.4 (1.45)
49.1 (1.76)
Publications
64.7 (1.97)
61.8 (1.71)
Meetings or Conferences
52.1 (2.07)
45.6 (1.75)
Informal Exchange
57.4 (2.06)
51.3 (1.76)
Hires
10.5 (1.27)
26.2 (1.54)
Licenses
39.4 (2.05)
18.3 (1.36)
Joint Ventures
42.9 (2.07)
34.4 (1.67)
Contracts
42.4 (2.06)
16.1 (1.29)
Competitors' Products
55.4 (2.07)
45.4 (1.75)
Trade Assns.
21.7 (1.72)
30.7 (1.62)
Japan
U.S
0
10
20
30
40
50
60
70
80
90
100
% of Respondents Indicating Source/Channel 'Moderately' or 'Very' Important
(Standard errors in parentheses. Japan N=590; U.S. N=812)

Figure 3. Mean Imitation Lags for Product and Process Innovations



Note: Average Lags computed using midpoints of following categories: less than 6 mos., 6 mos. - 1.5 years, 1.5-3 years, 3 - 5 years, greater than 5 years. For top category, we assumed an imitation lag of 8 years. (Standard errors in parentheses. For patented innovations: Japan N=533; U.S. N=551. For unpatented innovations: Japan N=538; U.S. N=703.)

Figure 4. Effectiveness of Appropriability Mechanisms for Product Innovatior

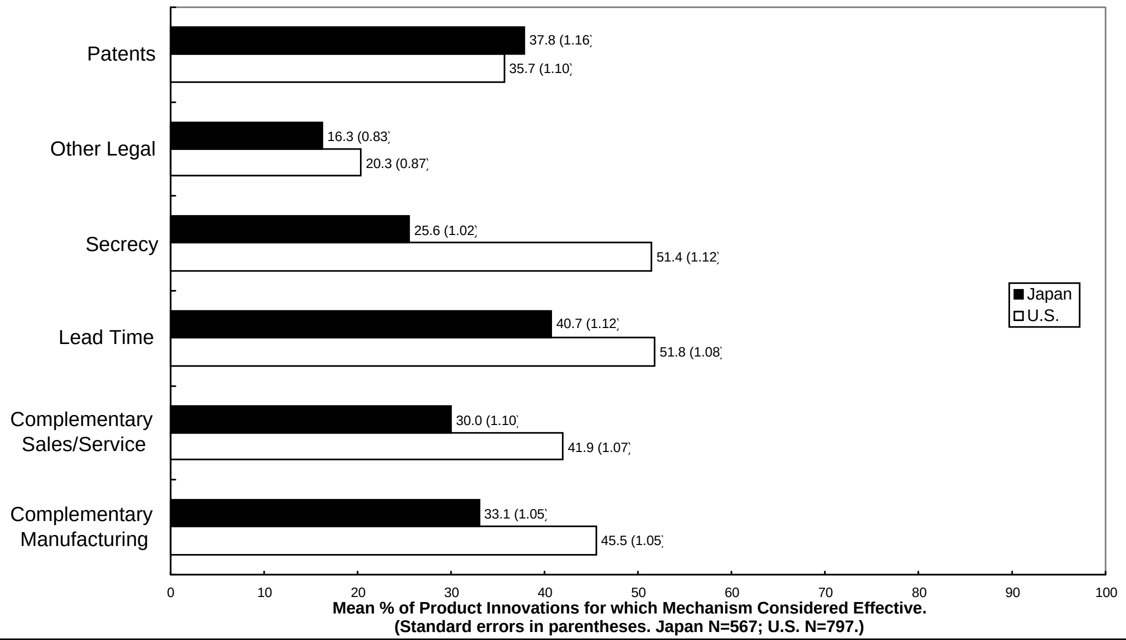


Figure 4 (cont.). Effectiveness of Appropriability Mechanisms for Process Innovatior

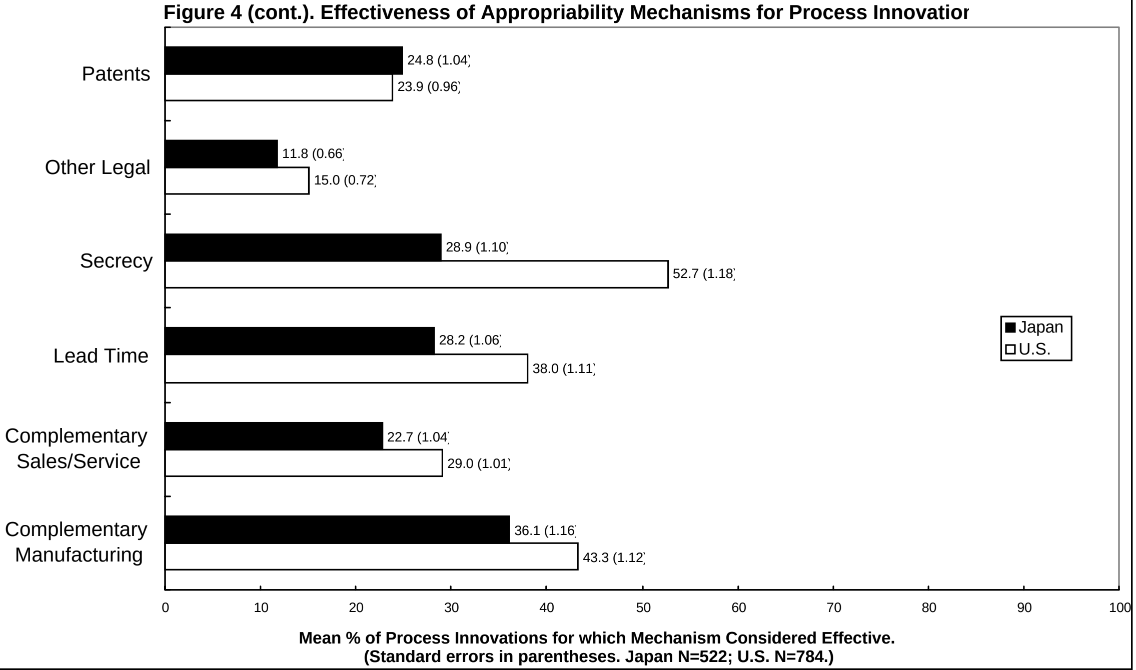


Table 6. Reasons to Patent Product Innovations

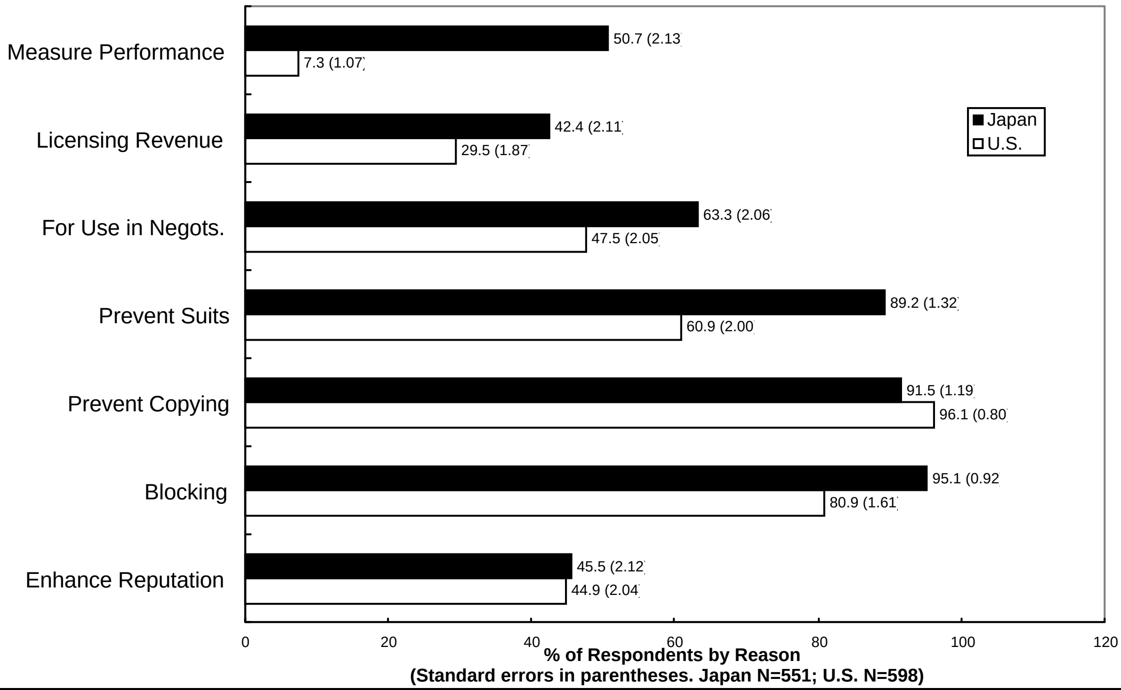


Table 6 (cont.). Reasons to Patent Process Innovations

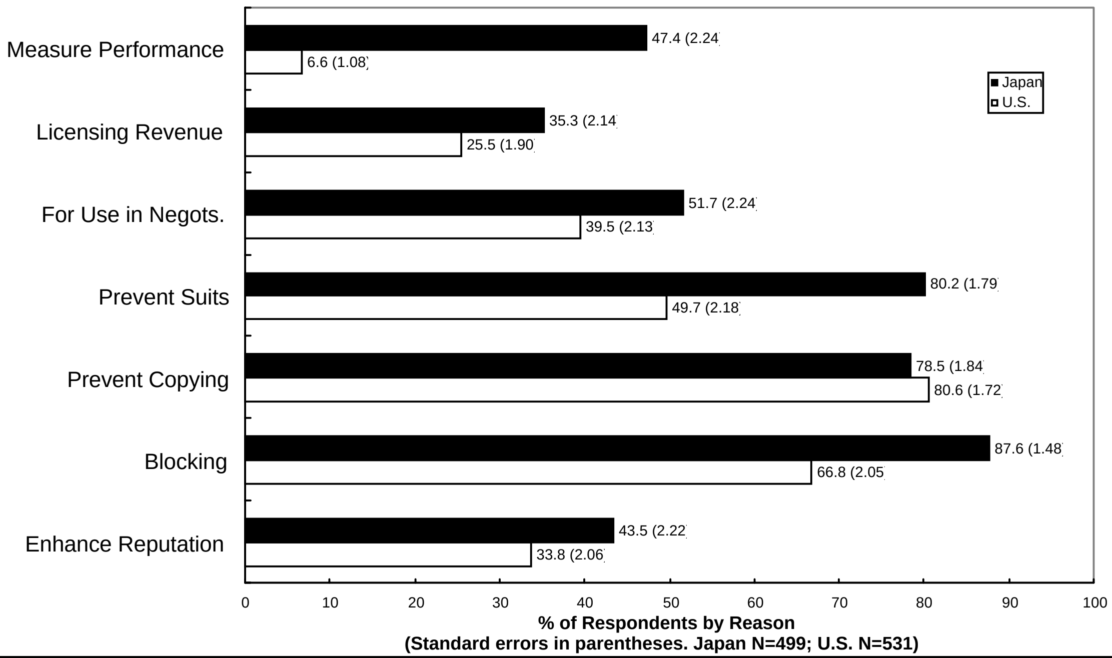


Figure 8. Reasons to Patent (Product Innovations), by Country and by Discrete and Complex Product Industr